3rd World Irrigation Forum
1-7 September 2019, Bali, Indonesia

Hosted by:

Indonesian National Committee of ICID (INACID)
Ministry of Public Works and Housing
Directorate General of Water Resources
SDA Building, 8th Floor, Jalan Pattimura No. 20
Kebayoran Baru, Jakarta Selatan 12110
Republic of Indonesia

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International Workshop on
Historical Water Sustainability (HIST)

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International Commission on Irrigation and Drainage (ICID)

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Indonesian National Committee of ICID (INACID)
Ministry of Public Works and Housing
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SDA Buiding, 8th Floor, Jalan Pattimura No. 20
Kebayoran Baru, Jakarta Selatan 12110, Republic of Indonesia

Supported by:
Ministry of Public Works and Housing; Ministry of Agriculture; Ministry of National Development Planning; Ministry of Foreign Affairs; Ministry of Tourism; and Provincial Government of Bali, Republic of Indonesia

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August 2019
INSTITUTIONAL SETUP OF IRRIGATION AND DRAINAGE IN AFGHANISTAN

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ABSTRACT

Farmers in Afghanistan have a long history of operating and managing irrigation systems by themselves through local communities. These informal systems account for an estimated 90% of the country’s irrigated area. Surface systems supply water to about 86% of irrigated areas but the process and operation of these organizations vary. Surface irrigation systems are extensively managed by local community as autonomous units under a well understood and respected Mirab system without external support. The Mirab or Water Manager is a community member selected by the farmers for distribution of water and maintenance of infrastructure, e.g. channels, structures, etc. Moreover, Mirabs of various neighbouring communities interact with each other for making decisions in matters related to water rights and periodic repairs of common structures servicing their systems. In both surface water and karez systems, water allocations are based on water entitlements and rotations, with customary rule and regulations, guiding rights and locations of access to water.

Water users’ involvement and participation act as a catalyst for successful implementation as well as sustainability of any irrigation related development undertaking. It is, therefore, planned to mobilize farmers to actively participate in all implementation and post completion stages of irrigation projects. Social mobilization will be imperative in the execution of all envisaged interventions. Physical improvements will take place gradually once the process of strengthening the Mirab system is completed through the establishment of Irrigation Associations (IAs).

This paper describes the existing institutional set up of traditional Mirab system, its strengthening through the establishment of IAs and its role in operation and maintenance of irrigation canals. It also covers the topic of capacity building and resolution of water management related issues under On Farm Water Management Project (OFWMP), Ministry of Agriculture, Irrigation and Livestock (MAIL). It outlines different mechanisms, processes and activities which can improve and modernize the traditional Mirab system with the help of IAs in terms of operation and maintenance, institutional strengthening and capacity building of water users. Capacity building can be achieved through the conduction of various activities like: workshops, trainings, field days and regional field visit of improved and rehabilitated irrigation canals. The paper also highlights the need and importance of social mobilization and capacity building of the institutional setup (Mirab system/IAs) in the development of irrigation infrastructure in Afghanistan which can lead to enhanced water and land productivity.

Keywords: Mirab System; Irrigation Association; On-Farm Water Management; Ministry of Agriculture, Irrigation and Livestock (MAIL); Afghanistan.

1. INTRODUCTION

The Afghan economy, like other Asian economies, still heavily relies on agriculture. The aridity of the climate causes water resources to be scarce and 80% of agriculture

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depend on irrigation. Like in other Central-Asian and Middle-eastern countries, farmers have over the ages learnt to cope with a limited and infrequent supply of water and have developed appropriate structures and mechanisms (Eric Viala 2004). Agriculture is the backbone of the Afghan economy. After the service sector, agriculture is the biggest contributor to national GDP with up to 31% (MAIL, 2015). It provides employment to 60 to 70% of the population. Recent remote sensing data shows that Afghanistan has 9.61 million ha of arable land out of which 5.5 million ha has irrigation potential (FAO, 2014). It is believed that only 2.1 million ha has irrigation facilities and another 2.26 million ha can be brought under irrigation.

Irrigation systems in Afghanistan are of five types, namely: i) modern surface systems, ii) traditional surface systems, iii) springs, iv) karezes, and v) wells. Modern systems represent about 10% of the total irrigated area; karezes represented about 5%; springs represent slightly more than 5%, and traditional canal irrigation systems with intakes from various rivers and streams represent more than 80% (Anderson, 2006; FAO and AIMS, 2004).

2. Irrigation Institutions in Afghanistan and their Characteristics

2.1 Irrigation Systems in Afghanistan

Historically, irrigation was supplied by traditional irrigation systems. These systems are with few or no engineered structures and which generally rely on earthen water conveyance and control structures for water delivery. They are widely distributed throughout Afghanistan. Their sizes vary widely from a few hectares in high mountain valleys to extensive networks covering thousands of hectares in the plains. Reflecting the distribution of irrigation in the country, these systems also exist most extensively in the larger lowland provinces (Qureshi, 2002). In most cases, they have existed for generations and have undergone many physical and social changes. They have expanded or, in some cases, contracted as a result of water availability or the challenges posed by conflicts (Viala, 2003). It is estimated that there are nearly 28,000 traditional irrigation systems in Afghanistan.

2.2 Traditional Irrigation Institutions

The traditional irrigation systems in Afghanistan have been historically well managed, maintained and organized by the local communities. Operation and maintenance of these irrigation systems are carried out by local water users, typically headed by a water master, locally known as Mirab. This word "mirab" comes from a combination of the Arabic word "mir" (or amir-emir) which designates a leader, and "ab", the Dari word for water. The same word is also used in Iran and Central Asia. Several previous studies on the topic describe the traditional role of the mirab as a service provider and the arrangements for water allocation and maintenance work over generations, both in times of war and peace (Lee, 2007). The mirab system has been
observed to have a long history and possess its own characteristics that have been well integrated into the country’s natural and social background (Roe, 2008).

2.3 Characteristics of Traditional Irrigation Institutions

The Mirab system is distinctly characterized in terms of: responsibility, apprenticeship process, flexibility of organizational structure, basis and process of water allocation and distribution, resource mobilization for operation and maintenance and process for conflict resolution.

The mirab is an individual, appointed from among the land owners by the land owners for a given period of time (one to several years). He is entrusted with the responsibility of irrigation water allocation and distribution within the system and is made responsible for all decisions. Mirabs generally belong to the same community and are elected through shura (the village or community gatherings).

They are usually respected elders that act altogether as a steward of the water conveying infrastructure, a controller of water flows and as a facilitator of allocation disputes. They spend a lot of time walking along the canals, inspecting regularly the river intake, the main canal, secondary canals, control structures and turnouts.

Another important feature of the Mirab system is that it includes an apprenticeship process. In most irrigation systems, Mirabs are being assistant by “chakbashi” at secondary and tertiary level of canal. Chakbashilook after the water allocation, operation and maintenance of irrigation canal at secondary and tertiary level. Some mirabs "inherit" the position from their father after having served as an assistant for a considerable length of time.

The organizational structure of the mirab is also quite flexible. It varies depending on the size and layout of the irrigation scheme. In some cases, there is one mirab (with some assistants called Chakbashi) for the main canal, who controls the canal intake and the distribution into secondary canals. Longer canals can be operated by two (or maximum three) mirabs, one being the upstream mirab and the other being the downstream mirab. They confer on major decisions, but each of them maintains his part of the canal and operates the turnouts. Secondary canals can be managed by sub-mirabs/chakbashi or directly by the communities.

Another characteristic of the mirab system is that water allocation regime is based primarily on land ownership and share of contribution to the infrastructure maintenance. There are usually different levels of allocation processes: the head mirab (mirabbashi) manages and allocates water along the primary canal, while along branch or secondary canals (each usually serving a village or a community), water resources are allocated by Chakbashi/sub-mirabs or directly divided by the communities/villages.

3. ROLES AND RESPONSIBILITY OF IRRIGATION INSTITUTIONS

3.1 Operation and Maintenance (O&M)

Based on the IAs' By-Law/ procedure and Afghan Water Law, IAs are responsible for managing the operation and maintenance of irrigation canals under the preservation of the traditional Mirab system, a cultural heritage designed for better management of water intended for irrigation (Afghan Water law/26 April 2009).

The Statute/guideline of IA’s is more focusing on overall management of IAs but specifically on the IA’s Term of Reference (ToR) of each members (Mirab/ Chakbashi,
Secretary, Treasurer and General body members). It is clearly mentioned in ToR to take very serious care of O&M and repaired canals in Defect Liability Period (DLP) and even after the final handover to the community.

3.2 Irrigation Associations (IAs) Bank Account Establishment

Each established IAs has bank account and based on the Irrigation Associations By-Law/ procedure member of each IAs collect their share base on land holding (usually 250 AFN/ha) for O&M of the Irrigations canals/ schemes or any other irrigation related activity. Collection of money and deposit to their bank account is also the responsibilities of IA’s members.

Bank Account is compulsory for each IA’s within the irrigation projects of Ministry of Agriculture, Irrigation and Livestock (MAIL) which has been implemented or will be implement in future. The bank account will help to save the collected money safe & secured and IAs member can withdraw money base on their need for operation & maintenance of canal.

MAIL have around 600 IA’s throughout the country and all of them have their Bank Accounts. The IAs deposit their collected money to their Bank account. The deposited money is not only for O&M but can also be used for other new schemes/ canal rehabilitation works. For the time being, the IAs have collected more than 8 Million AFN in their accounts. The purpose of this member fee is for O&M and to support other related irrigation activities.

3.3 Fund for the O&M

With respect to clear guidance of internal rule and regulations of each IA members who has land and water right should pay their member fee. Based on need assessment IA members can withdraw from bank account for repair and maintenance activities of irrigation scheme.

4. SPECIAL EFFORTS BY OFWMP

On-farm Water Management Project (OFWMP) is one of the major irrigation project under MAIL funded by the World Bank. OFWMP has rehabilitated the irrigation schemes with the huge investments and handed them over to the respective communities or stakeholders. With the passage of time, some part of the project maybe damaged by some reason, maybe physically damage due to low quality or any natural disaster (flood & earthquake). Hence, there isa need to havean institution to take care of the damage.

OFWMP has proper mechnism for operation and maintenance under Irrigation Association establishment to improve the sustainabiliy of the implemented irrigation project. Before the implementation of any irrigation, OFWMP follows the following steps:

- a) Social Mobilization
- b) IAs establishment
- c) IAs registration with MAIL
- d) Opening of Bank account
- e) Collection of land & water right fee (250 AFN/ha)
- f) Implementation of irrigation sub-project
- g) Handover of irrigation sub-project to the community
- h) Capcity building of IAs
- i) Operation & Maintenance
4.1 Capacity Building

OFWMP and other irrigation project working under the Ministry of Agriculture, Irrigation & Livestock (MAIL) to build the capacity of established Irrigation Associations (IAs) throughout the country. The aim of capacity building to improve the institutional strengthening of traditional Mirab System under Irrigation Associations, capacity building in O&M of irrigation canals and dissemination of modern agricultural and irrigation practices. Capacity building of IAs consist of arranging national IAs workshops, trainings, conducting field days and field visits. All the projects working in irrigation under ministry of MAIL are responsible to build the capacity of established IAs. Till now, 600 IAs have been established throughout the country and trained in O&M of canals, institutional setups has been upgraded under Mirab system, conflict resolution, modern irrigation and agriculture practices.

4.2 Resolving Water Management Problems/ Issues

During implementation of irrigation sub-project in different provinces of country, the project has different sort of issues either with community or contractor or any other stakeholder. The project has developed grievance redress mechanism (GRM) to resolve the related issues on time against the compliant received either from community, contractor and any other stakeholder.

4.2.1. Objective of OFWMP Grievance Redress Mechanism

In the context of OFWMP, a grievance/complaint is defined as an oral or written expression of dissatisfaction or concern about facilities or services provided, about the compensation of lost economic assets or about actions or lack of actions taken, and can be made by individuals or groups. Grievances might take the form of enquiries regarding the nature or purpose of services or facilities, or suggestions as to alternative ways in which the purpose of an activity might be achieved.

The objective of the OFWMP complaint handling system is to ensure that the views and concerns of those affected by OFWMP activities are heard/ noticed and acted upon in a timely, effective and transparent manner. The complaint or issues received through GRM will be resolved by social team of the project at regional level.

4.2.2. Type of Grievances

Grievances may arise from the implementation of the irrigation canal rehabilitation activities such as canal lining, installation of field turnouts, construction of culverts, labor hiring and tree cutting. While most grievances will arise from residents (residential and commercial structures etc), issues might also be raised by people who feel they have been or will be negatively impacted by someone else’s activities. It often marks the beginning of a dispute between them, or even by service-providers and other institutions. Before outlining, the procedures for recording complaints and obtaining redress at various levels, a tentative list of the types of grievances that have been handled through OFWMP are provided below:

a) Irrigation Association Formation and Management

There may be grievances regarding the process of election of members of the IA head and deputy head, or the role of OFWMP Regional Office in the negotiation and implementation of sub-projects. Failure to address these effectively at an early stage of the sub-project cycle could undermine the credibility of the IA and/or OFWMP Regional Office, thereby affecting the finalization and initiation of upgrading works.
b) Inter-community disputes

During the implementation of upgrading/ rehabilitation activities such as canal lining, installation of field turnouts, construction of culverts, labor hiring, alternate canal of providing irrigation water, tree cutting and these may have a direct impact on private property, public land or access by residents to services and infrastructure which result in community disputes.

c) Process delays

OFWMP procedures require a representative of the OFWMP Regional Office or PMU to endorse invoices submitted for payment by contractors, before these are forwarded to MAIL for payment. Delays in processing these invoices and making payments to the contractors could affect the pace of upgrading works on site, which may result in grievances from the contractor, residents or others directly affected by the sub-project. As with other contracted works under OFWMP, it is vital for the PMU to address any such grievances in a timely manner, in consultation with MAIL staff and others involved.

![Grievance redress resolving mechanizim](Figure.1 Grievance redress resolving mechanizim)
4.2.3. Principles, Procedures and Timeline for Resolving Grievances

All grievances submitted in writing to staff assigned under OFWMP will be formally recorded (and entered in a database), and a written acknowledgement issued. Grievances will be dealt with on a referral basis; those that the IAs are unable to resolve will be referred to a OFWMP Grievance Committee, with a final provision for appeal to MAIL, if an issue cannot be resolved with the Committee. Every effort will be made to address or resolve grievances within fixed time-lines, which will be an indicator against the performance of the handling system is evaluated.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The overall conclusion from the current situation of Mirab system and the strengthening of this system through establishment of IAs in projects working under MAIL has a significant effect on the performance of Mirab system in the context of institutional strengthening, operation and maintenance of canals, resolving water management related issues and capacity building of water users in modern agriculture and irrigation practices. The IAs have been registered with MAIL and it is a legal entity through which all other agriculture extension and agricultural mechanization practices have been carried out for the concerned community. The role of IAs is crucial at present in terms of institutional development and awareness campaign for the dissemination of modern irrigation and agricultural practices.

5.2 Recommendations

The mirab system in collaboration with WUA and IAs may result in better irrigation water management at community level. Considering the provisions made in the Water By-law and IAs’ Rule Regulations, establishment of WUAs and IAs at main canal and secondary/ tertiary level will strengthen the traditional Mirab system. However, necessary care must be exercised not to disturb the organizational set up of Mirab/ Chakbashi of centuries old irrigation water management. While establishing IAs, the Mirab should be its key person.

IAs should not be restricted only to Irrigation activities but it can be used for other agricultural and extension related activities to make it more active and multi-functional. However, most of Afghan mirabs are not well educated and do not have knowledge of modern irrigation practices. They need comprehensive trainings on irrigation water management and exposure visits to various irrigation facilities to observe the recent developments in the irrigation sector. Hence, our interventions should be well thought out to integrate the mirab system into the modern irrigation management functions. This will give continuity to accepted traditional practices and help make the systems more sustainable.

6. REFERENCES


New technology plays an important role in enhancing production and productivity. Historically transfer of new technology has led to the expansion of production in many parts of the world. However, technology alone can neither lead to innovation nor productivity increase. The process of internalizing the technology by creating enabling environments for implementing the technology is needed. Japan has imported agricultural related and other technologies from foreign countries and internalized them and succeeded in expanding production and productivity. First such event was the import of paddy farming technology and iron tools around 3-4 Century. B.C., followed by irrigation related technology from China or Korea around 7 Century AD., which laid the foundation of establishing the centralized state in Japan. After this period, internalization process proceeded, particularly when Japan isolated herself from other countries during Edo period (from 17 to 19 Century AD.). Then the third wave of technology import happened after 19 Century AD., when Japan opened the trade with western countries after Meiji restoration in 1868, which changed the system of governing the country from Samurai/ feudal system to modern western style governance. At the beginning of modernization, many foreign engineers and specialists were invited/ hired to work in Japan as a consultant, in addition government sponsored fellowship or scholarship to learn from western system and technology, opening the door for using technologies of industrial revolution and system of governance in western countries. In all these three events, there were people involved in bringing the technologies, and people who digested and implemented them systematically. In this paper, process of technology import and internalization of these technologies are examined and analysed to identify lessons for smooth import and digestion of new technologies.

Keywords: Technology transfer, migration, internalization of technology, rice cultivation, Japan.

1. INTRODUCTION

Rice cultivation was introduced into Japan 4,000-5,000 years ago possibly from China according to the DNA analysis. However, it was not paddy field based cultivation, rather it was upland or swamp rice cultivation without bund and irrigation canal. Paddy field cultivation originally started in Japan about 3,000 years ago in northern part of Kyushu Island, the technology of which seems to have been brought by the migrants from China or Korea. Even about 3,000 years ago, there were many interactions and trade between northern part of Kyushu Island and southern part of Korea peninsula.

First wave of migrants came to Japan around 2-3rd Century. B.C., who brought rice cultivation technology to Northern Kyushu region. The rice cultivation technology gradually spread from Northern Kyushu to Kinki region, central part of Japan. In addition, civil wars in China and its effects on Korea prompted large inflow of migrants into northern part of Kyushu. Those people brought technologies including paddy field...
cultivation and metal equipment or pottery. The life of people shifted from mainly hunting and gathering or cultivation of coarse cereal to rice farming based system.

Paddy fields can store water and nutrients and prevent erosion or soil degradation, which enhance and stabilize rice production. To construct paddy fields system, cooperative works, leaders and rules to operate/ manage the system were needed, which promoted the social and economic development for establishing a state. According to Chinese history book "Han book", Japan was subdivided into about 100 small states, which had tributary relationship with Chinese kingdom of "Han" at about B.C. 1 Century. Since then, these subdivided states were unified under the authority of Yamato Court in Kinki region at about 4 Century AD.

From the end of 4. Century to the middle of 7 Century., Korean peninsula experienced major scale wars, which again brought large inflow of migrants with advanced knowledge and technology from this area, such as iron wares for farming and irrigation related technology. Modern farming equipment and irrigation technology expanded the area of paddy fields and production, enabling the accumulation of wealth to the newly formed state. The population of Japan at about 2Century was about 600 thousand, which increased to about 5 million in 8Century., with large inflow of migrants and increased population with increased production.

Since then, internalization process of imported technologies and the management system proceeded. It seems that the level of water control technology was not sufficient to develop the water infrastructure of large rivers. As such, the expansion of paddy field area stagnated from 8 Century. to 15 Century. During the period of Samurai(after 12th Century), each local feudal lord needs to strengthen the wealth of their domain by developing new farmland or mines, and fortify their castle by moats and stone walls, which promoted the development of civil engineering technologies and capacity of engineering specialists to engage in large scale developments. During and after the civil war, which ended in 1603 by the establishment of Tokugawa government, agricultural land area expanded progressively through the development of new paddy fields by each local feudal lord

With the fear of increasing Christian believer, the Tokugawa government prohibited the trade with foreign countries except for Dejima port in Nagasaki and the Netherlands and China ships. With the reduction of technology inflow, the internalization of technology proceeded until Japan opened the trade with other countries in Meiji in 1868. Under such circumstances, proactive development of new paddy fields and progressive development of farming technologies, the farm production expanded. After the latter half of 17 C., further expansion of farmland become difficult, which suggest the potential area for development had already been exhausted by the level of technology. Efforts were focused on productivity increases by improving fertilizing and crop related technologies.

After opening the country, the Meiji government hired foreign advisors for industrialization including agriculture development. Similarly the government sponsored to send many clever government officials and students to learn from western countries and they brought back advanced knowledge and technology into Japan. At the same time, Japan did not rely solely on foreign knowledge and technologies for industrialization. Foundation of traditional technology and basic education had been laid during Tokugawa period and before, which together with newly introduced western knowledge and technology, accelerated the modernization of the country during the Meiji period.
2. PEOPLE INVOLVED IN TECHNOLOGY TRANSFER

It is interesting to note that the transmission or transfer of irrigation related technologies in the past had been associated with the migration or movement of people. Basic system of paddy cultivation and irrigation had spread through the movement of group of people who already had experiences of utilizing the whole technology package. After the foundation of cultivation system had been established, the system improvement has been realized through the internalization or adaptation of technology to local conditions.

2.1 Migrants from China and Korea

Among the migrants who are recorded in history, most famous is Hata-uchi (name of a clan). It is reported that they first came to Japan around 3 Century. from Korea with several thousand people with advanced technologies and equipment. One of the famous irrigation and flood control structure that was constructed by Hata-uchi is Kadono-Ooi (large weir) in Kyoto, build in latter half of 5 Century. There still remain a shrine that enshrine Hata-uchi (Matsu Taisha), and old remains of canal around 6 Century. in the area.

The descendants of migrants spread all over Japan and contributed to the development of Japan, particularly farming and irrigation, sericulture, weaving and metal works. There are several others clans and individuals who are recorded in literature, such as Yamatonoaya-uchi, Kawachinofumi-uchi, or Gokyo-hakase. Writing system, iron making, religion (Buddhism), calendar, and governing system all came with migrants from China or Korea or scholars dispatched from imperial court to learn advanced technology and system.

How could such imported technologies widely be accepted and spread in Japan in a short time span. In addition to its progressiveness, the technologies came in a package with people who already had know-how of utilizing them. The impacts of
cultivating rice from hunting/gathering and coarse grain cultivation society seems to have been very big in terms of higher population carrying capacity and creating ruling class and governing system, which in the end resulted in establishing Yamato Court (first unified state in Japan) in 7 Century. with centralized control of land and people.

