Study on Key Technologies of Ecological Civilization of Lishui Ancient City Water System

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Abstract. Starting from the historical dimension, this paper studies the historical documents and engineering cases of ancient water conservancy projects in Lishui, explores the transformation law of urban water system in Lishui, and summarizes the key technologies of water ecology contained in ancient water control practice. It was found that Chuzhou took advantage of geographical, geological and climatic conditions, followed the overall balanced water control strategy, planned the ancient city water system network, and completed the task of water distribution. Among them, guided by planning technology, supplemented by canal system network, water and sediment regulation, flood control, interchange diversion and other technologies, a perfect water system is finally formed, which can provide reference for modern water conservancy projects construction.

1. Introduction
At present, with the vigorous development of water conservancy projects in China, it has brought a burden to the natural environment and caused some harm to the local ecological balance. Problems such as water ecological imbalance and river depletion have become increasingly prominent. How to restore the ecological function of the water system is a problem to be discussed now. The ancients used natural terrain as a carrier to build weirs and canals, transformed the water system by means of river guidance, so that its space-time distribution was gradually balanced, and a water system network with overall consideration was formed. After hundreds of years or even thousands of years of historical tests, it still plays a role, which has very important application value and guiding significance. Studying the ecological wisdom inherited from the ancient city water system, guiding the construction of modern water conservancy projects, and making them continue to rejuvenate, is the demand of regional water system development, and also conforms to the concept of harmonious coexistence between man and nature. Ye Zhou¹ studied the water diversion project of Daliu weir in Xuanping River, and found that network and network flow are the key to successful water control, which accords with the traditional water control concept and modern science and technology theory. In the process of artificially transforming nature, Wang Mengying et al.² thought that ancient water conservancy projects always took advantage of the trend in the development process, relying on the natural water network and topography to transform them, and formed a systematic and effective water control strategy. Han Shuangyu³, inspired by the construction of ancient Chinese urban water system, thinks that modern ecological water system planning should adhere to ecological priority, harmony between people and water, and imitate the ancient ideas of adapting to local conditions, seeking advantages and avoiding disadvantages. Lu Yong et al.⁴ thought that water control in ancient China often took traditional philosophy as the guiding ideology, carried out the core concepts of dialectical unity and adapting to local conditions, followed the laws of nature as the code of conduct. On the
protection and utilization of ancient water conservancy projects, Xie Santao et al.\[5\] think that ancient water conservancy projects should take the road of coexistence of heritage protection and regional development, and give full play to their cultural value and water conservancy function while doing a good job in heritage protection. Wu Qingzhou\[6\] thinks that the ancient urban water system is composed of moat and lakes and marshes of the city, which has multiple functions and can be used for reference for flood control and drainage in modern cities. Wang Dingzheng\[7\] got inspiration from the successful water conservancy projects in ancient times. The ancients' understanding and rational use of river characteristics and natural laws are the experience and wisdom that modern water conservancy projects need to learn. The construction and utilization of water conservancy projects always run through the process of China's economic and social development, and play an important role in promoting economic development and social progress\[8\]. From the above scholars' research, it is found that the ancient people's idea of water control is generally recognized, but their research is not deep enough or they don't take ancient engineering technology as the research object, so how to apply the idea of water control thought to modern water conservancy projects construction remains to be studied. This paper analyzes the water system and water conservancy development history of Lishui city from the historical perspective, explores the transformation law of Lishui city water system, and summarizes the water control concepts and key technologies inherited for thousands of years, so as to further guide the construction of modern water conservancy projects.

2. Water system composition of Lishui ancient city

Lishui was called Chuzhou in ancient times, and its water system is well developed. It is called "the source of six rivers". It is the headwaters of the six rivers of Oujiang River, Qiantang River, Feiyun River, Jiaoxi River, Minjiang River and Jiaoxi River. Oujiang River runs through the whole mountainous area of southern Zhejiang from west to east, which is a typical mountain stream river with large longitudinal bottom slope, restricted by valleys on both sides of the river, rapid water flow, great inter-annual differences in water resources, extremely strong seasonal changes in the year, and frequent floods and droughts. Under this background, a group of water control sages emerged, who built weirs and canals, rationally planned, diverted water to irrigate farmland, drained water and resisted drought, and ensured the safety of the place. In 505 AD, Zhan and Nan founded the Tongji Weir, which crossed Songyin River and diverted water into canals. In the Tang Dynasty, Duan Chengshi built the Haoxi Weir, and ensured a bumper harvest of grain in the eastern suburb of Chuzhou City. In the Song Dynasty, Zhao Shanjian built Liyang Canal and diverted water into the city. At this point, the water system in the ancient city of Chuzhou is basically complete. In the west of the city, there is Songyin River water to irrigate the farmland of Bihu Plain, and to the east of the city there is Haoxi River to irrigate the eastern suburbs plain. The city's inland river water is mainly composed of Liyang Canal water, supplemented by Haoxiyan River, forming an urban water system network integrating irrigation, fire fighting, flood drainage and drought resistance, environmental water and domestic water.

