Integrated Physical and Ecological Management of Rivers – with Particular Reference to the East River (Final Report)

IRTCES Report – 2007 – 2 – 01

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PICTURES OF THE EAST RIVER (DONGJIANG RIVER)

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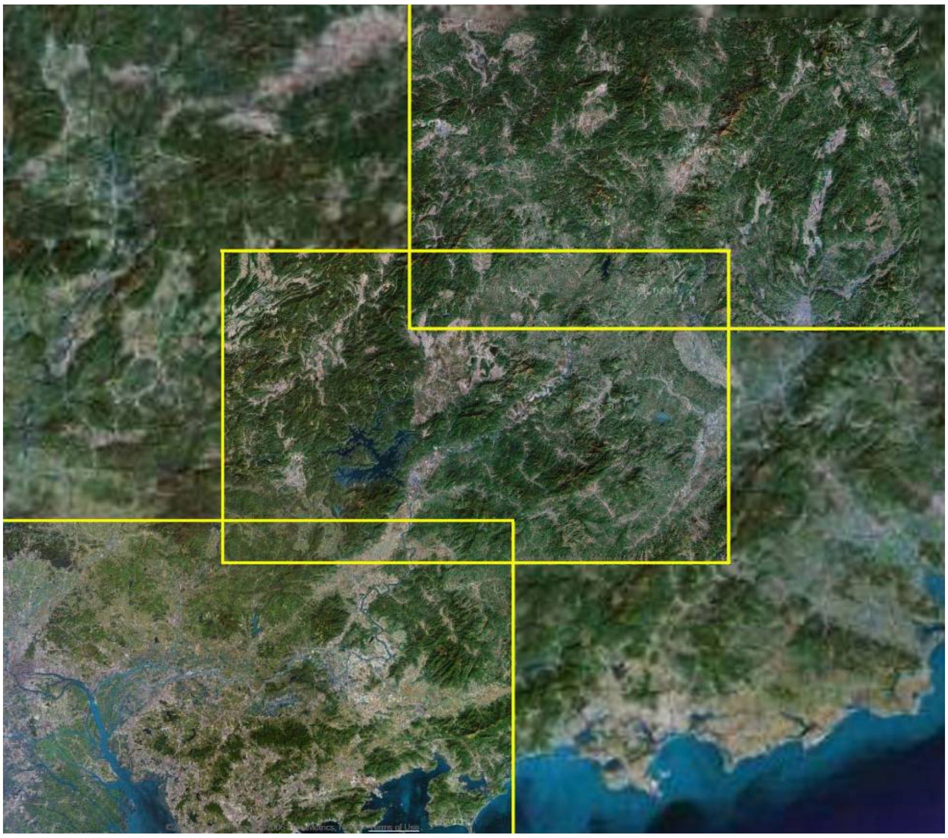


Picture 13 Satellite image of the East River Basin
(redraw by the images downloaded from Google Maps http://maps.google.com/)

Picture 13-1 Satellite image of the East River Basin (low left part)

Picture 13-2 Satellite image of the East River Basin (middle part)

Picture 13-3 Satellite image of the East River Basin (up right part)

INTEGRATED PHYSICAL AND ECOLOGICAL MANAGEMENT OF RIVERS – WITH PARTICULAR REFERENCE TO THE EAST RIVER

1. INTRODUCTION

River systems are very important for human development. They not only provide foods and water for industry, agriculture and human life, but also serve for communication, commerce and recreation, etc. The river ecological system is also one of main channels in the material circulation of the biosphere. Nutrients and pollutants can be transferred and degraded in a river system (Karr&Chu, 2000). But, in according with the quick development of industrial civilization in the past decades the water required by human society has been increased. Many rivers have been faced to the situation with little flow or even dry-up. Besides, as a large amount of pollutants are entering into river systems, and more and more forests are cleared for agriculture and riparian vegetations are destroyed due to human activities, the water quality of rivers are worsening and many of their service effects have gradually been lost.

The river and its basin affect and restrain each other, so the river basin management as a whole can be effective. Along with the development of human civilization, the leading object of river management has been turned to the reasonable and sustainable utilization of river natural resources and the aesthetics aspect of sightseeing, rather than the old object of water reservation, power generation and pollutant acceptor. Accordingly, the objects and styles of river management have been changing.

Ecosystem health refers to an ecological system in good condition. It not only reserves the chemical, physical and ecological integrity, which means that the ecological system in its own evolution process can reserve the normal structures and functions of the biotic community when it is not interfered by human being, but also reserve the functions of various services for the human society(Karr et al,1986; Karr,1999; Rapport,1999; Zeng et al., 1999). These management examples, such as the ecosystem restoration of Kissimmee River in USA and the natural feature restoration on the Rhine River by a lot of engineering measures, led to the consideration that the restoration and maintenance of a good river ecological system has been considered as an important object in the environment management.

In view of ecology, the object of river ecosystem management is to maintain the sound aquatic ecological environment of a river system and to ensure the normal development of its various service functions. A sound aquatic ecological environment of a river system is affected by various factors. Of which the river basin as an external factor of river ecological system, its meteorological, geological features and situation of land utilization determine its physical and aquatic chemical features such as runoff, riverbed and bed composition. In order to maintain a healthy river ecological system it is necessary to build a healthy river basin environment which in turn is the foundation of a healthy river basin as well. The river system should be considered as a basic unit of the river basin and has a mutual relation with the land ecological system of the basin. The systematization and integrity of a river basin must be emphasized. When evaluating the health situation of a river ecosystem and analyzing various service functions, such as water reservation, water energy, water quality and aquatic livings, etc., provided by the river ecosystem, the process should be based on monitoring various parameters such as the structure of the biotic community of the river ecosystem, ecosystem functions and river ecological process. At the same time, it should be based on surveying the intensity and forms of human activity (for example, change of land utilization, intensity and living habitation of local people).

1.1 Items and Objectives of the Study

The Items and objectives of the study are:

1) Field investigations on the watershed soil erosion and vegetation development, sediment transportation, river morphology and micro-morphology of the East River, collecting data of watershed morphology,

water resources and sediment, bio-community and habitat, biodiversity, human population, land use and river use and industries and pollution;

2) Water and benthic sediment sampling and measurements of ammonia, oil, heavy metals, nutrients and organic materials in water and sediment; source mapping; and analyzing the fate and transport of the pollutants;
3) Development and integration of hydrological and environmental material flow models; catchment, channel, and flood plain models; surface-ground water interaction; study impact of river and groundwater nutrients on coastal eutrophication;
4) Field investigations on the characteristics of biological community and aquatic habitat, human-induced stresses on the river ecology and restorations;
6) Conduct rapid bio-assessment using macro-invertebrate community index that emphasizes structural attributes of macro-invertebrate communities and compares it with a reference or control community;
7) Set up the objective values of the comprehensive river health index. Work out integrated river management strategies.

The objectives of this project are to have a better understanding of integrated physical and ecological management of rivers by the case study of the East River, to provide a sound scientific basis for sustainable water management of the East River, and it also aims at benefiting the development of decision support systems for sustainable development of coastal cities and marine resources. This is a critical step to provide a sound scientific basis for sustainable water management.

2. GENERAL DESCRIPTION

2.1 Overview

The East River (Dongjiang River) Basin, the third large river basin in the Pearl River Basin, is located in the Guangdong and Jiangxi provinces, in the region from 113°39′ to 116°45′, East Longitude, and from 22°45′ to 25°20′, Northern Latitude. The East River Basin is composed of the following cities, counties and districts (town) in Guangdong Province, such as, the Yuancheng District in Heyuan City, Dongyuan County, Zijin County, Longchuan County, Heping County, Lianing County, Xinfeng County in Shaoguan City, Huicheng District in Huizhou City, Huidong County, Huiyang City, Boluo County, Longmen County, Dongguan City, Longgang District in Shenzhen City, Zengcheng city, and the Luogang and Nangang towns in Guangzhou City and the Luofu town in Xingning City. The East River Basin also includes Anyuan, Dingnan, Longnan and Xunwu Counties in Jiangxi Province.