2.2 Buddhist Priests Who Learned Technology from China

Buddhist priests of Japan travelled to China to obtain Buddhist scriptures, and brought back with them not only scriptures but also in many cases advanced technologies, including irrigation related technologies. Many famous priests in the olden days associated themselves with the irrigation development and rehabilitation works in Japan.

Gyoki (668-749), is a Buddhist priest, whose father was from a family Korean migrant, learned Buddhism and civil engineering technology, and tried to help and save people from their suffering through engineering works, including construction and rehabilitation of irrigation ponds (Sayama Ike: WHIS 2014 registered, Kumeda Ike: WHIS 2015 registered, etc.), canals, bridge or port. Gyoki learned the technology at Kandaiji-temple (Imperial court supported temple) in Nara, which was established as the temple to pray for the security and prosperity of the nation and emperor, and only the place where civil engineering technology could be studied from priests who learned advanced technology from China. In fact, Gyoki learned various technologies from his master Dosho, who visited Tong dynasty in China from 653 to 661 in the official dispatch of envoy to China. The master of Dosho was Genjyo who travelled to India for Buddhist scriptures and brought them back to China. In those days, priests needed to master Gomyo (5 skills), including chanting rhythm, medicine, and civil engineering/astronomical calendar. To salvage people, these techniques were requirements for priests in those days. As such renowned priest received high respects from people and could mobilize large number of people to engage in construction works.

Manno Ike pond (2016 WHIS registered) was first constructed in the early 7 C but in early 8 C it was destroyed by the flood, and for enlargement and rehabilitation prominent priest Kukai was called in. He was sent from the Imperial court of Japan in 804 to learn Buddhism and advance technology from China (Tong Dynasty), and came back in 806. The pond has arch structure in embankment with spillways, which is very innovative in those days, and even now irrigates about 3,000 ha of paddy field. During the repair of Manno pond in 852, it is said that about 20 thousand laborers were mobilized with a cost of 240 tons of rice equivalent. By experiencing damages and repairs, the technological skill and capacity improved, which were accumulated to enable further development.

Official envoy to China continued from 7 C. to 10 C., which sent many scholars and priests to learn and import advanced culture, system and technology from China. However, at the end of 8th century, the power of Chinese Dynasty gradually declined.
and the communication between China and Japan was lessened, resulting in eventual abolition of Kento-Shi (Japanese Envoy to the Government of China) in 894. The official communication with China was closed, private trade with China and technology import had continued with successive Chinese dynasties of Sung, Yuang, Ming, and Ching.

2.3 Localized Development in the Medieval Ages. (9-15C)

The distinctive features of the Medieval Ages were the transition period from the national land and water management that had been adopted by the Yamato Court, to private control of land and water mainly in the form of manor by nobility, temples and shrines. In the latter stage, the control had shifted to powerful warriors and wealthy families. Due to this change, the natures and sizes of land, irrigation and drainage development in Japan, including those for river management and flood control, were substantially transformed, getting scattered in distribution and smaller in size.

The area of paddy fields in Medieval Ages is estimated to have been about 0.9 million hectares at the beginning of the 10 C., and around 1.1 million hectares in the middle of the 15 C. (see Fig. 1). The expansion of land and irrigation and drainage development in the Medieval Ages was relatively slow, however, it is important to note that 20-40% of paddy fields existed at the beginning of 10 C. were not cultivated due to frequent damages by floods and drought. All these paddy fields not utilized were put into cultivation by the improvements in water delivery and management as well as construction of small reservoirs. In addition to constructing small reservoirs, improvements were made in small weirs, water delivery facilities such as canals, conduit, aqueducts as well as water wheel for pumping.

In addition to the direct management of manors by aristocrats and shrines/temples, local land owning class that including local clans and powerful leaders started to emerge around 10C. At the initial phase of this class development, local land owning class contributed their land to powerful aristocrats and shrines/temples in the capital to establish the right of controlling the land. To escape taxes and intervention by central government, the group of private guards was established under the control of local leaders. These groups eventually accumulated their strength and developed into Samurai (warriors) class. These Samurais and local landowners gained political power and established their government in Kamakura in 1192.

To strengthen the economic power, provincial and estate level warriors had invested in developing new land, controlling flood, and rehabilitated degraded and abandoned land. The integration of political, economic and military power by feudal lords lead to the integrated management and development of water resources.

In this period, Bhuddhist priest Chogen (1121-1206), who visited China (Nang Song) 3 times and studied architecture and civil engineering, contributed to the rehabilitation of Todaiji temple in Nara, and also rehabilitation of Sayama Ike pond in 1202 with the cooperation of Chinese engineers including Cheng Heqing, who migrated to Japan in late 12 C. Newly introduced stone water intake structure, which originated in South Song dynasty in China, was utilized in this rehabilitation.

2.4 Samurai Engineers

2.4.1 Emerging Samurai lords

During the 13C and 14C, advanced irrigation and water control technologies were imported from China, which was accumulated during Sung, Yuang and Ming dynasties. Together with already available irrigation related technology in Japan, the development of large rivers and their delta area became possible.
During political turmoil and civil wars from the end of 15 C to the end of 16 C., Daimyo (Samurai lords) expanded their power by gathering subordinates around their castle, and ruled peasants through semi-autonomous villages. To consolidate the economic base of their domains, Daimyos engaged in large-scale agricultural development by applying technologies of flood control and irrigation.

One of the famous lord in engaging in such development work is Shingen Takeda (1521-1573), who fixed the river channel by building discontinuous embankment diagonally laid out, called Shingen-levée (embankment). The Shingen levees were so laid that the embankment was made the flow the more downstream the more distant from the river channel and the more flooding space left. This space thus created served as the retarding basin to absorb backward flow in the river (Figure 4). The river front side of the embankment was paved with rock and trees and bamboos were planted on the embankment to increase the strength. In addition, successive protection levees (Levees No. 1, 2, etc.) were stretched to the river channel to prevent flood water to hit the main embankment directly. By employing embankment that conforms to the principle of nature and applying rational method of flow energy dissipation, the flood protection in the area was realized.

**Figure 4. Layout of Shingen levee and flood protection work**

Many lords in this period followed the suit, and the flood control works in major rivers and its delta areas became possible.

Based on the mine technology and engineering works for building castles, irrigation and flood protection technology had advanced rapidly. Large-scale developments of alluvial plains were made possible with water from the upper stream of the major river and delivering water with long and wide canal system. In addition, flood protection works were implemented in the upper and middle section of major rivers by inventing peculiar river training techniques such as Kasumi-Tei (open levee), or bamboo gabion. With the development of flood protection works, diversion from big rivers, disaster prevention in flood plains, drainage works for waterlogged and marshy land were expanded large-scale development of hill areas, alluvial fans, and alluvial plains had proceeded.

Area of paddy fields was 1.1 million ha. in the middle of the 15 C., and with enormous expansion during civil wars and Tokugawa period, it reached approximately 2.6 million ha. at the time of Land tax reform in 1872. The enormous expansion achieved
during these periods was brought about by the continued efforts to strengthen the economic base of feudal lords or "Daimyos".

![Samurai engineers: Surveying by using the lantern light (source: JIID 1985)](image)

**Figure 5.** Samurai engineers: Surveying by using the lantern light (source: JIID 1985)

### 2.4.2 School of Samurai Engineers: Kanto and Kishu Schools

Schools of Samurai engineers were established during this period under each local lords such as Kamigata School or Koushu School, which was synthesized into two most famous schools, Kanto (Ina) School of early Tokugawa period and Kishu School during mid of Tokugawa period. Kanto School had its origin in Ina family who developed flood control and land development technology since civil war period and utilized under Tokugawa Shogun. Ina family managed the group of Shogun engineers and technicians under its school for about 200 years and they laid the foundation of the Kanto plain of the present day. River training works were implemented by using open levee, over flow levee, retarding basin, which controlled the flood by storing the flow within the winding river channels. In addition to river control works, Ina family developed new paddy fields in Kanto plain by Kasai irrigation system around 1660. The water source of this irrigation system was from three Tamei(water storages) formed by relocating and damming up old river channels. Such approach of securing water supply was typical style of Kanto School.

In the mid of Edo period, the urban and farming area expanded and received frequent flood damages because Kanto school controlled flood by allowing meandering river channels and controlled overflow. Under such system, drainage improvement was difficulty due to the dual uses of irrigation and drainage channel. The conflicts between the upstream and downstream became intense as the development proceeded. The Tokugawa Shogun Yoshimune at that time called Izawa Sobei to adopt his engineering approach (KishuSchool) in place of Kanto School. Kishu School abolished open levee or overflow levee, and fixed meandering river channels straight by providing stronger river embankment. High and continuous river levees were constructed in the middle and on downstream reaches of major rivers. Intensive paddy fields development was implemented in the middle and downstream of the river, which had been left unused because of meandering river channels. Good example is Minuma Dai Irrigation system (WHIS nominee 2019), which increased the diversion volume by directly withdrawing water from a major river and conveying water with larger canals to the middle and downstream alluvial plain. Kishu School also remodelled the use of dual purpose canal by separating irrigation and drainage canal, which eased and solved the water conflict between upstream and downstream area. The shift of technology from Kanto to Kishu School indicates the increase in the capacity of engineering works, which might have been affected by the technology import from Ming or Ching dynasties which conducted river training of the Yellow river and published civil engineering books, which were imported into Japan.
2.4.3 Farmer and Merchant Initiatives

Technology for developing irrigation system and paddy fields was mainly retained by Samurai engineers at the beginning, however, from the mid of Edo period farmers or merchants started to engage in developing new paddy fields by contracting (Hyakusho Yoriai Shinden, Chonin Ukeoi Shinden) the construction works or the development of irrigation systems. For example, Jikkokubori irrigation canal project (WHIS nominee 2019) was initiated by the village leader in 1668 and completed within 6 months in 1669 with the length of 13km through the contribution of labours from villages. Similar examples of farmer or village leader initiatives can be found in many WHIS registered sytems. Fukara Irrigation canal (WHIS 2014 registered) which diverts water from Ashinoko Lake with a tunnel of 1280m started with merchant contract (village leader initiative with cooperation from wealthy merchant), and the construction was completed successfully in 1670 with 834,000 labours and 4 years of time. Meiji Yousui Irrigation system (WHIS 2016 registered) was initiated by a wealthy farmer Tsuzuki Yako around early 19 C. with the help of a village resident scholar Ishikawa Kihei for surveying. After the project plan was submitted to Tokugawa and Meiji governments, the project was finally started in 1879 after 50 years of initial planning with the initiatives of two merchants, Okamoto Hyoumatsu and Ida Yohachi, and completed in 1880. With this development, the paddy fields area nearly doubled to 4,600 ha. In 1883, and converted the barren area into a major granary over the following years.

With accumulated experiences and knowledge, farmers also became experts in certain engineering works. For example, after the mid-Edo period (18 C.), earthwork groups called 'Kurokuwa', (named after their special equipment 'black hoe' used for construction works), emerged as a specialized contractor and they worked in many parts of Japan during off-seasons of farming. As they were strong in earthwork on flatland, they were extensively employed in new paddy field development and marsh reclamation.

2.5 Foreign Advisors (Meiji Period)

With Meiji restoration in 1868, Japan opened the interactions with foreign countries. To realize rapid modernization, Meiji government invited specialists of various fields from European countries and U.S.A. Up to about 1900, there were nearly 10 thousand invited foreign specialists, hired by Meiji government or private sector. One of the famous civil engineering specialist was Johannes van Doorn who came to Japan in 1872 from the Netherlands. He contributed in making river improvement plans and specifically made a plan for Asaka irrigation project (WHIS 2016 registered), which made trans-basin water transfer from Inawashiro lake and could irrigate about 2,000 ha of new land and provide supplementary water for 3,200 ha. Project initiated in 1880 and completed in 1883.

Rouwenhorst Mulder was also a foreign invited engineer from the Netherlands and made plans for river and harbour improvements as well as Kojima reclamation project. He came in 1881 and stayed in Japan until 1890. The plan of Kojima land reclamation was too expensive for Meiji government to undertake, and the plan was finally implemented by a rich merchant Fujita Denzaburo. New land tax system was introduced in 1873, and land ownership was officially recognized for owner cultivator and land owners. Thus people were keen to improve and develop new land and implement land improvement projects. The Kojima polder reclamation project was started in 1900 and completed in 1941 with total area of 2,970 ha.
3. DISCUSSION

As has been presented in the previous section, there would be four important elements in technology transfer and digestion; 1) packaged technology, 2) participation and knowledge sharing, 3) lessons from failure, and 4) Institution. As irrigation and paddy cultivation technology was brought into Japan at the early stage of development by Chinese or Korean migrants, it was packaged system of technology and equipment with group of people who had experiences of utilizing it before. Thus the transfer was relatively smooth and the technology package moved with those people and their descendants from northern Kyushu to the whole country in a relatively short period.

When the new system of cultivation was established, it had to be maintained and repaired. Buddhist priest, local leaders or Samurai lords took initiative, but local people had to be mobilized in repairing/rehabilitating the old system and developing a new system. Through the participation in such activities, even local people gained experiences of working with soil and water. The knowledge of Buddhist priests who learned the technology was shared to their subordinate priest. Samurai who was assigned to engage in development works and gained experiences and knowledge shared the know-how to his subordinates. Foreign advisors shared their knowledge and experiences in their home countries with Japanese engineers. Imperial court and Meiji government supported Buddhist priests and scholars to study China and western countries to learn modern and advanced technologies of the time. Those knowledge was shared when they came back from foreign countries, which enabled successive inflow of new technologies into Japan.

In the early stages of development, the structures were built by trials and errors. Thus there were many cases of failures. For example Sayama pond dam body bleached many times due to floods and earthquakes in its history, and rehabilitation and modernization of more than 10 times were recorded. As such, structures failed often in history, however, people learned lessons and gained experiences through such failures and modernized the structure with newly available technology of the time.

Imported technology was gradually adapted to local conditions and added minor improvements. Such process of digesting imported technology and adapting it to local environments was necessary to scale up the level of development. In the process of localizing the technology, experiences and wisdoms gained were synthesized into a form of standard and guidelines in each local area. In particular, during civil war period (14C-16C), feudal lords competed to strengthen the economic power of their domain by investing in developing new paddy fields, controlling flood, and rehabilitating and modernizing degraded system, which led to the integrated management and development of land and water resources. As such, Samurai class started to master the engineering technology by engaging in development works. Their knowledge and wisdom were synthesized into an institution and formed into schools of Samurai engineers. After the national unification by Tokugawa lord, technology was preserved and transmitted to the following generations through these Schools. Thus when Japan entered into modern age with Meiji restoration, foundation of technology for managing land and water was already in place. Such foundation was very useful in absorbing new technology of the West and modernizing the system with Western standards. Rapid modernization of Japan became possible with cooperation of invited foreign advisors.

4. CONCLUSION

In the history of land and water development in Japan, there has been people involved in bringing the technologies, and people who digested and implemented them systematically. In this paper, process of technology import
and internalization of these technologies have been examined and analysed to identify lessons for smooth import and digestion of new technologies. From the ancient times, Japan mostly imported land and water management technologies from foreign countries, China at the beginning and the West after the modern period, which was digested and adapted to local conditions through long lasting efforts of trials and errors. Important lessons that were identified in this study were; the importance of integrated technology package, knowledge sharing, learning lessons from failures, and institutions that enable the sharing and transmission of such knowledge. Irrigation and drainage system that extends all over Japan now has thus been established with the constant efforts of the people for survival and improvement of their livelihood.

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ANALYSIS ON DUJIANGYAN IRRIGATION SYSTEM AND ITS SUSTAINABLE DEVELOPMENT EXPERIENCE

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ABSTRACT

The Dujiangyan Irrigation System is a dam-less water diversion project that has been used continuously in its history of over 2,200 years. It is both a water resources project with great historical meaning which has played a role in the unification of China and a construction that wonderfully combines the liveliness of nature's creation and the scientific beauty of man's work. It uses different topography, water system and water potential to distribute water without dams, backup rivers and discharge sediment, adjust measures to local conditions, and self-flow irrigation. The value and contribution of Dujiangyan lies not only in the exertion of its engineering function, but also in the inheritance of water control thoughts and water culture for thousands of years. The water control principles of the water control rules of Three-character Classic, Eight-character formula and Eight-character aphorism constitute the rich and precious connotation of Dujiangyan’s water culture. This is the most precious heritage of ancient culture at Shu Country. It not only influences and enlightens the people who control water from generation to generation, but also enriches with the sustainable utilization and development of the project, which gives new enlightenment to the sustainable development of human society.

\textbf{Keywords:} Dujiangyan Irrigation System, sustainable development, experience, a dam-less water diversion project

1. INTRODUCTION

The Dujiangyan Irrigation System is a worldly-renowned water resources project. The headworks of the Dujiangyan Irrigation System is located in the city of Dujiangyan. The irrigation system was built in 256 BC. In over 2,200 years, it played a huge supportive role to local economic and social development and left rich water culture heritage to later generations. It is a monument in the history of the development of water conservancy projects in China. The irrigation system provides abundant water supply to the Chengdu Plain. Its canals have the benefits of irrigation, flood prevention and control, and water transport. It contributes to the creation of the prosperous scene of the Land of Abundance on the Chengdu Plain where “water is under control and man does not know what famine is”. Because of the irrigation system, the Chengdu Plain has become the granary of western China and the political, cultural, and economic center of southwestern China since the 2nd century.

The Dujiangyan Irrigation System is built at the point where the Minjiang River enters the Chengdu Plain. The river is a first-level tributary of the Yangtze River of a total length of 711 km. Its middle reach within the Chengdu Plain runs 216 km long, accounting for 30% of its total length. Here, the gradient of the river gradually drops from 10‰ to 1‰ and its slope is around 8.2‰. The left bank of the river is the ancient landslide belt of Er’wang Temple and the Mount Lidui is the product of geotectonic movement.

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At present, the Dujiangyan Irrigation System provides irrigation water to 710,000 ha of farmland in 38 counties in 7 cities of the Sichuan Province (as shown in table1). It has an exceptionally important status and role in the national economy and social development of the Sichuan Province.

Table. 1 Irrigation Area of Dujiangyan Irrigation System

<table>
<thead>
<tr>
<th>City</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chengdu City</td>
<td>Dujiangyan, Pi, Pengzhou, Wenjiang, Shuangliu, Tianluxinqu, Xinjin, Longquanyi, Xindu, Qingbaijiang, Jintang, Chongzhou, Dayi, Qionglai, Jianyang, Wuhou, Qingyang, Jinniu, Jinjiang, Chenghua, Gaoxin</td>
</tr>
<tr>
<td>Meishan City</td>
<td>Pengshan, Renshou, Qingshen, Dongpo</td>
</tr>
<tr>
<td>Deyang City</td>
<td>Guanghan, Shifang, Mianzhu, Jingyang, Luojian, Zhongjiang</td>
</tr>
<tr>
<td>Mianyang City</td>
<td>An, Fucheng, Santai</td>
</tr>
<tr>
<td>Suining City</td>
<td>Shehong, Daying</td>
</tr>
<tr>
<td>Ziyang City</td>
<td>Yanjiang</td>
</tr>
<tr>
<td>Leshan City</td>
<td>Kaiyan</td>
</tr>
</tbody>
</table>

2. HISTORY OF DUJIANGYAN IRRIGATION SYSTEM

All the rulers of the Shu (Sichuan) region in various dynasties took water resources work as a priority. The Dujiangyan Irrigation System has been constantly built and developed in different dynasties and ages. (a) The period of creation and improvement of the project. In 256 BC, Li Bing, the governor of the Shu Prefecture, started to build the Dujiangyan Irrigation System. The water of the Minjiang River was introduced into the heartland of the plain through building the Fish Mouth Levee and the Bottle Neck Canal. The project was mainly used for flood prevention and control, water transport and irrigation. In AD 662, the Flying Sand Weir was completed, which signified the formation of the distribution of the three major projects of the headworks of the Dujiangyan Irrigation System. (b) The period of relatively stable area. During the Tang (AD 618–907) and Song (AD 960–1279) dynasties, ancient China achieved prosperity. As a result, the irrigation area of the Dujiangyan project quickly expanded to cover 12 counties. By the end of 1940s, the project provided irrigation water to 188,000 ha of farmland in 14 counties on the Chengdu Plain. (c) The period of high-speed development. From 1949 to the present, the Dujiangyan Irrigation System
experienced large-scale transformations and showed quick development. The irrigation area has already reached 710,000 ha in 38 counties in 7 cities today.

3. IRRI GATION SYSTEM

The Dujiangyan Irrigation System is an engineering paradigm in utilizing and improving the conditions in nature. This project, which has existed for over 2,200 years, represents the outstanding technological achievement of water resources projects in ancient China. The Dujiangyan Irrigation System is an engineering system that consists of headwork, water diverting channels at various levels in irrigation district, ponds, weirs and farmlands. The project has created a water environment characterized by crisscrossing rivers and densely-distributed ponds, lakes and swamps on the Chengdu Plain. The headwork system mainly consists of the three major parts of Fish-Mouth Diverting Levee, Flying-Sand Weir (spillway) and Bottle Neck Canal and the auxiliary projects of the Baizhang Dike and the Renzi Dike. It is the water diverting hub of the irrigation system in which people fully utilize the terrain of the Minjiang River bed and scientifically resolve the issues of river water diversion, sediment flushing, inlet flow control and flood discharge, and achieve multiple benefits with the minimal engineering facilities. The headwork project has been improved and perfected in the evolution of the history and witnessed the history of the sustained development of the Dujiangyan Irrigation System. Starting from the point of the Fish Mouth Levee, the water flow is controlled by water diversion levees and overflow weirs made of bamboo cages and timber piles. Though no gate has been installed, the water of Minjiang River could reach the farmland and the residential communities smoothly. In the irrigation district, there are now 111 main canals and sub-main canals that run 3,664 km long, 260 branch canals that run 3,234 km long, each irrigating thousands of hectares of farmland, and field ditches below branch canals that run over 34,000 km.