3. Analysis of key technologies

Based on the analysis of the evolution law, structure characteristics and flow characteristics of the water system in the ancient city of Chuzhou, the key technologies of water ecology contained in the ancient water control practice are explored, which can provide experience for the construction of modern water conservancy projects.
Figure 1. Schematic diagram of ancient urban water system in Lishui.

Figure 2. Schematic diagram of modern urban water system in Lishui.

3.1. planning technique

In the historical development, the demand for domestic and production water makes people usually live by water, so water system planning and design is indispensable. From the research, it is found that the ancient water system planning takes water demand as the starting point, uses topography to select water sources, and uses water energy as the power to solve the distribution problems of flow and velocity of water resources for various purposes.

The ancients have been able to skillfully use water energy as power, so that the regional water network can be unblocked[9]. On the military side, in order to resist the invasion of the enemy, Chuzhou is surrounded by city walls, with mountains in the north as natural barriers, and in the south, according to the high and low terrain, taking advantage of the fast-flowing characteristics of Daxi River as a natural moat, it can also avoid flooding into the city. In terms of farmland irrigation, the Tongji Weir was built in the west of the city, Songyin River was chosen as the water diversion source, and the dam was built at the highest elevation in the southwest end of Bihu Plain. The gravity
irrigation of farmland was basically realized by using the terrain drop of nearly 20m in Bihu Plain. Haoxi Weir was built in the east of the city, and Haoxi River was selected as the water source for water diversion, irrigating 480 hectares of farmland. In addition, Chuzhou City has a high terrain in the southwest and a low terrain in the northeast. The water inlet canal is located at the southwest end of the dam, which can prevent the stream from flowing backwards and flooding into the city. Furthermore, by controlling the flow of the diversion sluice, the speed of Haoxi River is slowed down, the boats can be unblocked, and the transportation is convenient. In terms of living and production water, the Liyang Sluice is set, with Liyang Canal water in the north as the inner river water. The terrain of Chuzhou City is high in the southwest and low in the northeast, and it is divided into the southwest canal and the east canal, which can be used by the whole city. The water diversion sluice is located at the maximum slope of Liyang Canal (28.5%), and sufficient water can ensure that the canal water can flow and reduce water pollution. The design of the diversion sluice is also unique, with stratified water intake. The surface water quality is better to flow in through the southwest canal for residents’ daily use, while the lower water body is turbid and flows into Haoxi River through the east canal for farmland irrigation.

The ancients used terrain by planning various elevations, selected water sources and considered various demands to transform the water system. It is found that the diversion sluice, weir dam, flood dike and fishway can distribute water by selecting different elevations (Table 1).

| Name            | Elevation of weir crest. | Elevation of weir bottom. | Elevation of the top of the sluice. | Elevation at the bottom of intake. | Note                      |
|-----------------|--------------------------|----------------------------|-------------------------------------|-----------------------------------|---------------------------|
| Tongji Weir     | 76.85                    | 75.60                      | 78.04                               | 76.04                             | /                         |
| Haoxi Weir      | 65.67                    | 63.35                      | 68.04                               | 64.54                             | /                         |
| Liyang Canal    | /                        | /                          | /                                   | /                                 | The bottom elevation of Liyang Canal 87.73 |

Figure 3. Elevation data table of ancient city water system in Lishui.

In ancient times, there was no electricity, so we could only rely on natural water energy as power. Tongji Weir, Haoxi Weir and Liyang Canal all use the power generated by the head fall between the upstream and downstream to achieve the goal of water resource allocation through the self-flow of the water body, as shown in Figure 3. Moreover, the hierarchical water lifting systems such as dams and
sluices also rely on water energy to operate, through these buildings, effective distribution and utilization of water resources are realized, and the system of water diversion engineering network is enhanced.

3.2. Canal system network technology

The elevation system determines the utilization efficiency of the river, and the operation of the irrigation system depends on the canal system network technology. Canal system network is composed of water source, canal system and nodes. The water sources mainly include rivers, springs or wells, the canal system includes rivers, channels and pipelines, and the nodes include reservoirs, ponds and lakes.