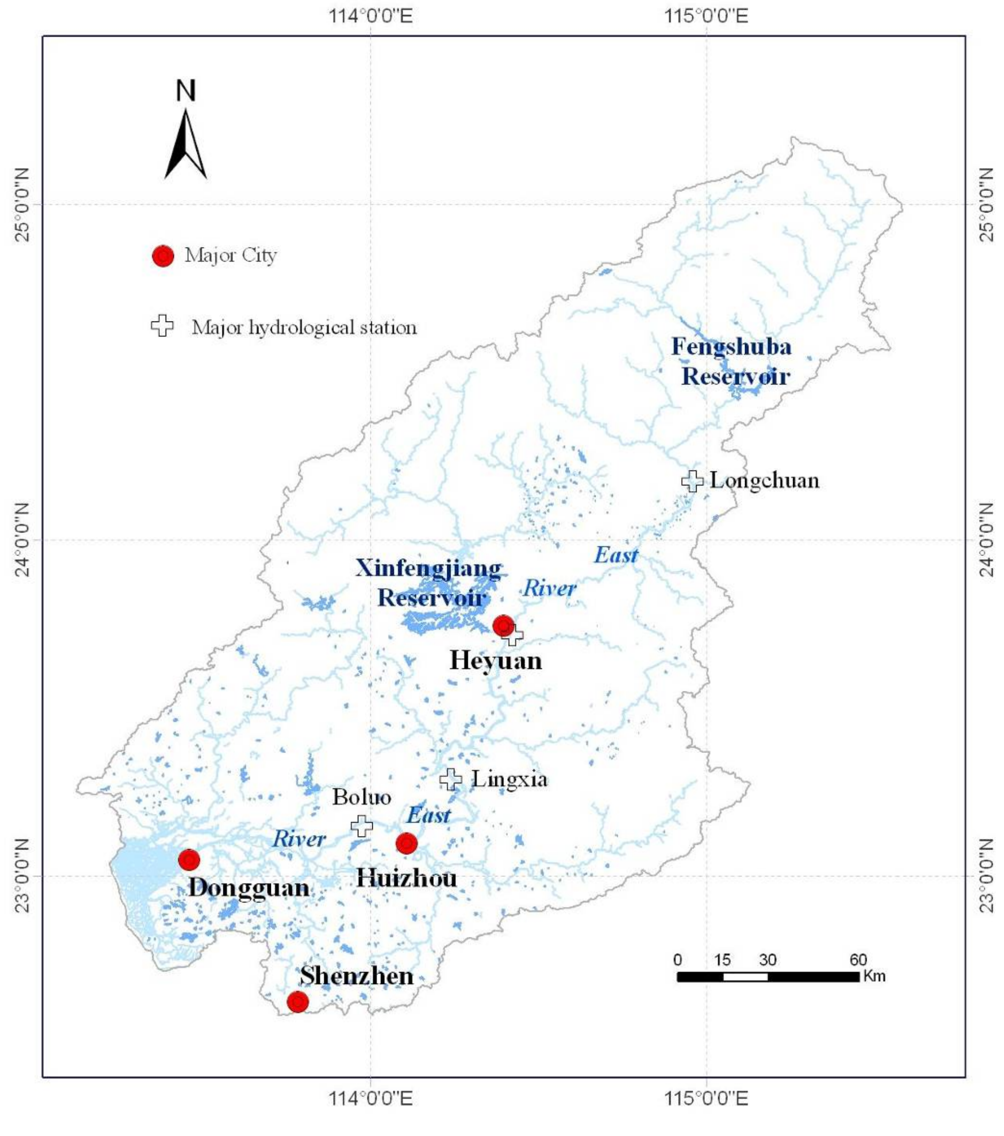


Fig. 2.1 River system in East River Basin

The East River originates from the Yabin Mountain in Xunwu County, Jiangxi Province. The total length of main stem is about 562 km with the mean river longitudinal gradient of 0.039%, in which 435 km is in Guangdong Province. The total drainage basin is about 35,340 km^2, in which 30,644 km^2 is in the Guangdong Province, accounting for 89.75%, and 3500km^2 is located in the Jiangxi Province, accounting for 10.25%. There are seven tributaries with the drainage area larger than 1,000 km^2 on the main stem upstream at Shilong. They are Anyuan, Lijiang, Xinfeng, Qiuxiang, Gongzhuang, Xizhi and Shima rivers, in which the Xinfeng, Xizhi and Shima rivers are the biggest three tributaries wirh drainage areas of 5,813 km^2, 4,103 km^2 and 2,364 km^2, respectively. There are also two tributaries with drainage area larger than 1,000 km^2, entering into the estuary delta of the East River. They are Zengjiang and Shahe Rivers with drainage areas of 3,114 km^2 and 1,235 km^2, respectively. Besides, there are also 18 tributaries with the drainage area between 1,000km^2 and 100km^2 in the East River System (Fig. 2.1 and Table 2.1).

Table.2.1 Tributaries with basin area larger than 100 km^2 and tributaries discharging into bay delta

Name of tributaries	Basin area (km^2)	Length (km)	Gradient (%)	Location of entering
Jianxi	127	17		From left bank
Shizhen	224	42	0.626	From right bank
Longtu	268	49	0.569	From right bank
Shuijin	278	46	0.437	From right bank
Liutian	188	32	0.874	From right bank
Shazhou	115	29	1.290	From right bank
Lofu	118	24	0.939	From left bank
Beiling (Anyuan))	2364	140	0.198	From right bank
Chetian	137	30	0.704	From right bank
Lijiang	1677	100	0.220	From right bank
Xiaomiao	181	32	0.303	From left bank
Zentian	108	21	1.130	From right bank
Huangcun	409	54	0.489	From left bank
Kanghe	413	68	0.402	From left bank
Jiushe	143	29	0.576	From left bank
Xinfeng	5813	163	0.129	From left bank
Bopu	446	68	0.289	From left bank
Guzhu	403	55	0.253	From left bank
Qiuxiang	1669	134	0.111	From left bank
Dalan	225	41	0.288	From left bank
Gongzhuang	1197	82	0.051	From right bank
Xizhi	4103	190	0.060	From left bank
Xiaojin	116	33	1.160	From right bank
Gaoshuxia	125	26	0.639	From right bank
Shima	1249	88	0.051	From left bank
Shahe	1235	89	0.064	Into northern stem
Zengjiang	3114	203	0.074	Into northern stem

2.2 Cross-sectional Profiles

2.2.1 Longitudinal and Cross-sectional Profiles on the main river

The river stem from river source to the Fengshu Dam in Longchuan County is called Wushui River, which is the upper stream of the East River and has the river length of 138 km and the mean longitudinal gradient of 0.221%. The Wushui River flows across a series of mountains and has the steep longitudinal gradient and narrow riverbed. The river stem from the Fengshu Dam to Guanyinge in Boluo County, merging with tributaries such as Lijiang River, Xinfeng River, Qiuxiang River, Gongzhuang River and Xizhi River is called the middle stream of the East River. It has the river length of 232 km and the mean river longitudinal gradient of 0.031%. The river stem from the Guanyinge to river mouth with two parallel dikes on both banks is called as lower stream, which has the river length of 159km and mean river longitudinal gradient of 0.017%. The sketched longitudinal profile of the main stem can be seen in Fig. 2.2.

Cross-section Longchuan is 53 km below Fengshuba Reservoir, which was commissioned in 1973. Comparing the cross-section in 1975 with that in 1965, the channel was migrated laterally and deposition took place (Fig. 2.3).

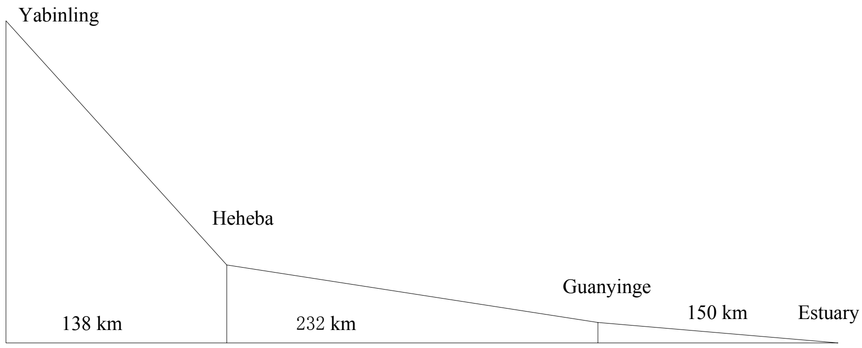


Fig. 2.2 Sketched longitudinal profile of the main stem

Generally, at the initial stage of reservoir operation the channel is eroded due to clear water releasing from the reservoir. The reason of deposition at Longchuan may be explained as follows. Channel erosion below a reservoir takes place in a certain distance below the dam, far below this reach deposition may take place; Longchuan is just in the reach of deposition. The decrease in longitudinal slope of river channel may be another reason; the slope of the upper reach below Fengshuba Reservoir is 0.055%, but the slope of the lower reach near Longchuan is only 0.045%. Density current venting was executed in Fengshuba Reservoir. Deposits released from the reservoir deposited in Longchuan reach, resulted in channel bed rising (Fig. 2.4). In 1986 the river channel was still rising and migrating laterally. In 2005 the channel was narrowed with scouring and depositing, the maximum thickness of erosion was over 2 m and the maximum thickness of deposition was over 1 m. Since 1990s sand mining has been executed in this reach, which might lead to channel bed lowering.

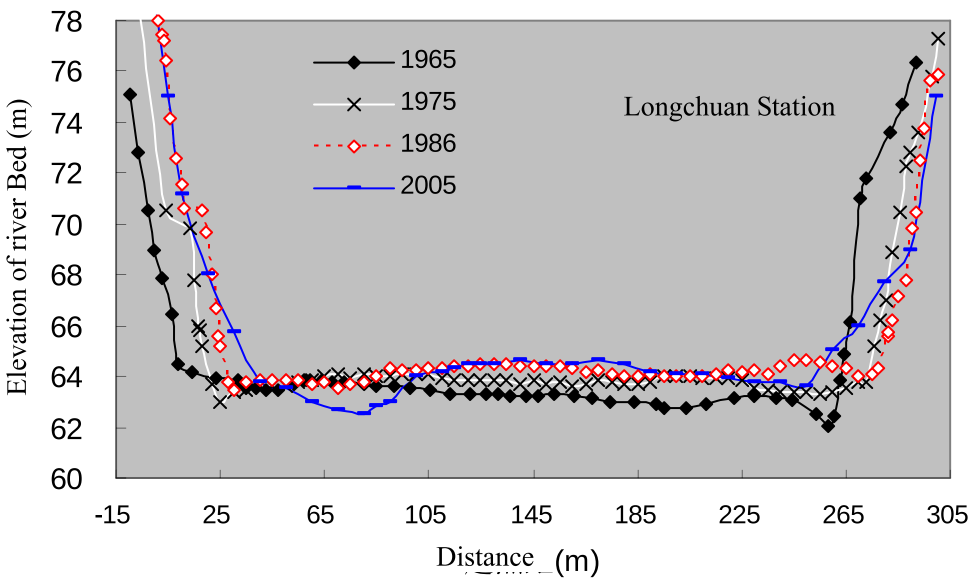


Fig. 2.3 Cross-section Longchuan of the main river

Comparing the cross-sections of Heyuan in 1965, 1976, and 1987, it developed from a single cross-section (in 1965) to a complex one (in 1987). From 1965 to 1976 the cross-section changed vigorously, the maximum thickness of erosion was over 3 m and the maximum thickness of deposition was also over 3 m. Comparing the cross-section in 1987 with that in 1976 the channel was lowered (Fig. 2.5).

Comparing the cross-sections of Boluo in 1965, 1976, and 1987, erosion and deposition in the cross-section were obvious with changing locations of erosion and deposition, but the amplitude of erosion and deposition was not large.

