



## **Community, Environment and Disaster Risk Management Emerald Book Chapter: Chapter 13 The water community case of Chou-Shui River in Taiwan**

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## CHAPTER 13

# THE WATER COMMUNITY CASE OF CHOU-SHUI RIVER IN TAIWAN

Jet-Chau Wen, Kuo-Chyang Chang, Shao-Yang Huang, Chia-Chen Hsu, Keng-Yu Chang and Wen-Ni Chen

## INTRODUCTION

Rivers flowing through the land are a source of life. They have different importance and functions such as for drinking, sailing, irrigating crops, generating electricity, sightseeing, fishing, and so on. In addition, animals like amphibians, birds, and mammals also live and propagate near the river environment. Therefore, rivers are ecosystems for some animals and plants that are special, rare, or on the brink of extinction (Water Resources Agency, Ministry of Economic Affairs, 2006).

When the economy develops quickly, people's quality of life improves as well as their leisure and recreational needs. Thus, many people are attracted by the huge hinterlands and abundant ecological species of the rivers (Water Resources Agency, Ministry of Economic Affairs, 2006). But, water is not an infinite resource. The natural geographical landscape, especially in Taiwan, makes it hard to reserve water resources. With the rise of improved economical lifestyles, many kinds of industries are developed. The needs, such as domestic, agricultural, and industrial water, have also increased. For people who live near water sources, water may play different beneficial roles

Water Communities

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such as tourism, irrigation for agriculture, or hydroelectric power for economic development as well as adverse effects on their lives such as floods.

Like the expression "every coin has two sides," we have to use water resources efficiently and persistently treasure it or one day man will suffer from nature's powerful forces.

This study takes the longest river in Taiwan – Chou-Shui River – as an example and explains the relationship between water and people by introducing its background and influences. In this way, we can understand the reason why it is called "the Mother River."

## **BACKGROUND OF CHOU-SHUI RIVER**

#### Geography and History

The Chou-Shui River, the largest river in Taiwan (about 186 km in length). originates in a Zuo-Jiu-Jian Saddle that lies between the main peak and eastern peak of Mt. Hehuan with an elevation about 3,200 m above sea level. The extreme upstream end of Chou-Shui River is known as Wushe River, which flows from the western slope of Mt. Hehuan and along Rift Valley. Taluowan River near Mt. Lushan then flows into Wushe River, which then changes back to the name Chou-Shui River after this point. Continuing downstream, many branches flow into Chou-Shui River, such as Wanda River near Wanda as well as Danda, Junda, Shuelli, Chenyoulan rivers, and many others. After passing through the valley, the land becomes a wide plain called the Chi-Chi Basin where lies Cingshueigou River. Further downstream, Dongbuna River and Cingshuei River join together with Chou-Shui River and enter the Chang-Yun Plain where Changhua and Yunlin counties join together. Then Chou-Shui River, as the boundary between Shiahaichian Village of Dacheng Township in Changhua County and Shutsuo Hamlet of Mailiou Township in Yunlin County, flows into Taiwan's ocean (Water Resources Agency, Ministry of Economic Affairs, 2002).

In 1723, Taiwan originally was one prefecture of three counties and then after Changhua County was added, the population relocated upstream of Chou-Shui River and transformed the land into farmland as far as Wushe River.

Chou-Shui River is famous for large amounts of silt, which makes it conducive for farming. The highest record of silt content is 10 times that of the Danshui River (in Taipei) and 15 times of the Gaoping River (in Kaoshiung and Pingdong). However, the lack of water during the dry season makes navigation difficult on Chou-Shui River.

#### Hypsography and Landform

The river basin and elevation of Chou-Shui River descends from east to west with increasing slopes from west to east. Watersheds exist east of the Central Mountain Range in Mt. Nenggao, Mt. Dashigong, Mt. Danda, and Mt. Mabolasi, and so on. The boundary to the south of Chou-Shui River is Mt. Yu.<sup>1</sup>

