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# Flood disasters in the Changjiang River and their geo-environmental implications

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## ABSTRACT

The archaeological records of past 5,000 years revealed that a period of high (13.6 m) flood occurred in the Changjiang River in 2,000 years BP. A serious flood disaster happened in the middle and lower reaches of the Changjiang River in 1998. This event reverberated through the whole country and led to the very important attention by many scientists and engineers.

In this paper, it is proposed to carry out the following three flood control measures. The first is to improve the flood control standard, which includes dredging river course and reinforcing dykes or dams. The second is to dig a channal through the Dongjing River (an old course of the Changjiang River) to divert the flood for avoiding the simultaneous flooding from different rivers and to remove the flood disaster for the Wuhan City. The third is to form gradually a great lake across the Changjiang River to contain the Dongting Lake and Jianghan Lakes, which will supply the fresh water to be enough for the society and economic development of the middle China in the 21st century.

## INTRODUCTION

Flood is one of those natural phenomena that are responsible for the environmental changes on the earth's surface. It is called a disaster when the flood destroys human lives, property, and infrastructure. A flood disaster results from a non-harmonious interaction among the atmosphere, hydrosphere, and human activity.

Though flood causes severe damage to the surrounding areas, it also plays a vital role in improving the environment. Hence, there are two attitudes while dealing with flood: one is to refuse it mechanically, and the other is to use knowingly water and soil resources brought by it. The latter is possibly the more important strategy for controlling the flood disaster ultimately.

## ECOLOGICAL AND GEOLOGICAL ASPECTS

In China, flood has become a serious national problem and it has become increasingly difficult to cope with it. It seriously hinders the development of the society and economy.

A flood disaster results from various factors such as regional tectonic subsidence, climatic abnormality in a large area, and human activities that are not consistent with the processes of natural change. It is known that a short-term climate change is often related to the El Nino and La Nina phenomena in the tropics of the Pacific Ocean.

The historical records show that the intensification of flood disaster in frequency and strength is well correlated with the population growth. In other words, a flood disaster results from the struggle between the humanity and floodwater for occupying additional land.

Generally, a flood disaster is not classified in the category of the geological hazards, but it is closely related to the geological environment when it happens frequently in a large territory. It indicates that engineering or economic activities of human society or a strategy for controlling floods is not compatible with the regional geological environmental changes. The principal rule to control flood disaster is to establish the best correlation of the following five aspects: the mankind (sustainable living), mountains (soil and water conservation), rivers (rational development), lakes or reservoirs (adjusting flood or drought), and oceans.

When a region is subsiding, it gradually becomes lowland and an ideal space for storing surface water or surface runoff. Consequently, the flood disasters become increasingly frequent, and the engineering solution to "block the water" by constructing dykes or embankments is not the ideal one. Instead, the method of "dredging away the flood" by changing the river course or allocating flood-diversion areas would be the right selections. In other words, it is desirable to establish a developmental system to control flood as well as utilise the floodwater resource at the same time. For the above purpose, the engineering geologist must be familiar with the evolutionary history of the flood-prone area, present flood dynamics, and future geo-environmental trends of the area.

Remote sensing and global positioning system can be handy tools for monitoring floods, and the human society can be highly benefited from them in the future.

Especially in the developing countries, there is no coordination between the utilisation of natural resources and environmental management. Thus, the enormous flood disasters are made mainly by the anthropogenic factors, such as deforestation, unplanned waste disposal, land degradation, and underground and opencast mining in the upper reaches of a river. These activities are responsible for accelerated soil erosion and surface runoff. In the middle and the lower reaches, frequent reclamation of marshland and lakes as well as construction of dykes and dams leads to the river channel shifting and siltation of lakes. These activities are also responsible for the loss of floodwater storage and retardation capacity of rivers and lakes.

## FLOOD CONTROL

Flood control consists of the following three main aspects: 1) engineering measures, 2) legislative measures, and 3) forecasting and early warning system.