Fig. 2.4 Up (left) and downstream (right) views of the Fengshuba Dam

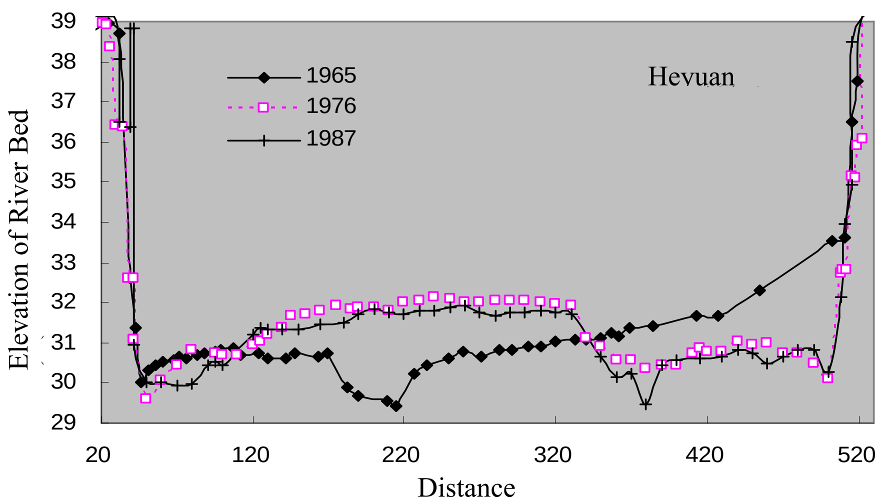


Fig. 2.5 Cross-section Heyuan in upper reaches of the East River

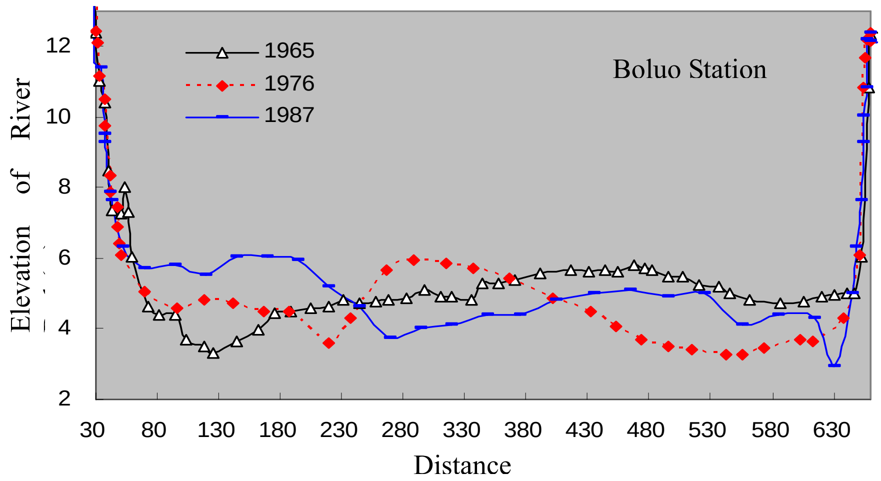


Fig. 2.6 Cross-section Boluo in lower reaches of the East River

From Figs. 2.3, 2.5 and 2.6 it can be concluded that lateral migration of cross-section of the main river was not significant, channel evolution mainly took place in the channel.

2.2.2 Cross-sections of tributaries

The changes of cross-sections of tributaries are similar to that of the main river. Several typical cross-sections of tributaries are shown in Fig. 2.7. Lateral migration of cross-sections of Shuibei (Xunwu River) and Pingshan (Xizhi River) is quite small with obvious vertical changes. As for cross-sections of Lantang (Qiuxiang River) and Honghuata (Gongzhuang River) they are stable.

From the above-mentioned it can be concluded that the river channel of the East River is stable.

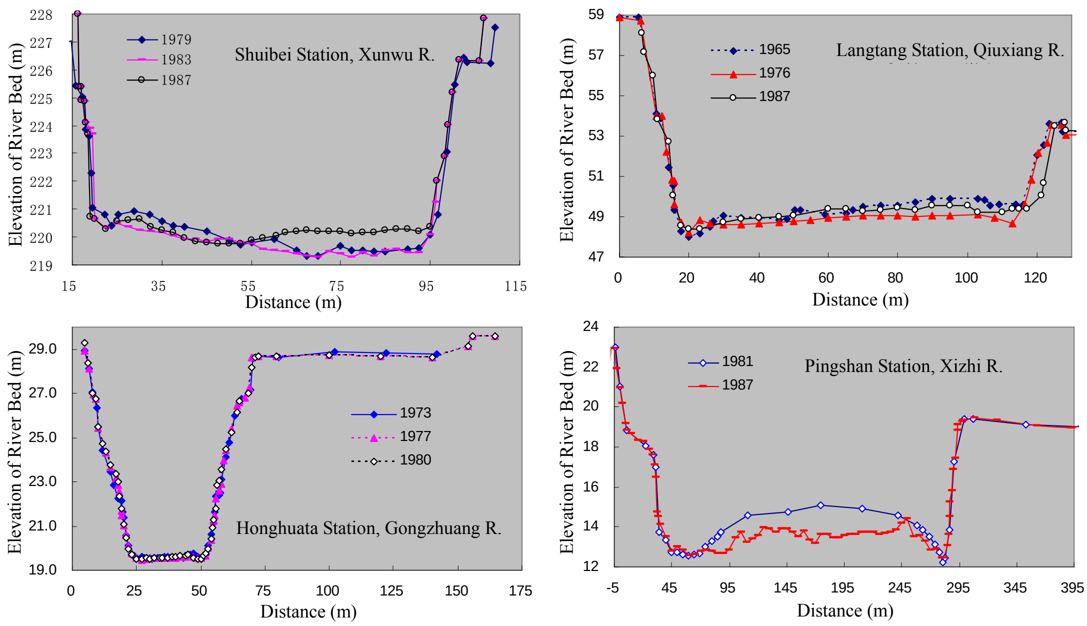


Fig. 2.7 Changes of the tributaries' cross-sections of the East River

2.2.3 Changes of cross-sections in a year

In the East River Basin the flood season is from May to September and the dry season is from October to next April. The maximum monthly average discharge generally appears in June.

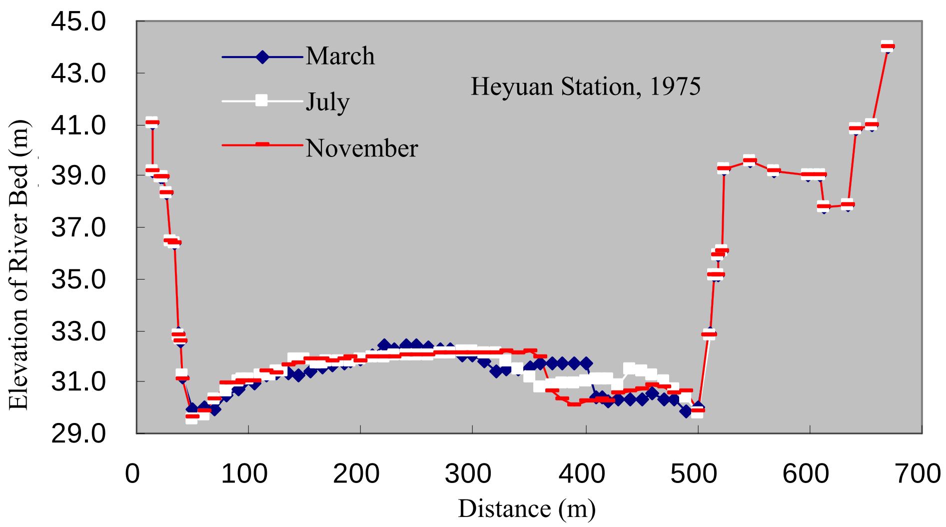


Fig. 2.8 Cross-section of Heyuan in 1975

Fig. 2.8 shows the change of cross-section Heyuan in 1975. At the initial stage of flood season deposition took place in the main channel, its thickness was more than 1 m; at the end of the flood season erosion took place, its thickness was nearly the same.

Fig. 2.9 shows the hydrograph at Heyuan in 1975, from the beginning of May to the end of June was the principal flood season, low discharges occurred in July, but large discharges appeared again in the middle of August.

Fig. 2.10 shows the cross-section below Fengshu Project. Its change was quite similar to that of Heyuan, deposition in the period from April to June, erosion in the period from July to December. Such a variation may be induced by the operation of Fengshu Project, which is "density current venting in the flood season and clear water releasing in the dry season".

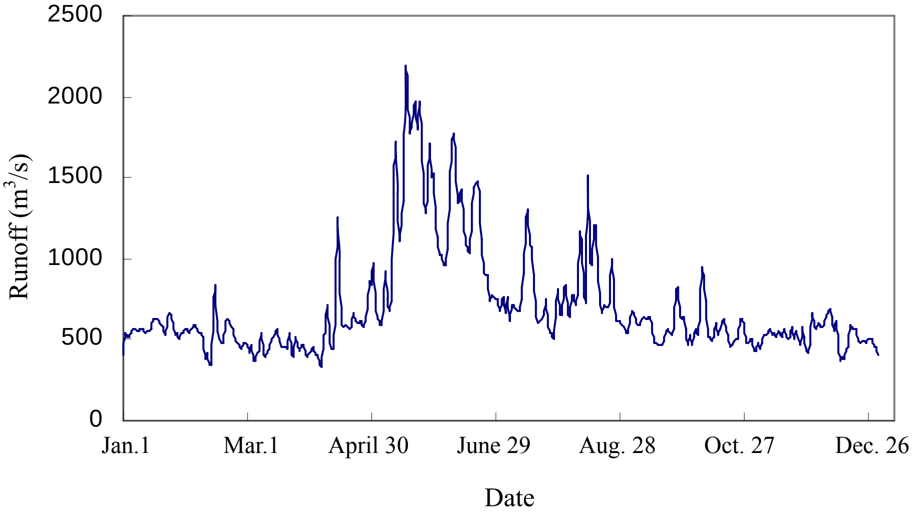


Fig. 2.9 Hydrograph at Heyuan in 1975

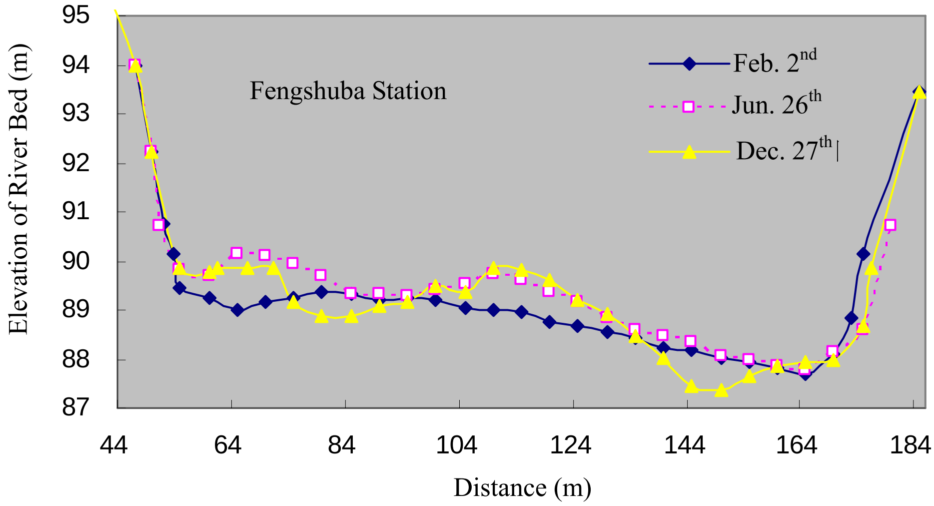


Fig. 2.10 Cross-section below Fengshuba Project

From the data of the cross-sections of Heyuan and below Fengshuba Project the changes of cross-section above Heyuan may be summarized as follows. Lateral migration of the cross-section is mild due to the effect of the Fengshuba Project and the vertical changes are significant, deposition in May and June and erosion in July to October.

Fig. 2.11 is the cross-section of Lingxia in the lower East River. Deposition and erosion took place all year round. From March to July deposition occurred in the left main channel while erosion in the right main channel; from July to November erosion occurred near the left bank and a new main channel was formed and deposition took place in the right main channel.

