Preliminary Study on Ecological Water Conservancy Strategy to Cope with Climate Challenge

Zundang Xie¹,a*, Xiaolong Lv¹,b, Xingliang Chen¹,c

¹Yellow River Engineering Consulting Institute Co., Ltd., Zhengzhou, Henan, 450003, China
*aCorresponding author’s email: xiez@yrec.cn
bemail: lvxl@yrec.cn, cemail: chenxl@yrec.cn

Abstract. Global warming has caused sea level rise, extreme meteorological events, flood and drought disasters. From the perspective of ecological civilization construction, taking China as a typical example, this paper explored how to deal with the adverse impact of climate change on human and ecosystem through the development of ecological water conservancy. The main measures were as follows: firstly, construct the national water network connecting the natural water systems in the South and North of China, play the role of the Yellow River as a link to ecologically replenish water in arid and semi-arid areas; secondly, recover the over exploited groundwater in North and Northeast China and the ancient lakes in Northwest China. By storing a large amount of water on land, the goal that slowing down the speed of the sea level rise, reducing the flood damage in the south and coastal areas, repairing and improving the ecological environment in the north and northwest regions of China and spurring the local economic development could be achieved.

1. Introduction

Global warming caused by industrial greenhouse gas emissions has become a potential crisis threatening human security and causing ecosystem collapse. Tackling climate change is one of the most important global tasks in this century [1]. The latest commitment of Paris Climate Agreement and governments of major developed economies is to achieve carbon neutrality by 2050-2060. According to the prediction of the Intergovernmental Panel on Climate Change (IPCC), the sea level will rise by 0.26-0.77m even if the global temperature rise is controlled at 1.5°C by 2100 through emission reduction [2], which will cause flood, inundation, sea water invasion and other disasters in island countries and coastal economic developed areas. According to the current population distribution, every 0.1m rise of sea level will affect about 10 million people in the world. The adverse effects of climate warming include frequent extreme weather events, aggravation of flood and drought disasters, deterioration of regional ecosystems, damage to food security and even political instability, which significantly increase the vulnerability and risk of the continental and marine ecosystems and human society [3]. Therefore, it is very realistic and urgent to deal with the global crisis caused by the climate change.

The core of the adverse effects of global warming is the adverse distribution of water. In essence, the rapid increase of water in the ocean leads to the inundation of islands and coastal lowlands, and the further imbalance of the spatial and temporal distribution of rainfall and water resources. From the point of view of water storage, all the lakes, reservoirs and oceans are basins that can hold water. There are pores in the earth and rock, the land can absorb and store a large amount of water, so the land can also
be regarded as a basin full of earth and rock that can store water. Using water conservancy projects to keep plenty of water on land, especially in the underground, lakes and basins in arid areas, can avoid or slow down the rapid rise of sea level, repair and improve the ecological environment of arid areas, so as to effectively alleviate the adverse effects of climate warming and expand the space for economic development.

2. Storing water on land is a feasible way to reduce sea-level rise

The ocean area is about 361 million km². For every 0.1m decrease of sea-level rise, about 36.1 trillion m³ of water needs to be stored on land. The land area is about 149 million km², of which 36 million km² is desertification land. Through the water conveyance projects, considering the replenishment of average depth of water 1 m to the lake basin, depression and stratum in the desert area, the sea level rise can be reduced by 0.1m. There are also many huge inland lake basins around the world, with huge water storage potential, for example, the Caspian Sea covers an area of 386000 km², and the elevation of the lake is 29m lower than the sea level[4], for every 1m rise of the lake level, at least 368 billion m³ of water can be stored.

Global warming is inevitable. Fortunately, the Paris Climate Agreement has specified that more than 100 billion US dollars will be raised to deal with climate crises such as sea level rise. In order to avoid the rapid rise of sea level, the a feasible way is to store water of land rainfall and melting glaciers on land, which needs the concerted efforts of all countries in the world. The increased amount of water into the sea due to climate change is shall be apportioned to every country in proportion to the land area in principle. China has a total area of 9.6 million square kilometers, accounting for 6.44% of the global land area. The amount of water required to reduce sea level rise by 0.1m is 36.1 trillion m³, and the amount of water required to be stored on the land of China is 2.32 trillion m³. North China has a vast plain of more than 700000 km². Due to drought and over exploitation, the groundwater level in many areas is very low. There are 2.67 million km² of desert Gobi in the west of China. Most of the huge lakes that once existed in history have shrunk or dried up. By replenishing groundwater and restoring ancient lakes, the share of China to store water on land can be achieved if the average water depth of 0.7m can be stored in arid areas.