### Engineering measures

Engineering measures are often used to block up and retard water in the upper reaches of the river system, such as to build reservoirs, plant trees and grasses, and retain soil and water. A combination of blocking up and dredging measures are often adopted in the middle reaches of the river. These measures include dyke or embankment construction, river course dredging, and retarding basin construction (from where the flood can pass slowly). Among them, river course dredging and embankment construction are the main means to control flood disaster in the lower reaches of a river.

Lowlands or wetlands (i.e., low-lying land, marsh, swamp, wasteland, and flood and sea beaches) are called "the earth's kidney". They are "natural conditioners" for the flood. Hence, the lowland research and development must be given a high priority in controlling the flood, because these lowlands play an important ecological function in regulating climate, conserving water resource, purifying water body, and reducing drought or water-logging.

### Non-engineering measures

Non-engineering measures consist of a series of social functions to be stipulated by the state or country, such as the flood control law, flood insurance law, evacuation procedure, and reasonable land use planning. For example, it is not permitted that any civil engineering structure or residential colony is planned and constructed in the flood-diversion area. It is necessary to build a "safety island" in the floodplain to dodge the flood disaster for the moment.

In August 1997, the Flood Control Law of the People's Republic of China was passed by the 27th Meeting of Standing Committee of the Eighth National People's Congress of China. Some important legal provisions, such as the declaration of an emergency flood prevention period, mandate for removing obstacles of flood passage, and decision on selection of flood-diversion area, are made clearly in the law. The law played an important role during the flood prevention in the middle reaches of the Changjiang River in 1998.

### Flood forecasting and early warning system

It is necessary to set up a scientific and reliable flood forecasting and early warning system for evacuating the inhabitants in time. The warning system should be based on monitoring of some principal factors related with flood development. They consist of such factors as climate change in a regional and a global scale; process of rain storm formation; main characteristics of the regional geo-environment, soil composition, and moisture content; land use; economic resources; and population distribution.

## GEO-ENVIRONMENTAL CONDITIONS

According to the historical records from AD 285 to 1868, the return period of disastrous floods was about 41 years in the Dongting Lake area. At present, it is from 4 to 5 years. To compare with the historical floods, the floods in 1998 had many features similar to the historical ones, such as the middle flow, high water level, and excessive disaster in the Changjiang River.

Extensive felling of trees, construction of sloping cultivated land, haphazard mining, and discriminate disposal of soil and mine slag resulted in an ecological disaster. It also endangered the lower reaches of the Changjiang River by triggering debris flows and mudflows in the main river and its tributaries.

In the middle reaches of the Changjiang River, especially in its Jingjiang section (i.e., from the Yichang City to the Wuhan City), the embankment is already more than 13 m high (in places, up to 18 m higher than its northern plains). It resulted from a long-term strategy called "giving up the southern area (i.e., the Dongting Lake area of the Hunan Province) to save the northern area (i.e., the Jianghan Lakes area of the Hubei Province)". The Jingjiang section of the Changjiang River has become a "suspended river". The northern dykes in the Jingjiang section can withstand the incoming flood for next twenty years. In contrast to the northern area, the southern area of the Dongting Lake is being filled up by sediments. Consequently, the surface elevation in the area of northern Jianghan Lakes is lower than the lowest water level in the Changjiang River. It has resulted in the rise of groundwater level, loss of fertile farmland, spreading of endemic diseases, and recurrence of waterlogging problems. When the dykes of the Jingjiang section of the Changjiang River breach in the high-water season, the area of Jianghan Lakes in the Hubei Province is inundated and it leads to catastrophic consequences.

During the last 500 years, the northern embankments in the Jingjiang section have breached frequently. Generally, piping and undermining of the riverbank take place along the northern slopes in the high-water season, and the southern slopes collapse and slide in the dry season. These phenomena demonstrate that the high water level in the Jingjiang section is not compatible with the surrounding geo-environment.