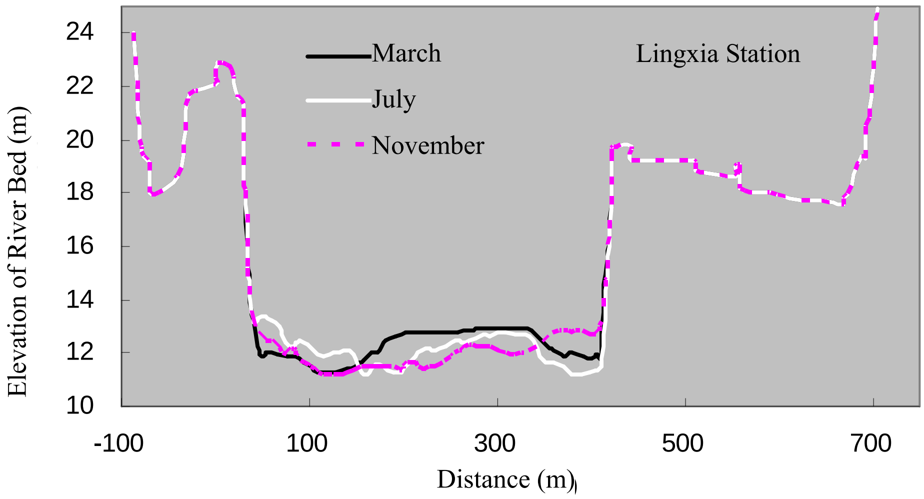


Fig. 2.11 Cross-section of Lingxia in the lower East River

2.3 Human Impacts

2.3.1 Impacts of reservoirs on river channels

Reservoirs change the hydrodynamic conditions of rivers, induced a series of changes in river morphological processes both in the upstream and downstream of reservoirs. The local base level of erosion is raised up, deltas and mouth bars may be formed in the main stem and in tributaries. Bank erosion may take place, which may occur for several decades, affecting the stability of reservoir banks. Submersion and immersion may happen in the nearby areas of the reservoirs and water leakage may take place.

The Fengshu Dam on the Beiling River was commissioned in 1973. The Beiling River is a large tributary of the East River. Fig. 2.12 shows the changes of a cross-section of the tributary. Sediment deposited in the main channel with a maximum thickness of over 1 m from 1977 to 1982; then the main channel became narrow (over 1 m) and deep (the maximum eroded depth was about 1.5 m) from 1982 to 1987. Such changes were induced by the fluctuation of the pool level of the reservoir.

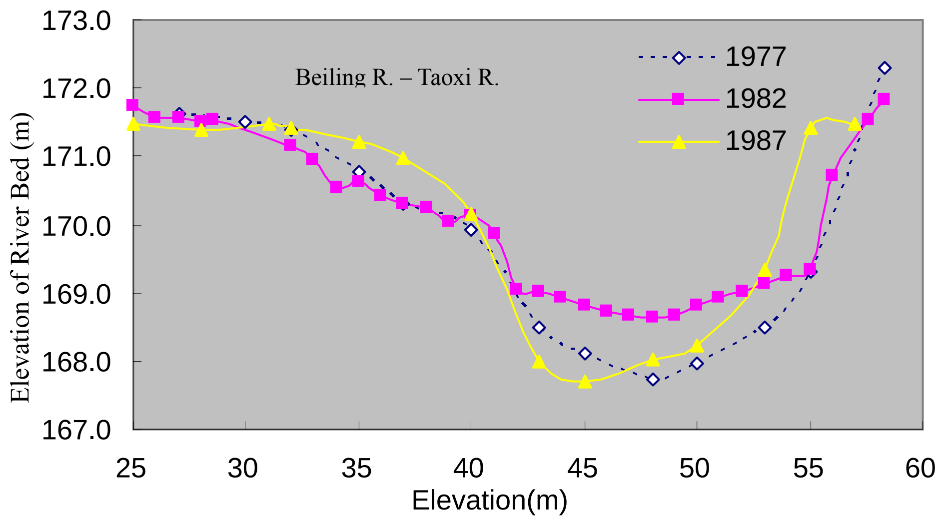


Fig. 2.12 Changes of a cross-section of Beiling River above Fengshu Dam

Fig.2.13 shows the changes of a cross-section below the dam. From 1973 to 1984 the cross-section became narrow and deep and the width-depth ratio became smaller than the pre-dam period.

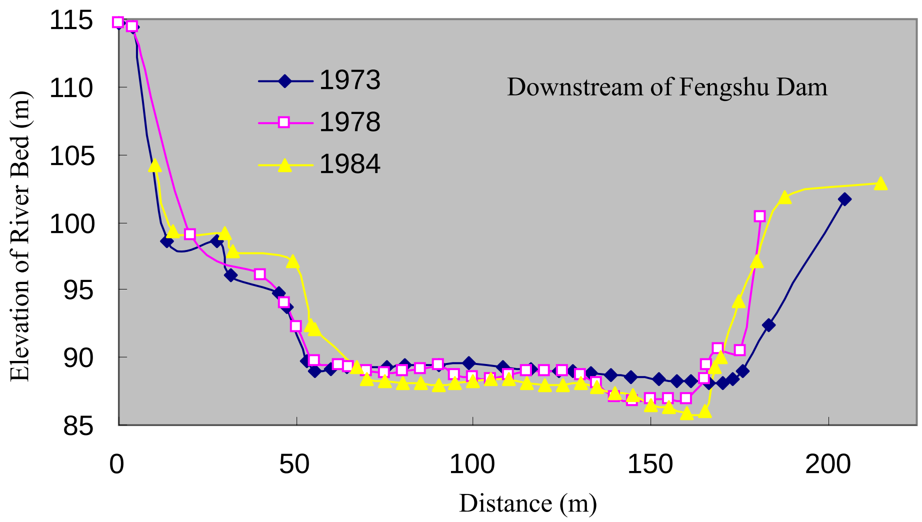


Fig. 2.13 Changes of a cross-section below Fengshu Dam

Zhentouzhai Hydropower Station is located below the Longchuan Hydrological Station. The operation of the power station affected the normal condition of the Longchuan Hydrological Station. In 1991 the dam of the power station was further raised up with a dam crest elevation of 67.0 m, thus the gauge discharge curve of the Longchuan Hydrological Station was changed significantly. Fig. 2.14 shows the changes of the cross-section of Longchuan Hydrological Station before and after the flood season in 1991. The main channel was obvious before the flood season, but it was deposited by sediment and became flat after the flood season. Such changes were induced by the backwater effect of the Zhentouzhai Hydropower Station.

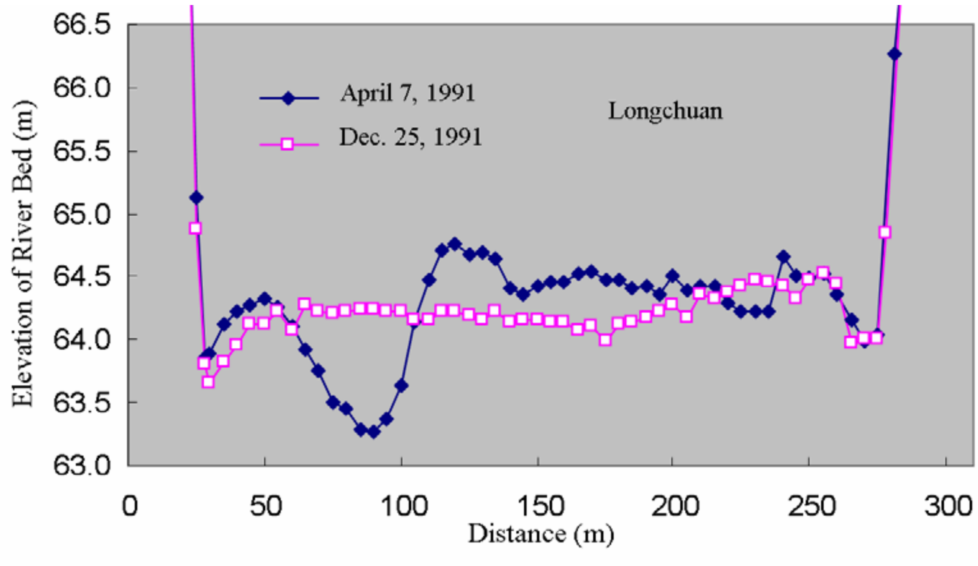


Fig. 2.14 Changes of a cross-section at Longchuan Hydrological Station

2.3.2 Wet excavation of sand

Along with rapid economic development in the region of Lower East River since 1990s, the demand of sand for construction has been increased greatly. A large scale of wet excavation of sand in the river reach below Boluo by local inhabitants was carried out (Fig.18). Owing to the amount of sand excavation was much larger than the incoming sediment load of the East River, the river channel was lowered seriously. Kang and Wang (1999) studied the fluvial processes of the Middle and Lower East River by remote sensing technology. The major changes of the river channel were as follows. (1) In the upper region the river channel was lowered seriously from 1988 to 1993, then this tendency was weakened, even deposition appeared in 1995; but in the lower region the river channel was lowered continuously, particularly after

1995. Wet excavation of sand was the main reason of such changes. Serious abnormal changes of the river environment took place near the region of Shilong, induced abnormal river development. (2) The river channel was lowered with maximum values of 10 m in some localities. (3) Shoals were collapsed owing to channel lowering, the water surface lines shifted in various years and the channel widths were changed correspondingly.

Fig. 2.15 Sand excavation downstream of the East River

The river channel in the Lower East River and delta area was lowered in the past decades. From 1960s to the middle of 1980s the amount of river channel lowering was not large and it was induced by natural scour. From the middle of 1980s human activities started to affect the river channel, serious scour appeared in the delta area first, then it developed upward to Boluo reach. Fig. 2.16 shows the changes of longitudinal profiles from Boluo to Shilong. In about ten years the average elevation of the riverbed was lowered 3.5 m to 5.6 m (the maximum was 12 m). Owing to the reduction of the incoming sediment load to the Lower East River in recent years and the effect of large-scale wet excavation of sand, the tendency of river channel lowering will continue in the near future.