In order to solve the problem of water shortage in Western China, many experts and scholars put forward the idea of transferring water to change the drought situation in Western China. Three representative schemes deserve to be mentioned, they are diverting the water of Bohai Sea into Xinjiang, transferring desalinated water to the Western China, and transferring water in Estuarine area from the east to the West. Huo Youguang et al. put forward the plan of diverting the water of Bohai Sea into Xinjiang, which takes 5 billion m³ seawater from the Bohai Sea near Tianjin, and pump it by step through pipelines to high ground, then make use of long-distance self flowing channel of 1900km to lead it to Shule River, and then flowing by gravity into Lop Nur[5]. Zhang Hengxu et al. proposed to vigorously develop desert renewable energy, desalinate and transfer sea water to the Western China, which estimated that the power required for desalinating and transporting fresh water equivalent to the average flow of the Yellow River 1774.5m³/s (56 billion m³ per year) to Xinjiang is 100 million Kilowatt, and the power fluctuation of renewable energy can be restrained by the desalination and transfer system to the West[6]. Zhao Dingfeng proposed to draw water from estuaries of the Yangtze River, Pearl River, Minjiang River and other rivers, divert 1325.5 billion m³ of fresh water to Xinjiang every year through a 4000km tunnel[7].

As noted above, these research show that the water source problem of transferring water of 100 billion m³ per year is not insurmountable, and the energy supply capacity of pumping water is no longer a constraint. However, as the water transfer project is a strategic project with great impact, involving many regions and fields, it is highly controversial in the academic circles and difficult to unify the views of various local and industrial departments. Generally, large scale water transfer project can change the geographical features of arid areas in scientific principle, the main controversy lies on whether the economic and environmental costs of water transferring are worth paying, and whether it can be replaced by other means such as water saving[8].
Thomas frederikse et al. analyzed the causes of sea level rise since 1900, the data confirmed that a sharp increase in water impoundment by artificial reservoirs is the main cause of the lower-than-average rates during the 1970s, which indirectly confirms the feasibility and effectiveness of storing water on land to reduce sea level rise[9]. Considering the current energy structure dominated by fossil fuels, large-scale water pump and transfer project is contrary to the goal of energy conservation and emission reduction to deal with climate change, which is difficult to implement immediately. In fact, more than 2 trillion m$^3$ of fresh water flows out of China every year, a large part of which is produced in the higher altitude steps and mountainous areas. Rational allocation of water resources in higher altitude areas can provide a large number of ecological water sources on the premise of meeting the needs of people's livelihood, environment and economy. According to the temporal and spatial distribution characteristics of water resources in China, the development of ecological water conservancy with the main purpose of coping with climate change, repairing and improving the ecological environment could be able to gradually achieve the goal of storing a large amount of water on land and significantly reducing sea-level rise at a small economic and environmental cost.

3. The water storage potential of land in China

3.1. The available groundwater storage capacity in Northern Plain

The soil in Northern plain is generally clay, silt and sand, with dry bulk density of 13~18kN/m$^3$ and saturated bulk density of 18~23kN/m$^3$. The preliminary analysis is based on the average groundwater level in the monthly report of groundwater level in October 2018 issued by the Water Resources Department of the Ministry of Water Resources, and the hypothesis that the groundwater level is raised to 3m below the surface and the soil water content per unit volume is increased by 5kN/m$^3$. The calculation results are shown in Table 1. As shown in Table 1, the available groundwater storage capacity in the main plain areas in north China can be increased by 1.9 trillion m$^3$. The plain of northern China where groundwater can be stored is shown in Figure 1.

| Region            | Average groundwater level (m) | Area (million km$^2$) | Available underground water storage capacity (billion m$^3$) |
|-------------------|-------------------------------|-----------------------|----------------------------------------------------------|
| North China plain | 7.36                          | 0.30                  | 654.0                                                   |
| Northeast China plain | 5.86                          | 0.35                  | 500.5                                                   |
| Fenwei plain      | 24.00                         | 0.07                  | 735.0                                                   |
| Total             |                               |                       | 1889.5                                                  |

Figure 1. Available underground water storage region in the main plains of northern China.
3.2. The available storage capacity of desert lake basin in Northwest China

There are numerous lakes in the arid inner flow area of North China, which can provide natural reservoirs for storing water on land. According to the satellite data, based on the principle of less impact on the existing residents and infrastructure, the available storage capacity is estimated that it can store more than 3.7 trillion m$^3$ of water in the Dabuxun Lake, Baitinghai Lake, Juyanhai Lake, Lop Nur, Hami Basin and Turpan Basin. The calculation results are shown in Table 2. The distribution of ancient lake basins in northwest desert where water can be stored is shown in Figure 2.