The turbidity of Chou-Shui River is due to a gorge that extends from the Zuo-Jiu-Jian Saddle in Mt. Hehuan to where Chenyoulan River connects with Chou-Shui River. This river meanders through many high mountains and deep valleys and has treacherous rugged terrain with high cliffs and frequent landslides. The other connecting tributaries upstream of Chou-Shui River also meander throughout the area. The height of the mountains in the river basin rises to about 3,000 m, which includes Mt. Ganjhuowan and Mt. Jhuoshe in the north, Mt. Dongluga and Mt. Dongjyun in the south, Mt. Jhihyuan and Mt. Siluan in the west, and so on.<sup>1</sup>

The middle stretch of Chou-Shui River extends from the gorge to Ershui Bridge. The flow is smooth and calmer on the plain, and the valley gradually becomes wider going from east to west. The major topography is river terraces and mesas, specifically the Pingdingbo Mesa and Mt. Ju river terraces where Chou-Shui River and Cingshuei River meet. The Dongpuruei River is also an affluent of Chou-Shui River and flows through Lugu Village, which also has a terrace landscape. Located on the north bank of the middle stretch of Chou-Shui River is Puli with many peaks of slate mountains as well as Mt. Chi-Chi, Nantou Hill, Bagua Mesa, and so on. In the south are Mt. Yu, Mt. Fonghuang, and Jushan Hill.<sup>1</sup>

Below Chi-Chi, the valley topography of Chou-Shui River at the southeastern part of Ershui, where Bizitou mountain pass is located, consists of an alluvial fan, which begins to widen at a distance of 40 km from the head of the fan to its outer edge and is the largest alluvial fan in Taiwan. There are five radial rivers on the alluvial fan, which are Maiyutsou River, Shiluo River, New Huwei River, Old Huwei River, and Beigang River.<sup>1</sup>

Chou-Shui River has important agricultural boundaries downstream on Taiwan's western plains. The subtropical climate north of Chou-Shui River's boundary grows rice and the tropical climate south of its boundary grows sugar cane. The southern downstream segment has a three-year crop rotation.



Fig. 1. The Drainage Area of Chou-Shui River.

#### Drainage Area

Chou-Shui River runs through Changhua County, Yunlin County, Nantou County, and Chiayi County; it is also the boundary of Changhua and Yunlin counties (Fig. 1). The river width of the mainstream is about 2–4 km. It flows from east to west, separates western Taiwan into two parts, and then runs into the Formosa Strait in Mailiao Township of Yunlin County. Its downstream crosses many townships and forms a large alluvial fan.

## THE REPRESENTATION OF THE "WATER COMMUNITY" IN CHOU-SHUI RIVER

Cultural Representations

Cultural Sites

Chou-Shui River is the largest river in Taiwan. Cultural sites of the Chou-Shui River consolidate the relationship between the people and the river.

- (1) *Dapingding cultural site*. The Dapingding cultural site is located in Ailiao of Chi-Chi Township, which was the river terrace of Chou-Shui River and its branches 3,000 years ago. Plenty of cultural relics including stone axes, stone hammers, grindstones, and stone flakes to mention a few were excavated from this area.<sup>1</sup>
- (2) *Tungchiao cultural site*. Tungchiao cultural site is located behind the Endemic Species Research Institute in Chi-Chi Township. Three thousand years ago, the location of the site was between Chi-Chi Mountain and Chou-Shui River. Chou-Shui River's main river terraces was where both pottery and stone relics were found. The pottery found was comprised mainly of sand and two kinds of stone relics were also found, which were stone mortar used for holding water and the whetstone used for grinding.<sup>1</sup>
- (3) *Chuping cultural site*. This site is located in the southeast corner of Renai Township in Nantou County. It is also a river terrace area of the upstream valley of Chou-Shui River. The distance was 1.5 km north of Wanfeng Village 1,500 years ago. People migrated to this place to carry out fishing and animal husbandry. The Chuping cultural site helped to increase the Taiwanese knowledge of the prehistoric culture that existed upstream of Chou-Shui River. Unearthed stone tools were discovered here: many pieces of pottery shards, 10 stone axes, and 1,000 spun nets. Unearthed fishing nets revealed that the people had close connection with the river. This area was also one of the areas high in using slate.<sup>1</sup>

#### Cultural Tribes

The main groups of aborigines who lived upstream of Chou-Shui River were the Tayal and Bunun tribes and also some Thao lived in the area nearby Sun-Moon Lake. Some settlements were located in the wide valleys with most of them living on the high-leveled river terraces at elevations from 1,000 to 2,500 m above sea level. These aboriginal tribes lived mostly at high elevations compared to other residents of Taiwan.<sup>1</sup>