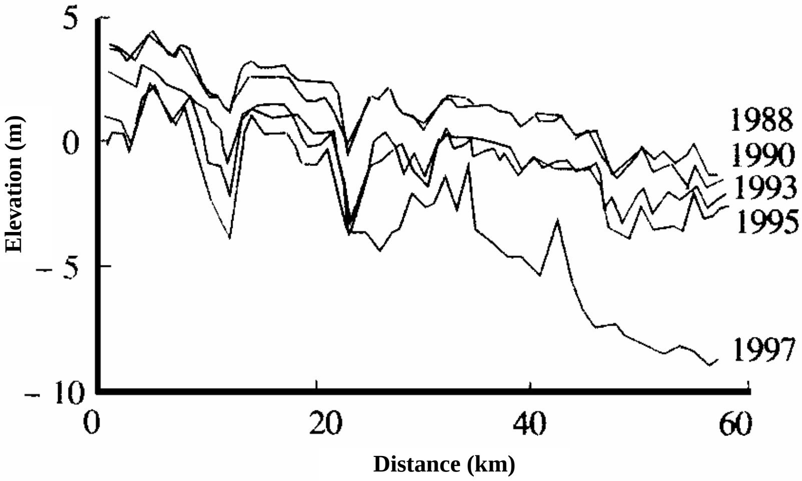


Fig. 2.16 Changes of the longitudinal profile of river channel between Boluo to Shilong on the East River

Table 2.2 lists the hydraulic geometry of the Lower East River and delta area, indicating the reduction of the value of $B^{1/2}/H$ from 6.21 in 1964 to 3.89 in 1997. The main reason of the rapid reduction was human activities.

Table 2.2 Hydraulic geometry of Lower East River (Zhu, 2001)

Year	Discharge at Boluo (m^3/s)	Average sediment concentration at Boluo (kg/m^3)	Average longitudinal slope (%)	$B^{1/2}/H$
1964	702.51	0.139	0.01198	6.21
1972	661.80	0.121	0.01279	6.18
1988	814.59	0.105	0.01269	6.06
1997	717.52	0.072	0.01865	3.89

2.3.3 Water supply

Dongguan-Shenzhen Water Supply Scheme is a large-scale interbasin water transfer works to supply fresh water to Hong Kong built by the Chinese Government. The first-phase works started in February 1964. The total length of the canal is 83 km from Dongguan Qiaotouzhen at the bank of the East River to Yantian Reservoir. The water is raised up 46 m by 8 pumping stations (Qiaotou, Sima, Qiling, Matan, Tangtouxia, Zhutang, Shaling and Shangpu). Then, the water is transferred to Shenzhen Reservoir in another river basin. At last the water is transferred by a 3.5 km long pressure steel pipeline with a diameter of 1.4 m to Shenzhen Sanchahe, where Hongkong receives the water. The works are a multiple-purpose project of water supply, flood control, irrigation and power generation. The initial amount of water supply to Hongkong was 68.2 million m^3 annually. Along with the increasing demand from Hongkong Dongguan-Shenzhen Water Supply Scheme have been enlarged three times. The first-stage of extensions in 1974-1978 increased the amount of water supply to 3.168 billion m^3. The second-stage of the uprating engineering works in 1987 increased the amount of water supply to Hong Kong 9 times as that of the initial stage. The Third Stage of uprating works that started in November 1989 was of a grand scale. The annual volume of water supply in the Dongguan-Shenzhen Water Supply System was increased to 1,743 million m^3. The highest pumping rate was about 69 m^3/s. Of the water supplied, l,l00 million m^3 went to Hong Kong, 493 million m^3 to Shenzhen, and 150 million m^3 for irrigation along the river.

The lowering of the riverbed of the Lower East River affected the work of intakes of water supply. On December 1995 the lowest water level was 0.41 m, which was lower than the demand of water level of the intakes. To maintain the same water level a larger discharge is needed, as the gauge-discharge curve has been changed by wet excavation of sand. Thus, water from three large hydroprojects in the upper basin, i.e. Xinfeng Project, Fengshu Project and Baipenzhu Project, has been diverted to the Lower East River to maintain the minimum water level of 1.78 m at Dongjiang pumping station. The maximum discharge of diverted water is 800 m^3/s, which is much larger than the regulatory capacity of the three above-mentioned projects.

2.4 Population, Land Use and Social Economical Situation

Since the policy of reform and opening up, the economy in East River Basin has been quickly developed, owing to the location superiority of linkage with the Hong Kong City and the Shenzhen Extraordinary Region and the human relationship of broad companions in Hong Kong and Macao. The GDP in the East River Basin (including Shenzhen, Baoan and Longkong) was 76.518 $\times 10^9$ RMB Yuan in1993, accounting for 23.72% of GDP in Guangdon Province. But the GDP in the East River Basin was 221.03$\times 10^9$ RMB Yuan in 1998, accounting for 27,91% of GDP in Guangdong Province.

The large difference existed in the economy development situation between the basins of upper stream and lower stream in the East River Basin. Shenzhen, Guangzhou and Dongguan, located in the basin of lower stream, are the quickly developing regions in Guangdong Province and also one of most developing regions in China. But, the Heyuan city in the basin of upper stream and the Dingnan, Anyuan and Xunwu counties in the source region of river are the slowly developing regions in Guangdong Province. The social and economical situation of various cities and counties is shown in the following:

(1) Xunwu County

Xunwu County is a typical agricultural county, having 15 towns, 179 villages and 289 $\times 10^3$ people. According to the results of land survey in 1995, the areas of cultivated field, vegetable plot and fruit garden and forest were 152.65km^2, 10.58km^2 and 1853.04 km^2, separately, accounting for 6.57%, 0.47% and 79.77% of its total land area. The mountainous area has large potentiality for economic development, but the conflict between the less cultivated field and large population is very serious. The area of re-cultivated field was about 325.33 km^2, in which the area of food re-cultivated field was about 183.33 km^2 and the area of cash crops re-cultivated field was 142.00 km^2.

Xunwu County is one of poor counties in China. Its economy development is very lower in comparison with that of Heyuan, Dongguan, Shenzhen and Guangzhou. In 2002, the GDP in Xunwu County was 861×10^6 RMB Yuan. The total financial incoming was 65.94×10^6 RMB Yuan, the incoming per every farmer was 1358 RMB Yuan and the mean salary of the staff and worker was 7312 RMB Yuan.

(2) Heyuan City

Heyuan City is located in northern part of Guangdong Province, on the upper stream of the East River. It is jointed with Jiangxi Province and has the land area of 15,665 km^2 and cultivated field of 101.384 $\times10^3$ha. Heyuan City, including Heyuan District itself and five counties as following: Dongyuan, Heping, Lianping, Longchuan and Zijing, is one of slowly developing regions in Guangdong Province. In 2000, Heyuan city had 3219.4 $\times10^3$local residents and GDP 9.134 $\times10^9$ RMB Yuan with 2837 RMB Yuan per capita, and is one of most low GDP among 24 cities in Guangdong Province. The total value of industrial output was 3.031×10^9 RMB Yuan ,with 841RMB Yuan per capita. The financial incoming and expenditure was 255 $\times10^6$RMB Yuan and 1,678 $\times10^6$RMB Yuan with financial deficit of 63%. According to the statistic data in 1998, all counties of this city belonged to the poor county, accounting for one third of 16 poor counties in Guangdong Province. Its GDP per capita was less 1/5, 1/11 and 1/13 than that of Huizhou, Dongguan and Guangzhou, and Shenzhen, respectively. Its industrial output per capita was less 1/31,1/34, 1/52 and 1/63 than that of Huizhou, Guangzhou , Dongguan and Shenzhen, respectively.

(3) Xinfeng County

Xinfeng County, having total land area of 2,015 km^2 is located in the east part of Shaoguan City and on the upper stream of Xinfeng River, High mountains rise in its middle part, being a watershed boundary, separating the East River Basin and the North River Basin. The Xinfeng River flows across its middle part. In1998, there were 154.7 $\times10^3$ local residents, and cultivated field of 6,670 hm in the East River Basin. Its values of industrial and agricultural output were 313 $\times10^6$ RMB Yuan and 170 $\times10^6$ RMB Yuan, respectively.

(4) Huizhou City

Huizhou City is located in the southern part of the Guangdong Province and in the northern east part of the Pearl River Delta and is joined with the Shenzhen. It is composed of the Huicheng and Huiyang districts, Boluo, Huidong and Longmen counties, having land area of 11.2 $\times10^3$ km^2, accounting for 1/4 of the Economic Development Area in the Pearl River Delta. The Dayawan Eco-technical Developing District and Zhongkai High-technology Developing District are located in this city. About 4,520 $km^2$of marine area with 223.6 km of coastline is also located in this city. In 2002, the local residents were about 3.21×10^6 and the GDP was 52.52 $\times10^9$ RMB Yuan, in which the total value of industrial output was 121.63 $\times10^9$ RMB Yuan. About 8,000 enterprises of foreign investment, including 17 enterprises of 500 most rich enterprises in the world has entered into this city. At present, Huizhou City is one of production bases of televisor, gramophone set, camera set and supper electric equipment in China. Huizhou City is also the most large production base of battery and radium equipment in the world and the most large production base of telephone set and computer motherboard in the Asia. So, Huizhou City is now one of the most quickly developing, most living and most potential city in the Southern China.

(5) Dongguan City

Dongguan City is located on the alluvial plain of the Pearl River and East River and in the southern part of the Guangdong Province. Its land joins with the land of Guangzhou City in the north and the land of Shenzhen City in the south. Dongguan City is rich in bountiful cultivated field and forest resource. The subtropics marine meteorological is very mild. The mean annual temperature is about 23.3℃ and the mean annual precipitation is 2042.6 mm. The most part of its territory is consisted of alluvial plain and earthen mound, which is the traditional agricultural region of high output. The main agricultural products are as following: rice, banana, lichee, pineapple, oranges etc. Dongguan City now is composed of 32 towns and has land area of 2,465 km^2 and local residents of 1.562×10^6. In 2002, the GDP was 67.227 $\times10^9$ RMB Yuan, including industrial output of 160.167 $\times10^9$RMB Yuan and agricultural output of 5.367×10^9RMB Yuan. Up to 2002, the total foreign investment reached 15.42 $\times10^9$American dollars. In 2002, the total import and export values were 44.247 $\times10^9$ American dollars, in which the export value was 23.736 $\times10^9$ American dollars. The Dongguan City is carrying out "the policy of international economy, developing the international trade and accepting the foreign investment". The electronic communication equipment production, paper production, drink production etc are the major modern industries. So, Dongguan City is one of international industrial production bases and export bases in China

(6) Shenzhen City (Longgan District)

Shenzhen City, having land area of 1952.84 km^2, is located in the southern part of Guangdong Province, joining with Hong Kong City and is one of Four Special Economic Zones, established by Chinese Government in1980. Longgan District is located in the northern-east part of the Shenzhen City and in the upper stream basin of the Danshui River, has land area of 844.07 km^2 and 10 towns. In 1998, it had 528.5×10^3 local residents, total industrial output of 8.626 ×10^9 RMB Yuan and total agricultural output of 310×10^6 RMB Yuan.