Table 2. Water storage capacity of several ancient lake basins in Northwest China

| Lake basins   | Elevation of water level (m) | Lowest elevation of lake bottom (m) | Average depth (m) | Water surface area (km$^2$) | Water storage capacity (billion m$^3$) |
|---------------|-----------------------------|-----------------------------------|------------------|-----------------------------|---------------------------------------|
| Dabuxun Lake  | 2690                        | 2680                              | 5                | 4500                        | 22.5                                  |
| Baitinghai Lake | 1300                        | 1190                              | 50               | 4250                        | 212.5                                 |
| Juyanhai Lake | 950                         | 740                               | 50               | 23500                       | 1175.0                                |
| Lop Nur       | 800                         | 790                               | 8                | 19900                       | 159.2                                 |
| Hami Basin    | 400                         | 73                                | 265              | 7600                        | 2014.0                                |
| Turpan Basin  | -50                         | -156                              | 50               | 2500                        | 125.0                                 |
| Total         | 62250                       | 3708.2                            |                  | 3708.2                      |                                       |

Figure 2. The distribution of ancient lakes in northwest desert.

Based on the analysis above, replenishing groundwater in the main plains of northern China and restoring several ancient lakes in Northwest China can store more than 5.6 trillion m$^3$ of water. Besides, by measures of converting farmland to lake, new reservoir, and soil and water conservation can store even more water on the land. All in all, corresponding to the share of China to store 2.3 trillion m$^3$ of water on the land to the reduction of sea level by 10 cm. There is enough capacity to accommodate the increased amount of sea water due to climate change in China.

4. The available water sources for storing water on land

According to the water resources bulletin of China in 2017 issued by the Ministry of water resources[11], the amount of surface water resources in China was 2.8 trillion m$^3$, of which 1.7 trillion m$^3$ flowed into the ocean, and 0.7 trillion m$^3$ flowed out of the country or into the boundary river. The total water supply in China is 604.3 billion m$^3$, and the total water consumption is 320.7 billion m$^3$.

According to the China Sea Level bulletin in 2014 issued by the State Oceanic Administration of China, the coastal sea level rise rate of China from 1980 to 2013 was 3mm/year, which is consistent
with those in the fourth assessment report of IPCC. In order to offset sea level rise by 3mm, the total water to be stored on land is 69.6 billion m$^3$ per year for China. Based on the situation of water resources in 2017, the storing water on land is equivalent to 4.1% of water flowed into the sea discharge and 11.5% of the total water supply. Therefore, it can be realized step by step to allocate the fresh water resources to offset the sea level rise and leave them on the land for ecological water supplement.

Figures 3 and Figure 4 show the water resources and utilization of major drainage basins of China. As shown in figures, there is more water in the South and less water in the north, the utilization rate of water resources in the southwest and Southeast rivers is low, and the utilization rate of water resources in the north is very high. In general, storing water on land could be achieved by transferring water from south to north.

![Figure 3. Comparison of total water consumption and unused water in major river basins in China (billion m$^3$).](image1)

![Figure 4. Utilization ratio of water resources in major river basins in China (%).](image2)

**5. Preliminary study on storing water on land and Ecological Water Conservancy Strategy**

5.1. Preliminary study on the scheme of storing water on land

The Middle Route and East Route of the South to North Water Diversion Project, and the water diversion project from Yangtze River to Huaihe River and from Hanjiang to Weihe River, which have been built or are under construction, will be used to supply water along the line. The water diversion will be increased to supplement for the Huai River, Yellow River and Haihe River. The ecological water will
be supplied to Beijing, Tianjin, Hebei, Henan and Shandong through the Yellow River Diversion Sluice, so as to replace part of the water used in lower reach of the Yellow River for the upper and middle reach to use.