**Flood levels in 5000 BP**

In the past, people used to move from place to place in search of water and their residential areas were located higher than the ordinary flood level. Therefore, we can reconstruct the high flood level for the past 5000 years in the Jingjiang section of the Changjiang River from the archaeological data.

It is found that the rising period of the flood level was mainly in 2000 BP in the Jingjiang section and it can be compared with the sediment accumulation value of 13.6 m (the data up to 1954) in the northern plains. The average rate of apparent flood level rise was 6.8 mm/year in 2000 BP in the Jingjiang section. The rate was 1.4 mm/year from 2000 to 1000 BP, 4.0 mm/year from 1000 to 500 BP, 19.6 mm/year in 500 BP, 27.8 mm/year in 200 BP, and 26.9 mm/year in 100 BP. These data illustrate that the rate of flood level rise is increasing rapidly in the Jingjiang section (Fig. 1).

A comparison of the flood level of 1998 with that of 1954 at the same site revealed that the former was higher than the latter. However, the latter flood flow was bigger than the former. For example, the difference between the former and latter flood levels was 0.55 m and 1.74 m in the Jingzhou City and Jianli City, respectively. That is to say, the average apparent rate of flood level rise is not less than 40 mm/year as revealed from the 1954–1998 data of the Jianli hydrometric station. The data demonstrate that the dykes or dam reinforcement is accompanied by the accumulation of sediments in the lake or riverbed and the flood level rise.

There were the following three periods of dyke construction for reclaiming land from marshes (or lakes) at a large scale in the Chinese history: from the East Jin Dynasty (AD 317–420) to the Northern and Southern Dynasties (AD 420–589), the Southern Song Dynasty (AD 1127–1279), and the New China (1949 onwards). Thus, the rapid flood level rise results from the following two reasons: one is the rapid deposition of sediments on the riverbed or lake bottom and the other is the construction of dykes for reclaiming marshland at a large scale. The first activity decreases the floodwater velocity whereas the second one diminishes the floodwater storage space.