![Figure 2. Headwork of the Dujiangyan Irrigation System in 1910](image-url)
Table 2. Inventory List of Dujiangyan Irrigation System

<table>
<thead>
<tr>
<th>Heritage Item</th>
<th>Name</th>
<th>Number</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headwork</td>
<td>Fish Mouth Levee</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Flying Sand Weir</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Bottle Neck Canal</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td>Main Canals and Sub-Main Canals</td>
<td>Total</td>
<td>111</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Puyanghe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Bailaohoe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Zoumahe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Jiang’anhe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Shagouhe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Heishihe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td>Branch Canal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field Ditches at Various Levels Below Branch Canal</td>
<td>Many</td>
<td>irrigation system area</td>
<td></td>
</tr>
<tr>
<td>Important Projects of Branch Canals and Those Below This Level</td>
<td>Yangliuhe River</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Baimayan Weir</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Yangliuhe River</td>
<td>1</td>
<td>Wenjiang District</td>
</tr>
<tr>
<td></td>
<td>Dalangyan Weir</td>
<td>1</td>
<td>Shuangli District, Xinjin County</td>
</tr>
<tr>
<td></td>
<td>Guofoyan Weir</td>
<td>1</td>
<td>Shuangli,Pengshan,Renshou</td>
</tr>
<tr>
<td></td>
<td>Jiuilidi Dam</td>
<td>1</td>
<td>Jinniu District</td>
</tr>
<tr>
<td></td>
<td>Zhuihuoyan Weir</td>
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<td>Shifang County</td>
</tr>
<tr>
<td></td>
<td>Qiangongyuan Weir</td>
<td>1</td>
<td>Chongzhou City, Dayi County, Xinjin County, Qionglai County</td>
</tr>
<tr>
<td></td>
<td>Huoshaoyan Weir</td>
<td>1</td>
<td>Gaoxin District</td>
</tr>
<tr>
<td></td>
<td>Zhugejing Well</td>
<td>1</td>
<td>Qingbaijiang District</td>
</tr>
<tr>
<td></td>
<td>Sanbodong Canal</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td>Buildings for Sacrifice and Worship</td>
<td>Erwang Temple</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Fulong Temple</td>
<td>1</td>
<td>Dujiangyan City</td>
</tr>
<tr>
<td></td>
<td>Water Resources Administration Office</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

4. MANAGEMENT EXPERIENCE OF DUJIANGYAN IRRIGATION SYSTEM

In various historical periods, multiple management types have brought orderly management and full vigor to the Dujiangyan Irrigation System. The management of the irrigation system involves both highly-centralized administrative system, in which the water resources officials in provincial, prefectural and county governments carry out water administrative management with respect to headwork, channels and weirs at main canal level, and those at branch canal level, and rural water resources bodies are responsible for the management of field ditches, in which water use entities join. Such management system combining government and non-government resources allows all benefited parties to bear their respective management responsibilities and corresponding obligations. The management system of the irrigation project has been
used continuously till today. At present, the project is operated under a management system that combines both centralized management and level-to-level management, and professional management and management by the public. The provincial water authority is the competent department in charge of the irrigation system. It sets up the Dujiangyan Administration to take charge of the centralized management of the irrigation system and the specific management of the headwork. Various administrative offices in the irrigation district are responsible for the management of the water conservancy projects such as the water diverting facilities on main canals, sub-main canals and various branch canals within their spectrum of duty.

During its 2000 years of sustainable utilization, Dujiangyan Weir has generated rich irrigation culture. This magnificent building is Er’wang Temple, the weir temple. In the 3rd century, to encourage the development of agriculture, the central government of China enshrined Li Bing as the water god and worshipped him on the national level. A memorial temple was built for him on the left bank of the Minjiang River. Since then, Li Bing has been worshipped by generations of Shu people. After the 10th century, the water god temple became a Taoist temple, and the memorial temple of Li Bing was turned into Er’wang Temple which worships both Li Bing and Er’lang God, a deity of Taoism. The religion used the irrigation project to enlarge its impact and at the same time built a bridge between the government and the local people for the management of the project. This is the stele inscription at the Er’lang Temple. On it carves a summary of the key points of flooding control and annual repair which serves as a reference for the weir managers. In the Qing Dynasty, Er’wang Temple was where the government officials and weir managers met to discuss project management issues and solve water use conflicts. In the ancient time, the government was responsible for the management of headwork, main canal and branch canals; canals below the branch-canal-level were managed by the water users. Local governments at the irrigation district did their job of management by collecting water fees, distributing water and organizing labors.

5. VALUE OF DUJIANGYAN IRRIGATION SYSTEM

The canal network of Dujiangyan Weir has created a lot of rivers and ponds at the Chengdu Plain. Starting from the point of the Fish Mouth Levee, the water flow is controlled by water diversion levees and overflow dams made of bamboo cages and timber piles. Though no gate has been installed, the water of Minjiang River could reach the farmland and the residential communities smoothly. This 2000-year old irrigation project is truly an outstanding example of the engineering technology in ancient China.

(1) Its enormous benefits have lasted until today. It is a brilliant example of the water resources projects that have a good effect on the environment and achieve the harmony between man and nature. The benefits of the irrigation system mainly include the following several aspects.

(2) It was ahead of its times in terms of project formulation, engineering design, construction techniques, and structure dimensions; it was an example of engineering marvel at the time of its construction; it was innovative in its ideas at the time of its construction; It contributed to the evolution of efficient and contemporary engineering theories and practices. The planning, design and construction of the Dujiangyan Irrigation System all possess good scientific and creative features. The headwork system mainly consists of the three major parts of Fish-Mouth Diverting Levee, Flying-Sand Weir (spillway) and Bottle Neck Canal and the auxiliary projects of the Baizhang Dike and the Renzi Dike. It is the water diverting hub of the irrigation system. The Chinese people adopt proper measures to bring the advantages of local
geographical and climatic conditions into play. They fully utilize the terrain of the Minjiang River bed and scientifically resolve the issues of river water diversion, sediment flushing, water transport and flood discharge, and materialize the development philosophy of the harmonious coexistence of man and nature.

(3) It was unique in some positive and constructive way. The Dujiangyan Irrigation System was built in 256 BC. In over 2,200 years, it played a huge supportive role to local economic and social development and left rich water culture heritage to later generations. It is a monument in the history of the development of water conservancy projects in China. The irrigation system provides abundant water supply to the Chengdu Plain with its artificial water channels. Its canals have the benefits of irrigation and water transport. It contributes to the creation of the prosperous scene of the Land of Abundance on the Chengdu Plain where “water is under control and man does not know what famine is”. Because of the irrigation system, the Chengdu Plain has become the granary of western China and the political, cultural, and economic center of southwestern China since the 2nd century. The construction of the Dujiangyan Irrigation System at the end of the Warring States Period (475–221 BC) laid a good foundation for the development of water resources projects on the Minjiang River. Since the Western Han Dynasty (206 BC–AD 24), the irrigation district of the project saw rapid development. The headwork was gradually improved and perfected. Irrigation channels quickly extended on the Chengdu Plain and formed a crisscrossing river network. The water channels in the irrigation district, similar to natural streams, provided not only irrigation water but also the convenience of flood discharge and water transport. The developed regional economy made Chengdu Plain the political, cultural, and economic center of southwestern China. From the Three Kingdoms (AD 220–280) to the Five Dynasties and Ten Kingdoms (AD 907–960) after the Tang Dynasty (AD 618–907), Chengdu became the center of locality separatist regimes for five times. In contrast to the Central Plains in turmoil at that time, the affluent Chengdu Plain was prosperous and lively so that it won the reputation of the “Land of Abundance”.

(4) It is an outstanding example of Operation & Management over a long period of time. The management mechanism characterized by the combination of governmental and non-governmental management and the system of annual maintenance have been adopted in the Dujiangyan Irrigation System and have been used continuously until the present. Such arrangements ensure the sustained development of the irrigation district and provide historical experience that people can draw from when managing present-day water resources projects. The water regulation technology and system in the Dujiangyan Irrigation System saw continuous development. Weir engineering technology and annual maintenance system were formed with unique features. People summarized the water regulation principles and philosophy epitomized by “digging riverbed deep and building weirs low” and created the Dujiangyan water culture with great charm and rich implications. The management of the irrigation system involves both highly-centralized administrative system, in which the water resources officials in provincial, prefectural and county governments carry out water administrative management with respect to headwork, channels and weirs at main canal level, and those at branch canal level, and rural water resources bodies responsible for the management of field ditches, in which water use entities join. Such official and non-governmental management system allows all benefited parties to bear their respective management responsibilities and
corresponding obligations. At the same time, multiple management types have brought orderly management and full vigor to the Dujiangyan Irrigation System.

6. CONCLUSIONS

The Dujiangyan Irrigation System is a dam-less water diversion project with the longest history in the world. In this project, the issues of irrigation, flood prevention and control and water transport have been scientifically addressed. It is an engineering paradigm of the harmonious coexistence between man and nature and the sustained development of the mankind. It is both a water resources project with great historical significance which has played a role in the unification of China and a construction that wonderfully combines the liveliness of the nature’s creation and the scientific beauty of man’s work. The project integrates the functions of flood prevention and control, irrigation, water transport, social water uses and ecological water use. It retains its effectiveness over long history and its enormous benefits have lasted until today. It is a brilliant example of the water resources projects that have a good effect on the environment and achieve the harmony between man and nature.

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RESERVOIR REGULATIONS IN 1662 BY THE GOVERNMENT OF JOSEON DYNASTY, KOREA

Kim, Ju-Chang¹ and Lee, Seok-Woo²

ABSTRACT

Rice culture was the most important agricultural industry in Joseon Dynasty, which had a long history of 518 years from 1392 to 1910. It depended completely on irrigation or rainfall, therefore, kings and government officials gave much attention to the construction, operation and maintenance of reservoirs and diversion weirs in rivers. Reservoir Regulations were prepared for reservoir-related central government officials and local head officials in 1662 by the Relief Agency (恤廳) of the Government, which was responsible for the relief works after drought damages. The Regulations are composed of 1 preamble and 15 articles.

The contents of the Regulations include different items such as water saving, irrigation canals, reservoirs, diversion weirs in the rivers, labour mobilization, selection of competent construction engineers, excavation of silted ponds, construction methods, reporting, rewarding and punishment for good maintenance, etc. Especially, several Chinese historical examples for successful reservoirs are also included. This paper explains the contents of the 1662 regulations and analyzes key factors. From these regulations, we could understand that successful irrigation for rice culture in olden days required many different technical and administrative measures and find the wisdom of our ancestors for water sustainability.

Keywords: Joseon Dynasty, Reservoir, Diversion Weir, Reservoir Regulation, Reservoir Administration Unit, Relief Agency.

1. INTRODUCTION

The main industry of the Joseon Dynasty was agriculture, especially rice cultivation. Rice cultivation was so important that kings and government officials gave much attention to irrigation using reservoirs and diversion weirs from rivers. Frequent drought in the springtime brought poor or no harvesting in the autumn and famine next year. Construction of reservoirs and diversion weirs required mobilization of large numbers of labours. Also, the maintenance of such structures needed additional labours because of flood damages during the summer seasons. One of the serious problems in the reservoirs was illegal cultivation of reservoir site area by the royal family or local strongman. Reservoir site was usually flat and fertile, bringing good harvest, therefore, it enticed illegal cultivation.

Reservoir regulations were usually related to new construction, labour mobilization, maintenance of reservoirs, excavation of silted reservoir, illegal cultivation of reservoir site area, responsibility of the Local Chief, rewarding and punishment, etc. In the era of Joseon Dynasty, there were more than 3,000 reservoirs in the country, including old reservoirs constructed in the previous dynasties. There were no data available for new construction during the Joseon Dynasty.

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In ICID Heritage Irrigation Structure, Korea has four reservoirs registered, among which two reservoirs, Manseokgeo and Chukmanje reservoirs, were constructed in Joseon era, each in 1795 and 1799.

2. BACKGROUND OF JOSEON DYNASTY

Before description of the reservoir regulations, it is necessary to grasp the general situations of Joseon Dynasty. There were several achievements related to water, reservoir, agriculture, etc.

2.1 Major Records of the Dynasty

1) Family name of the Dynasty: Lee (李)
2) Period of the Dynasty: 519 years (1392-1910)
3) Number of kings: 27 kings (Length of a reign per king in average is 19.2 years; Max. 52 years, Min. 13 months)

2.2 Important Achievements of the Dynasty

1) The world first rain-gauge was invented in 1441 and distributed at each province and started to be used in 1442. It is 198 years earlier than the rain gauge invented by Benedetto Castelli (Italian) in 1639. And continuous measurements of daily rainfall records in Seoul were made during 137 years from 1770 to 1907. No data from 1442 to 1769 were available.
2) Yearly rainfall records for 8 years were reported to the King Jeongjo in 1799. The concept of yearly rainfall record data was used in the Government.
3) Korean Alphabet was invented in 1446, however, most historical records were made using the Chinese characters.
4) Three royal documents were well preserved in printed books and included in the UNESCO's Memory of the World Register [a. The Annals of the Joseon Dynasty; b. The Diaries of the Royal Secretariat (Seungjeongwon ilgi); c. Records of the Daily Reflections (Ilseongnok)]. Therefore, many historical data, including daily rainfall data and Reservoir regulations were preserved.
5) Total number of reservoirs in the country were 3,527 in 1728, 3,378 in 1781 and 3,685 in 1808.

2.3 Famine Due to Drought

Many famines due to drought were recorded in the three royal books of the Joseon Dynasty. During the famine period, the Joseon Government distributed relief grain to the people affected. Irrigation to the paddy field using reservoirs and diversion weirs was the best way to reduce famine after drought.

As an example, 20 year-records of relief works from 1779 to 1798 are given below.
Table 1. Relief Works for 20 years from 1779 to 1798

<table>
<thead>
<tr>
<th>Date</th>
<th>Year of King Jeongjo</th>
<th>Number of people affected</th>
<th>Yearly rainfall (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1779</td>
<td>3rd</td>
<td>893,100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1780</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1781</td>
<td>5th</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June 1782</td>
<td>6th</td>
<td>1,445,900</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1783</td>
<td>7th</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June 1784</td>
<td>8th</td>
<td>4,115,600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 1785</td>
<td>9th</td>
<td>58,960</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1786</td>
<td>10th</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 1787</td>
<td>11th</td>
<td>3,555,300</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1788</td>
<td>12th</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>July 1789</td>
<td>13th</td>
<td>543,500</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June 1790</td>
<td>14th</td>
<td>1,562,900</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1791</td>
<td>15th</td>
<td>-</td>
<td>-</td>
<td>1,787</td>
</tr>
<tr>
<td>May 1792</td>
<td>16th</td>
<td>463,400</td>
<td>-</td>
<td>1,517</td>
</tr>
<tr>
<td>May 1793</td>
<td>17th</td>
<td>1,703,700</td>
<td>934</td>
<td>-</td>
</tr>
<tr>
<td>May 1794</td>
<td>18th</td>
<td>155,000</td>
<td>1,206</td>
<td>-</td>
</tr>
<tr>
<td>May 1795</td>
<td>19th</td>
<td>5,586,800</td>
<td>882</td>
<td>-</td>
</tr>
<tr>
<td>May 1796</td>
<td>20th</td>
<td>195,700</td>
<td>1,425</td>
<td>-</td>
</tr>
<tr>
<td>1797</td>
<td>21st</td>
<td>-</td>
<td>-</td>
<td>948</td>
</tr>
<tr>
<td>May 1798</td>
<td>22nd</td>
<td>1,308,700</td>
<td>1,156</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: 1) Rainfall record of Seoul 2) 13 famines among 20 year-period 3) 9 famines over 500,000 people affected among 20 years 4) 7 famines over 1 million people affected among 20 years 5) Total population was about 7.4 million people

2.4 Government Organization

The main Government organization of the Joseon Dynasty is shown below.
Local Governor (300 or more cities and counties - 7 groups)[3-year term]
- Special City (about 6 cities) - 府(府尹) [6th rank]
- Major City (about 5 cities) - 大都護府(大都護府使) [5th rank]
- Medium City (about 20 cities) - 府(府使) [5th rank]
- Small City (about 40 cities) - 郡(郡守) [6th rank]
- County (about 80 counties) - 県(縣令) [8th rank]
- Medium County (about 30 counties) - 県(縣監) [10th rank]
- Small County (about 140 counties) - 郡(郡守) [12th rank]

Note: 1) There are 18 official ranks for government officials of Joseon Dynasty.
2) 2nd rank officials are Court officials, royal family members, etc.

Figure 1. Government Organization

2.5 Reservoir Administration Unit (RAU – 堤堰司)

In the early period of the dynasty, 1418, the fourth King Sejong ordered to prepare Reservoir Register of the country. In 1441, rain gauge was invented to be used from 1442. In 1455, the 7th King Sejo appointed one official for reservoir administration, which initiated Reservoir Administration Unit later. The correct date of establishment of the Reservoir Administration Unit is unknown, but it is assumed that the RAU was established in 1400s, because the name of the RAU appears first in the Annals of the Joseon Dynasty, on August 13, 1472 (King Seongjong 3rd year) as shown in Figure 2. And the total number of records of the RAU appeared in the Annals is 58 during the period of 417 years from 1472 to 1889.

The RAU was a central government organization, but not a permanent organization, because construction, operation and maintenance of the reservoirs were carried out by Local Chief. It was a planning, advising and inspecting organization for irrigation works.

Therefore, the head and all the staff of the RAU were in concurrent positions.

Table 2. Major Records of RAU Activity

<table>
<thead>
<tr>
<th>Date</th>
<th>Contents</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 13, 1472</td>
<td>First record of RAU</td>
<td>Annals of King Seongjong</td>
</tr>
<tr>
<td>Aug. 18, 1472</td>
<td>Report of RAU to the King</td>
<td></td>
</tr>
<tr>
<td>1593-1662</td>
<td>No record in war period</td>
<td>Invasion by Japan &amp; Mongol – 1592, 1598, 1628, 1636</td>
</tr>
<tr>
<td>Mar. 6, 1624</td>
<td>Propose re-install RAU</td>
<td>Bibyeonsadeungnok</td>
</tr>
<tr>
<td>Jan. 26, 1662</td>
<td>Prepare 1662 Reservoir Regulations</td>
<td></td>
</tr>
<tr>
<td>Jan. 13, 1778</td>
<td>Prepare 1778 Reservoir Regulations</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Annals of the Joseon Dynasty, on August 13, 1472 (King Seongjong, 3rd year).

3. RESERVOIR REGULATIONS
3.1 Simple Regulations of the Dynasty

There were two types of regulations; one is several articles included in the Law Books, and the other is separated independent regulations. The former appears in the early period of the dynasty, while the latter in the mid period.

There were three simple regulations included in the Law Books enacted during Joseon Dynasty,

1) Gyeonggukdaejeon Law Books in 1485,
2) Sokdaejeon Law Books in 1746, and
3) Daejeontongpyeon Law Books in 1785.

Regulations related to the reservoirs and banks described in the Law Books are as follows.

**Gyeonggukdaejeon Law Books**

- Local Chief shall report the repair works of the banks or dams to the Provincial Governor, in every spring and autumn seasons, to the King in case of new construction.
- Protect dams or banks by planting trees upstream and downstream slopes of them.
- Prohibit logging or cultivation in the bank and reservoir area and flog offenders with 80 hits.
- Confiscate all criminal proceeds.

**Sokdaejeon Law Books**

- Land reclamation in the hilly area is prohibited, except cultivation in lower hilly area already reclaimed. The Local Chief shall be punished if he could not control offenders.
- All the dams or banks shall be surveyed based on the existing register.
- Reservoir Administration Unit shall send officials to the local areas to inspect and find illegal cultivation in the reservoir site area, punish offenders and report to the King.
- The land reclaimed from the bank area shall be returned to wasteland, and offenders including related officers shall be exiled after flogging of 100 hits, and the Local Chief punished for the reason of violating King’s order.
- In case of negligence of maintenance of the reservoir, the Local Chief and related officials shall be punished by River Improvement Law.
- In case of new canals, the land for canal site shall be compensated by the beneficiary of the new canals.
- In case of new construction of irrigation facilities such as reservoirs, diversion weirs, etc., farmers shall propose, and the Local Chief study them, report to the Reservoir Administration Unit and assist the construction works by mobilization of labours, if the facilities are beneficial to many farmers.
Daejeontongpyeon Law Books

Prohibit mobilization of forced labours in construction and repair works for banks, and punish offenders.

- The lands belong to the banks shall not be transferred to other purposes, except allotted by the late King.
- Anybody including eunuchs who reported deceivingly reservoir-site paddy field or garrison farm as royal farm shall be exiled to a remote island after flogging.

3.2 Independent Reservoir Regulations of the Dynasty

There were two Reservoir Regulations in 1662 and 1778

- 1662 Reservoir Regulations
- It is the first Regulations accompanying re-establishment of the Reservoir Administration Unit by the Government.
- The Regulations were composed of 1 preamble and 15 articles.
- The details of the Regulations are presented below.

1778 Reservoir Regulations

- After 116 years from the first Regulations, 2nd Regulations was prepared in 1778.
- The Regulations were composed of 1 preamble and 11 articles.
- The Regulations will be explained later in some other time.

4. 1662 RESERVOIR REGULATIONS

4.1 Re-establishment of Reservoir Administration Unit

In March 1662, a long drought was followed by months of severe famine in the area of Gyeongsang province located in the southeastern part of the country. Therefore, the Government prepared reservoir regulations together with re-establishment of Reservoir Administration Unit. The Unit was in name only since the invasions of Japanese army in 1592 to 1598, and Mongolian invasions in 1627 and 1636.