2.5 Soil and Soil Erosion

Soil erosion in the East River Basin assumes discontinuous distribution of patches. The parent rock in the valley is mainly granite. The weathered crust of granite is deep, generally about 10 m, with the maximum of 30-40 m. The weathered crust contains much quartz with low cohesion, high percolation and loose structure. The upper layer of the primary soil developed from granite with dense vegetation is a layer of red soil with rich clayey particles, about 1-3 m deep. The surface layer (A layer), 10 cm-30 cm deep, is fertile and of good structure and percolation, which is favorable for vegetation growth and soil erosion is slight. Once the vegetation cover is destroyed, soil erosion will be developed rapidly. In hilly granite areas with poor vegetation not only surface erosion is generally developed, but also gully erosion, sliding and slope disintegration are common. Discontinuous distribution of hilly granite areas and local destruction of vegetation are the main reason of discontinuous distribution of patches of soil erosion.

Soil erosion in the East River Basin mainly takes place in areas with heavy human activities. Soil erosion in areas near villages is more severe than remote areas, where human activity is less and vegetation is dense. Irrational reclamation on sloping lands to increase farmland enhances soil erosion in hilly areas. In addition mining, quarrying and road construction lead to soil erosion.

In the 1980's the area of soil erosion in the river source region was 70 thousand hm^2, among which 12.8 thousand hm^2 area was severely eroded. In 1996 the area of soil erosion increased to 77.6 thousand hm^2, accounting for 19.3% of the total area; in 1998 it increased to 141.5 thousand hm^2, 23.6% of the total. There are three counties in this region, Anyuan, Xunwu, and Dingnan Counties. Soil erosion in Anyuan is most severe and in Dingnan is the lightest (Zhang, 2002). Based on the data from Jiangxi Province the area of soil erosion in Xunwu County was 277.8 km^2 in 1988, accounting for 12.0% of the county's land and it increased to 322 km^2 in 1997, accounting for 13.9% of the total. The increased area of soil erosion induced by rare-earth metal mining was 13.3 km^2 in the same period of time. At present soil erosion is still increasing in this county. In Xunwu County not only the area of soil erosion but also the intensity of erosion is large. In 1997, the area of light soil erosion was 3766.7 hm^2, accounting for 11.7% of the total area of soil erosion (322 km^2); the area of moderate erosion was 8980 hm^2, 27.89% of the total; and the area of severe erosion was 19453.3 hm^2, 60.41% of the total (Hu and Xong, 2004).

Table 2.3 Soil erosion in East River Basin of Guangdong Province

City	Dongguan	Huizhou	Heyuan	Shenzhen
Total area of soil erosion (km^2)	14713	65629.1	199919	23173
Surface erosion (km^2)	2817.38	27057.3	80253.9	5834.18
Gully erosion (km^2)	750.81	12131.8	62138.1	508.19
Slope disintegration (km^2)	48.37	1373.75	35936.4	474.92
Melting (km^2)	0	0	1735.96	0
Sliding (km^2)	0	0	0	0
Subtotal of geologic erosion (km^2)	3616.56	40562.85	181064	6817.29
Mining (km^2)	0	12.09	0	0
Quarrying (km^2)	1582.89	1598.67	110.89	2708.11
Reclamation on steep slopes (km^2)	121.33	0	4.474	24.24
Road construction (km^2)	181.656	244.9	805.3	278.0
Urbanization (km^2)	5385.06	6334.74	625.35	9506.58
Hydroprojects (km^2)	0	0	0	261.73
Other man-made erosion (km^2)	0	55.51	55.25	0
Farming on sloping land (km^2)	3825.52	16820.4	17253.4	3577.02
Subtotal of accelerated erosion (km^2)	11096.5	25066.3	18854.6	16355.7

Soil erosion in the East River Basin is unevenly distributed. In the watershed in Guangdong Province soil erosion is most severe in the upper reaches, where the area of soil erosion is 1029.64 km^2, accounting for

72.03% of the total eroded area. The area of soil erosion in the middle reaches is 383.8 km^2, 26.85% of the total and the area of soil erosion in the lower reaches is 1.12% of the total. From Heyuan to Huizhou, Shenzhen and Dongguan the area of soil erosion decreases, but the area of man-made soil erosion is increasing. In Heyuan the area of man-made erosion accounts for 10% of the total area of soil erosion, but in Dongguan it is about 80% (Table 2.3).

In the past 40 years large-scale soil erosion in the East River Valley was not under effective control except in local areas, particularly severe soil erosion took place in some areas due to mining and quarrying. The ecological environment has been worsening with the increase in flood disasters and drought, etc.

2.6 Natural Resources

The East River Basin enjoys subtropical marine monsoon climate with fairly distinct four seasons. The annual mean temperature is about 20.4℃ and the annual mean precipitation is between 1500 mm and 2400 mm. The climate in its southern part is different from that in the northern part. The oceanic climate, influenced by the vapour inflow from the Southern Sea and the West Pacific Ocean, and the southern-west and southern-east monsoon and typhoon, is dominant in the southern part. But the influence of the oceanic climate is relatively weak in the northern part. There is less precipitation, from 1,500 mm to 1,800 mm, in the region of upper stream and it increases continuously from upper stream to lower stream. The changes of rainfall with different seasons in different river basins are large. About 80% of annual precipitation appear in the wet season from April to September. In the basin of upper stream the precipitation in the summer and spring is accounted for 38%-45% of the annual precipitation, in autumn- for 15% and in winter-for 8%-10%. In the basin of lower stream the precipitation in the summer is accounted for 45% of the annual ones, in autumn and spring-for18% and 25% and in winter - for 5%.

The East River Basin enjoys abundant water resources. According to the analysis of runoff data from 1951 to 1997, the surface water resource in the East River Basin is about 32.4×10^9 m^3, in which 29.1×10^9 m^3 is in Guangdong Province , and 3.3×10^9 m^3 is in Jiangxi Province. In 2000, the average water resource per capita in the East River Basin is 3,439 m^3, that is higher than 2,480 m^3, the average value of the Guangdong Province. The water quality in the basin of upper stream and in the river stem belongs to Grade I or II of the State Standard of Surface Water Environment Quality, which means the best water quality in the main river systems in Guangdong Province. However, the runoff distribution in the duration of a year and of different years is not uniform due to the similarly non-uniform distribution of precipitation. In accordance with the changes in precipitation the runoff in the wet season is accounted for 75%-85% of the annual runoff. In the basins of upper and middle streams the runoff in the Summer is accounted for 37%-60% of the annual runoff, in the Spring for its 23%-43%, in the Autumn for its 15%-28% and in the Winter for its 6%-8%. The runoffs in the basin of lower stream are accounted for 42%-57%, 16%-30%, 18%-25% and 6%-9% of the annual runoff in the Summer, Spring, Autumn and Winter, respectively.

The sediment concentration in the East River is rather low. The mean sediment concentration at Boluo Hydrological Station is 0.13 kg/m^3 and the mean sediment load is 2.96×10^6 tons/yr, accounting for 3.5% of the total sediment load in the Pearl River Basin. The change in sediment concentration is related with the rainfall and intensity of the storm. The monthly mean sediment concentration is 0.008-1.16 kg/m^3 in the wet season from the April to September, and the maximum monthly mean sediment concentration appears in June or July. The monthly mean sediment concentration in the dry season (from October to March of next year) is 0,001-0.57 kg/m^3. Most sediment is transported in the wet season. The sediment load in the period from April to September is accounted for 90.7%-94.9% of its annual value. The maximum monthly sediment load appears in the June or July and the sediment load is accounted for 30% of the annual totals.

The complete development of land stratification and the complex rocky composition are the geologic and geomorphologic features in the East Rater Basin. It is composed of various rocks, including various kinds of sandstone, shale, lime, schist and alluvial material etc. Mountains and gorges intersect each other and river systems intercross. Accumulation platforms and hollows widely distribute and deltas are formed in river mouths. The types of earth are very various, such as, alluvial soil, distributed in alluvial plain along rivers, cumulosoil, distributed on mounds and red soil, yellow soil, limestone rocky soil, distributed on earthen mounds. The land topography in the watershed is higher in northern-east and lower in southern-west. The area of mound and hill at the elevation of 50-500m is accounted for 78.1%, the area of plain at the elevation of lower 50m is accounted for14.4% and the mountain area at elevation higher 500m is accounted for 7.5%.

2.7 Situation of Water Resources Development in the East River Basin

The integrated development and management in East River Basin had carried out by the Guangdong Provincial Government since the 1960s. A series of engineering, such as water reservation, water diversion, water pumping and dyke had been constructed. These engineering have been playing important role in water supply, electric generation, navigation, water pollutant management and saline management.

Up to 1998, 5 large reservoirs with total volume of 17.423×10^9 m^3 and power generation of 508×10^3 kw had been constructed, in which the Xinfengjiang and Fengshuba reservoirs are the first and second large reservoirs in Guangdong Province. These reservoirs have effects of integrated development and utilization. The 48 middle reservoirs control the watershed of 1,949 km^2 and have total water volume of 1.17 $\times10^9$ m^3. The 6,826 small reservoirs have the total water volume of 107.7 $\times10^3$ m^3. In addition, 10,368 water diversion stations with flow discharges of 306.8 m^3/s, 10368 water supply stations with water discharges of 268.2 m^3/s, 2165 km dykes (protecting the area of cultivated field of 129.4 km^2), hydro-electric generations of 673.3 $\times10^3$ kw and electric pumping stations with 83.6×10^3 kw had been constructed. All these engineering have been playing distinguish roles in flood protection, irrigation, power generation, navigation, water supply, and soil and water conservancy.

The Dongguan-Shenzhen Water Supply Project is one of large cross-basin water supply project in order to meet the need of Hong Kong which for years has suffered from shortage of fresh water. The first phase of the project started in February 1964. The canal, having the length of 83 km starts from the Qiaotou town in Dongguan City and ends in Yantian Reservoir. The water level is risen for 46 m by 8 pumping stations, such as Qiaotou, Sima etc. Then, the water is transferred in a pressure pipeline, which has length of 3.5 km, to Sanchahe, Shenzhen City and accepted by Hong Kong relative company. According to the first agreement, 68.20×10^6 m^3 of water was provided to Hong Kong City every year. Due to the quick development of economy in Hong Kong, the water supply demand had been gradually rising. The Dongguan-Shenzhen Water Supply Project had been enlarged three times. The water supply capability increased to 0.228 $\times10^9$ m^3 after its first reconstruction in 1974-1978 and to 1.743 $\times10^9$ m^3 after its third reconstruction in 1990. Up to 2003, total water volume of 7.28 $\times10^9$ m^3 had been supplied to Hong Kong City by the Dongguan-Shenzhen Water Supply Project, which is accounted for 70% of the total water required of Hong Kong. The Dongguan-Shenzhen Water Supply Project has been a huge contribution to the economy development and prosperity of Hong Kong.