(1) *Tayal tribe*. The Tayal tribe is separated into three ethnic groups based on the boundary lines formed by the connection between Peikang River in Nantou County and Heping River in Hualien County. They are the Techitaya tribe, which resided in Huchu Village and Nanfeng Village; the Taotse tribe, which resided in Jingying Village and Chunyang Village; and the Tuoluge tribe, which resided in Songlin, Lushan, and Jingguan of Renai Township.<sup>1</sup>

- (2) Bunun tribe. The Bunun tribe resides on the banks of Chou-Shui River between Chuping and Shennong Bridge, and the Jyunda, Luanda, Danda, and Chenyoulan rivers as well as other rivers. This tribe migrated to other areas to find new land for hunting and farming. After a period of time, they settled on the banks upstream of Chou-Shui River, and gradually they developed into five social groups, which were the Ke, Dan, Zhuo, Jun, and Lan social groups. They mainly dispersed into the Jhongjheng, Fajhih, and Wanfong villages of Renai Township: the Dili, Shuanglong, Tannan, Mingde, Fongciou, Sinsiang, Wangxiang, Renhe, Luona, Dongpu, Donguang villages as well as other villages of Xinyi Township.<sup>1</sup>
- (3) *Thao tribe.* Most Thao live in Rihyue Village near Sun-Moon Lake. Some Thao who were originally from the Toushe lineage lived in Dapinglin of Dingkan Village in Shuili Township. Currently, the total population of Thaos of these two areas is 283 and is one of the smallest ethnic groups in the world.<sup>1</sup>

#### Ecological Representations

The river ecological system includes biological and nonbiological factors. Biological factors are animals and plants, which inhabit the river or exist near it, and nonbiological factors are air, sun, water, rock, soil, metals, and chemical compounds. Such diversified river biota and habitats build a colorful and vital water world (Fourth River Management Office, 2003).

The drainage of Chou-Shui River is so wide and the geographical environment is so complex that the biological system presents an abundant variety of life forms. An investigation shows that there are many kinds of species that live in the drainage area of Chou-Shui River, like birds, freshwater fish, shrimp, crabs, mammals, amphibians, butterflies, reptiles, and so on. Some of them are also endangered animals.<sup>1</sup> Take birds for example, the most common species like *Zosterpos japonica* (Japanese whiteeyes), *Egretta garzetta* (little egret), *Streptopelia tranquebarica* (red-collared dove), *Hirundo striolata* (creater striated swallow), and *Dicrurus macrocercus* (black drongo) are distributed from midstream to downstream (Fig. 2). Because the drainage area is wide, there are different bird habitats upstream and downstream. Upstream, the elevation is higher with prolific forests; mountain birds appear more often, especially in the tourism sites like Mt. Hehuan, Aowanda National Forest Recreation Area, Sitou Natural



*Fig. 2.* The Distribution of Birds in the Drainage Area of Chou-Shui River (Fourth River Management Office, 2003).

Education Area, and so on. These places are also where many bird watchers visit, whereas downstream, water birds appear more often on the sandbanks, estuaries, or seacoasts. Different kinds of birds have different images. The vivid feathers and pleasant sounds of endemic mountain birds attract people to spend time here. On the other hand, intriguing behavior of aquatic birds walking or searching for food also amaze people (Fig. 3).

The ecological resources of Chou-Shui River are abundant; therefore, people should know more about the ecological environment to enrich conservation measures, to treasure biological resources, and to love and protect nature. As a result, people, biota, and the environment can coexist together.

#### Sightseeing Representations

There are many kinds of aesthetic beauty such as reservoirs, springs, and streams upriver of the Chou-Shui River Basin, and there are also some fabulous structures like Siluo Bridge, for instance, downriver where people can visit. "Being close to water" is an extra value for a river; it can give people the feeling of affinity to it in the same sense that the river is a

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 a. Niltava vivida (Rufous-bellied Blue Flycatcher)



b. Liocichla steerii (Steere's Babbler)



c. Actitis hypoleucos (Common Sandpiper)



d. *Myiophoneus insularis* (Formosan Whistling Thrush)

Fig. 3. Different Birds Appear in the Drainage Area of Chou-Shui River (Fourth River Management Office, 2003).