4.2 Contents of the 1662 Reservoir Regulations

The full articles of the 1662 Reservoir Regulations are too long to be included in this paper. The contents of the Reservoir Regulations are summarized as follows;

<table>
<thead>
<tr>
<th>Article</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 1(RAU)          | - Re-establish Reservoir Administration Unit (RAU).  
- Appointment of officials for the RAU (Chief Advisor - Premier level; Head – Minister of Finance or Head of Relief Agency; Official in charge – Staff of the Ministry of Finance). |
| 2(Importance of irrigation) | - Explanation of importance of farming.  
- Duty of the king and officials for leading people.  
- Explanation of importance of irrigation. |
| 3(Illegal cultivation, duty and punishment) | - Local Chief should shall personally examine the reservoirs in his district area, and completely and firmly reconstruct the collapsed parts, excavate silted earth and store water in time.  
- Illegal cultivators of reservoir sites shall be reported, punished and relocated to the remote area. |
<table>
<thead>
<tr>
<th>Article</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 4 (Chinese example for irrigation) | - Chinese examples of irrigation development such as Dujiangyan Irrigation System (都江堰 by Li Bing, 李冰), etc. were explained.  
- Recommend for Local Chief and people to construct and maintain dams and banks to prevent the drought disasters. |
| 5 (Surveying & labour mobilization) | - Local chief shall survey all the rivers to find proper locations to construct diversion weirs and report to the Provincial Governor, and the Governor report to the Reservoir Administration Unit.  
- Local beneficial farmers shall be mobilized as construction workers in force.  
- If the local farmers are not enough, all the one-labour-per family of the district should be additionally mobilized. If more labours are required to complete the construction works, labours from adjacent districts should be mobilized. |
| 6 (Monk soldier mobilization) | - Monk soldiers shall be mobilized, because they depend on grain offerings from farmers for their living. It is no wonder that each monk is mobilized to assist farmers in preparing for the drought.  
- There was a history in China that Su Shi (苏轼, 1037-1101, 北宋) gave monk license cards for their participation in the construction work of the bank for the West Lake (西湖).  
- Mobilize monk soldiers as forced labour for the construction, within the limit of 20 days for the monks with condition of providing license cards. For the monks who have license cards, work period should properly be reduced. |
| 7 (Construction material collection) | - Usually, many timbers and stones are used to construct banks on large rivers.  
- Local chief should establish a separate temporary marketplace near construction work site, and report to the Provincial Governor and prohibit people from going to other neighbouring markets.  
- Everyone who comes to the marketplace should gather timbers and stones. |
| 8 (Relief works & construction works) | - Mobilization of labour shall be made according to customs in the areas, and for the hungry people in poverty-stricken areas, relief grain supply shall be made according to the number of families.  
- Relief grain shall be supplied to accomplish both relief policy and construction work at the same time.  
- In olden days, Chinese scholar such as Fànwénzhèng (范文正) proposed construction work together with relief work at the same time. A famous Chinese scholar, Zhu Xi (朱子, 1130-1200) also proposed to construct big banks during famine to give food grain to the hungry people in his chapter of relief work. We should follow the lessons. |
| 9 (Compensation of canal site) | - Where irrigation canals are constructed, there are many benefits and fewer losses, even if there is land loss because of canal sites.  
- Land owner may oppose canal construction because of the loss of his own farmland. In such cases, construct canals according to law, but compensate for his farmland to be included in the canal site. |
| 10 (Use of trees, branches and stone for bank construction) | - Most of the large riverbed materials are usually sand, so bank will be easily destroyed in a small flood.  
- Large trees should be placed slant, entwine them horizontally and then support them so that they do not swing, like the shape of a house.  
- There should be lots of stones at the bottom of the bank, and if there are no stones, a lot of pine branches will be built up to prevent destruction due to overflowing water. |
| 11 (Duty of Local Chief & good examples) | - The first thing for the Local Chief to do is to develop irrigation facilities and encourage farming.  
- When Myeongdo (明道程), Chinese official, ruled the town of Sangwon (上元), he mobilized 1,000 workers and made a big reservoir, bringing good harvest year by year, and |
Fànwénzhèng (范文正) also benefited the people with the construction of big reservoirs.  
- We should follow their good examples as responsible government officials. I ask you, local governors, to initiate beneficial irrigation works and relief works for the people, and those who made good achievement will be rewarded.

For successful construction, it is necessary to assign skilled and talented supervisor to the site. The Local Chief shall select good supervisors. The Provincial Governor also shall find good engineers in the Province and send them to the local districts.  
- The title of the selected personnel will be Supervisor of RAU, and each of them should be sent to work site and provided with food. If you find any person among your officials who can cope with the responsibility, give them the assignment of the supervisor.  
- Also, if you know any talented person who can manage successfully construction supervision for banks and canals, you should employ them as officials, so that they can do their assignment with responsibility.

The construction process of the dams and banks shall be reported to the Provincial Governor and the Reservoir Administration Unit.  
- The Reservoir Administration Unit will send often inspector to check the construction processes, examine the diligence and negligence of the Local Chief and construction supervisor for reward and punishment.  
- The frozen land is gradually being melted and farming season is approaching, therefore, dam or bank construction work is urgent. Provincial Governor and Local Chief should be alert to the completion of the work within designated time without any delay.

Use the old seal of the Reservoir Administration Unit, kept by the Ministry of Economy and Finance.

Water Saving is not mentioned in the Reservoir Regulations because stored amount is too small to consider water saving in dry year for rice cultivation.

5. CONCLUSIONS

In Joseon Dynasty, rice production and prevention of famine were major concern of the kings and government officials. Many kings thought the drought and famine occurred due to his lack of virtue. Therefore, wise king maintained good interests in irrigation structures such as reservoirs and diversion weirs.

The government of Joseon Dynasty established Reservoir Administration Unit (RAU) to make policy, plan, inspection, monitoring, etc. And two Reservoir Regulations were prepared by the RAU in 1662 and 1778, respectively.

This paper describes 1662 Reservoir Regulations, the first one of them. The 2nd paper for 1778 Reservoir Regulations will be prepared later.

Reservoir Regulations prepared in 1662 deals with 15 articles, covering 1) Re-installation of RAU, 2) Importance of irrigation, 3) Illegal cultivation, duty & punishment, 4) Chinese example for irrigation, 5) Surveying & labour mobilization, 6) Monk soldier mobilization, 7) Construction material collection, 8) Relief works & construction works, 9) Compensation of canal site, 10) Use of trees, branches and stone for bank construction, 11) Duty of Local Chief & good examples, 12) Skilled & talented good
construction supervisor, 13) Reporting, inspection & completion, 14) Seal of the RAU, and 15) Others.

The 1662 Reservoir Regulations has characteristics different from modern day’s regulations or articles. They include explanation about irrigation and farming, Chinese examples of irrigation and relief works, etc. in addition to construction labour, material collection, supervisor, relief works, maintenance, rewarding and punishment, reporting, etc.

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Bibyeonsadeungnok (Lunar calendar) Jan. 13, 1778
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WATER SUPPLY AND WATER DEMAND – A MODEL FOR A BETTER UNDERSTANDING OF ASSYRIAN WATER MANAGEMENT ALONG THE LOWER ḤĀBŪR RIVER

Prof. Dr.-Ing. Klaus Röttcher

1. INTRODUCTION

In arid and semi-arid regions, the supply of water is limited for people, animals, and agriculture, setting the maximum means of subsistence for a population presently as well as in antiquity. The most important factor is the amount of water available for agriculture. With less than 300 mm rainfall per annum, rain-fed agriculture is risky. Other important factors are the yearly variations of the total and the available amount of water during the growing season. If this is not satisfactory, additional sources are needed and temporary or local water transfer becomes necessary.

In areas where humans did not introduce sustainable water management, people generally left the area temporarily or permanently due to insufficiently available water resources. The understanding of water management can therefore be key to the understanding of cultures. The collaboration between archaeology and water management gives rise to new and interesting insights into the function and use of hydraulic structures and water management in ancient civilizations. This particularly applies to the irrigation of agricultural surfaces necessary to provide the population with sustenance. Such a collaboration was experienced during the excavation season of 2009 at Tall Šēṭ Hāmād within the scope of a collaborative exploration. The civil war in Syria has unfortunately prevented further and more intensive on-site studies, so that the potentials were studied based on available data and recommendations for future actions were developed. The results of the study and the reflections and discussions pertaining to the relation between archaeology and water management are presented in the present article. The results show that further intensive research bears significant potential for gaining deeper insights, contributing to a better understanding, particularly of matters pertaining to settlement and irrigation agriculture. The rapid developments in the field of Geographic Information Systems (GIS) and the availability and quality of digital data allows for analyses at reasonable effort which were unthinkable ten to fifteen years ago. However, this paper does not draw on currently available data but rather to the drastically improved accessibility of older data. The availability of older satellite images and the digitisation of maps and aerial imagery allows for the processing of larger areas, a virtually insurmountable task with analogue methods. As it currently stands, the processing and re-analysis of the accessible data will provide a significant increase of knowledge pertaining to ancient irrigation systems on the Lower Ḥābūr. The thus developed assumptions will be subject of verification on-site when the particular region will be accessible again for archaeological research. Research with GIS can clearly demarcate the potential areas worthwhile for archaeological exploration. However, the methods presented here can also be applied to different regions and projects.

2. POSSIBILITIES OF HYDRAULICS AND WATER MANAGEMENT

Hydraulic and hydrological calculations in archaeological projects have the advantage that the physical behaviour of water remains unchanged over time. Based on the

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archaeological record, the hydraulic performance capacity of piping or canals can be calculated and the amounts of transported water estimated. Reflections on building and construction principles can be applied in combination with building technologies and materials used to reconstruct potential routes, also in areas where no archaeological investigation has been carried out to date. These considerations can be used to support or also reject theories relating to populations and the use and operation of hydraulic devices. However, hydraulic calculations of performance capacity only provide a maximum-capacity scenario. A maximum load is achieved only a few times a year for short periods. Further hydrological considerations are necessary to determine whether the required water amounts were actually at the disposal of populations during the year. Sinter deposits can provide us with clues regarding the utilisation of the canal sections and the period during which they were used. The river area that needs to be included in the research spreads out over the catchment. This in turn means that information needs to be collected on the entire drainage area for this research.

In the context of this paper, this aspect has been considered only marginally, as resources were lacking to create a precipitation-runoff model. However, expansive precipitation data have been analysed (Fig. 1), and these modern data can also be applied for historical considerations under the assumption that the climate of the Middle East has not changed significantly over the past 5,000 years as pollen analyses by Gremmen and Bottema (1991) have demonstrated.

The analysis of the data shows the alternating succession of dry and wet years. However, it also demonstrates that the validity of the average annual precipitation amounts is insignificant pertaining to the importance of irrigation and to the reliability of population supply. This shows that a further water management perspective, e.g. over the course of the year, is sensible. For the investigation of these problems, the parameter of yearly water management has to be introduced. “Water management” is an overarching concept relating to the management of water resources with the goal of aligning water supply with human water demand. In arid and semi-arid regions, the amount of available water directly correlates to the number of people that can be supplied with water in a region. Permanent transport of drinking and service water in containers to supply people is only feasible for individual outposts with lower staffing. Transporting water in piping systems and through canals is more realistic, also over longer distances. The largest share of water that people need is necessary to produce food.

A flow chart (Fig. 2) has been developed during this research, considering archaeological projects, which depicts how water supply and demand can be
estimated and compared. The depicted approach has been tested in the model case of the Ḫābūr. The proceedings following the flowchart in Figure 2 will be described in the subsequent paragraphs using this specific case.

3. SYSTEMATIC APPROACH TO ESTIMATE SUPPLY RELIABILITY

In the context of the present study, the question should also be answered to which extent the Eastern Canal was able to secure the nutritional and water supply of the population sizes estimated for this area. To answer this question, the approach depicted in Fig. 2 was developed and applied. With this approach, it could be established that this canal potentially provided water to an estimated 14,000 people in the eastern part of the Ḫābūr, with sufficient irrigation water to sustain them in dry years as well. How the population was estimated will be explained later. The approach is based on an estimation of water demand and supply for historical situations and a subsequent comparison to test whether the water supply of people was guaranteed and sustainable. A supply and demand comparison offers three different scenarios. In the first scenario, the water supply suffices, covering the water demand of the population. This means that no water is stored, as enough water is available at all times. In this case, it should be tested whether all data used are plausible and if all potential unfavourable circumstances – such as dry years – have been considered. With natural water supply, it is assumed that this water resource regularly regenerates. A second possibility is that the natural water resources approximately meet water demands. It should then be estimated whether the risks associated with e.g. particularly dry years, a growing population, or similar situations were acceptable or if precautions were taken to counteract such scenarios, e.g. through the storage of food or alternative supply possibilities. In a third scenario, water demand at least temporarily exceeds available water resources. In this case, it should be examined how the deficiency was compensated for. If there is enough available water during the year and only temporary shortages occur, a possible solution can be the storage of water (temporary transfer), e.g. using dams, in reservoirs, or also in groundwater. If there is a general shortage of available water to cover demand, as in the case of the Ḫābūr without the supra-regional irrigation canals, water needs to be supplied from outside the affected region (eventually also as virtual water in the form of food). If no structures for temporary or spatial transfer of water have been identified or if the capacity of these installations is insufficient, all data need to be re-examined, additionally questioning previous estimations of population sizes if necessary. Alternatively, a search can be started for additional water resources or relevant buildings or structures. If the available water resources, including spatial or temporary transfer, are plausible and sufficient to cover the demand, the assumed population sizes can be accepted from a water management perspective.

4. ESTIMATED WATER DEMAND

The first fragments of the supra-regional irrigation canal parallel to the Ḫābūr were discovered in 1982 and dated to the Middle and Neo-Assyrian era. Ergenzinger, P. and Kühne, H. (1991) provide the first extensive description of the canal and the current state of knowledge at the time. Kühne (2016) complements these considerations with current findings from translations of preserved Middle Assyrian texts (13th century BC).
Fig. 2: Diagram to assess water supply and demand

The population in the Lower Ḥābūr region is estimated to have been 24,000 in the Late Assyrian period (Morandi Bonacossi 2008:197-198) and that of the regional centre Tall Seh Hamad as 7,000 people (Kühne 1991:32). The population for the eastside of the lower Habur was estimated as 14,000 inhabitants by the population density of 150 inhabitants per hectare (Morandi Bonacossi 2008:197) and 75% of the area of the cities. For the west side were 10,000 inhabitants estimated to have in total 24,000 people for the lower Habur. This raises the question as to how these people were provided with supplies and whether this was possible with regional resources or to which extent supply from outside the region was necessary. External supply, in turn, raises the question as to how the food products were transported. Research of the various identified canal sections in the digital terrain model show that this was a hydraulically coherent system, allowing for the transportation of irrigation water and goods over this route. The consistent size of the canal supports the assumption that it was used as a transport route. If it were merely used for irrigation purposes, a gradual reduction of the canal cross-section size could be expected. The question as to how the canal was generally used and operated can only be answered after further intensive research.

The vast body of knowledge and data that has been gathered over the decades within the scope of the “Lower Ḥābūr Archaeological Project”, led by Prof. Kühne, could be used to estimate water demand. The water demand per person, including domestic animals as well as for trades, was estimated by the author considering the various quality demands (drinking or service water). The grain demand was estimated based on data on monthly barley rations paid to workers as wage in Ḥarbe (Tell Chuera, around 300 km north west from Tall Seh Hamad) (Kühne, C. 1999). The determined amounts still do not cover current calorie intake requirements, but it can also be assumed that people did not exclusively eat these barley rations. Information from Röllig (2008: XXXIII) and Reculeau (2011:175) was used to estimate the potential grain yields on irrigated fields. This information are related to middle Assyrian times...
(13. century), they will be used also for the neo assyrian period. Soil parameters to estimate the demand for irrigation water were taken from Smettan (2008: 11). The demand for irrigation water could subsequently be estimated and checked for plausibility in a comparison to other sources using FAO Cropwat 8.0 software. The result is shown in Table 1, clearly displaying that most water was needed for irrigation, with 99% of the water demand used to produce food. A part of this demand could be covered by natural precipitation during the growing season. It is assumed in further considerations that seeds were sown once a year in October / November, during the rainy season, and crops were harvested at the end of April / May (growing period of 165 days). Only the area between the canal and Ḫābūr River is accessible for agricultural use and irrigation due to topographical reasons. For the area around Tall Šēḫ Ḥamad Smettan (2008: 24) has determined that about 700 hectares could be used for agriculture in the region.

This amounts to around 78% of the total land area. For the entire Ḫābūr Valley, it is assumed that 70% of the surface between the canal and Ḫābūr River could be used for agriculture. This would amount to around 16,500 hectares. As the Assyrians only tilled their fields each second year (Altaweel (2008); Wirth (woher wissen Sie das? Dazu sollten Sie ein Zitat geben!)), this means that around 8,000 hectares per year were available. Assuming that the available fields were adequately irrigated, these estimations show that, under these boundary conditions, enough food would be available for around 14,000 people – also in drier years. This is in accordance with the assume population size of 14,000 for the east side of the Ḫābūr Valley. Furthermore, it is assumed that around 10,000 people lived on the west side, where another supra-regional canal was accessible. It can be surmised that the conditions on the east and west sides were largely similar. This shows that the supra-regional canals provided adequate water to feed a population of around 24,000 people. Without them the amount of land that could be irrigated would be drastically reduced, no longer sustaining the regional population.

Table 1: The annual average water demand in the Lower Ḫābūr Valley (Hoppe 2014: 24)

<table>
<thead>
<tr>
<th>Location</th>
<th>Population</th>
<th>Drinking and service water</th>
<th>Trades</th>
<th>Animals</th>
<th>Agriculture on 8,000 hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>[E] m³ a</td>
<td></td>
<td>m³ a</td>
<td>m³ a</td>
</tr>
<tr>
<td>Demand</td>
<td>-</td>
<td>4.4 m³ a</td>
<td>3.7 m³ a</td>
<td>3.7 m³ a</td>
<td>1,900.0 m³ a</td>
</tr>
<tr>
<td>Unit</td>
<td></td>
<td>[E]</td>
<td></td>
<td>m³ a</td>
<td>m³ a</td>
</tr>
<tr>
<td>Tall Schech Hamad</td>
<td>7,000</td>
<td>30,800</td>
<td>25,900</td>
<td>25,900</td>
<td>13,300,000</td>
</tr>
<tr>
<td>Tall Tnenir</td>
<td>1,000</td>
<td>4,400</td>
<td>3,700</td>
<td>3,700</td>
<td>1,900,000</td>
</tr>
<tr>
<td>Tall Taban</td>
<td>300</td>
<td>1,320</td>
<td>1,100</td>
<td>1,100</td>
<td>570,000</td>
</tr>
<tr>
<td>Tall Agaga</td>
<td>500</td>
<td>2,200</td>
<td>1,850</td>
<td>1,850</td>
<td>800,000</td>
</tr>
<tr>
<td>Tall Fadgami</td>
<td>1,000</td>
<td>4,400</td>
<td>3,700</td>
<td>3,700</td>
<td>1,900,000</td>
</tr>
<tr>
<td>Tall Brik</td>
<td>300</td>
<td>1,320</td>
<td>1,100</td>
<td>1,100</td>
<td>570,000</td>
</tr>
<tr>
<td>Tall Abu Hamda</td>
<td>300</td>
<td>1,320</td>
<td>1,100</td>
<td>1,100</td>
<td>570,000</td>
</tr>
<tr>
<td>Other locations</td>
<td>3,500</td>
<td>15,400</td>
<td>13,000</td>
<td>13,000</td>
<td>6,650,000</td>
</tr>
<tr>
<td>Sum</td>
<td>around 14,000</td>
<td>61,200</td>
<td>51,500</td>
<td>51,500</td>
<td>26,600,000</td>
</tr>
<tr>
<td>Share [%]</td>
<td></td>
<td>0.23</td>
<td>0.19</td>
<td>0.19</td>
<td>99.20</td>
</tr>
</tbody>
</table>
5. ESTIMATED WATER SUPPLY AND CAPACITY OF THE CANAL

As far as the discharges of the year-round aquiferous rivers are concerned, an average discharge of 40 m³/s was determined for the Upper Ḩābūr River (Wirth 1971:109). The combined discharge of the more than 10 sources of the Ḩābūr was also determined to be 40 m³/s by Sprenger (1990: 15). For the Lower Ḩābūr, after the confluence of the Gağğağ River, an average discharge of 52 m³/s, a minimum discharge of 36 m³/s, and a high-water discharge of around 300 m³/s was defined (Sprenger, H. 1990: 16). No secure sources can be found for the Gağğağ, but Wikipedia (2017) lists it as 8 to 12 m³/s. However, these discharges are influenced by a modern dam and therefore cannot be equated to those of the Assyrian era. The catchment areas of the Gağğağ and Ḩābūr are approximately the same size at the mouth of the Gağğağ. The drainage rates are not consistent over the large areas. Therefore, the discharges do not equally correlate to the catchment areas. It does however provide a good indication. This aspect needs further investigation, taking also into account the discharge of the irrigation water into the eastern supra-regional canal.

The groundwater lies at a depth of around 4-5 m underneath the site. In the steppe, however, it is partially at a low depth of 2 m. However, the water is saline (5.3 mS/cm) and bitter and therefore only of limited use for irrigation or drinking purposes. It was probably used before the canal was constructed as well as for contingencies.

Examinations within the scope of this study have resulted in the identification of an additional water demand of 140 mm, already taking into account the precipitation from October to May with a growing period of 165 days. The estimated average water demand ranges from 10 mm at Hassaka (demand 220, precipitation 210) to 270 mm at Deir-Ezzor (demand 400 mm, precipitation 130 mm) and thus increases significantly as the Ḩābūr flows further downstream.

A total water loss of 50% is assumed for the canal and irrigation system. This is a common order of magnitude for earth canals and is also used in modern calculations. The hydraulic examination of the canal demonstrated an average performance capacity of around 4 m³/s, providing around 187,000 m³ of water per day. This was sufficient to provide the estimated cultivated area with sufficient water during the growing period, also in drier years. It is also realistic that these amounts of water could alternatively have been tapped from the Ḩābūr or Gağğağ Rivers. The structural effort for tapping this water depends on the height relations and the ratios between the discharges at the tapping point. The question as to where the water was tapped will be considered separately later on, taking into account the respective advantages and disadvantages.

The expositions so far show that the canal was of central importance to the development of the Lower Ḩābūr region. According to the current state of research, the Assyrians had the technological capacities to erect all the structures necessary for such a canal. Bagg, A. (2000) has described the Assyrian hydraulic structures from the 17th until the 14th century BC in detail, particularly by analysing the original cuneiform sources. He shows that the Assyrians realised the clear advantages of flood irrigation through water drainage from a canal against lifting water from springs or streams and, in turn, used this preferred method wherever possible. They were also capable of performing the necessary survey work for large projects, such as the canals, with the necessary high level of precision. This was the case especially about the gradient (at the Ḩābūr, averaging 0.5 per mil), and at the same time they used the natural topography optimally. They also mastered the large organisational challenges – workers, building materials, supply, and transport – posed by the construction of the canal. It became clear that the Assyrians had knowledge of the
various structures necessary for the operation of the canal, canal bridges, and tunnels and could erect these structures as well.

The natural water levels fluctuate strongly as a function of the discharges. Transverse structures in the natural body of water are necessary to lead a certain amount of water into the canal under these circumstances. Bagg (2000: Chart 65-67) presents various types of channel heads (outlet locations from the stream). A similar structure must have been present for the Ḥābūr canals. However, the author has no information that such structures are substantiated by archaeological findings until now. The eastern Ḫābūr canal must have been of such importance for the supply of water and food that it is certain that no efforts were spared to provide the canal with sufficient amounts of water. The barrage construction in the stream can have been either a dam or a masonry dam such as at al-Gila (Fig. 3) or also a weir (Fig. 4). The upstream water level, and with that the amount of water drained into the canal, could be regulated through various openings or spillways. This construction in the stream needs to be of such stability that it also withstands floods, contrary to constructions in the canal system itself, which are generally not subject to occasional flooding. A further weir in the canal can reduce water amounts in the canal or even temporarily close it for maintenance work, for example. In this case, moveable locks are required. Under favourable topographically conditions, one weir in the inlet area of the canal suffices to regulate the outflow. Further structures similar to those in the inlet area are likely further down the canal, guaranteeing even distribution of the water, especially at the junctions to the various settlements. In addition to the irrigation season, particularly in the summer when there is only little available water in the streams, such regulating structures are also necessary to allow for ships to navigate the canal, guaranteeing highenough water levels with little discharge.