3. GOVERNANCE ISSUES BETWEEN USERS AND USES

In the East River basin, a large number of users have different needs and requirements. In the upper reaches catchments, uses and users of basin management related affairs might be different than those of middle and lower reaches catchments. Below, stakeholders and their needs are presented for the upper, middle and lower reaches of the East River basin.

3. 1 Stakeholders of the Upper and Middle Reaches Catchments

The upper reach of the East River is from the river source to the Fengshu Dam in Longchuan County with length of 138 km and mean longitudinal gradient of 0.221%. The upper reach of the river flows across a series of mountains and has the steep longitudinal gradient and narrow riverbed. The middle reach of the East River is from the Fengshu Dam to Guanyinge in Boluo County, with length of 232 km and the mean river longitudinal gradient of 0.031%. The river catchments in the upper and most part of the middle reaches are poorer regions with slow economic development compared with other parts of the basin, especially in the source region of the river. In these areas, interactions between uses and users and river basin managment related problems are mainly governed by the needs of protection against soil erosion, soil loss and damage (land, forests, settlements, agriculture, etc.), power and water supply and construction. Other uses are conservation of nature like habitat protection and recreation (Fig. 3.1).

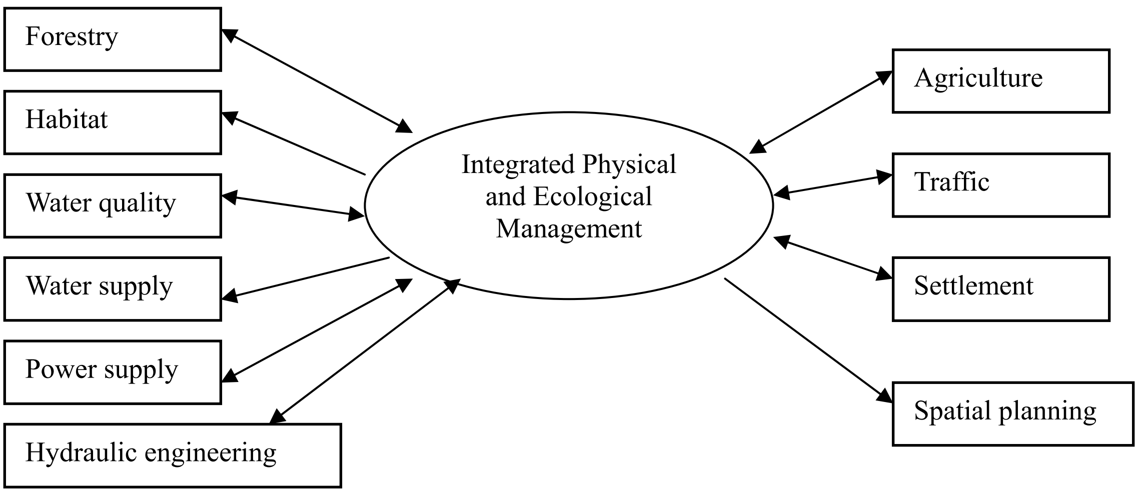


Fig. 3.1 Some of possible stakeholders in the upper/middle reach catchment of the East River

3.1.1 Needs for protection (mainly natural hazards, soil loss)

Integrated physical and ecological river basin managment requirements include all stabilization and hydraulic works for erosion control, sediment retention and deviation and canalization. Also soft measures like forestation and bio – engineering are part of the integrated physical and ecological managment. Protection against natural hazards do also include measures like spatial planning (construction recommendations and restrictions).

As a compare to natural hazard protection, soil loss as an agricultural damage is of minor importance, but needs special attention at places with relatively intensive agricultural production.

3.1.3 Agriculture and forest products

In the upper and most part of middle reaches of the East river regions, there is little industry; the incomes for the residents there are maily come from agriculture and forest products. Therefore, users of agriculture and forest products face the following problems related to the integrated physical and ecological river basin management:

- ✧ Relation between agriculture and forest activites with soil erosion;
- ✧ Conversion cropland into forest for water source protection;
- ✧ Measures for both fighting poverty and saving the environment;
- ✧ Irrigation.

3.1.2 Power and drinking water supply (reservoir sedimentation, abrasion of turbines etc.)

Some water-power plants are located in the upper and middle reaches of the East river. Therefore, users of water power face the following sediment related problems:

- ✧ Planning, construction and operation of water intakes (sedimentation)
- ✧ Construction and operation of water power installations (choice of location, problems of accretion, wash out and erosion, bank protection measures)
- ✧ Infiltration and exfiltration
- ✧ Turbines work properly only as they are driven by clean water. Sand and finer material result in abrasion and damage.

3.1.3 Other uses (habitat protection, recreation, environmental protection)

Natural river behavior with altering river banks and rich variety of sediment transport favors the development of diverse fauna and flora. Natural river stretches are also popular recreation spots for local residents. Therefore, some specific uses might derived:

- ✧ Nature and landscape protection within the areas of influence of water
- ✧ Treatment of accretion problems in shallow waters (fishery)
- ✧ Watershed management (reforestation, stabilization of slopes)

3. 2 Stakeholders of the Lower Reach Catchments

The lower reach of the East River is from Guanyinge to the river mouth with length of 159 km and mean river longitudinal gradient of 0.017%. The industry and economic growths in the region are the fastest in the basin, as well as in China. Over the last two decades, the economy has rocketed as a result of rapid urban and industrial development. Stakeholders of this region have some same interests and conflicts with problems related river basin management as the people in upper and middle reaches, but more problems will be faced in this region (Fig. 3.2).

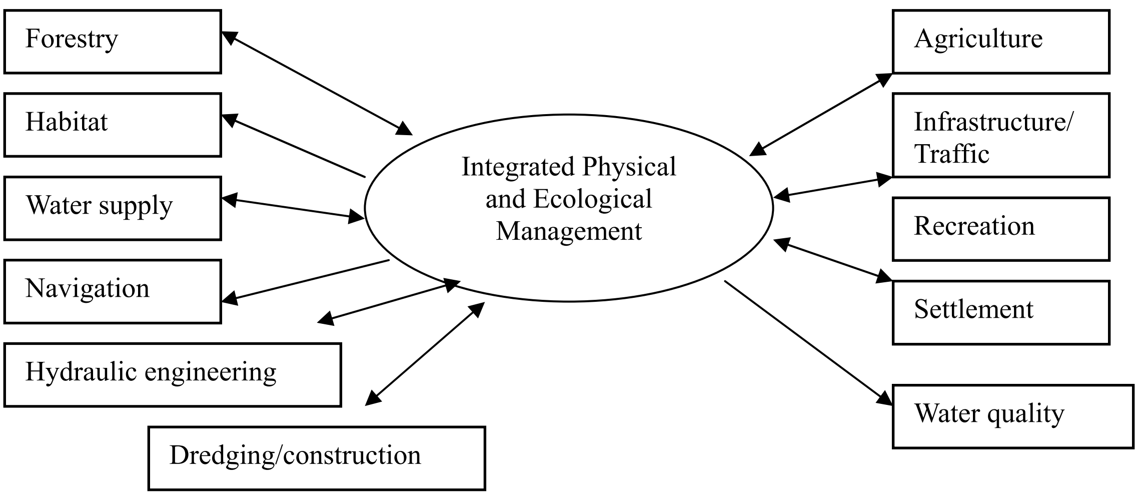


Fig. 3.2 Some of possible stakeholders in the lower reach catchment of the East River

3.2.1 Needs for protection (mainly water quality)

Integrated physical and ecological river basin managment requirements in this region include all measures protecting the water quality and bio-restoration.

3.2.2 Industry, urbanization and population

In the lower reaches of the East river regions, the rate of industry, urbanization and population growth are very high. The gross domestic product (GDP) of Guangdong has shot up 86 times, from RMB 18.6 billion Yuan in 1978 to RMB 1,604 billion Yuan in 2004 (Statistics Bureau of Guangdong Province, 2005), and this region in the major contributor to this massive increase. From 1978 to 2004, the contribution to GDP from traditional primary industries (farming, forestry, animal husbandry and fishery) in Guangdong dropped from about 30% to only 8%. In contrast, secondary industry (mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction) as well as tertiary industry (service industries such as those providing finance, transport and public administration) have increased their contribution to the Guangdong economy. Large areas of farmland were converted to industrial, commercial and residential use and urban areas increased by more than three times between 1980s and 1990s. From 1985 to 2004, the total permanent resident population of Huizhou and Dongguan grew about 53% and 43% respectively, while the resident population in Shenzhen rose 416% (Leung, 2007). With these greatly changes in two decades, the following problems related to the integrated physical and ecological river basin management are faced:

- ✧ Relation between economy growth with environmentatl protection;
- ✧ Water pollution controlling in the condition of fast industry development;
- ✧ Measures for saving the environment;
- ✧ Rehabilitation & restoration for rivers.

3.2.3 Sediment excavation

Since 1990s, the demand of river sediment used for construction purposes has been increased greatly. A large scale of sediment excavation in the river reach below Boluo was carried out. Disadvantages of sediment excavation are lack of sediment downstream, which often results in increased bed erosion with damage of hydraulic works, walls, bridge foundation etc. The following problems related to the integrated physical and ecological river basin management are faced:

- ✧ Influence on river channel;
- ✧ Influence on river mouths;
- ✧ Influence on fishery;
- ✧ Damage to hydraulic works and bridge foundations

3.2.3 Other uses (habitat protection, recreation, environmental protection)

Natural river behavior with altering river banks and rich variety of sediment transport favors the development of diverse fauna and flora. Natural river stretches are also popular recreation spots for local residents. Therefore, some specific uses might derived:

- ✧ Nature and landscape protection within the areas of influence of water
- ✧ Treatment of accretion problems in shallow waters (fishery)
- ✧ Watershed management (reforestation, stabilization of slopes)

3. 3 Stakeholders Coordination

The entire East River Basin runs across two provinces, and a number of cities and counties under different administrative bodies. A number of national institutions are responsible for water management in China in various aspects, including the authorities on environmental protection, resource management, planning, public services and public health. While the provincial governments are responsible for the water management issues at the local level. So for the integrated physical and ecological river basin management in the East River basin, the coordination among various management authorities is important.

Table 3.1 lists various stakeholders and their possible interenst and opportunities for the East River basin management (Leung, 2007). One of the major challenges in determining the way forward is how to establish a coordinated institutional structure for various stakeholders with different interests and in different locations of the basin to work together and manage the river basin they share. Ultimately, for a healthy East River, an integrated approach is required to address the use, allocation, and management of water resources for humans, as well as the water ecosystems and biodiversity in the river system.