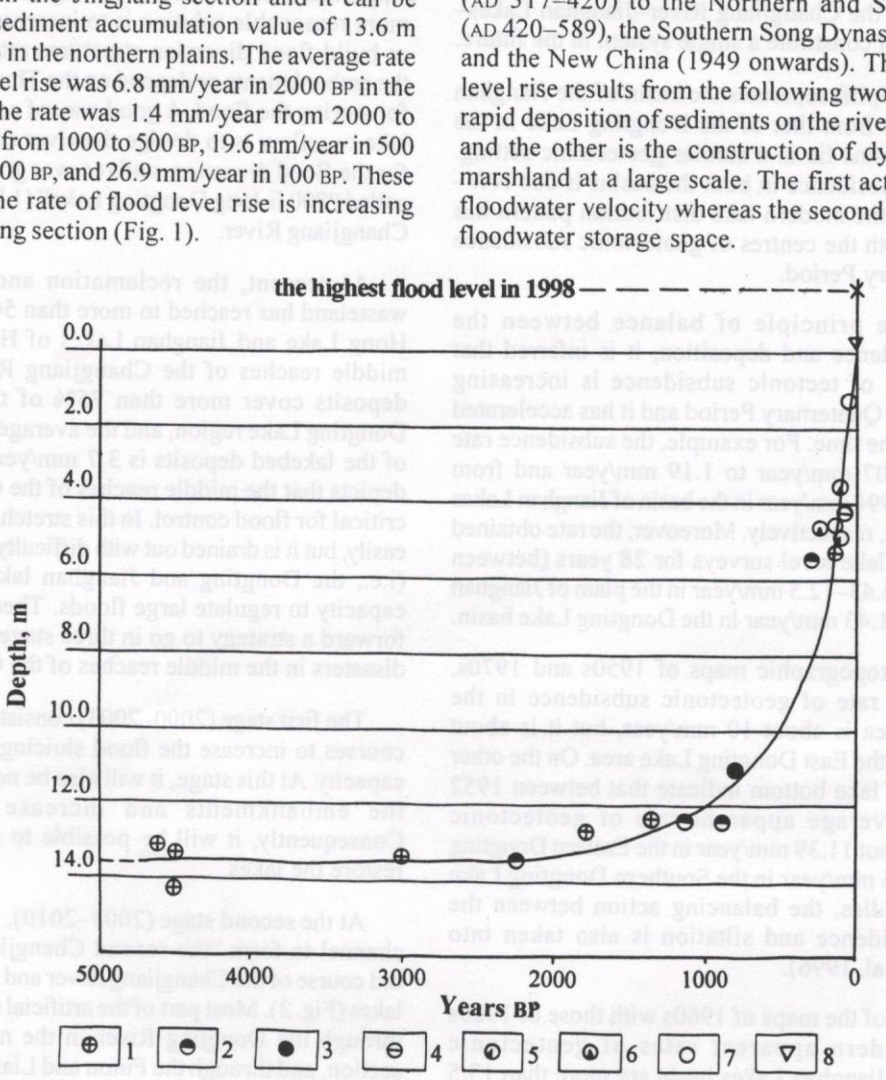


**Fig. 1: Flood level rise in 5000 BP at the Jingjiang section of the Changjiang River (after the Hubei team of hydrogeologists and engineering geologists 1995, and modified by Liu 1999) 1. Ancient ruins, 2. Ancient graves, 3. Unearthed relics, 4. Flood marks, 5. Ancient dykes, 6. Stone tablets, 7. Field survey, and 8. Highest water level in 1954**

## Modern geo-environment

The study of the Changjiang River, Dongting Lake, and Jianghan Lakes revealed that the middle reaches of the Changjiang River have undergone rapid geo-environmental changes since the Quaternary Period. These changes can be grouped into the following four stages. The first stage was the formation of the Changjiang River–Dongting Lake system from $Q_1$ to $Q_2^2$; the second was the Changjiang River–Jianghan Lakes system from $Q_2^3$–$Q_3^3$; the third was the Changjiang River–Dongting Lake system in $Q_4^1$–2000 BP; and the fourth was the Changjiang River–dykes–Dongting Lake system in 2000 BP. The fact that the Changjiang River is being diverted naturally towards the north indicates that a new distribution pattern of the river and the lakes will be observed in the future. In other words, the Changjiang River–Jianghan Lakes or the Changjiang River–Jianghan Lakes–Dongting Lake will constitute a single system in the future.

The Huarong Uplift separates the basin of the Jianghan Lakes in the north from that of the Dongting Lake in the south. Both the basins lie in a similar geotectonic setting. The direction of subsidence in both the basins is due NW–NE. Furthermore, the modern lake distribution pattern has been consistent with the centres of geotectonic subsidence since the Quaternary Period.

Following the principle of balance between the geotectonic subsidence and deposition, it is inferred that the apparent rate of tectonic subsidence is increasing gradually from the Quaternary Period and it has accelerated during the Holocene time. For example, the subsidence rate increased from 0.07 mm/year to 1.19 mm/year and from 0.06 mm/year to 1.994 mm/year in the basin of Jianghan Lakes and Dongting Lake, respectively. Moreover, the rate obtained from the repeated lake level surveys for 28 years (between 1925 and 1953) is 6.43–12.5 mm/year in the plain of Jianghan Lakes, and 8.56–11.43 mm/year in the Dongting Lake basin.

Based on the topographic maps of 1950s and 1970s, modern apparent rate of geotectonic subsidence in the Dongting Lake area is about 10 mm/year, but it is about 11–42 mm/year in the East Dongting Lake area. On the other hand, the maps of lake bottom indicate that between 1952 and 1988, the average apparent rate of geotectonic subsidence was about 11.39 mm/year in the Eastern Dongting Lake area and 8.06 mm/year in the Southern Dongting Lake area. In these studies, the balancing action between the geotectonic subsidence and siltation is also taken into account (Zhang et al. 1996).