Fig. 3: Dam wall at al-Gila, view from the northwest (picture Trustees of the British Museum, from Bagg 2000: Chart. 55b)
An important question is where the water for the canal came from. From a topographical perspective, drainage from the Ǧaggaġ at Tell Bab or from the Ḫâbûr at Tell Kerma north is possible. Both routes carry with them technical difficulties and plenty of unanswered questions. These unanswered questions are considered below from a purely watermanagement and technical perspective.

Drainage from the Ǧaggaġ constitutes the problem of overcoming the watershed between the Ǧaggaġ and Ḫâbûr. The exact height difference could not be determined due to differences in the geographic coordinates of the different maps; it will be up to 20 m at several points and more than 10 m over longer distances. To overcome this watershed, either a sufficiently deep cut in the terrain or tunnels needed to be realised, this cuts should have a maximum depth of 20 m landscape would be and still is visible today (cf. Kühne in this volume).

The Assyrians were also capable of constructing canal tunnels. However, as shown by Bagg (2000), the dimension of the tunnel was smaller than the cross-section of the canal. Therefore, multiple tunnels would have to be constructed adjacent to each other to provide the canal with sufficient water, making it virtually impossible to navigate ships. Transhipment and transportation of goods by land would need to be made at least for the length of the tunnel. In this case, an appropriate infrastructure would be necessary at the beginning and end of the tunnel.

Diverting the water from the Ḫâbûr offers a greater water supply, as the Ǧaggaġ already discharges into the Ḫâbûr, allowing the water from both catchment areas to be used. It would be likely that a dam in the Ḫâbûr was constructed to allow for constant discharge into the canal. A dam in the Ḫâbûr would certainly have to be larger, as in the Ǧaggaġ. Moreover, the Wadi Hammar would have to be traversed closer to the confluence with the Ḫâbûr, in turn necessitating a larger structure.

An advantage of this route is its shorter length and no watershed need to be overcome. Depending on the height ratios, the canal would have to be led over a dam for a longer distance in order to limit height losses. There also the author has no information about an archaeological evidence for such an dam or other noticeable structures in the landscape.
Also, no noticeable structures can be found in the landscape. Das ist mal eine konkrete Aussage, die aber zur Relativierung Ihrer vorhergehenden Postulate führen müsste.

Diverting water for the eastern Ḥābūr canal from the ḡāḡāḡ River brings with it the advantage that the shipping route to the Assyrian heartland is significantly shortened. Tunnel sind oben als Alternative zu den tiefen Einschnitten angesprochen deshalb hier diese Erläuterung. This leads to the questions if and under which circumstances – and for which ship sizes – navigation on the Ḥābūr and ḡāḡāḡ was possible. Supra-regional navigation on the strongly meandering Lower Ḥābūr, with its mainly boggy floodplain, can be excluded. When used for navigation, canals have the advantage that the cross-section of the canal remains the same size – which would certainly have been the case if the canal were solely used for irrigation.

In any case, the canal is an efficient shipping route and certainly used as such.Remains of a weir-system in the ḡāḡāḡ River are also missing, as well as conforming transformations in the landscape and leftovers of a tunnel. The point of discharge for the eastern irrigation canal could be explored using a high-resolution digital elevation model and georeferenced maps to avoid further collection of on-site data. Wir haben doch schon einen Anfang gemacht, warum honorieren Sie das nicht? Sie ziehen alles ins Negative!

Elaborate and coordinated irrigation management would have been necessary to operate the canal for irrigation. In this way, individual canal sections could be provided with water relative to demand, thus using the available water resources optimally. This applies to the main canal as well as to the fields irrigated by the canal outlets. For Shaddade on the west side and Maraza Agaga on the east side, the structure of the local irrigation systems from the Assyrian age has been researched and presented by Sprenger, H. (1990 Communicating information in a fast and timely manner when controlling the water flow in the main canal would have been a special challenge, due to its large length of around 200 km and flow velocity of 0.5 to 0.75 m/s (1.8 to 2.7 km/h). Therefore, it can be assumed that an irrigation calendar, with a set schedule for the irrigation of the individual areas, was used. In this case, only deviations needed to be communicated.

Kühne, H. (2016) presents two examples of cuneiform writings of the 13th century BC where the relocation of a “fast deployment force” was mentioned. In one case, the regulation of the water runoff is also discussed. Was meinen Sie konkret? As previously mentioned, weirs or other obstructing features would have been necessary for optimal control of water flow in the main channel and distribution for irrigation or for navigation during the dry season. It can be assumed that stones used for these structures would have been used for other purposes later on and that the wood has rotted or been burned by now. Remains of such structures may be found during larger excavations in the area of the effluents of the city canals. Was soll das? Was hat das miteinander zu tun? In jedem Fall ist das völlig nebensächlich, während Sie sich weiterhin weigern die Aussage dieser Texte zu würdigen.

To analyse the canal route, three types of elevation data were used in the scope of the SRTM (Shuttle Radar Topography Mission) research project. Digitised aerial imagery could be used for some regions. Images of the CORONA reconnaissance satellites were used for other regions. However, the various data sources did show significant position deviations (of up to around 100 m). The results of these observations show that a continuous canal route was feasible and plausible and that its construction could be realised (Fig. 5). It would have been possible to erect the
canal with a relatively consistent gradient of around 0.5 thousandth. Warum Konjunktiv? Das Höhenprofil bestätigt doch gerade dass die Spuren im Gelände auf den Bau eines durchgehenden Kanals zurückzuführen sind.

This would have offered operational advantages, as it does not lead to varying degrees of erosion or sedimentation in the different canal sections. The digitisation of further aerial imagery and the use of a digital terrain model with higher resolution could lead to a better understanding of the exact position of the canal route and the various potential effluents. An optimally visualised canal route in those areas where no structures are recognisable could also reduce the depth of the necessary terrain cuts. The defined cut depths of more than 10 m in Fig. 5 are partially the result of positional disparities between the digital maps and the terrain model. After these corrections are completed, the transported soil masses and the building effort necessary for the construction of the canal can be estimated. For the considerations presented here, it can assumed that the option of digging in the terrain was preferred over leading the canal over a dam, as the densification of soil material and waterproofing against seepage plays a particularly important role with dam sections. Insufficient soil compression and sealing in dam sections present long-term structural weaknesses. The question as to how the laterally discharging Wadis River could have been traversed can also be researched with more precision using more detailed digital map data.

Fig. 5: Longitudinal cut of the eastern Ḥābūr canal (Hoppe, J. 2014:38) (green line average slope of 0.5 per mill)

6. OUTLOOK

Water management is presented in this report, displaying its essential contribution to the understanding of the canal system along the Ḥābūr and its importance for the local population. Extensive research into the processing and incorporation of all available data can further refine the route of the canal. Such data can also provide information on the origin of the irrigation water, the crossing of the Wadis, and the water distribution within the studied region. By combining these insights with archaeological findings, a comprehensive image can be made about the function and use of the supra-regional canal and irrigation system. The presented systematic comparison between water resources and demand can also be elaborated on and tested in further research projects. A further discussion from an archaeological and water management perspective about the data sources used and about the validity of the results is also desirable.
7. **Bibliography**


Kühne, Hartmut 1991


ABSTRACT

Agriculture is the foundation of the establishment of the country, and irrigation of farmland is the foundation of agriculture. Dangxiang is a nomadic nation that has never engaged in agricultural production, after a long period of inter-ethnic exchanges, integration, and convergence. And the establishment of a new Xixia country, facing the harsh natural environment, the Xixia rulers attached great importance to the development of farmland water conservancy. Not only agriculture and animal husbandry, but also in the comprehensive code of Xixia, we have formulated very detailed and unique water conservancy regulations around the establishment of institutions in the water conservancy construction, the labor system, the Juan Sao system, the spring opening of the canal, the discharge of water in turn, and the management and maintenance. It also pays attention to using laws to regulate people's water use behavior, mediate water disputes, regulate social water use order, and scientifically manage and maintain water conservancy facilities. Xixia's water conservancy regulations not only promoted the social and economic development of Xixia, but also made great contributions to the development of Northwest China, and added a splendid color to the history of Chinese ancient water conservancy.

Keywords: Water Conservancy Legislation, DangXiang, Xixia, TianSheng Law, Hai Nian Xin Fa.

1. INTRODUCTION

DangXiang was group of nomadic people who originally lived on the Qinghai-Tibet Plateau, not engaged in production or agriculture. In the "Old Tang Book", DangXiang was recorded as "shepherding yak, horse, donkey, and sheep, as food. They cannot tell the five cereals apart, know nothing about agriculture, and there are no grains in the fields." At was not until the Tang Dynasty that DangXiang moved to the Central Plains to live in the mainland, and gradually entered the Han agricultural area and began to engage in agricultural production. Some of the DangXiang people began a historic change from a nomadic lifestyle to a settled lifestyle, from animal husbandry to agriculture.

Until the party project established Xixia (1038-1227), it was successively with the Northern Song Dynasty and the Liao Dynasty; the Southern Song Dynasty and the Jin Dynasty presented a situation in which political power was established. However, Xixia's geographical position is in the northwest of China, and its terrain and landforms are complex and diverse. The eastern and southern parts are the Loess Plateau; the north is the Ordos and Alashan Plateaus of the Mongolian Plateau, the desert and the Gobi are dominant, the grassland area is small, there are the Mu Us Desert, the Tenger Desert and the Badain Jaran Desert; the west is the north of the Qinghai-Tibet Plateau, Qilian Mountain and Hexi Corridor. The climate in Xixia is a typical continental climate. It is a year-round drought with low annual rainfall. The

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annual precipitation is about 39-400 mm from west to east, and the annual evaporation is very large, about 200-600 mm. The total amount of resources is relatively small, and the distribution is uneven, and natural disasters occur frequently, which brings great difficulties to agricultural development. Facing the harsh natural environment, the rulers of Xixia attach great importance to the development of agriculture, implement the development of agriculture and animal husbandry, enhance the development of irrigation and irrigation of farmlands in Hetao Plain and Hexi Corridor, and build a dense irrigation channel like spider web. Established a sound and complete management system, and also passed laws and legislation to protect the implementation of water conservancy. Through these measures the ability to resist natural disasters has been improved, as recorded in the "Song Shi": "Therefore, Xixia has been harvesting water for irrigation which can satisfy the food supply of the Xixia people, and there is no need to worry about drought year after year". It also has an important impact on the development of the Northwest region. For example, in the Ming Dynasty, Li Mengyang wrote a poem describing the Xixia homeland. "There are many Xixia temples that are not only covered in clouds in the mountains, but also Tang Lai qu, which has been used from ancient times till today the Ming Dynasty)."

2. LEGISLATION ON IRRIGATION IN XIXIA

2.1 TianSheng Law

One is "The changed and re-approved code of Heavenly Prosperity" (Referred to as "TianSheng Law"). It used butterfly packaging book format, Xixia text engraved. The "Tiansheng Law" was a systematic and comprehensive code issued by Emperor Renzong of Xixia in the early days of Tiansheng (1149-1156). It was discovered in 1909 at the Khara-Khoto in Ejina Banner, Inner Mongolia, and is now in the Oriental Literature Institute of the Russian Academy of Sciences. The "Tiansheng Law" has twenty volumes, nine volumes are relatively complete, ten volumes have different degrees of damage, One volume is lost, only entries. Among them, the legislation on water conservancy is mainly in the 15th volume, including the "Cui zu zui gong men" (nine articles), "Chun kai qu shi men" (four articles), and "Yang cao jian men" (five items only), "Qu shui men" (eighteen), "Qiao dao men" (six), "Di shui za shi men" (sixteen), etc, a total of about sixty articles. Because the code was printed with the Xixia script, the text was clear, relatively easy to interpret, and had a complete Chinese translation, which provides valuable information for the study of water conservancy scholars.

2.2 Hai Nian Xin Fa

One is "Hai Nian Xin Fa". It Used the butterfly-packed book binding form, used the Xixia text cursive manuscript, and the "Hai Nian Xin Fa" was a code of law issued before and after the emperor of the Xixia Zunxu Guangding four years (1214). It was also discovered in 1909 at the Khara-Khoto in Ejina Banner, Inner Mongolia, and is now Collected in the Oriental Literature Institute of the Russian Academy of Sciences. The "Hai Nian Xin Fa" is more serious, with only fifteen volumes, and there are eight different versions. Among them, the provisions on water conservancy legislation are also in the 15th volume, there are "Zu di fu yi men",

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1 Tang Lai qu is an important irrigation channel that has been built in the Hetao Plain since ancient times and has been used in the Xixia, Ming Dynasty and contemporary times.

2 Hai Nian is also the meaning of the pig year, Xixia combines the zodiac and the twelve earth branches, using the method of animal years.
"Shang tang lai fu yi xiao jian men", "Tang lai deng lian tiao cao fa men". The Code was promulgated in the late XiXia Dynasty, social unrest, and economic development was slow. The country not only organized large-scale publication of the Code, but also revised many of its provisions. Because the "Hai Nian Xin Fa" was a copy of the Xixia text cursive script, the writing was difficult to interpret. There is currently no complete Chinese translation of the book, only a few translated articles. Therefore, some provisions in the Code on water conservancy legislation have not been understood by the academic circles. These provisions have become an important supplementary material for comprehensively understanding the status of Xixia water conservancy legislation and comparing the development of water conservancy irrigation in the middle and late Xixia.

The law is a rule of conduct enforced by a state power, a manifestation of the will of the ruler, a guarantee of the basic order of society, and a reflection of social life. The Tang Dynasty water conservancy regulations mainly include "Tang Kaiyuan Shui Bu Shi" (disintegrated volume), which is now collected in the National Library of Paris, France, numbered Dunhuang Instrument P.2507. The water conservancy laws of the Song Dynasty mainly include "Qingyuan Tiao Fa Shi Lei" and "Nong Tian Shui Li Yue Shu". In the Tang Dynasty and the Song Dynasty, the comprehensive code of the "Tang Lv Shu Yi"and the "Song Xing Tong" were not related to water conservancy. However, the Xixia "Tiansheng Law" and the "Hai Nian Xin Fa", which inherited the legal spirit of the Tang and Song Dynasties, were very detailed. The land regulations regulated the development and management of farmland water conservancy, which is a great progress in the history of ancient Chinese water conservancy.

3. CONTENTS OF XIXIA WATER CONSERVANCY MANAGEMENT

3.1 Establish an Institution

Farmland water conservancy management is an important task of Xixia and plays an important role in the social economy of Xixia. For the management of farmland water conservancy, not only Zhong Shu, Zai Xiang, and Zhu Si Da Ren are involved, but the Xixia government has also set up central and local institutions for managing water conservancy. The central management agency is called Nong Tian Si, and the local responsible agency is called Shui Li Ju Fen. Xixia's water conservancy bureau has set up Da Ren, Cheng Zhi, Si Li, Fu Shi Xiao Jian, Qu Tou Xun Jian, Qu Tou, Qu Zhu, etc, only "The Da Dou Du Fu to Ding Yuan along the canals as a canal inspection, Qu Tou Xun Jian and Qu Tou was one Hundred and fifty people." It can be seen that Xixia has a sound management system with complete management system and numerous management personnel, which provides political and personnel protection for Xixia water conservancy management.

3.2 Juan Sao

Every winter, there is no grain in the field, no need to irrigate, the Xixia government will use the river water to freeze, and used the firewood and sand to block the channel of the main channel. This was called Juansao. In the spring of the second year, the temperature gradually increased and the river began to melt. However, because there was no river inflow through the channels, it was kept dry, which was convenient for the Xixia people to repair the dredging channels in time to ensure the smooth irrigation of water conservancy. In order to get enough firewood to block the canal, Xixia "Tiansheng Laws", Volume 15 "Qu Shui Men" stipulates: In Xixia, the owner of each land tenant pays Caopeng Zi, Xiapang and other items in winter. One
acre of land also has to pay a five-foot bale, which can be composed of various weeds. A family that reaches fifteen acres of land is required to pay a four-foot bale, which is composed of Puwei, Liutiao, Mengluo, etc. If some families do not pay enough bales as required, the insufficient part should be calculated with the same amount of price to compensate, and the guilty punished by the crime of theft.

3.3 Open the Canal.

The opening of the spring channel is very important for the management of Xixia water conservancy. The Xixia law stipulates the procedures for deciding the decision-making process and the institutions and personnel participating in the decision-making. "Cui Zu Zui Gong Men" in "Tiansheng Law" records: "When the canal is opened every spring, the relevant management units of farmland water conservancy will put forward discussions on the prescribed date, and then Fu Shi Xiao Jian, Zhushi and Zhuan Yun Si Da Ren, Cheng Zhi, He Men, Qian Gong Shi and Xun Jian Qian Gong Shi and other people, together in front of the Zai Xiang to discuss. In the same year from the imperial court sent a capable person to the local presidency to open the channel, the farmland water conservancy management department seriously implemented the canal work."

The people responsible for the opening of the canal are all farmers who have been recruited by the government to work. They generally calculate the number of days of labor according to the number of farmland occupied by each family. This is the "Chun Kai Qu Shi Men" in the "Tiansheng Law". There are special regulations: Families with one mu of land to ten mu of land need to send people to work for five days. Families with eleven mu of land to forty mu of land need to send people to work for fifteen days. Households with forty one mu of land to seventy-five mu of land need to send people to work for twenty days. A family with seventy-five mu of land to hundred mu of land needs to send people to work for thirty days. A family with hundred mu of land to one hectare of twenty mu of land needs to send people to work for Thirty five days, and has one hectare of twenty mu of land to fifty hectares of land. The family needs to send people to work for forty days. Usually, the canal should not exceed forty days. If the task of opening the canal is not completed, it is necessary to extend the working time. The official who presides over the canal project will make a request, re-negotiate in front of the Zai Xiang according to the regulations, and then obtain the consent before continuing to open the canal. If you do not get the consent of the higher level government, you will be punished by the law if you advocate the opening of the channel for more than forty days. The specific "Chun Kai Qu Shi Men" stipulates that more than one day will be sentenced to three months in prison, more than four days to seven days. The sentence of imprisonment is four months, and the sentence of imprisonment for more than Seven days to ten days, and the sentence of imprisonment for more than ten days is two years.

Through the above laws, we can see that the government of the Xixia period attaches great importance to the opening of the canal in the spring, and the laws are very carefully and rigorously prescribed. It not only protects the rights of farmers who participate as labor, but also tries not to consume the people's strength, does not delay the farming, and also ensures the cleanup and maintenance of water conservancy channels, laying a good foundation for the smooth irrigation of water conservancy throughout the year.

3.4 Water Supply in Sequence.

Due to the dry climate and little rainfall in Xixia, the development of crops is very dependent on the irrigation area, and the time node of irrigation is also very important. According to the process of growth and development of crops, the crops in Xixia area
mainly have three water time nodes, head water, second water and three rounds of water. The head round of water mainly refers to the water used for watering crops within one month after Li Xia, mainly in May; the second round of water mainly refers to the water used for watering crops from Xiao Man to Xia Zhi, mainly in June; the three rounds of water mainly refers to the water used to irrigate crops during Xiao Shu to Da Shu, mainly in July. If you can get timely and sufficient water for watering in these time periods, it will become a guarantee for a bumper harvest. However, the irrigation channel is a public facility, which is built by the government and used together. In the process of use, it will be difficult to avoid the competition for water use rights.

Therefore, the Xixia law stipulates that water supply should be sequentially in accordance with the order of the fields. It is strictly forbidden to occupy water conservancy, or to accept bribes in the canal, and not to release water in sequence. "Qu Shui Men" stipulates that "Jie Qin, Zai Xiang, and other people with status, richer people, etc, if they beat Qu Tou, cause Qu Tou to disperse water in order because of fear of others, and cause channels to break, causing other people's livestock and articles. Loss of property, crops, grasses, etc, and to compensate for these losses, it is necessary to compensate for one-half. If Qu Tou accepts bribes, it will not have water in advance in the field where it is in turn, and the channel will be broken. For all losses, Qu Tou assumes primary responsibility, and the bribe is an accomplice and assumes secondary responsibility."

In addition to the main canal, capillary channel irrigation is also very likely to cause water rights disputes. In the Xixia "Di Shui Za Zui Men", it is stipulated that when Zu Hu Jia Zhu is irrigated along the capillary channel of the water supply, the person who releases the water should monitor it well and do not allow water to be released in the middle of the field.

3.5 Maintenance of Water Conservancy Facilities.

Careful management and maintenance of water conservancy facilities is the basic condition for long-term and effective use of water conservancy projects. It is an important guarantee for water conservancy projects to give full play to the social functions of irrigation, water use and flood control. It is the promotion of Xixia economic and social development by water conservancy projects. Inexhaustible power. In order to effectively manage and maintain water conservancy projects, Xixia has made the following provisions in water conservancy legislation:

First, determine the responsibility for managing and maintaining staff. In the "Cui Zu Zui Gong Men" in "Tiansheng Law", when the relevant water conservancy management department negotiated in front of Zai Xiang, the central organization required the "water conservancy management department to open the canal well and carry out maintenance on Dian Ban, ZhaMen and other facilities in the water conservancy project. It is necessary to make them strong and intact. The management and maintenance work time has been from the summer season to the end of the winter." In the long-term management implementation process, if the channel of the Qu Zhu Ju Fen jurisdiction is found to have Dian Ban, ZhaMen, etc. If the important facilities are not strong, damage occurs, or even breaks, etc, Qu Zhu did not find it beforehand, and did not report it to Qu Shui Xun Jian, so the penalty was the same as the Qu Zhu negligence duty. If Qu Zhu finds it in advance, it also reports it to Qu Shui Xun Jian in time. As a result, Qu Shui Xun Jian does not listen, Qu Zhu does not continue to report Shui Li Ju Fen, resulting in damage to water conservancy facilities, Qu Zhu is lighter than Qu Shui Xun Jian crime. Although the water conservancy facilities are damaged, but they are not broken, then Qu Zhu has
no responsibility. There is an official Qu Shui Xun Jian penalty for a horse, and there is no official Qu Shui Xun Jian inspection for 13 sticks.