"mother" to the land. The writer Wu Cheng described the Chou-Shui River like this (Wu, 2002):

Playing and running in the riverbed, tumbling on its embankment, you have made my childhood so abundant. And it is all because your flow help raised our land [like a mother raises her children]. This scenery, occurring in my dream, made the river feel so close yet so far from me, always calling me to search its water source ... .

The Chou-Shui River source lies in the valley between Mt. Hehuan's main peak and its lower eastern peak, and there are many branches extending from the river. These places are located with mountain scenery; so when people walk along the tributaries, they get a spectacular view of the mountains along the river. These tourist sites bring abundant business opportunities for local residents, and the special style and feature of the aborigines living here draws attention to these districts.

From most people's impression, Sun-Moon Lake is one of the very famous tourist sites upriver of Chou-Shui River. After the Chi-Chi Earthquake, the Sun-Moon Lake National Scenic Area Administration Tourism Bureau was established. It holds many kinds of activities to attract people, especially at this moment more and more tourists from China are visiting Taiwan. Sun-Moon Lake is the place that almost every tourist will visit, so it is the best site for advertising the beauty of Taiwan. One particular spectacular event, a swimming marathon, is held each year "with 10,000 people swimming across Sun-Moon Lake."

Besides the scenery upriver of Chou-Shui River, the red Siluo Bridge is another impressive site downriver. It crosses over the boundary of Changhua and Yunlin counties and is the landmark of Siluo Township. This bridge has a total length of 1939.03 m with 31 arches and used to be the number one bridge in the Far East and only next to the Golden Gate Bridge in San Francisco.<sup>2</sup> The purpose of building this bridge was to supply tourists and inhabitants a way to cross over the Chou-Shui River. After the other larger bridge, Shijo Bridge, was completed, Siluo Bridge gradually became a tourism bridge. Governments of Changhua and Yunlin counties also plan to turn the area into a scenic forestial park for walking and having close contact with water. The activities held in this area can add to the publicity of the local agricultural production and the social and educational functions of the bridge. In this way, tourists can get a better feel for the local characteristics and culture, thus improving the quality of tourism.

#### Economic Representations

Because Chou-Shui River has a steep slope upstream, it is used for generating power. Theoretically, the total installed capacity and annual energy output generated by the Chou-Shui River drainage area through both hydroelectric and pumped storage hydroelectricity are 3.248 million kW and 8,030 million kWh, respectively. The installed capacity of the Sun-Moon Lake power system during 1955 was 15,300 kW, which possessed

55% of the total installed capacity in Taiwan. Hydroelectricity in the Chou-Shui River drainage area plays an important role in the economic development of Taiwan and has laid the ground for its economic takeoff (Water Resources Agency, Ministry of Economic Affairs, 2002).

Previously, there were eight hydropower plants built in the Chou-Shui River drainage area. But after the 1999 Chi-Chi Earthquake, some of the power stations were destroyed except for Sun-Moon Lake's hydroelectric power plant. According to the analysis data made in 2001, the total energy output of the Chou-Shui River drainage area power system was 4,940 million kWh (Water Resources Agency, Ministry of Economic Affairs, 2002).

#### Social Representations

The main industry of the drainage of Chou-Shui River is agriculture. Recently because the population has increased and the economy has grown, domestic and industrial water uses have also increased. Since the soil of the alluvial plain is suitable for cultivation, people who live here mostly devote themselves to agriculture.

The alluvial plain created by the Chou-Shui River is also a place for Changhua and Yunlin counties for cultivation. Because the water source of the river is used for irrigation, agricultural production has become the pride of the local people. The canals belonging to Changhua and Yunlin Irrigation Associations are the main irrigation sources for these two counties. Therefore, the agricultural production here has a very close relationship with this river.

The irrigation canals in Changhua County irrigate about 40,000 acres of land, and one of them was even built during the Ching Dynasty (Fig. 4). On the other hand, the irrigation canals in Yunlin County irrigate about 66,000 acres of land (Fig. 5). The inhabitants living in this river basin have to use its surface water and groundwater to irrigate; without these abundant water sources, the agricultural production may not have achieved the scale it has now. Therefore, we can call this river "the Mother River" (Chen et al., 2000).