In the near future, the project of diverting water from Tongtian River to Qaidam Basin is being designed, whose transferable water quantity can reach 1.5~3.0 billion m$^3$ per year. Utilizing the abundant photovoltaic resources in Qinghai Province, about 3 billion m$^3$ of water can be pumped from Longyangxia reservoir to Qaidam Basin. The project of diverting water from the Yellow River to Xining should be launched as soon as possible to divert water from Longyangxia reservoir to the surrounding areas of Xining. Guxian and Heishanxia reservoirs will be built to increase the water storage capacity of the main stream of the Yellow River and supply water to Shanxi, Shaanxi, Ningxia and other surrounding areas. The Heishanxia reservoirs in Ningxia province can be used to allocate water into Alxa Plateau, Ordos Plateau and Xinjiang. In this way, the 10~50 billion m$^3$ water of the West Route of the South to North Water Diversion Project and replaced water of the middle and lower reaches of the Yellow River can be allocated reasonably. Further, the Bailong River water diversion project, Xiaojiang River water diversion project, the water diversion project from Hanjiang to Weihe River, which have already carried out preliminary work or started construction, can transfer water to Gansu and Shaanxi nearby, so as to meet the demand of groundwater recovery in the Loess Plateau and Fenwei plain. Through the West Route of the South to North Water Diversion Project, the water from the southwest rivers and the upper reaches of the Yangtze River is transferred to the Yellow River. With the above water diversion projects, the goal of increase storing water on land by 100 billion cubic meters per year could be basically realized by gravity flow, which will effectively slow down sea-level rise, reduce floods and droughts, and promote the improvement of ecological environment. The main water diversion schemes are presented in Figure 5, in which the solid line indicates the built project, and the dotted line indicates the planned project.

![Figure 5. The layout of storing water on land in China.](image)

The water diversion projects are listed below: ① The Middle Route of the South to North Water Diversion Project; ② The West Route of the South to North Water Diversion Project; ③ The East Route
of the South to North Water Diversion Project; ④ The water diversion project from Yangtze River to Huaihe River; ⑤ The water diversion project from Hanjiang to Weihe River; ⑥ The water diversion project from Tongtian River to Qaidam Basin; ⑦ The water diversion project from Longyangxia reservoir to Qaidam Basin; ⑧ The water diversion project from Yellow River to Ningxia Province; ⑨ Guxian reservoir; ⑩ Heishanxia reservoir; ⑪ The water diversion project from Bailong River; ⑫ The water diversion project from Xiaojiang River; ⑬ The water diversion project from Yellow River to Shanxi Province; ⑭ The water diversion project from Songhua River; ⑮ The water diversion project from Dahuofang reservoir; ⑯ The water diversion project from Irtysh River to Urumqi; ⑰ The water diversion project of ABH; ⑱ The water diversion project from Yunnan Province.

5.2. The concept of ecological water conservancy

Traditional water conservancy projects are mainly built for flood control, irrigation, water supply, power generation, shipping and other purposes. With the development of human society from the stage of industrial civilization to the stage of ecological civilization, water and soil conservation, ecological water supplement of rivers and lakes, groundwater restoration, river and lake connection and other ecological water conservancy projects have gradually increased, which has become a new focus of water conservancy work. In 2017, the total amount of water supply for the improvement of ecological environment in China has reached 16.19 billion m³[11]. With the amount of water stored on land through returning farmland to Lake, soil and water conservation and new built reservoirs, the scale of storing water on land has taken shape. However, from the perspective of coping with climate change, ecological water conservancy projects are still in its infancy. On the premise of meeting the needs of economy, people's well-being and environment for water resources, it is necessary to explore new ways of ecological water conservancy in line with the new development concepts of "innovation, coordination, green, opening and sharing".

For the ecological water conservancy, the premise is to maintain the current situation of water use pattern, and use more or less water in case of water shortage. Namely, in the wet year and wet period, the water resources which are not beneficial or even harmful to people's livelihood, environment and economy will be stored as much as possible in arid areas. In dry years, priority should be given to ensuring water use for people's livelihood, environment and economy, even the stored water should be used to alleviate the problem of water shortage if necessary. In this way, the goal of more reasonable and balanced using of water resources to improve the ecological environment can be achieved.