Second, clearly establish the stone and determine the scope of the inspection. In order to determine the scope of work of the staff and clarify the job responsibilities, Xixia set up mounds along the main channel and set up stone tablets to express their respective duties and scope. "Qu Shui Men" stipulates: along the Tang Lai qu, Han Yan Qu and other large canals, it is necessary to clarify the scope of work of the staff in each area, set up a mound at the junction, and set up a large stone on it, clearly marking the responsible person responsible for supervision and inspection. Name, and require each lot to set up a stone in the order of the channel. The Qu Shui Xun Jian and Qu Tou whose names have been printed must work conscientiously, and carefully inspect the Qu Gan, Qu Bei, Tu Zha, grass, etc. within the jurisdiction, and the channels must not be destroyed. If someone destroys the channel, They has the right to arrest the criminals and escort them to the water management office, and They is fined according to the law.

Third, protect the canal and plant trees. The water irrigation channel is a huge engineering system. In addition to Gan Qu, Zhi Qu, Dou Qu and Mao Qu, there are large and small bridge roads and criss-cross protection forests. Xixia also attaches great importance to the cultivation and protection of protected forests along the channel. The "Di Shui Za Zui Men" in the "Tiansheng Law" stipulates that the farming or renting families living along the main canals along Tang Lai qu, Han Yan Qu, etc. should follow their own channels. Planting willows, cypresses, poplars, eucalyptus, and other trees will protect the newly planted trees from the original trees. In addition to the necessary trimming of trees, trees are not allowed to be cut down at will, and the Transit Division dispatches capable people to monitor the planting and protection of trees.

Fourth, select high-quality materials and make good material reserves. "All things are carefully prepared to be successful. If they are not prepared seriously, they will fail." Xixia should also carefully select the materials collected and stored on weekdays, and choose high-quality materials for the construction and maintenance of irrigation channels. "Hai Nian Xin Fa" Volume fifteen "Tang Lai Deng Lian Tiao Cao Fa Men" stipulates: water in Tang Lai qu, Han Yan Qu is the domestic water for the diet of the Xixia people, is the irrigation water for food, and is the water for the protection of the Xixia military grain. Unlike the weeds, Tiao Chuan and other materials paid by other channels, the size of the main canal is in and out of the warehouse, and is used to repair the material of the canal. If it is a good material, it cannot accommodate generally bad materials. When materials come into the national treasury, the size of the responsibility and the seriousness of the plot are determined based on how many poor quality materials. Zhi Shi Xiao Jian, Qu Zhu, Xun Jian should choose good Tiao Chuan and weeds, and the size should be made into a bundled income warehouse.
For those homeowners who have paid poor quality weeds and regulations, the supervisors can determine their guilt according to the book vouchers registered at the time.

4. CONCLUSIONS

Xixia's water conservancy regulations were formulated on the basis of inheriting the water conservancy laws of the Tang and Song dynasties, and were the first comprehensive code promulgated in ancient Chinese water conservancy history. Xixia "Tiansheng Law" and "Hai Nian Xin Fa" two water regulations, "Tiansheng Law" was formulated in the middle of Xixia, and it is also for the political stability of Xixia, the economy is developed, and the social civilization is the highest. The regulations are very important for the management and maintenance of water conservancy.

Detailed and specific provisions. The formulation of "Hai Nian Xin Fa" has been in the late Western Xia, social unrest, economic stagnation, and the difficult period of the surrounding political power. The main provisions of the regulations on water conservancy are embodied in the taxation and levy. The provisions are rough and there is no time to take care of the long-term project of water conservancy projects. By contrast, we can clearly see that if the country prospers, water conservancy construction can flourish; and the development of water conservancy construction also promotes the country's prosperity. If the country declines, water conservancy construction will inevitably decline along with.

The provisions of the Xixia Water Conservancy Law not only reflect Xixia's emphasis on farmland water conservancy, but also reflect the wisdom of the Xixia people. The water conservancy laws and regulations fully reflect the orderliness of agricultural production organizations, the planning of watering fields, the scientific nature of agricultural time, the strictness of water conservancy construction and management, and the comprehensive characteristics of legal system construction.

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HISTORICAL WATER SUSTAINABILITY: A CASE STUDY OF THE PHAD IRRIGATION SYSTEM OF MAHARASHTRA STATE, INDIA

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ABSTRACT

In this paper an attempt is made to study historical community managed sustainable Block Irrigation System popularly known as Phad Irrigation System from the Khandesh region of Maharashtra State, India. There has been a rich historical tradition of community managed sustainable irrigation systems in India. Such irrigation systems are found all over India. Some of these systems are so old that it is impossible to establish their antiquity. It is surmised that the existence of Phad irrigation system has been in practice since the time of Mouryas rule over Khandesh (300 BC). The history testifies that the Phad system received patronage in the tenure of kings of Yadavas (around 1000 years back) and Queen Ahilyabai Holker (in the Seventeenth Century).

Phad irrigation system is one of those sustainable community managed irrigation systems which have relevance even today for providing predictable, reliable and equitable water to farming community for maintaining sustainability in agriculture.

The system envisages construction of masonry weir across the river and divert the water so impounded for irrigation through canals. The area under irrigation used to be divided into four parts and each one was recognized as a Phad (Block). Only one type of crop used to be harvested in a single Phad. However, different crops were taken in different Phads, which were decided by the people. Once crop pattern was decided, crop cycle is maintained and crops are rotated every year among the Phads so that after every four years same crop is grown in the same Phad.

It helps to sustain soil fertility and no soil is ever rendered saline or water logged in Phad system of irrigation. The farmers share, both prosperity and distress equitably. The system is still surviving at some places but is under threat due to change of environment. Up-gradation and modernization is needed for the smooth function of these community managed sustainable Phad irrigation systems under changing environment.

Keywords: Phad irrigation system, Historical community managed irrigation system, Sustainable irrigation system

1. INTRODUCTION

The management of natural resource like water requires a great degree of participation by those who benefit from the productive use of this resource. Irrigation water management is an interdisciplinary, multi system science, fitting to the socio-cultural aspirations. Historically, this has remained a less highlighted dimension in exploitation, development and use of water resources. The earlier participatory efforts were not further expanded and groomed to solve the irrigation water management issues on a larger societal scale. At a later stage, more emphasis was given on

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creation of physical structures like dams, canals and other on-farm structures overlooking the socio-cultural, organizational and economic aspects in their proper contexts, resulting in lower performance of such irrigation projects. In Indian context, there were certain efforts under-taken in different ways in different states, because development of water resource is the state’s responsibility. Intermittent efforts for Participatory Irrigation Management were either through social groups, devoted individuals or through the initiative of the state Government and their officials (WALMI 1999).

2. GLOBAL EXPERIENCES IN PARTICIPATORY IRRIGATION MANAGEMENT

Participatory Irrigation Management (PIM) has gained increasing importance and recognition all over the world in the last half century. The trend towards expanded state control over irrigation system has changed and Participatory Irrigation Management is becoming the global trend (David Groenfeldt, 1997). Most of the countries have adopted the Participatory Irrigation Management system. Some of the notable countries include USA, Taiwan, France who adopted PIM in early period of 20th century. This was followed by many experiments of PIM in Latin American, European, and Asian countries and others. The examples of countries include Mexico, Chile, Peru, Brazil, Colombia, Zimbabwe, Tanzania, Sudan, Somalia, Vietnam, China, Indonesia, India, Shri Lanka, Bangladesh, Pakistan, Philippines, Egypt, Jordan, Turkey, etc. which have adopted PIM with varying degrees and success.

USA made pioneering effort of PIM as early as irrigation facilities constructed by the United Bureau of Reclamation and other federal agencies and are generally transferred to local water user entity for operation and maintenance (David Geoenfeldt. 1998). Certain examples of PIM transfer in the case of USA are, Columbia Basin Irrigation Project in Washington State (1969), King River Irrigation System of Fresno, California, Big Thompson Irrigation Project of Colorado State etc. Mexico had made very successful efforts for transfer of management of irrigation to farmers' association. Government has created National Water Commission in 1989. Top priority was given for transferring public irrigation districts to private organizations. Now more than 75 per cent of transferred area belongs to Water Users' Associations (WUA). Several irrigation districts including Alto Rio Lerma had been transferred to various Water Users' Association. Mexico's PIM programme has attracted worldwide attention (David Geoenfeldt, 1998).

Indonesia had prepared a policy statement on transfer of small irrigation systems in 1987 (having area of 500 ha each) and actually implemented the same in 1989. In Indonesia, several irrigation schemes were constructed during 18th Century, such as Penali Canal Irrigation Systems. Irrigation Systems are classified on the basis of management responsibilities whether the system is administered by Government or by Non-Government Organization. Four popular irrigation organizations and farm water management exist in Indonesia viz. The Subak Irrigation system, the Village Irrigation System, The Ulu-Ulu Desa Scheme and the Tertiary Level Water Management System (David Geoenfeldt, 1998). China had made efforts of reforms in management of irrigation in 1980s. In 1990s, a system of farmer, Stock holding arrangement began.

In Nepal, PIM activities were initiated on direction of irrigation policy of 1992 based on participatory approach of irrigation management. The minor irrigation systems have been entirely transferred to WUAs and large systems are managed by the Government and WUAs. Water Users' Groups is the mechanism for farmers' participation. In the Narayani Irrigation Project, there is a tertiary based, two-tire organization, and the beneficiaries served by each division box form a gross-root
Water Users Group. The same organizational pattern is followed in the Mahakali Irrigation Project expect that the organizations are registered under the Cooperative Act. In the Kankai Irrigation Project, there is a complex hierarchical multipurpose organization similar to co-operatives (David Geoenfeldt, 1998).

Philippines Government created a body called National Irrigation Administration (NIA) in 1964 for development of irrigation in the country. But due to poor performance of irrigation system, a new scheme of farmers’ participation in irrigation water management was introduced in 1988. Farmers’ Irrigation Organizers were employed as catalysts and assistance of NGOs was taken for formation of Association (David Geoenfeldt, 1998).

Farmers’ involvement in the irrigation management in Sri Lanka is from the 11th Century. One of the largest six thousand acres tanks in north-eastern Sri Lanka, Parakrama Samudra near the ancient capital of Pollannaruwa, was built under the guidance of King Parakramababa in the 11th century. Sri Lanka had declared PIM as official Government policy by 1988. The farmers’ organizing efforts are seen at different levels. Several farmers’ organizations are formed in the Mahaweli Development Scheme and the Gal Oya Scheme. Operation and maintenance at distributory level are completely looked by farmers’ organization and main canals are managed by project management committees in which farmers’ representatives are in the majority, while several Government departments are also represented. It is recommended by Irrigation Management Policy Support Activity (IMPSA) that there would be no more minor irrigation and major irrigation categories but only farmer managed and joint managed system.

South Korea is also on the lead in the process of farmers’ participation in irrigation water management. Irrigation projects are planned by the Ministry of Agriculture and Fisheries. However irrigation project commands are managed by the Farm Land Improvement Association. General Manager heads the organization of the association, who is elected by the members (farmers) of the association.

In Malaysia, farmers have constructed traditional irrigation facilities such as Brushwood Weirs and Water Wheels in small paddy area. The Drainage and Irrigation Development has undertaken these community efforts, and provided proper irrigation and drainage facilities. Realizing the role of farmers in managing irrigation water, Drainage and Irrigation Department has encouraged farmers’ involvement and participation in the maintenance and operation of tertiary canal and drainage systems. A major experience of farmers’ participation in the process of planning tertiary irrigation and drainage system is seen in Muda Irrigation Project (David Geoenfeldt, 1998).

Different terminologies have been used by these countries to refer PIM, such as Turnover (Indonesia and Philippines), Management Transfer (Mexico and Turkey), Privatization (Bangladesh), Disengagement (Senegal), Post Responsibility System (China), Participatory Management (India and Sri Lanka), Commercialization (Nigeria), Self-Management (Niger) (David Geoenfeldt, 1998).

3. PARTICIPATORY IRRIGATION MANAGEMENT IN INDIA

There have been rich historical traditions of Participatory Irrigation Management in India since fourth century till the recent past. Community managed traditional irrigation systems are found all over India. Some of these systems are so old that it is impossible to establish their antiquity. In the fourth century, Chanakya the author of “Arthshastra (Economics)” reported that political and economic treaties were made to assist farmers in giving assistance or incentives to manage irrigation systems. In Vijay
Nagar Empire of 13-16th Century, now part of modern Karnataka, a practice of farmers’ participation in construction of diversion weirs and canals was prevalent. In Tamil Nadu, the Chola King Karikala built annicut on the river cauvery and lower part of irrigation system was managed by the farmers, known as “kudimaramat” (farmer maintenance). Himachal Pradesh had an ancient system called “Kuhi” in which irrigation was managed by the community. In the hilly regions of Uttar Pradesh also a tradition of farmers managing diversion streams is found. In Maharashtra the “Phad System” and “Malgujari Tank System” farmer managed irrigation systems were existing since last 300 to 400 years (Agarwal Anil and Narain Sunita, 1997).

Participatory Irrigation Management activities have gained momentum in all the major states of India, which include Maharashtra, Karnataka, Andhra Pradesh, Gujrat, Madhya Pradesh, Rajasthan, Tamil Nadu, Uttar Pradesh, etc. by way of formation of Water Users’ Association (WUA), Water Users’ Co-operative Societies (WUCS) and other institutions (Lele S.N. and Patil R.K, 1994). The other states also followed suit in this matter. At present, these states have made legal provisions and Acts for smooth transfer of management to Water Users’ Associations formed by the beneficiary farmers in India.

4. COMMUNITY MANAGED OLD PHAD (BLOCK) IRRIGATION SYSTEM IN INDIA

In the North – West part of Maharashtra i.e. in the Khandesh region, there are a number of community managed small irrigation schemes in the Tapi basin. These are popularly known as “Phad Systems”. Phad means a block. The irrigation scheme consists of diversion weir (Called Bandhara) across a river and irrigation channel commanding area, mainly from one village. A series of weirs were built in this basin on the rivers viz. Panzara, Mosam, Aram, and Girna to divert water for agricultural use. These schemes are prevalent in Nasik and Dhule districts, i.e. of Maharashtra State. The Phad irrigation system existed since the time Mouryas ruled over Khandesh (300 BC) (Chitale M.A., 1999). Further, during the seventeenth and eighteenth centuries phad system had received patronage in the tenure of Queen Ahillyabai Holkar and it appears that the true development of equitable water distribution had taken place in this period which has relevance in the 21st century.

5. DIFFERENT COMPONENTS OF THE PHAD SYSTEM

There are different components of the Phad system. These are related to technical aspects of these diversion weir, main canals, number of Phads (Blocks), cropping system and management of the Phad system. These aspects are briefly discussed below:

5.1 Weir (Bandhara)

Surface irrigation is a boon for this area. A weir (Bandhara) mostly supplies water to one village. The rights of water have been fixed by tradition, which are strictly adhered to. River wise existing weirs (Bandharas) and their command areas are shown in Table 1.

There are 66 weirs irrigating 5569 ha land. Maximum number of weirs across the Panzara River are 30 and Mosam river are 20, commanding 3594 ha and 1500 ha area respectively. The command area of individual weir varies from 4 ha to 192 ha. All weirs are masonry weir, with height above river bed ranging from 2 m to 10 m. Most of the weirs are located on the turns of rivers. To take advantage of this geographic situation, there was a tradition to construct weirs across the perennially flowing rivers at this location. The technique of construction of weirs and diverting the
river water for irrigation were developed from the dynast Mourayas period (300 BC). Construction of the weir was a community activity. In some cases, the capital cost of these schemes were met by the kings or rulers. But once completed, farmers were supposed to operate them on their own. The distance between two successive weirs varies from 2 km to 6 km, depending upon the topography and availability of suitable sites (WALMI, 1991).

Table 1. Number of Weirs and Area Irrigated

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>River</th>
<th>District</th>
<th>No. of Weirs</th>
<th>Command Area (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Panzara</td>
<td>Dhule</td>
<td>30</td>
<td>3594</td>
</tr>
<tr>
<td>2</td>
<td>Mosam</td>
<td>Nashik</td>
<td>20</td>
<td>1500</td>
</tr>
<tr>
<td>3</td>
<td>Aram</td>
<td>Nashik</td>
<td>08</td>
<td>275</td>
</tr>
<tr>
<td>4</td>
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<td>08</td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>66</td>
<td>5569</td>
</tr>
</tbody>
</table>

Source: Approach paper on “Phad system of Irrigation in Maharashtra state”, National workshop on phad system held at Dhule, Jan 3-4, 1991, published by WALMI, Aurangabad (M.S).

5.2 Canals

There is no control structure at the head of main canal. The length of these canals varies from 2 km to 12 km. Each canal has a uniform discharge capacity of about 450 litres per second throughout the length (head to tail). The canals terminate in to a natural drain/river. The components of phad irrigation system are shown in figure1.

Figure 1. Phad Irrigation System

5.3 Number of phads (Blocks)

The irrigated command (Kayam baghayat) is usually divided into four blocks called phads. The size of a phad can vary from 10 ha to 300 ha. Each Phad has a number of beneficiaries. The division and size of phads depends on topography and physical boundaries viz. natural depression, nallas (rivers), roads, etc. a common layout of the phads is shown in Figure 2.

Figure 2. Layout of the Phads

Water is supplied to each phad and individual field through branch canal and field channels respectively. All the phads get water simultaneously, if the flow in the river is
sufficient. Otherwise, individual phads are rotated, if the available flow is less. Within an individual phad, water is supplied from head to tail.

5.4 Cropping System

The cropping pattern consists of cash crops like sugarcane, groundnut and food crops like wheat, gram, sorghum etc. Only one type of crop is allowed to grow in one phad. Cropping pattern is decided so wisely that, it helps in utilizing the available water efficiently; equality in water distribution ensured and fertility of land is maintained.

Generally sugarcane is grown in one or two phads, depending upon availability of water. In other phads seasonal crops are grown. In monsoon, rice or sorghum is grown. The irrigated crops are rotated every year from one phad to the other so that after every four years same crop is grown in the same phad. As shown in Table 2.

Table 2. Crop Rotation in the Phads

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Year</th>
<th>Phad I</th>
<th>Phad II</th>
<th>Phad III</th>
<th>Phad IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I</td>
<td>Sugarcane (Ratoon)</td>
<td>Sugarcane (New)</td>
<td>Wheat</td>
<td>Gram</td>
</tr>
<tr>
<td>2</td>
<td>II</td>
<td>Gram</td>
<td>Sugarcane (Ratoon)</td>
<td>Sugarcane (New)</td>
<td>Wheat</td>
</tr>
<tr>
<td>3</td>
<td>III</td>
<td>Wheat</td>
<td>Gram</td>
<td>Sugarcane (Ratoon)</td>
<td>Sugarcane (New)</td>
</tr>
<tr>
<td>4</td>
<td>IV</td>
<td>Sugarcane (New)</td>
<td>Wheat</td>
<td>Gram</td>
<td>Sugarcane (Ratoon)</td>
</tr>
</tbody>
</table>

Source: - Approach paper on “Phad system of Irrigation in Maharashtra state”, National workshop on phad system held at Dhule, Jan 3-4, 1991, Published by WALMI, Aurangabad (M.S).

The phad wise rotation of crops helps in maintaining the fertility of the soil and reducing the danger of water logging & salinity as high water consuming crops are rotated (WALMI 1991).

5.5 Management of the Phad

Every village has an effective system of management. A village level committee is formed by the irrigators. The members of the committee are elected mostly by consensus in the general body meeting. The elections are generally held once in every two to four years. The general body also chooses the chair person. The chair person may continue for several years. The number of committee members is not fixed. It varies from place to place and village to village.

The phad system of irrigation is entirely managed by the community. It has its own controlling organization. Generally, the command lies in one village boundary only. All the important functions like choice of crops to be grown, water distributions (watering), maintenance of water distribution system etc; are managed by the committee.
5.6 Functions of Committee

The functions of a village level committee are as follow:

(a) Protect, supervise, and administer the irrigation system.
(b) Employ supervisors, canal inspectors and water guards for irrigation.
(c) Solve disputes and impose fine on the offenders.
(d) Decide the cropping pattern
(e) Decide sequence of irrigation of the fields in a Phad.
(f) Call an annual general body meeting.

5.7 Functions of Irrigators

The functions of irrigators/beneficiaries are as follow:

(a) Elect the committee members and decide the chair person.
(b) Maintain the field channels and distributaries.
(c) The operations like tillage, sowing, removing weeds from the fields, applying fertilizers, applying pesticides and harvesting are to be done by the irrigators.
(d) Take the type of crop as decided by the committee.

6. RELEVANCE OF PHAD IRRIGATION SYSTEM IN THE PRESENT SITUATION

Though the phad irrigation system is a very old community managed system, it has relevance in 21st century as well. This irrigation system is useful even today on following grounds:

(a) Social Environment: The system is responsive to its changing social environment. For example, the composition of the committee can be increased or decreased according to the needs and dedication of the members. The number of irrigation staff may change as per need.
(b) The system shows flexibility: The committee memberships are renewed regularly. The new members generally have dynamic relationship with the village power structure.
(c) Equity: Irrigation operations are performed by the staff and farmers are not allowed to interfere. The irrigated crops are rotated every year from one phad to the other so that after every four years same crop is grown in the same phad. Thus equity in water distribution is maintained.
(d) Easy to farmers: The farmers need not worry about the irrigation and guarding the crops in their field. Specially engaged supervisory staff takes care of watch and ward of the standing crops, as they have to get share from the individual field produce.
(e) Collective maintenance: Maintenance is a group function. All farmers contribute proportionately both in labours and leadership. Discipline is strictly enforced.
(f) Sustainability: The Phad system has continued to survive despite political changes taking place, during the last several centuries. The system shows
that governments influence is not necessary for making self management possible.

(g) Effective participation: The Phad system shows that small farmers can organize themselves and can form a sustainable irrigation system. There is scope to have Phad (Block) irrigation system in Waghad irrigation project of Maharashtra, India and in similar other projects. Also in Kolhapur and Sangli Districts of Maharashtra, there are a number of private and co-operative lift irrigation schemes, where farmers are organized. In these schemes also there is a scope to have Phad (Block) irrigation system.

(h) Productivity of land: The crops are rotated from one Phad to another and frequently one Phad is kept fallow in rotation. Because of frequent non irrigation and crop rotation, the lands neither gets water logged nor gets saline. Thus fertility of the land is maintained.