(1) water source. The water sources of Tongji Weir irrigation area include the upstream Songyin River, the mountain streams and rivers in the irrigation area and natural precipitation. Among them, the spatial and temporal distribution of natural precipitation is uneven, and the mountain streams and rivers in the irrigation area are mainly springs and pits, which are still limited by precipitation and time and space. The water retaining dam in Tongji Weir is built at the highest elevation in the southwest end of Bihu Plain. The site selection is reasonable. By using the natural topography and the head difference between upstream and downstream, the average daily water amount from Songyin River to Tongji Weir is 200,000 cubic meters. Generally speaking, Songyin River is used for water diversion projects in Tongji Weir. When there is insufficient water in Tongji Weir in dry years, ponds and lakes are used to store water, which plays an important role in regulating climate and feeding back rivers. In addition, the arch dam is built above the confluence of Songyin River and Daxi River. During the flood period, the dam is supported by the natural back flow of Oujiang River, which reduces the pressure of flood on the dam and makes the dam always strong[10]. The water source of Haoxi Weir irrigation area is mainly from Haoxi River, and the water retaining dam is built on Haoxi River at the foot of Lingjiu Mountain. Choosing Haoxi River as the first water source has many functions. Its main functions are as follows: First, irrigation of farmland. Haoxi Weir provides irrigation water. Second, it provides domestic water, which greatly facilitates the domestic water of coastal people. Third, it is convenient to provide transportation. By changing the river to control the flow of the diversion sluice, the speed of Haoxi River is slowed down, and the boats can be unblocked. The water source of Liyang Canal is mountain stream water, which is the first water source of urban inland river and the second water source of Haoxi River. This can not only ensure sufficient water in drought, but also divert mountain torrents from streams during flood, thus reducing floods in villages near canals.

(2) Canal system. The characteristics of water consumption in irrigation area require the reliability and stability of canal water, and the regulation of water consumption mainly depends on the canal system network on the weir. There are three sluices, and the weir is divided into middle branch, south branch and north branch. Yexue Sluice is in front of it, and it opens floodgates when the canal water surges to prevent the canal head project from being damaged. Fengtai Sluice, Xiagaitou Sluice, Muxihua Sluice, Chengtang Sluice and Jinsi Sluice are behind it, which are connected in turn but each has a branch canal. Kaituo Sluice is divided into three branches, the middle branch is Fengtai Sluice, the south branch and the north branch have less water, which is used to irrigate the nearby farmland, and some of its branches communicate with Fengtai Sluice to supplement the water. The upstream water is gradually reduced, and the sluices are all connected in parallel. The insufficient water quantity is supplemented by the upper sluice branch. If the water quantity is sufficient, the tail sluice can save the surplus water to form a network flow, and it can also prevent the system from being paralyzed due to the damage of a certain sluice. Combined with the corresponding channels, straight and uniform in width as the water delivery channel, and tortuous and uneven in width as the water intake channel, so as to ensure that the canal water can be fully utilized, it can be used for more than a thousand years. There are more than 50 large and small sluices along the canal of Haoxi Weir. At the same time, 5 flood diversion dams and 3 interchanges are built to control water diversion, diversion, water supply and drainage[11]. Liyang Canal is divided into southwest canal and east canal. Most of the southwest canals are irrigation water, which is used in conjunction with Ying Xing Sluice. Water is stored in case
of drought, and water is released in case of waterlogging. The east canal is mostly used by people for fire fighting, living or production.

(3) node. River ponds and lakes, including natural lakes and artificially reconstructed and excavated ones, are important components of canal system network\[^{12}\]. It saves the surplus water of the weir when the water is abundant, and supplements the shortage of the weir water when the water is dry. It can be used for flood discharge and waterlogging, and can also play an important role in regulating the climate and feeding back the river.

Tongji Weir, Haoxi Weir and Liyang Canal have the same characteristics. In the aspects of water source, canal system, nodes, etc., according to the ideological concept of guiding according to the situation and adapting to local conditions, the dam site is selected reasonably, and a canal system network combining irrigation and diversion is formed. Moreover, Tongji Weir, Haoxi Weir and Liyang Canal constitute a water network as a whole. It irrigates farmland with "two weirs in the east and west", and Liyang Canal is the city's inland river, which integrates functions of irrigation, fire fighting, drainage and drought resistance, environmental water and domestic water, etc. It conforms to the concept of "harmonious coexistence between man and nature" and is worthy of reference for modern water conservancy projects.

3.3. Water and sediment control technology
Sediment transport is an important hydrological phenomenon in rivers, which has great influence on the changes of rivers. Sediment deposition in the diversion canal system will lead to insufficient diversion flow, greatly reduce water supply efficiency, raise flood level, reduce the ability of river channel to vent flood, and increase flood disaster and loss. The ancients reduced sediment deposition by adjusting the flow velocity of canal. Take Tongji Weir as an example. Tongji Weir is adjusted by 72 sluices\[^{13}\]. The main sluices are divided into three branches on the left, middle and right. The height difference at the bottom of the three branches is different, the middle canal is the lowest. When all the sluices are opened, the canal water only goes down the middle canal, and the left and right branch canals are basically waterless. When the last one is generalized, the canal flow goes to the left and middle branches. When the two blocks are generalized, there are water flows in all three branches. When all three pieces are covered, the canal flows to the left and right branch canals, leaving no water in the middle canal. That's it, the water diversion is adjusted by the opening of the sluice, and then the channel flow velocity is adjusted. Sediment is easy to deposit on the left bank side of the northern hemisphere river, while the right bank side is affected by geosteering force, so the river has strong
erosion force and sediment is not easy to deposit. On the far left side of the canal system network in Tongji Weir, there is Yexue Sluice to monitor sediment deposition. If sediment deposition occurs, the floodgates can be opened when the river surges, and the natural impulse can be used to remove sediment.