Because the water contains black sandy soil from upriver, the Chou-Shui River alluvial plain is suitable for growing crops. The black sandy soil makes the land productive, so most people grow their crops on the flood plains of Chou-Shui River. It is convenient to draw water for growing crops as well. But during the dry season, water quantity decreases and the riverbanks become dry, and the dry ground is dispersed by the wind.



*Fig. 4.* The Irrigation Scope of Changhua Irrigation Associations (Water Resources Agency, Ministry of Economic Affairs, 2002).

This phenomenon happens every year, which not only affects agricultural production but also the inhabitants residing there.

Because the land in Changhua County is irrigated by the Chou-Shui River, the soil quality has been regained. And after the water source of Chou-Shui River was developed, the Changhua plain became a prosperous agricultural area. The Changhua plain produces rice of good quality and quantity, and other crops such as vegetables, flowers, and fruits have become famous too. Almost each township has its own special crop. Because of the fertile soil, fair climate, sufficient amounts of rain, and the use of excellent water pumps and irrigation systems in Yunlin County, agricultural production also plays an important role in this county. For this reason, Chou-Shui River, the mother



Fig. 5. The Irrigation Scope of Yunlin Irrigation Associations (Water Resources Agency, Ministry of Economic Affairs, 2002).

of the land, causes the plain to develop well agriculturally (Water Resources Agency, Ministry of Economic Affairs, 2002).

Crops grown in the fertile land of Chou-Shui River include rice, fruits, vegetables, and so on. For people living around Chou-Shui River, they happily share their crops with their friends or relatives. It helps people to communicate with others and to share their friendship. Furthermore, everyone knows that the crops grown at Chou-Shui River are of high quality, like the rice of Siluo Township, watermelons of Erlun Township, garlic of Cihtong Township, flowers of Shijo Township, guava of Shetou Township, and so on. In order to show respect to the Chou-Shui River, people feel they must make a contribution to the river by producing crops here (Fig. 6).

#### Physical Representations

The most direct natural resource from rivers is water resources. Annual mean runoff of the Chou-Shui River is 6 billion m<sup>3</sup>. In spite of abundant water, the usage of water resources is restricted by a steep grade, supercritical flow, and high turbidity. Water amounts are evidently distinct during abundant-water periods and low-water periods, creating the difficulty of uneven distribution of water resources; and in addition, spatially, the different topography of the Chou-Shui River Basin of mountains, hills, and plains also creates an uneven distribution of water resources. Water resources from mountain areas and



*Fig. 6.* The Watermelons which are Grown at Chou-Shui River and Sold in a Vegetable and Fruit Market in Siluo (Photo by Chia-Chen Hsu).

plain areas are used in hydroelectricity and agriculture, respectively. Domestic water and industrial water are supplied by groundwater because the water quality is better and more stable (Water Resources Agency, Ministry of Economic Affairs, 2002).

Agricultural irrigation is the largest consumptive water use of the Chou-Shui River water resources; the river directly supplies 2.2 billion m<sup>3</sup> of agricultural water, which includes about 100,000 ha of farmland in the Chou-Shui River alluvial fan, aquaculture use, pasturage use, and excludes 0.7 billion m<sup>3</sup> of groundwater supply (Water Resources Agency, Ministry of Economic Affairs, 2002).

Furthermore, high demands on domestic and industrial water usage caused by rapid population growth and formation of industrial parks result in water supply difficulties on the Chou-Shui River alluvial fan and an increased use of groundwater, which is the main reason for land subsidence (Water Resources Agency, Ministry of Economic Affairs, 2002). Some problems with the water supply of the Chou-Shui River drainage area are as follows:

(1) Unstable irrigation water and mud problems. Agriculture is well developed and stream flow diversion is the main irrigation method of

the Chou-Shui River alluvial fan. Water amounts are evidently distinct during abundant-water periods and low-water periods; water drafting is difficult due to water shortage during the low-water periods and destruction of the water intake devices caused by floods during the abundant-water periods. Besides, turbidity is high in the Chou-Shui River, which may cause deposits in the water diversion routes and increase the difficulty for water resources transmission and distribution (Water Resources Agency, Ministry of Economic Affairs, 2002).