7. CONCLUSIONS

(a) Maharashtra State has a long experience of Participatory Irrigation Management. Phad System is the best historical example of the Participatory Irrigation Water Management, in India.

(b) The community managed Phad System of irrigation worked successfully since last several centuries together. It is a basic principle of PIM strategy being implemented on large scale in Maharashtra state of India.

(c) The Phad irrigation management of the available water in the weir is said to be one of the best systems of management. The water distribution practice and the management rules are so framed that they sustain for a long period.

(d) The involvement of farmers' is one of the best examples in the irrigation water management. Phad irrigation system can be set as a good example of equitable distribution of available water and its proper management.

(e) The crops are rotated from one Phad to another and frequently one Phad is kept fallow in rotation. Because of frequent non irrigation and crop rotation the lands neither gets water logged nor gets saline. Thus fertility of the land is maintained.

(f) The Phad system shows that small farmers can organize themselves and can form a sustainable irrigation system in small and medium irrigation projects and also in lift irrigation schemes.

(g) Up-gradation and modernization is needed for the smooth functioning of these community managed phad irrigation systems under changing environment.

(h) Now, this age-old Phad Irrigation system is under threat due to climate change. The water flow in the rivers has been badly affected due to construction of dams upstream of the rivers. Further, setting up too many sugarcane factories in the area encouraged sugarcane plantation which badly affected availability of water in the area of Phads.

The ancestors were far ahead in field water management. They were taking utmost care for equitable distribution of water harvested and stored in water bodies. Therefore, the techniques and the systems lasted for centuries together. Unearthing these wise principles can give immense knowledge to the water users in the present situation.
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CHARACTERISTICS AND VALUES OF IRRIGATION
HISTORICAL SUSTAINABILITY IN CHINA

LI Yunpeng¹, ZHOU Bo² and TAN Xuming³

ABSTRACT

In the Chinese irrigation history of more than 2000 years, myriad irrigation projects were constructed for agricultural development. As excellent models of sustainable irrigation, many of historical irrigation structures have been used for hundreds of years, even thousands of years, and are still playing a role today, 17 of them have been declared into ICID List of the World Heritage Irrigation Structure. In this paper, the historical context of Chinese irrigation development was narrated in brief by six stages. Through typical cases, the paper systematically analyzed the basic characteristics and scientific value of Chinese sustainable irrigation in methods and concepts of water resources development, technical features of engineering planning and structure design, continuity of the management system, ecological environment impacts of long-term used engineering operation, et al.. The dissertation intends to summarize historical experience of sustainable irrigation in China, which may have specific value for the sustainable development of modern irrigation.

Keywords: irrigation, sustainability, heritage irrigation structure, China history.

1. INTRODUCTION

China has time-honored history and civilization of water projects, which is determined by its unique natural environment. In China with a vast territory, the natural conditions such as topography, landform and monsoon climate vary greatly in different regions, resulting in different water conservancy issues.

China has a typical East Asian monsoon climate and its spatial and temporal distribution of precipitation varies greatly, with annual precipitation decreasing from more than 1,600mm to less than 200mm from China’s South-East coastal areas to northwest inland. The eastern China not only has high precipitation, but also 60-80% of the annual precipitation is concentrated in the four months, i.e. June-September. Rainfall distribution is often not compatible with water storage period for crop growth. The regional irrigation and water conservancy conditions for agricultural production need to be improved, and farmland water regime needs to be regulated and changed through engineering facilities. Different irrigation and water conservancy conditions promote different types of irrigation and water conservancy projects. The arid areas in China mainly rely on groundwater for irrigation, while the semi-arid areas mainly depend on canal system projects which divert water from rivers for irrigation, with mostly dry crops; and the semi-humid Northeast and North China Plains are also dominated by dry crops. Among them, the North China Plain has a large area of saline-alkali soil, and attention should be paid to drainage, while humid areas are mainly composed of paddy fields.

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From the point of view of geomorphic conditions, China is high in the northwest and low in the southeast in the general topography, with mountains of about 33%, plateau of about 26%, hills of about 10% and plains and basins of about 31%. Most rivers flow from west to east along the topography. Under complex geomorphic conditions, the working people of past dynasties also created many kinds of irrigation agriculture forms, such as plain irrigation area agriculture, lake and coastal tidal flat agriculture, polder agriculture in hydrographic net area, mountain terraced agriculture and so on.

Since ancient times, Chinese society has high food demand due to the large population and wide distribution, making agricultural irrigation irreplaceable. The construction of irrigation projects runs through China’s 5,000-year history. The agricultural taxes are the main source of finance. The construction of irrigation and water conservancy projects has always been the focus of development and of concern for all dynasties.

This paper focuses on discussing the historical stages and laws of irrigation and water conservancy development in China, analyzing the technical characteristics of irrigation projects in ancient China from the perspective of sustainable development and recognizing the scientific and technological, cultural and ecological value from the perspective of heritage.

Figure 1. Rivers, lakes, and irrigation belts in China.

2. BRIEF IRRIGATION HISTORY OF CHINA

2.1 Origin: 3000B.C.-476B.C.

The irrigation and water conservancy of China originated from the legend of King Yu Tamed the Flood in which King Yu balanced harness of soil and water and opened the era of irrigation and water conservancy development. According to the current archaeological discoveries, paddy field sites and 20,000 jin of carbonized rice were found in Liangzhu culture around 3000B.C. The remains of main canal and branch canal systems for irrigation were discovered in the capital of Shang Dynasty around 1600B.C.; and the well irrigation model was found in the Yuzhuang tomb of Han Dynasty of 200B.C., revealing that the primitive ditches for water storage, diversion, irrigation and drainage appeared very early in China, and irrigation and drainage technologies were burgeoning.
2.2 First Construction Climax: 475B.C.-100A.D.

The period of 475B.C.-100A.D. is the first climax of irrigation and water conservancy development in China. At that time, dukes or princes under an emperor struggled for hegemony. For the purpose of enriching the country and increasing its military force, many feudatory states attached great importance to the construction of irrigation and water conservancy works and constructed many representative irrigation projects.

Qin State built the famous Dujiangyan irrigation system in the Minjiang River Basin of Western Sichuan Plain in 256-251A.D. and its outstanding design concept, technology and management system are still the model of irrigation projects in China. The irrigation canal system in the Guanzhong area, the political center of Qin and Han Dynasty, has been very developed. Besides the famous Zhengguo Canal and Baiqu Canal, there is Chengguo Canal, Caoqu Canal and Longshou Canal. Zhengguo Canal was built in the first year of First Qin Emperor (246B.C.), diverting water from Jinghe River, a tributary of Weihe River, to Luohe River in the east, with the total length of more than 300 miles. The survey of canal line of main canal and rational utilization of terrain show a high level of engineering technology.

In the agricultural area of the middle reaches of the Huaihe River, the Quebei Irrigation Project in Shouxian County was constructed in the period of King Zhuang of Chu in the Spring and Autumn period (601B.C.-593B.C.). It is a typical impounding reservoir catchwork irrigation project with a history of more than 2,600 years, collecting rivers and water from the southern mountains to irrigate the downstream farmlands. It still works nowadays. The construction of Quebei Irrigation Project has promoted the agricultural development in the middle reaches of the Huaihe River and made this area become an important grain-producing area in China. Historically, the irrigation area of Quebei Irrigation Project reached 10,000 hectares at most.

Irrigation and water conservancy projects have also been developed in the Northwest China and North China. During the reign of Emperor Wu of Han, the climate of Tarim River and North Bank of Lop Nor was mild, and farmland with irrigation conditions reached more than 5,000 hectares. The reclaimed field of Xinjiang in the Han Dynasty was extended to Loulan (now North Bank of Lop Nur). There are still remains of Hanqu Canal. Therefore, the irrigation and water conservancy has been developed to a certain level. In addition, irrigation projects have been widely constructed in the Hetao area and Hexi Corridor..

2.3 Eastern Han Dynasty- Northern and Southern Dynasties: 25A.D.-589A.D.

In the late Western Han Dynasty, the prolonged war in the Central Plains forced a large number of people to move southward, which promoted the spread of irrigation and agricultural technologies. Especially with the rapid development of irrigation agriculture in the Huaihe River Basin and the southern area of the Yangtze River, these areas quickly became emerging economic areas.

Impounding reservoir was well developed in the area of Huaihe River and its northern tributary Ruhe River. During the period of two Han dynasties, Hongxibei Irrigation Project in the north of Xixian County was the most famous for its large-scale water storage irrigation works. In Runan County, impounding reservoirs like Hongxibei Irrigation Project were widespread and often connected with irrigation canals in series, forming a canals joining reservoirs type irrigation system. At this time, Cao Cao promulgated the “Reclamation Order” in the Wei State, which diverted water from Yinghe River for irrigation. Baishuitang Irrigation Project was the most famous one among the impounding reservoirs, which is located 80 miles southwest of Baoying,
near Huai’an in the north and bounded by Xuyi in the west. Its total length was 250 miles and it irrigated more than 10,000 hectares of land.

During the nearly 300 years from the Eastern Jin Dynasty to the unification of Sui Dynasty, Nanjing was relatively stable because it was the capital, providing the necessary environment for the construction of irrigation and water conservancy projects. At this time, Chishan Lake in Jurong County and Lianhu Lake in Danyang County were important impounding reservoir type irrigation projects. During this period, the Qiantang River Basin was also well developed. Jianhu Lake and Dongqian Lake in the south of Qiantang River were well-known irrigation projects. Jianhu Lake is located 3 miles south of Shaoxing City. In the fifth year of Emperor Yonghe in the Eastern Han Dynasty (140), Kuaiji Prefecture Chief Ma Zhen presided over the construction. Jianhu Lake ingeniously utilizes the local terraced terrain of mountain-plain-sea to build a 310-mile dike around the lake on the north side of the swampy lake, which intercepts and impounds the stream originating from Kuaiji Mountain to form a reservoir. Such reservoir irrigated more than 9,000 hectares of fertile paddy fields by gravity.

Tongji Weir built on Oujiang River was also an important irrigation and water conservancy project in this period. Located in Lishui County of Zhejiang, it was built in the period of Liangtianjian (502-519) and was a diversion irrigation project where low weir was built to dam a river so as to increase the upstream water level and then a canal was built to divert water. Diversion bridge was built at the intersection of main canal and mountain stream and “caves” were also constructed for draining excessive water. In addition to main canal, branch canals and lateral canals were formed into an irrigation network and gates were installed on the channel which are closed and opened by fixed water gauge, thus achieving effective water quantity control. Lishui Tongji Weir has its own management system. Weir rules of all dynasties were compiled into a book in the Qing Dynasty, namely Tongji Weir Annals, which became an annals model of irrigation and water conservancy projects.

Irrigation and water conservancy projects have also been developed in the Tangbai River Basin, a tributary of Hanjiang River. During the reign of Emperor Hanyuan, Zhao Xinchen was appointed to Nanyang, and built dozens of irrigation and water conservancy projects there, with a total irrigated area of 30,000 hectares. Among them, the most famous projects are Liumen Weir and Qianlubei Irrigation Project. Liumen Weir was so named for six irrigation gates successively built on the lake embankment. The irrigation water was diverted from the gate and then connected with 29 impounding reservoirs in series to irrigate more than 5,000 hectares of land. The irrigation water system of “Equal Water Restrictions” was established for the irrigation area, improving the irrigation level.

2.4 Prosperity and Development: Sui, Tang and Song Dynasties 581A.D.-1279A.D.

For more than 700 years in Sui, Tang and Song Dynasties, the political environment was relatively stable, and the unified control situation created a prerequisite for economic development. During this period, the economy in the Yangtze River Basin made considerable progress, and the economic center shifted from the middle reaches of the Yellow River to the lower reaches of the Yangtze River. Bai Juyi once described the government’s fiscal revenue as follows: “Taxes come from the whole country, with the south of the lower reaches of the Yangtze River accounting for 90%.” China’s irrigation and water conservancy construction entered a new stage of consolidation and development. The flourishing of polders in the lower reaches of Taihu Lake, the large-scale colmatage in the Yellow River Basin and the gradual perfection of irrigation and water conservancy management regulations were the
important characteristics of irrigation and water conservancy construction in this period.

It was a foregone conclusion that the southern economy surpassed northern economy in the Northern Song Dynasty, which lasted until modern times. The polders in the south of the lower reaches of the Yangtze River were developing rapidly, with dense irrigation channels inside, polder embankment around and sluices on the embankment. In drought time, the sluices were used to divert water to irrigate the polders; in flood period, the sluices were opened to drain the water into the river. A large polder was often tens of thousands of mu in size, without worry about drought and flood and with stable and high yield. The full-time polder leader and polder workers for construction were responsible for the polder embankment management. They inspected and repaired the polder embankment every year in accordance with the relevant regulations. Since the Northern Song Dynasty, the Taihu Lake area has been called the “Granary of the State”. The irrigation and water conservancy systems in the lower reaches of Taihu Lake usually became tessellated water network polder systems. The farmland around them was separated from the external water and irrigation and drainage channels were built inside and gates were constructed on the embankment. Relatively speaking, the embankment of tessellated water network polder system was undersized, while polder was tall and big.

In the southeastern coastal plain, salt tides often flow backward into rivers along the coast, hindering agricultural production. In this special geographical position, an irrigation project “resisting saltwater and storing fresh water” was developed to prevent the backflow of seawater and divert fresh water for irrigation, which has brought important irrigation benefits into play. Tashan Weir in Ningbo and Mulanbei Reservoir in Fujian are two irrigation projects of this type, which are still in use today. The irrigation and water conservancy construction was also developed in the Northern China due to stable society in the period of Tang and Song Dynasties.

During the Tang and Song Dynasties, water diversion from Jinghe River for irrigation was improved. Jingqu Canal had three main canals, namely Taibai, Zhongbai and Nanbai in the Tang Dynasty, so it was also called Sanbai Canal. In the Tang and Song Dynasties, Ningxia made great progress in the irrigation by diverting water from the Yellow River, with the construction of Liwang Canal with a length of more than 300 miles. During this period, Northern China made full use of lakes and ponds of different sizes to develop agricultural irrigation. Sitting irrigation and colmatage were continuously conducted in the sediment-laden rivers in the Northern China to improve saline-alkali soil.

The development of irrigation and water conservancy has promoted the development of some families of irrigation and water conservancy projects and wide application of water-driven irrigation machinery. Large-scale masonry projects such as gates, dams and aqueducts were widely constructed, and hydraulic irrigation machines such as water wheel and scoop waterwheel were widely used. Water became the control standard of water level in irrigation areas during the Tang and Song Dynasties.

The management of irrigation and water conservancy projects was very mature in this period, and a large number of mature irrigation and water conservancy regulations were promulgated, such as Constraints on Irrigation and Water Conservancy, promoting the irrigation and water conservancy climax in the reign of Emperor Xining of Song Dynasty. The famous Water Law for Western Xia and “Dunhuang Irrigation System” were promulgated for ethic minority area.
2.5 Stable and Rapid Development: Yuan, Ming and Qing Dynasties 1271A.D.-1911A.D

Yuan, Ming and Qing Dynasties had relatively stable regimes and created stable development situation of irrigation and water conservancy. The long-term complete unification and rapid population expansion promoted the development of irrigation agriculture in China to a situation of filled expansion and stable rapid development and improvement in the areas which are more difficult to develop. The scale and engineering technology level reached the highest level before the industrial revolution.

The formation of new irrigation agriculture areas witnessed rapid development of polders in the Yangtze River Basin and Dongting Lake; rapid development of embankment works appeared in the Pearl River Delta, especially characterized by Sangyuan Embankment in the southwestern Foshan City, Guangdong; under the construction, consolidation and development of seawalls along the coast of Jiangsu and Zhejiang Province, Yulin Stone Pond was built in the Qianlong period and great achievements have been made in dam technology.

In Ming and Qing Dynasties, the water resources in Haihe River Basin were often called Jifu Water Resources. In order to the various supplies to the capital, Ming and Qing Dynasties spent a lot of manpower and financial resources to maintain the water transportation between the north and the south of the Grand Canal and tried to build farmland irrigation projects in the north to renew, expand and develop paddy fields.

During the Yuan, Ming and Qing Dynasties, much progress was made in the irrigation and water conservancy construction in border areas. In the Qing Dynasty, irrigation of Inner Mongolia diverted from the Yellow River developed greatly. There were more than 9,700 hectares of farmland basically irrigated by water. Water resources had a close relationship with reclamation in Xinjiang. During Yongzheng period, Xinjiang reclamation began to recover, and irrigation and water conservancy were popularized, represented by Qapqal Canal and Taiping Canal. In the 25th year of Emperor Daoguang (1845), Lin Zexu vigorously promoted karez in Xinjiang, which was expanded and disseminated. Irrigation in Yunnan was mostly concentrated in Dianchi area. Important achievements have also been made in irrigation in Guangxi, Northeast China, Taiwan and Hainan Island.

During this period, regional systematic planning appeared, comprehensively considering the irrigation and water conservancy and flood control planning. Taihu Lake area took into account shipping and irrigation and water conservancy, water storage and discharge, flood drainage and tide control, water discharge and reclamation, etc. to excavate and dredge downstream water channels for tessellated water network polders and set up sluices at the inlet to block tide as well as increase the height and thickness of polder embankment, which became the basic solution for Taihu Lake improvement in Yuan, Ming and Qing Dynasties. In addition, many planning opinions were put forward on the relationship between flood control and irrigation and water conservancy in the development of Haihe River Basin, the planning of Yellow River water conservancy, the flood control of the Yangtze River and the construction of polder station in Dongting Lake and embankment in the Pearl River Delta.
2.6 Modernization Development under the Influence of Modern Western Science and Technology Since the 17th Century

Since the late Ming Dynasty, modern Western hydrotechnics have been gradually introduced into China, and the process of improving and replacing ancient hydrotechnics began. During the reign of Kangxi in the Qing Dynasty, modern measuring techniques were used to conduct geodetic surveying nationwide. The river remediation plan was implemented in the early 20th century and has promoted the application of geodetic surveying, hydrographic survey and address exploration in water resources. The application of measuring techniques was gradually extended to irrigation and water conservancy. In 1912, China built the first Shilongba Hydropower Station and used new building materials including cement and reinforced concrete in some large-scale irrigation and drainage projects. In 1924, Wujin County in Jiangsu Province was the first to apply the electric pumping motor for farmland irrigation and drainage, with the irrigated area reaching more than 20,000 mu.

During the Republic years, the most outstanding achievement in the construction of irrigation and water conservancy was "Eight Irrigation Areas in Shaanxi", which were constructed under the advocacy of Li Yizhi, a famous modern Hydraulic Engineer in China. "Eight Irrigation Areas in Shaanxi" is the collective name of eight irrigation projects diverting water from Jinghe River, Weihe River, Luohe River and other rivers. Thus, irrigation and water conservancy projects in Shaanxi have developed rapidly. In addition, many new channels were built in Hetao Irrigation Area in Inner Mongolia, with Fuxing Canal built in 1943 being the most effective. In the 1930s, Dujiangyan Remediation Plan was formulated for Dujiangyan Irrigation Area to reconstruct the traditional canal head and system works, which has attracted the attention of water conservancy scientists at home and abroad.

After 1949, the modernization of irrigation and drainage developed and the irrigated area expanded rapidly, represented by the construction of "Ten Irrigation Areas". In 2016, China ranked the first in the world with 65,870,000 ha of irrigated area and third in the work with 3,730,000 ha of sprinkling irrigation area. At the same time, the institutionalization level of irrigation management has been improved and modern water conservancy research and education have also made considerable progress.

3. CHARACTERISTICS OF SUSTAINABLE IRRIGATION IN ANCIENT CHINA

Irrigation projects transform the natural environment to a certain extent to meet the needs of agriculture and food for social development. The realization of sustainable irrigation requires that irrigation projects can not only meet the needs of agricultural economic and social development, but also coexist harmoniously with the environment and ecological system. Irrigation projects need to evolve harmoniously with social economy and natural environment to achieve a reasonable balance. Currently, China has 17 world irrigation engineering heritages, which are widely representative of Chinese traditional irrigation technology and reflect the prominent characteristics of sustainable irrigation engineering from different aspects.
Table 1. World Heritage Irrigation Structures in China

<table>
<thead>
<tr>
<th>No.</th>
<th>WHIS</th>
<th>Irrigation Area (ha)</th>
<th>No.</th>
<th>WHIS</th>
<th>Irrigation Area (ha)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Dongfengyan Weir</td>
<td>5153</td>
<td>10</td>
<td>Zhengguoqu Canal</td>
<td>97000</td>
</tr>
<tr>
<td>2</td>
<td>Mulanbei Weir</td>
<td>10867</td>
<td>11</td>
<td>Ningxia Irrigation Area</td>
<td>552000</td>
</tr>
<tr>
<td>3</td>
<td>Tongjiyan Dam</td>
<td>2000</td>
<td>12</td>
<td>Hanzhong Weirs</td>
<td>14500</td>
</tr>
<tr>
<td>4</td>
<td>Ziquejie Terraces</td>
<td>6416</td>
<td>13</td>
<td>Huangju Irrigation System</td>
<td>1333</td>
</tr>
<tr>
<td>5</td>
<td>Quebei Pond</td>
<td>44900</td>
<td>14</td>
<td>Dujiangyan</td>
<td>710000</td>
</tr>
<tr>
<td>6</td>
<td>Tuoshanyan Weir</td>
<td>13829</td>
<td>15</td>
<td>Lingqu Canal</td>
<td>4333</td>
</tr>
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<td>7</td>
<td>Zhuji Shadoof- Wells Irrigation</td>
<td>27</td>
<td>16</td>
<td>Jiangxiyan Weir</td>
<td>2333</td>
</tr>
<tr>
<td>8</td>
<td>Chatanbei Weir</td>
<td>3300</td>
<td>17</td>
<td>Changqu Canal</td>
<td>20000</td>
</tr>
<tr>
<td>9</td>
<td>Taihu Lougang &amp; Polder Lands</td>
<td>28000</td>
<td>合计</td>
<td>1515992</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Distribution of the World Heritages Irrigation Structures in China.

3.1 Relationship Between Engineering and Environment

Traditional irrigation projects often show a high degree of harmony with the environment and ecology, which is not only a model of low-impact development mode, but also creates a beautiful water conservancy landscape. Due to China’s wide geographical range and diversity of natural environmental conditions, irrigation projects in China also present significant diversity. In terms of the relationship between engineering and environment, traditional irrigation in China mainly reflects the basic characteristics of low-impact development and adaptation to local conditions.