A comparison of the maps of 1960s with those of 1980s reveals that modern apparent rates of geotectonic subsidence in the Jianghan Lakes basin are more than 13.5 mm/year. This value is greater than that obtained from the survey carried out for 28 years (i.e., between 1925 and 1953). A possible reason for the discrepancy may be the small scale of the maps used for this purpose.

## A STRATEGY TO DREDGE THE RIVER AND LAKES

The flood in the middle reaches of the Changjiang River has its own characteristics, such as a long duration, high flow velocity, high water level, and a greater probability of coincidence of flood peaks from various streams. As an example, in 1954, the total flood volume passing through the Yichang hydrometric station in 120 days was $3960 \times 10^8$ m$^3$, and it was $5590 \times 10^8$ m$^3$ through the Chenglingji station because of the floods coming simultaneously from the four rivers (i.e., the Xiang, Zi, Yuan, and Li). They all belong to the Dongting Lake water system. Moreover, the total volume of $6000 \times 10^8$ m$^3$ of flood passed through the Wuhan station because of the arrival of flood from the Hanjiang River. Apparently, for the flood lasting for a longer period, the more reasonable solution is to increase the flood discharge or build flood diversion structures rather than to reinforce the embankments or depend on the Three Gorges Reservoirs for storing the flood. A good way of controlling the river or lake overflow is to dredge the river courses, dig a channel for the flood diversion, and recover gradually the large lake called "800 li-long Dongting Lake" (1 li = 0.5 km) across the Changjiang River.

At present, the reclamation and cultivation of the wasteland has reached to more than 50% of the area of the Hong Lake and Jianghan Lakes of Hubei Province in the middle reaches of the Changjiang River. Mud and sand deposits cover more than 75% of the total area of the Dongting Lake region, and the average rate of accumulation of the lakebed deposits is 3.7 mm/year since the 1970s. It depicts that the middle reaches of the Changjiang River are critical for flood control. In this stretch, the high flood enters easily, but it is drained out with difficulty. The two lake regions (i.e., the Dongting and Jianghan lakes) have the natural capacity to regulate large floods. Therefore, the author put forward a strategy to go in three stages to control the flood disasters in the middle reaches of the Changjiang River.

The first stage (2000–2003) consists of dredging the river courses to increase the flood sluicing and the lake storage capacity. At this stage, it will also be necessary to strengthen the embankments and increase the dyke height. Consequently, it will be possible to reclaim the land and restore the lakes.

At the second stage (2003–2010), it is proposed to dig a channel to form "the second Changjiang River" along the old course of the Changjiang River and through some existing lakes (Fig. 2). Most part of the artificial river course is planned through the Dongjiing River in the north of the Jingjiang section, and through the Futou and Liangzi lakes in the south of the Changjiang River from where it enters the Yangtze River near the Echeng City. This plan has the following merits. Firstly, it avoids the floodwater from the upper reaches of the Changjiang River to meet with the flood from "the Four