In the frame of ecological water conservancy, the concept to conform to nature, respect nature and protect nature should be established. The projects should make full use of natural rivers, natural lake basins and existing projects, focus on the restoration of surface and underground water. Improve local climate through natural water circulation, rather than directly develop economy and man-made ecosystem with the traditional irrigation technology. From the point of view of storing water on land, as long as the leakage and evaporation can return to land through water circulation, there will be no water loss, so ecological water conservancy projects located in deep inland can simplify the anti-seepage and anti-evaporation measures. The allocation of water resources is realized through the large water network connecting natural rivers and lakes, which complements the wet and dry year. The storing water is realized through recovering natural lakes and groundwater, rather than building large reservoirs in valley.

The ecological water conservancy projects should follow the laws of economy and nature. The national water network should adopt the principle of gradual connection from south to north and minimize the adverse impact to economy and environment. Instead of transferring water resources across other river basins to dry areas at one time, it should adjust measures to local conditions, gradually connect rivers and lakes nearby, make full use of natural rivers and lakes and existing projects, and finally form a large water network to transfer water from south to north. Most of the surface water resources in China are produced in the high altitude steps and mountains. In order to reduce the energy consumption of pumping projects, the ecological water conservancy projects should ensure that the water resources of the higher steps be used for the high steps or adjacent steps. The resources of land,
fishery, forestry, agriculture, tourism and hydropower increased by ecological water conservancy projects can be used appropriately to develop economy and then improve the efficiency and sustainability of ecological water conservancy projects.

5.3. **Layout of ecological water conservancy projects**

The amount of water stored on land in response to climate change is unprecedented. Different measures should be taken according to local conditions to conserve land water and reduce the amount of water into the sea. Specifically, in the South and other humid areas, storing water on land is mainly through soil and water conservation, returning farmland to lakes, protecting wetlands and building new reservoirs, which can also provide water source for the water diversion project to arid areas. In the northern plain, the main measure is to build plain reservoirs, seepage canals and seepage wells to replenish groundwater and to store water in depressions and lakes. In the western desert, a large amount of water will be stored in natural lake basin through water diversion project to improve local climate. The West Route of the South to North Water Diversion Project is a hot topic in recent years. Academician Deng Mingjiang commented the planning scheme with the annual total water transfer volume ranged from 17~300 billion m³[12], and suggested that the West Route of the south to North Water Diversion Project is an indispensable major project for the implementation of national strategy, the government should organize and carry out the preliminary work as soon as possible.

Ecological water conservancy is of great scale and far-reaching influence, which needs decades to complete. So the layout of water diversion project should be carried forward based on the status of economic and social development. Firstly, in the near future, take the South to North Water Diversion Project as main artery to transfer 44.8 billion m³ of water from the Yangtze River every year. Secondly, in case the water resources of the Yangtze reduce with the water diversion projects, connect the Yangtze River with the Pearl River, Southeast and southwest rivers, and transfer more than 50 billion m³ of water into the Yangtze River. In this way, the national water network has the ability to transfer 100 billion m³ of water to the north every year.

Some of the water transferred from the South China with good quality directly deliver to the receiving area through the first phase of the Middle Route South to North Water Diversion Project, other is mainly allocated to the west and both sides of the Yellow River. In order to reduce energy consumption and avoid large-scale pumping, in the coastal plain area with the abundant water and relatively low water transfer cost, as much water is transferred from the south to the north as possible to replace part of the water originally supplied by northern river, and the replaced water is used for the upstream areas where water diversion costs more.

6. **Conclusion and discussion**

(1) The sea level rise caused by global warming can be effectively alleviated by storing water on land. Particularly in China, storing water on land can be achieved by restoring groundwater in the North China and restoring ancient lakes in the Northwest. The available water source can be allocated with the national water network connecting the South and North water systems.

(2) The concept of ecological water conservancy is different from the traditional water conservancy project. The main purpose of ecological water conservancy project is to repair and improve the ecological environment, and the method is to restore the surface and underground natural water. In the frame of the ecological water conservancy, the natural circulation process of water is used to influence the local climate on a large scale and support the improvement of ecosystem and economic development.

(3) This paper is only a preliminary exploration on the ecological water conservancy. The construction of ecological water conservancy projects in response to climate change need to launch an joint research involved water conservancy, meteorology, ecology, geography and other disciplines. A huge amount of effort should be taken to achieve the goal of ecological water conservancy with lower environmental cost and better ecological benefits.
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