Low-impact development mode is a common characteristic of sustainable utilization of traditional irrigation projects. Low impact is relatively speaking, which means that the impact of engineering construction and operation on the environment and ecology will not cause extreme deterioration, just like the huge changes in landform and ecological diversity will cause serious damage even impossible or difficult to restore, but with low-impact development that could achieve a new stable balance and harmony. A good traditional irrigation scheme usually adopts mild ways to collect water, and such examples include the traditional damless diversion forms such as Dujiangyan, Ningxia Irrigation canalsr and Zhengguoqu Canal, the low dam water intake of Tongjiyan weir, Tuoshanyan weir, Chatanbei weir, Hanzhong Weirs, etc.
and the shadoof irrigation of Zhuji, and in this way, the impact of irrigation projects on the environment has been minimized. The natural environment is not being remoulded in a blunt and rough way, but is being optimized in accordance with the natural law. Taihu Lougang irrigation system use the systematic drainage network to optimize the habitat of the beach along the lake, develop the field agriculture as well as the advantage of shipping, which has created the reputation of "Huzhou is the most livable place of the world". Under this development and construction concept, most of the artificial canal systems gradually integrate into the organic part of the natural geographical environment, and show the ecological environment characteristics similar to the natural water system.

According to local conditions it is necessary to ensure the low impact development of irrigation projects, and also a common characteristic of traditional irrigation projects in China. Vast in territory, China is country with manifold diversity in terms of terrain and hydrological conditions, which is reflected in the various layouts, types, structures and materials of irrigation schemes. Taking the Heritage Irrigation Structures as examples, they are located in the arid and semi-arid area in the inland northwest, the rainy area in the south and the coastal area, the terrain covers plains, hills, mountainous areas, basins, lakes, lakes and lakes, etc., and the corresponding irrigation engineering types show significant diversity and adaptability. For instance, the Historic Irrigation Scheme Quebei Pond is a water storage irrigation scheme constructed by building dikes along three sides of a piece of water-logged low-land. The irrigation systems like Dujiangyan, Ningxia Irrigation Area, Zhengguoqiu Canal, Dongfengyan Weir, Changgu Canal use different historical diversion forms without dam, Tongjiyan weir, Hanzhong Weirs, Chatanbei Weir and Jiangxiyan Weir are all diversion systems with dams to irrigate farmland in the plain basin, the type and system layout of weirs/dams are also different because of the different topography and water system environment.

Tuoshan Weir and Mulanbei Water Conservancy Project, located at coastal flatland, are built to resist saline water and retain fresh water, and Mulanbei sets up a gate at the weir so as to handle the drastic variation in water level and to adjust its flood discharge capability; Zhuji Shadoof Irrigation System has perfectly made use of the advantageous local underground water condition; Ziquejie Terraces have made the most of local soil, geological and water conditions, including the natural stream network and plot distribution. Other contributory factors of the diversity include project features and local culture. However, diversity is not what traditional irrigation schemes pursue on purpose; instead, it's a natural result of maximizing the profit of water use with the minimum projects and facilities by comprehensively considering natural, social and cultural conditions and coordinating among water for irrigation and for domestic use.

### 3.2 Project System and Structure Characteristics

Scientific and reasonable engineering system planning and architectural structure design is necessary for irrigation engineering system used hundreds of years. A good planning for traditional irrigation systems is usually featured with great vision and systematicness. Systematicness refers to the fact that components of the system work as an organic whole instead of a stiff combination, and a perfect example would be the headwork of Tongjiyan Weir, the dam, shiplock, flushing sluice, intake gate, and flood discharge gate of which are laid out in an organic way; the engineering system and the natural geography are systematically integrated, and the environment has not been modified in a rigid way, which can be seen in Quebei Pond’s utilization of the low-land landscape and natural water system; land and water development and water supply are considered in a systematic and comprehensive approach, and examples include the overall planning of land and water resources and irrigation
system at the Ziquejie Terraces, Zhuji Shadoof-wells, Taihu Lougang drainage system; and the multifunctional Mulan Weir and Tuoshan Weir which are capable of resisting salty tide and storing fresh water, on the basis of water transportation function to ensure, Lingqu Canal fully developed its irrigation water efficiency. Besides, compared to the steel and concrete used in modern projects, the traditional materials such as stones and wood are more environment-friendly and have no negative impact on soil and rivers in the long term.

3.3 Fair and Effective Irrigation Management

Perfect irrigation management is the basic guarantee that irrigation projects can continue for hundreds of thousands of years. Traditional irrigation management covers two aspects: project management and water management. And the management is government-led and private-sector participation is encouraged so as to ensure the fairness of water distribution among upstream and downstream users. The shifting of three irrigation water sources at Tongji Weir is a model system taking a variety of water demands into consideration. The joint management by official and people was born of China traditional social structure and cultural background. Namely, local governors have the duty consciousness and cultural background of building water conservancy projects to be benefiting the local people. The water conservancy projects prompted local people to form social community for the regular manage the water conservancy projects. Based on this, the local government was responsible for building, maintaining and repairing of the projects, and making management regulations.

The local people in the social community performed regular management under the supervision of local government. Historic irrigation schemes in China are repaired each year in winter when the agricultural demand for water is small. During this period, water storage structures and canal systems are dredged and water gates are repaired. For instance, the annual repair practice at Quebei Pond was established during the Three Kingdoms Period (220-280 AD). Another outstanding feature of irrigation management in pre-modern China is the connection of the public and the government through worshipping river god and sacrificial rites. By commemorating the founder of and the contributors to the project, people formed a consensus on appreciating the contribution made by previous generations and the determination to protect the heritage. During the rites, the management meeting is held. In this way, the authority of the management system is enhanced.

3.4 Advancing with the Times

From the perspective of long history, most of the heritage of irrigation engineering shows the characteristics of keeping pace with The Times, which is one of the connotations of sustainable development of irrigation. The fact that many historic irrigation schemes have lasted for hundreds or even thousands of years correlates closely with their capability to adapt to the social demand and changes. In the cases of Dongfeng Weir, the headwork has been moved upstream several times due to riverbed undercutting so as to ensure the water supply. In the case of Quebei Pond, as the population grows, the area of land reclamation expands, and the capacity of water regulation improves through the building of dikes, watergates and canal system. Lingqu Canal is also in the process of social and economic development of XiangGui Corridor region, with the increase of permanent population and the need for agricultural livelihood, irrigation engineering facilities are gradually developed on the canal system of water transport, and the water conservancy function expands with the increase of social demand. As the society develops and the project system evolves, the management regulations of Tongji Weir and Quebei Pond are also improving.
4. CONCLUSIONS

The unique natural and geographical conditions make irrigation with an important role on the civilization process of China. The origin and development of irrigation engineering sometimes are of historical significance, which represent the evolution and spread of civilization of the regions. In China, there are many irrigation projects with history of more than several centuries or even millennia. The continuation of projects is the continuation of management and culture accumulation, which reflect the wisdom of ancient people to deal with the relationships between human and water, and their values for water resources. Irrigation project management and water administration promoted the close links between water and the societies as well as the culture, which merged with the regional folk customs, religious, and architectural culture.

Traditional irrigation projects, whether the different styles of water conservancy engineering, ecologically valuable engineering structures and hydraulic components, or valuable management literature and archives, are precious cultural heritage. The traditional irrigation projects those have been utilized for hundreds of years or even more than thousand years have the historically scientific nature and rationality. The empirical knowledge and engineering philosophy reflected in these heritages, such as adaptation to local conditions and advancing with the times, systemic and low impact planning, and especially management mechanism giving consideration to both upstream/downstream area, thorough annual repairs systems, and division of responsibilities between and cooperation of government and private sector, can serve as a valuable reference for contemporary irrigation construction and development.

Since the 20th century, in the rapid development of modern technology, we have lost the necessary attention to the ancient water conservancy projects and many ancient irrigation works were destroyed in the so-called modernization process. Obviously, modern irrigation has much advanced on engineering materials, technology and efficiency. Motivations for quick success and short-sighted behaviors drive people in some regions to obtain economic benefits from conversion or demolition of ancient water conservancy projects. Whereas extremely skillful projects just like Dujiangyan, Ziquejie Terraces, could not be created by means of modern engineering planning and designing theories. Much more engineering design specifications and technical standards have been enhancing security level and construction efficiency, but also constraint of engineers. To learn history wisdom and maintain irrigation civilization, it is necessary to protect the ancient irrigation heritage as the start, which may be the best example of sustainable development.

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RESEARCH ON JIANGXIYAN IRRIGATION SYSTEM

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ABSTRACT

Jiangxiyan Irrigation System is a model of mountain-river diversion projects constructed in ancient China. It was built between 1330 and 1333. The project has been in use for over 680 years, and falls under the categories of water diversion structures and canal systems.

It represents a milestone/turning point in development of irrigated agriculture and bears an exceptional testimony to development of agriculture and increase in food production along with the improvement of economic condition of farmers.

Jiangxiyan is an example of attention to environmental aspects in its design and construction, and bears the stamp of a cultural tradition or a civilization of the past. It is also an outstanding example of Operation & Management over a long period of time. This paper focuses on the above issues.

Key word: Jiangxiyan Irrigation System, Value Assessment

1. INTRODUCTION

The Jiangxiyan Irrigation System is located in Jinqu Basin, west of Zhejiang Province, China. The System is located at the key place where the Lingshangang River, tributary of the Qujiang River, flows from the mountainous area to the plain. Longyou County of Zhejiang, situated in the subtropical moist monsoon climate region, boasts abundant rainfall, with annual average precipitation totaling 1761.9 mm.

Historically, there are many water-diversion weirs along the Lingshangang River. Apart from irrigation, they also power scoop waterwheels and trip-hammers. As a matter of fact, Jiangxiyan Irrigation System is the best preserved and the most representative part of the weir system of the Lingshangang River. The irrigation project of Jiangxiyan Irrigation System makes full use of the terrain and its features.

It takes the 5.33 ha of sandbank in the riverway as the link, connecting Jiang Weir and Xi Weir, hence an angle-square-shaped retaining dam flowing from west to east with a length of around 570 m, and a side-direction overflow weir, which realizes dam-less water diversion. Following the completion of Jiangxiyan Irrigation System, irrigation of the farmland at the lower reaches is guaranteed, ensuring stable yields despite drought or excessive rain.

This has promoted not only agricultural development of Longyou County but also the economic development of the whole irrigation district. Thanks to the irrigation project, the county has become an important grain production area of Zhejiang Province.

Currently, Jiangxiyan Irrigation System has basically maintained its original layout and structure ever since its construction more than 680 years ago. Irrigating over 2,333 ha of farmland, the Jiangxiyan Irrigation System is a model of mountain-river diversion projects constructed in ancient China.

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2. JIANGXIYAN IRRIGATION SYSTEM

2.1 History

In the 14th century, with the drastic increase in population in southern China, it was imperative to develop agriculture. As a result, many crucial regional irrigation projects were launched in this period. Jiangxiyan Irrigation System was constructed from 1330 to 1333 under the supervision of a Mongolian official. Having attached high importance to agricultural development and water conservancy, he presided over the construction of many weirs, and Jiangxiyan is only one of them built over 680 years ago, which is still in use today.

The pivotal project of the Jiangxiyan Irrigation System, clearly recorded in the documents of the 16th century, was composed of a barrage (Jiang Weir), an overflow weir (Xi Weir) and a water inlet. Jiangxiyan Irrigation System of the 16th century experienced three times of washouts, and three times of overhauls, and hence acquired a perfect engineering system and a management system which combines government supervision and management by the general public. The annual repair system, established in the Ming Dynasty (1368–1644), was passed on from generation to generation.

Moreover, the System was closed on June 1 every year. In 1640, County Magistrate Huang Dapeng, who had the well-being of the masses at heart, attached great importance to construction of hydraulic engineering. On every June 1st, he would make personal appearance at the site where the weir was closed. “Once any leakage was found, he would have it closed up”. Besides, as he was afraid the diverted water could not reach the highly-positioned water inlet of the village weir, he ordered that the old water inlet be replaced by a new one.
Figure 2. Ruins of Weir Cave

The canal system of the Jiangxiyan Irrigation System, extending to the county town of Longyou, became a water conservancy project with comprehensive profits of irrigation, navigation and municipal water supply. In 1736, County Magistrate Xu Qiyan had Jiang Weir and Xi Weir rebuilt, diverting water into the city trench. In 1886, County Magistrate Gao Ying organized local gentry for donation for the construction of Jiangxiyan Irrigation System. Moreover, he was engaged in establishing the Weir Administration, formulating systematic rules and regulations for weir building and a system of fund raising and management and accountability system, and printing and distributing Report of Contributions to Rebuilding the Longyou Jiangxiyan Irrigation System.

In 1927, the provincial government presented a plaque to the farmers of the irrigation district. It was inscribed with four Chinese characters—“Benefiting Our Farmers”. Management Committee of the Jiangxiyan Irrigation System was established which had over 20 members. In 1932, the Committee formulated and issued Management Regulations of Jiangxiyan Irrigation System. In October 1935, Cooperative of Farm Irrigation and Application of Jiangxiyan Irrigation System was established.

In 1948, the Management Committee of the Jiangxiyan Irrigation System organized the construction of weir channel sluice project. By the period of the Republic of China, public properties such as Jiangxi Homestead, Wei God Association, and Wei God Temple, as well as the daily incurred expenses of the Management Committee of the Jiangxiyan Irrigation System and the Cooperative were still preserved.

Since the 1950s, the headwork and the canal system of the Jiangxiyan Irrigation System have experienced several renovations. And the latest renovation was completed in 2014. It has maintained its original layout, structure, and the weir building technology ever since its construction more than 680 years ago.

3. IRRIGATION SYSTEM

The Jiangxiyan Irrigation System is composed of water-diversion headwork, irrigation and drainage canal network and control work.
The water-diversion headwork includes Jiang Weir, Xi Weir, intake gate and scouring sluice. Jiang Weir and Xi Weir are also called the Upper Weir and the Lower Weir respectively. Jiang Weir is located to the right side of the sandbank on the upper reaches of the Lingshangang River. It is 100 m long, its bed is 32 m wide and 63.2 m high. Xi Weir is located to the left side of the end of the sandbank on the lower reaches.

It is 50 m long and its bed is 30 m wide and 63.1 m high. Xi Weir is arc-shaped, diverting water into the main irrigation canal through the intake gate. Thanks to the proper design of the elevation of the weir crest, Jiang Weir and Xi Weir regulate and control the water level, and the volume of water diverted. The weirs can guarantee the volume of the water needed for irrigation; whereas the rest of the water, when spilling over the weir crests, runs downward.

A scouring sluice has been built between Xi Weir and the intake gate for preventing sludge from accumulating at the river intake. The Lingshangang River was an important waterway historically. A raft sluice was specially built on the weir. It was closed when the water was diverted for irrigation, and was opened for navigation at the rest of the time.

In light of the local geographical conditions, the headwork was constructed to divert water, drain flood, discharge sand, and create conditions for river traffic.
the weir surface when the weirs were repaired. About 30 m away from the rock mass of Sheshan Hill on the left bank of the upper reaches of the Lingshangang River, there are ruins of a water inlet constructed in the early days of Jiangxiyan, and the water inlet is nicknamed “Yan Dong,” meaning weir cave. The ruins were the site of the irrigating gate abandoned by County Magistrate Huang Dapeng in 1641.

There were two main canals in the ancient Jiangxiyan Irrigation System—the east canal and the west canal. According to a historical record, the irrigated area was more than 3,333 ha during Emperor Qianlong’s reign of the Qing Dynasty. Jiangxiyan Irrigation System has been optimized since 1973. At present, the system is composed of a general main canal, four main canals, namely the east canal, the west canal, the middle canal and the Guancun canal, and 15 branch canals. The four main canals have a total length of 18.8 km.

The 15 branch canals have a total length of 30.87 km. The whole system mainly irrigates 21 administrative villages under the jurisdiction of Longzhou neighborhood, Donghua neighborhood and Zhanjia Township, with the irrigated area totaling 2,333 ha. 24 sluices of different sizes are distributed on the canals. They regulate and distribute water, and drain floodwater.

As the irrigated land is hilly and undulating, it is necessary to use sub-weirs in some areas to elevate water level to irrigate farmland. According to historical records, there were 72 sub-weirs under Jiangxiyan Irrigation System in the 17th century. Water-powered devices such as water-powered trip hammers and scoop waterwheels were installed along the canals to help farmers process products and lift water to irrigate farmland. These devices were in use till the 1970s. The ruins of water-powered trip hammers canstill be found in some places; and those places are named after the trip hammers. Jiangxiyan Irrigation System had multi-functions: irrigation, municipal water supply and drainage, water transport and hydraulic application. Paddy rice is the main grain crop in the irrigation district. Vegetables, tea bushes, oranges and tangerines are the main cash crops.

![Figure 5. Irrigation Area of Jiangxiyan Irrigation System](image_url)

### 4. DESIGN SPECIALTIES OF JIANGXIYAN

Jiangxiyan irrigation project lasted more than 680 years. Its scientific site selection, ingenious layout, sound engineering system and effective management, secure
prolonged comprehensive benefits, including agricultural irrigation. The project has witnessed natural, social and economic changes and development of the region, with pronounced historical, cultural, scientific and technological and landscape value.

The Jiangxiyan Dam lies at the throat between the mountain and the plain in Lingshangang. The weir location is scientifically selected, with the river sandbank linking the upper and lower weir; the layout is adately designed, materials for the weir are simply taken locally and dam-building technology is state-of-the-art. All of these are of high scientific value, making the weir an excellent example of China’s ancient irrigation project built in mountainous areas and rives.

Scientific site selection. The Jiangxiyan Dam lies at the throat between the mountain and the plain in Lingshangang, ensuring irrigation by gravity of the farmland with the largest possible area in the downstream plain. It’s composed of upper and lower sections; the upper section functions as damming, diverting river water into the diversion conduit, while the lower one functions to overflow, discharging excess water entering the diversion channel into the river so as to control the amount of water into the irrigation channel. The upper-lower dam structure helps not only water diversion but drainage during the underwater operation, and also assists in flood diversion, reducing the pressure resulting from excessive flow flushing.

Smart layout. Jiangyan Weir is located in the exposed part of rocks, which is conducive to the safety of the weir body and saves investment. At the same time, there’s a wider river channel in the location of the weir, which is conducive to draw off floods; the diversion channel uses the natural access between the She Mountain rock and the sandbank, which is suitable for local conditions. The entire hub forms a 600-meter long retaining dam, with the river sandbank as a bond connecting Jiangyan Weir at the top and Xiyan Weir at the bottom. This bold idea that the river sandbank is used to constitute an entire weir is extremely rare in the history of water governance and is of drastically important value scientifically.

Reasonable structure. Jiangyan Weir (upper weir), which is straight-line shaped, is perpendicular to the main river channel from south to north, and the slope gradient of the weir surface downstream is gently 1:8, which exerts a good effect of energy dissipation. Xiyan Weir (lower weir), which runs from east to west and is arc-shaped, was built between the sandbank and the head of She Mountain; such design increases the overflow length while expanding the intake, reducing discharge per unit width when flood flowing through the weir.

The accumulation body of Jiangxiyan abdomen uses pure river pebbles of different sizes as filling of the abdominal cavity; random use of sand-containing mixture is forbidden to prevent the sand material from being carried away by the seepage water flow to form interspace in the abdominal cavity and thus affect the stability of the weir. The body of Jiang weir is buried into the river bed and has rock wall connected by quartzite, which closely clings to the water surface and exerts good anti-seepage effects. The slope gradient of Jiang weir downstream slope is a slope protection which dry pitching by large pebbles, and the lower Xi Weir body is designed with pine frame (commonly known as “bullbarn”) that supports the weir, all of this protects the weir body in an effective manner. Such a structure remains in use today.

Exquisite craftsmanship. For the masonry of Jiangxiyan, local large pebbles are used by placing the larger-head ones down and smaller-head ones up and making every piece of pebble closely against one another in line with weir slope standards, which not only stabilizes the weir body, but also helps dissipate energy; the pores between stones laid are triangular to ensure that impacts of water on the stones laid are transferred in a balanced manner. The pine frame that supports the lower weir body is
connected with tenons and mortises, which enhances the stability of the foundation. As a result, despite flood impacts many times over hundreds of years, save repair many times over the period though, no major damage has been done to the foundation and the skeleton of the weir site. This can be considered to be a miracle, proving extraordinary craftsmanship employed in constructing the weir that time.

Using local materials. Large pebbles in the river are used as masonry material of the weir, which has the merits of using locally sourced materials at a low cost. The concrete material (debris triple-combined soil) used not only contributes to structural stability, but well functions to prevention seepage. Xi Weir abdomen selects pine wood which are not eroded till now.

Hydraulic processing and irrigation. The eastern and western trunk canals run where water heads of the village’s bleeders have better fall. Some gifted persons good at grain and oil processing once set up water mill and barrow (for oil pressing workshops) processing workshops, and 32 water mills were equipped along the canals, which facilitated processing for farmers and was deeply welcomed by the masses; and the workshops were thriving then. For parts of irrigation areas along the western canal, fields were higher than the canal; given this, bamboo was used to produce cylinder wheel which was are placed over the canal for irrigation by using impacts of canal water. The two tools were used for irrigation with no additional external power and had been in use until the seventies. At the end of the western canal, ingenious inverted siphon tubes that were made of moso bamboo and large pine wood were used for diverting water for field irrigation because it’s necessary to cross higher-lying Fangmen River.

5. MANAGEMENT

Since its construction in the 14th century, Jiangxiyan Irrigation System has been supervised by the local government and managed by the general public. Traditionally, county-level officials, granted with the management power, assigned specific tasks to prestigious local gentry who would later distribute the work of maintenance to farmers benefiting from the irrigation system. The annual repair system was established no later than the end of the 16th century, and posts of weir official were also established for handling the matters of annual repair, water management, opening and closing the weir and collecting relevant fees. The weir administration was established in the Qing Dynasty (1644–1911). Under the supervision of the prefectural and county governments, the local gentry were specifically responsible for repairing weirs and canals, managing relevant funds, and formulating relevant rules and regulations. This management mode is still adopted to this day and has guaranteed the sustainable operation of the System. At present, the System is under the management of the water user association of Longzhou and Donghua neighborhoods which is under the guidance of the County Bureau of Water Resources.

6. CONCLUSION

The Jiangxiyan Irrigation System has scientific site selection, ingenious layout, sound engineering system and effective management, secure prolonged comprehensive benefits, including agricultural irrigation. It’s a model of mountain-river diversion projects constructed in ancient China.

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