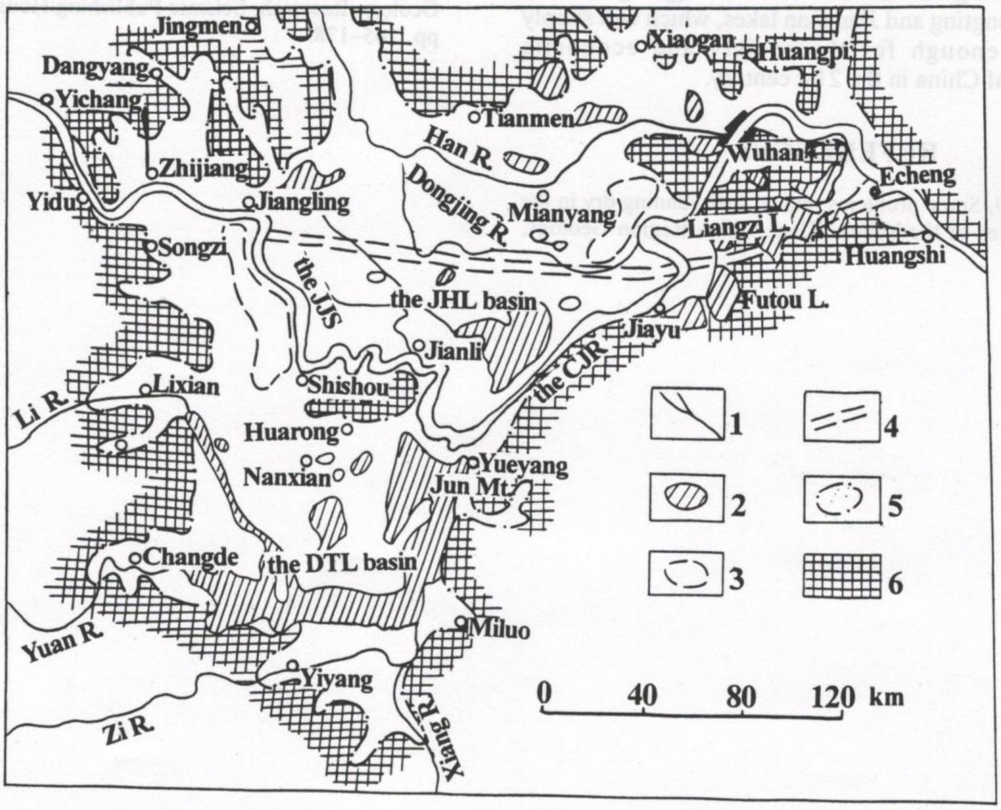


**Fig. 2: A plan to control the flood in the middle reaches of the Changjiang River. 1. Water system, 2. Lakes, 3. Flood-diversion area, 4. Planned channel, 5. Subsidence area in Holocene time, and 6. Upwelling area in Holocene time.**

Rivers" through the Dongting Lake. Secondly, it avoids the possibility of simultaneous flooding from the Changjiang and Hanjiang Rivers. Thirdly, it makes a detour to keep the large Wuhan City away from the disastrous consequences of large floods over a long period. Fourthly, it is technically as well as economically viable within the given time limit of the project, as "the second Changjiang River" is dug by utilising the existing river courses and lakes.

The main aim of the third stage (2000–2015) is to combine the Dongting Lake and the Jianghan Lakes to form gradually a united wide lake across the Changjiang River. The total area of the wide lake will be about $4x10^4$ km$^2$. It would store the valuable fresh water resources for the sustainable development of Chinese society in the middle period of the 21st century. Therefore, many important problems, such as environment, ecology, geology, economy, society and humanities, and the interrelation among them, have to be researched. This project may be planned in, and constructed in 2016–2030.

## CONCLUSIONS

The region of "one river (i.e., the Jingjiang section of the Changjiang River) and two lakes (i.e., the Dongting and Jianghan lakes)" has been one of the highly disaster-prone areas of China. It is an urgent need to find a better solution to the problem, instead of following the present practice of flood control between the Changjiang River and the Dongting Lake.

It is proposed to follow the flood control measures in three stages in the middle reaches of the Changjiang River. The first stage is planned between 2000 and 2003, which consists of dredging the river courses to increase the flood sluicing and the lake storage capacity. The second stage is proposed between 2003 and 2010 is to dig a channel to form "the second Changjiang River" along the old course of the Changjiang River and through some existing lakes. It will divert the floodwater as well as avoid the possibility of simultaneous occurrence of peak floods from different rivers and thus save the large Wuhan City. The third stage is to form gradually a great lake across the Changjiang River to contain the Dongting and Jianghan lakes, which will supply fresh water enough for the society and economic development of China in the 21st century.

## REFERENCES

Liu, C. Z., 1999, Some problems related with running dry in the lower reaches of the Yellow River. China Region Geology, v. 18 (4).

Zhang, R. Q., Liang, X., and others, 1996, Geotectonic subsidence study on the Dongting Lake region. Environmental Geology Research, Seismic Publishing House, Beijing, v. 3, pp. 165–178.