3.4. Flood control technology
It is the guiding ideology of the ancients to avoid water disasters by water conservancy[14]. There is a Yexue Sluice in Tongji Weir water conservancy project, which is an approximate sluice connected with Daxi River. Ye Xue Sluice leads directly to Daxi River, and takes advantage of the difference in terrain to open floodgates when the canal water surges. At the same time of flood discharge, the natural impulse is used to remove the silt in the channel, so that Tongji Weir has the function of self-metabolism. Moreover, the main canals in Tongji Weir are all close to Daxi River, which can play a role in preventing dams destruction during flood season. The water diversion sluice of Liyang Canal also acts as a diversion gate. When flash floods occur, the water in Liyang Canal flows out from the southwest canal and finally flows into Daxi River through Ying Xing Sluice. There are five flood diversion dams along the canal of Haoxi Weir, all of which are overflow dams and small gravity overflow dams. During the flood period, the weir water overflows from the dam crest to achieve the purpose of flood discharge and ensure the safe operation of Haoxi Weir. See Table 2 for related parameters.

### Table 2. Main dimensions of water diversion projects.

| Name (flood diversion weir) | Length (m) | Height (m) | Slope ratio |
|----------------------------|------------|------------|-------------|
| Wayaotoufan                 | 8          | 1.5        | 1:3         |
| Gongchanba                  | 3          | 2          | 1:3         |
| Shanghefan                  | 7          | 3          | 1:2         |
| Liangtangfan                | 8          | 3          | 1:2         |
| Haichao                     | /          | /          | 1:2         |

3.5. Interchange diversion technology
During the flood period, the mountain stream water is rapid and large. If it flows into the weir directly, the sand and stone carried by the mountain stream flood often silts the weir and even destroys the weir. Through the construction of Shihan overpass, Tongji Weir combines drainage with traffic, and passes through people, diverts water from spring pit to Daxi River, and the canal water flows from Shihan Bridge to the East without interfering with each other. It not only solves the problem of sand silting up the channel when the spring stream water is concurrent, but also solves the traffic between weir and both sides of the river. The water interchange of Haoxi Weir is similar to that of Shihan Bridge in Tongji Weir. There are Liangpengxia interchange, jiuliwan interchange and luxiaomen interchange. Among them, Liangpengxia and jiuliwan interchange are divided into aqueducts with certain depth, which leads the mountain stream from Haoxi Weir, so that the weir water and the stream water do not interfere with each other. Luxiaomen interchange is located at the intersection of Donghuancheng River and Haoxi Weir. The water level of Donghuancheng River is low and that of Haoxi River is high, so overpass is adopted for diversion.

4. Conclusion
The study found that ancient Chuzhou took advantage of the geographical, geological and climatic conditions, followed the overall balanced water control strategy, planned the ancient city water system network, and completed the task of water distribution. In the early stage of water control, agricultural civilization was in the primary stage. The ancient water conservancy projects focused on disaster prevention and irrigation. In the middle stage, water conservancy technology was significantly improved, and the functions of water conservancy projects expanded to flood control, irrigation, shipping and other aspects. In the later stage, water conservancy projects were gradually systematized
and focused on integrity, with weirs and dams for water diversion, ponds and lakes for water storage, and artificial canal water system for regulating water volume and river direction. In order to achieve the goal of ecological sustainable development, we should combine scientific water control with urban planning. Engineering technology is first reflected in the allocation of water resources among various uses. Canal network and diversion sluice regulate the relationship between river water quantity and farmland irrigation water demand, and the reasonable distribution of water energy should be considered in engineering technology. Rivers, canals and ponds constitute the water diversion network, and on this basis, the kinetic energy system is formed. The dam and sluice are operated by hydraulic energy. The network flow composed of each node cooperates with each other, and each system is linked together, which enhances the integrity and systematicness of the water diversion project network. Finally, with the help of relevant technical means, such as water and sediment control, flood control weir, interchange diversion, the whole system can operate normally. From the ancient urban water system of Lishui, it can be seen that the complete water system network needs to be realized by engineering technology. The key technologies of water ecology contained in it can provide experience for the construction of modern water conservancy projects.

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