- (2) Groundwater overpumping and land subsidence. A shortage of water supply caused by the usage of streamflow diversion and the distinct water amounts during abundant-water periods and low-water periods make some irrigation works draft groundwater as a water source. Groundwater is also the main water source on the coastland because of its end position in the irrigation system where water supply is not sufficient, thus making high demands on the water supply due to the well-developed aquaculture industry. Overpumping of groundwater has resulted in serious land subsidence problems; the maximum amounts of subsidence in the most serious areas are approximately 2m in depth (Water Resources Agency, Ministry of Economic Affairs, 2002).
- (3) Lack of effective management on water resources. The Chou-Shui River supplies agriculture water to Changhua and Yunlin counties, with constant disagreements between the two counties. Also, no regulation control over groundwater usage has caused land subsidence to become even more serious (Water Resources Agency, Ministry of Economic Affairs, 2002).

Rivers are one part of the natural environment, and the relationship between them and people bring not only positive benefits, but also cruel disasters. Because Taiwan is located on the west side of the North Pacific Ocean, it experiences frequent typhoons and torrential rains, it has steep terrains and rivers, the rainfall rapidly gathers in the river channels, and the middle and downstream stages rise quickly, causing floods and disasters. So Chou-Shui River does inevitably bring some natural or man-made disasters. Natural disasters that happen in the river include debris flows, landslides, and so on; man-made disaster like land subsidence is brought on by overpumping of groundwater.

Take upstream of Chou-Shui River, for example, as it is located in the mountain, inhabitants always suffer from serious debris flow or landslides when rainstorms or earthquakes occur. On the other hand, people who live from midstream to downstream have to suffer floods caused by land subsidence after typhoons or rainstorms have passed through. As mentioned above, inhabitants living in the drainage area of Chou-Shui River may not only live there because of the river water, but also may be destroyed by it. What we need to consider is how to make the river bring the greatest benefit to the people, and then eliminate the bad influences brought by it.

## STRATEGIES TO REDUCE PROBLEMS RESULTING FROM THE CHOU-SHUI RIVER

To eliminate natural or man-made disasters in the drainage area of Chou-Shui River and make inhabitants have better lives, the government has engaged in several projects. Those projects, which have already been completed, include flood warnings, potential debris flow stream markings, and the Chi-Chi common diversion project (CCCDP). Those still in progress include a regulation project of flood-prone areas, building of a new reservoir known as Hu-shan Reservoir, and a groundwater recharge project. We will describe these strategies in the following text.

#### Flood Warnings

To reduce flood disasters, the Water Resources Agency (WRA) of the Ministry of Economic Affairs (MOEA) has taken measures that suit local circumstances to execute flood mitigation, and has established flood and drought forecasts and an emergency measure system to reduce calamity and loss. Moreover, enhancing precaution and preparedness against flood disasters not only protects social, public life, and property, but also helps development in the economic areas.

The flood and runoff forecasting system for the Chou-Shui River basin was completed in May 2002. A system of a hydrological information center and 10 hydrological stations were built and 49 rainfall gauge stations belonging to the Central Weather Bureau (CWB) were connected to the system by a special cable as a primary facility and by a very small aperture terminal (VSAT) as a secondary one. The system collects data from all the hydrological stations every 10 min. Then the data are fed into the simulation models to provide forecast during the high-water or tide season to use as a reference for disaster defense.

#### Potential Debris Flow Stream Markings

Debris flow is a natural phenomenon, and people cannot control it from happening. But if we can know in advance which places have higher possibility of such flow and mark them as potential debris flow streams, most disasters can be prevented. To determine these potential areas, the effective tools used were disaster prevention software and hardware.<sup>3</sup> From 1992 to 1996, the Council of Agriculture completed the first time potential debris flow streams investigation. The investigation showed that there were 485 potential debris flow streams in Taiwan. After the Chi-Chi Earthquake (1999) and Toraji and Nali typhoons (2001), the Council of Agriculture updated the number of such potential streams. In 2009, there were 1,503 potential debris flow streams in Taiwan, and of them, 208 are located from midstream to upstream of Chou-Shui River.<sup>3</sup>

#### The Chi-Chi Common Diversion Project

To improve the water resources usage problems of Chou-Shui River, a permanent common diversion port was presented during the colonial period of Taiwan. The Sixth Naphtha Cracking Factory was established during 1991 in the Yunlin Offshore Industrial Zone, which is located in the estuary of Chou-Shui River. The CCCDP was executed after the authorization of the establishment plan for the industrial water equipment. Total expenditure was 23.8 billion TWD; the main body was completed and a trial run was executed in 2001, and the equipment has been completed and operating since 2002 at the Chi-Chi Weir (Figs. 7; Water Resources Agency, Ministry of Economic Affairs, 2002).

After operating the CCCDP in 2002, CCCDP supplied 1,770 million m<sup>3</sup> of irrigation water to Changhua and Yunlin counties each year. Due to CCCDP, 270 million m<sup>3</sup> of groundwater will not be pumped each year and, therefore, will retard the process of land subsidence. Also, CCCDP will supply 300 million m<sup>3</sup> of industrial water to the Yunlin Offshore Primary Industrial Zone each year leading up to and including 2019. For civilian water use, CCCDP will supply 0.2 million m<sup>3</sup> each day to Yunlin County. In addition to the different targeted water supplements previously described, CCCDP supplies irrigation for drought periods to the Bagua Mountain tableland region and general hydropower by using water flow from higher elevations to fall into the channel during wet periods. There have been several significant changes in water resource management for the Chou-Shui



Fig. 7. Chi-Chi Weir (Water Resources Agency, Ministry of Economic Affairs, 2002).

River after the operation of CCCDP (Water Resources Agency, Ministry of Economic Affairs, 2002).

- (1) *Common diversions*. After the operation of CCCDP, 25 irrigation channels in the north and 30 in the south are supplied with water. For this reason, problems such as the maintenance of diversion facilities, unstable diversions, and channel depositions had to be overcome (Water Resources Agency, Ministry of Economic Affairs, 2002).
- (2) Simultaneous deployment. There is simultaneous deployment when each target of water supplement is diverged by the common diversion facilities of CCCDP. Furthermore, there is an adjustment pond with 10 million m<sup>3</sup> in front of the Chi-Chi diversion weir. The adjustment volume of the pond has a supplement water resource of emergency capacity, especially when civilian and industrial water demands are insufficient. The Chi-Chi diversion weir, Wushe Reservoir, and Sun-Moon Lake Reservoir can operate together to raise the stability of water supplements (Water Resources Agency, Ministry of Economic Affairs, 2002).
- (3) *Joint application*. After the operation of CCCDP, the water resources from the Chou-Shui River are diverted to each irrigation region. Therefore, overpumping of groundwater is reduced in those regions. Furthermore, surface water resources from CCCDP and groundwater

resources from the aquifer can be applied jointly by effectively monitoring the groundwater levels (Water Resources Agency, Ministry of Economic Affairs, 2002).

A milestone in the water resource management of the Chou-Shui River happened when CCCDP began operating. Under the situation of common diversions, effective strategies of management are the most important. To manage water resources of the Chou-Shui River, several systems that are the monitoring and controlling system of runoff forecasting, the monitoring system of groundwater level, and the geographic information system were established. These systems were used to collect geographical and hydrological data, which could be used to improve the strategies of water resource management. Beside the foregoing monitoring systems, there are diversion facilities operating systems like the gauge operating system, which confirms whether CCCDP is operating normally. There are several additional projects, for example, one plan is to build Hu-shan Reservoir, and then, the efficiency of CCCDP will be more outstanding (Water Resources Agency, Ministry of Economic Affairs, 2002).

#### Regulation Project of Flood-Prone Areas

To improve the flood problems that happen in areas of land subsidence as well as low-lying and urban areas, the MOEA brought about an eight-year plan for flood reduction (Regulation Project of Flood-Prone Areas) to protect people's life and domestic economics. Referring to the model of dealing with Keelung River, the government has systematically managed the rivers, regional drainages, and industrial dikes to solve the flood problems effectively. In 2007, rainwater, soil and water conservation upstream, and farm drainage were even brought into this project to achieve more effects. There are five demonstration areas in this project, and one is the coastal area in southern Yunlin.<sup>4</sup>

#### Hu-shan Reservoir

Because of the insufficient water resources in Changhua and Yunlin counties, the Water Resource Agency planned to build Hu-shan Reservoir on the west side of Douliou Hills. Water is drawn from the Ching-Shuei River to be stored in the reservoir during rain seasons and to supply water during dry seasons. The Hu-shan Reservoir is planned to be used conjunctively with the CCCDP after it is completed. That is, by using the water resource of CCCDP during the rainy seasons, and the Hu-shan Reservoir during dry seasons. The daily water supply is about 694,000 tons. It can bring good quality and steady amounts of surface water to Yunlin County. The Hu-shan Reservoir is the substitute water resource for domestic water use as well as for any developing regional water use. It will be completed in 2014.<sup>5</sup>

#### Groundwater Recharge Project

The measures of groundwater recharge include natural and man-made structures. Here, the man-made structures are discussed. The manmade structures can be divided into direct and indirect ones. There are different kinds of direct groundwater recharge measures such as irrigation methods, subreservoirs, artificial recharge wells, infiltration basins, and so on. Because of the geology of the alluvial fan of Chou-Shui River, the top part of alluvial fan is suitable for recharging. In addition, to prevent the situation of land subsidence from becoming worse, groundwater recharge is thought as one of the practicable measures. Therefore, the Water Resource Agency has started to take comprehensive measures to provide man-made lakes, check dams, and storage structures to meet the water demands, thereby eliminating overpumping of groundwater in Changhua and Yunlin counties.

### CONCLUSION

As the history of Chou-Shui River is traced, it can be found that it has gone through many changes. It not only supplies water for agricultural, industrial, and domestic uses, but also is associated with specific social cultures. As a result, we are well aware of the importance it has played in the economic and cultural development of central Taiwan.

Although the rivers are economically advantageous to the communities, they also are apt to flood and create unaffordable disasters caused by typhoons and torrential rains that frequent the island. As a result, considerable measures toward flood mitigation to improve the livelihood of the people and to reduce damages have been taken. Therefore, the



Fig. 8. Time History of Chou-Shui River (Water Resources Agency, Ministry of Economic Affairs, 2002; Tsai, 1999; Website of Udnnews: http://issue.udn.com/FOCUSNEWS/GROUND/HISTORY/history1.htm).

communities can be warned of any impending disaster before it strikes and make necessary preparation.

"Every coin has two sides" should be the best phrase to describe the Chou-Shui River. As "the Mother River," Chou-Shui River provides its inhabitants leisure, hydroelectricity, and irrigation on one hand, and on the other, it brings disasters such as debris flows, landslides, floods, and land subsidence.

"Water Community" is a concept of "the relationship between people and water." Natural forms of water resources like ocean, lakes, rivers, ponds, and estuaries, or man-made forms like reservoirs, retention ponds, and sewers all coexist with us. No matter what form water exists as, as long as the people use it or rely on it, water will influence the people's lives or even climate. Because recently it has been observed that climate change gradually affects people's lives, we have to think about the responsibility of treating nature well. Water resource usage is not only for people to use, but also for maintaining biodiversity. Thus, people should try their best to coexist with nature's biota.

Therefore, what should be considered as the main focus is how to build a safe, biological, and multiple water environment; how to make sure to have enough quantity, good quality, and persistent water resources; and even how to establish a culture that provides public awareness of the water situations as well as creating values among the people to treasure and conserve water. For humans to have a long coexistence with water, everyone should take whatever responsibility they can to better safeguard this relationship.

Some important events that happened are summarized into a timetable shown in Fig. 8. From such information, we can know more clearly about this river and see how much it contributes to life in central Taiwan.

#### NOTES

1. Website of the story of Chou-Shui River, Fourth River Management Office, Water Resources Agency, http://www.wra04.gov.tw/RIVER\_STORY2.HTM

2. Website of Siluo Township, http://www.hsilo.gov.tw/english/8tourist.htm

3. Website of Debris Flow Prevention Information System, Soil and Water Conservation Bureau, http://246.swcb.gov.tw/School/school-potential.asp

4. Website of Regulation Project of Flood-Prone Areas, Water Resources Agency, http://fcp.wra.gov.tw/

5. Website of Hu-shan Reservoir Project, Water Resources Agency, http://www3.wracb.gov.tw/index.asp

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