Table 3.1 Various stakeholders and their possible interests and opportunities (Leung, 2007)

Sectors	**Interests**	**Opportunities**
Government	- Policy formulation and implementation - Law formulation and enforcement - Landuse planning - Planning and development of infrastructure, such as flood control and pollution control works - River basin management - Natural resource and biodiversity management - Protected area management - Raising public awareness	- Enhancement and improvement of environmental policies and laws - Enhancement in law enforcement - Coordination of development and enhancement of landuse planning at different geographical locations within the river in a sustainable and integrated manner - Providing incentives for clean development - Enhancement in habitat and natural resource management in protected area - Capacity building
Planners, engineers and Professionals	- Urban planning - Technological solutions	- Incorporate environmental considerations into the urban planning and engineering designs
Commercial, industrial and agricultural sectors	- Investment in development - Landuse conversion - Waste and sewage generation - Natural resources exploitation and extraction - Large-scale consumption of energy and water	- Investment to technologies on clean development and production - Waste and sewage reduction and management - Enhancement on resource management and efficiency on resource use
Academia	- Building knowledge - Incubation of solutions - Advisory	- Reviewing the status of biodiversity - Determining the needs of the freshwater ecosystems - Offering scientific solutions to other stakeholders
Government/Non-Government Organisations	- Monitoring environmental conditions - Conduct studies and surveys - Translation of solutions into actions - Communicating conservation issues with various stakeholders	- Prioritization of conservation actions - Providing support and participating conservation actions - Offering easy-to-follow solutions to various stakeholders - Community education and awareness raising
General public	- Monitoring environmental conditions - Consumption of natural resources - Waste and sewage generation	- Supporting conservation actions - Reduction of wasteful consumption - Waste and sewage reduction

4. METEOROLOGICAL CONDITION

A stable climate is one of important conditions for a healthy river. So, the meteorological factor is important for a healthy ecology of a river system. The different combination of temperature and precipitation could form different types of meteorological and the different ecology system of the river system. The study in this aspect has attracted the concern of ecologists.

The meteorological data from 1953 to 2000 was obtained from the Center of Meteorological Data, China Meteorological Bureau. These meteorological stations, such as, Xunwu, Heyuan, Zengcheng, Huiyang and Shenzhen, distribute in the basins of source region, upper stream, lower stream and river delta of the East River. The locations of these stations are shown in the Fig. 4.1. The anomalous data of mean temperature in the world (based on the mean temperature of 1951-1980) were analyzed from the observed data on 7,200 meteorological stations in the world from1880 to 2003, which were obtained from NASA GISS Surface Temperature (GISTEMP).

Fig. 4.1 Distribution of the meteorological stations in East River Basin

Table 4.1 Locations of meteorological station and duration of data

Names of meteorological station	Longitude & latitude	Duration of data
Xunwu, Jiangxi	24° 58′Nl, 115° 39′ El	1956-2000
Heyuan,Guangdong	23°44′Nl, 114 °41′ El	1952-2000
Zengcheng, Guangdong	23°18′ Nl, 113° 49′ El	1958-2000
Huiyang, Guangdong	23°05′ Nl, 114° 25′ El	1952-2000
Shenzhen, Guangdong	22°33′ Nl, 114° 06′ El	1952-2000

Note: Nl---North latitude; El----East longitude

4.1 Climate Situation

The graphs of climate situations are used in this report to analyze the climate situation in the basin and their distribution in space and time duration. The graph of Climate situation was adopted by Heinrich Walter (1985) and was a tool to study the relationship between the Climate and plant cover in a river basin. The graphs were composed of a lot of meteorological information, such as, seasonal changes of temperature and precipitation, duration and intensity of dry and wet seasons. The graphs are plotted as follows: (1) The horizontal axis shows the months, the left vertical axis shows the mean monthly temperature, and the right vertical axis shows the mean monthly precipitation. (2) The unit scale on right axis is 30 mm of precipitation and the accordant unit scale on left axis is 10℃ of temperature. (3) The name of meteorological station and the multiyear mean annual temperature are shown on the top of graph at the left side and the land Elevation of accordant meteorological station and multiyear mean annual precipitation are shown on the top of graph at its right side. (4) The mean monthly temperatures are shown on the graph by the black points and the mean monthly precipitation by the white points.

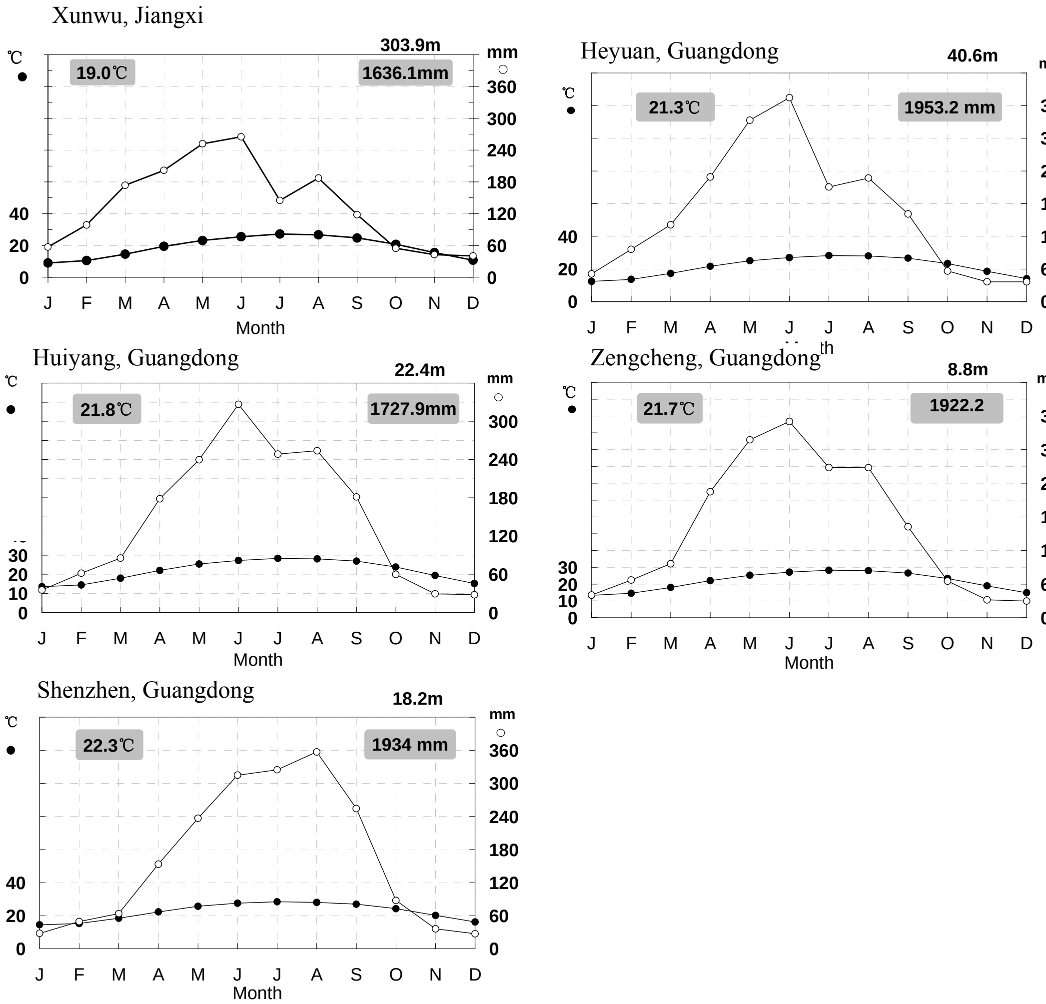


Fig. 4.2 Climate situation graph in East River Basin

If the curve of precipitation on the graph is located upon the curve of temperature, it means that the observed region, where the station is located, belongs to wet region, and the temperature is the dominant factor for the changes of ecological system in the observed region. If the temperature is higher than 0℃, the observed region belongs to warm wet region and the natural plants should grow plentifully. If the temperature is bellow than 0℃, the observed region belongs to cool region with swamps or snow cover and the growth of natural plants is restrained. If the curve of temperature on the graph is located upon the curve of precipitation it means that the observed region belongs to dry region and the precipitation is the dominant factor for the changes of ecological system in the observed region. In dry region rainfall is rare and the natural plants are sparse and the desert is the typical region. However, in the region of monsoon both the curves of temperature and precipitation on the Climate situation graph intercross each other and the transition type of two Climate situations may exist. In the dry season the curve of temperature is located upon the curve of precipitation and the Climate situation becomes cool and dry. On the contrary, in the wet season the curve of precipitation is located upon the curve of temperature and the Climate situation becomes wet and hot.

It can be seen from Fig. 4.2 that the most low mean annual temperature at Xunwu, Jiangxi Province was

19℃, and the mean annual temperatures of others were higher than 20 ℃. The most low mean annual precipitation, being 1,636.1mm, was also at Xunwu, Jiangxi Province. The higher mean annual precipitation, being 1,953.2 mm, was at Heyuan. It means that the East River Basin has higher temperature and plentiful rainfall. It can also be seen from Fig. 4.2 that the curves of precipitation at most meteorological stations were upon the curves of temperature. That means the watershed belongs to wet and warm region and plant cover is plentiful. In months from February to October the curves of precipitation of all stations were located upon that of temperatures, which means that the temperature was the dominant factor for the change of ecological system. In the duration from October to December the curves of temperatures were located upon that of precipitation, which means the precipitation was the dominant factor for change of ecological system. But, in January and February the curves of precipitation at different stations from the river source region (Xunwu) to river delta region (Shenzhen) gradually changed from the upper locations of the curves of temperature to their under locations. It means that the dominant factor gradually changes from temperature to the precipitation in according to their locations from the source region to delta region.

Therefore, it can be seen that the meteorological situation in East River Basin is simpler and fundamentally belongs to wet and warm region.

4.2 Quantitative Analysis of Humidity Status

The graph of climate situation describes the temperature situation of different region in East River Basin, but can not describe the quantity of humidity status in different regions. Here, the non-dimensional humidity degree (w) is induced to quantitatively analyze the combinative situation of temperature and precipitation in different meteorological regions. Its definition is as follows:

$$W = R' - T' = R/300 - T/100$$

in which, T (℃) is mean annual temperatures and R (mm) is mean annual precipitation.

According to the results of calculation, the standard error of change in the non-dimensional humidity degree at the Xunwu station in the river source region of the East River was 0.0132, the most minimum value in five meteorological stations. The second minimum value at Huiyang station was 0.0135. The values at Zengcheng and Shenzhen on the river delta were 0.0156 and 0.0158, respectively. The largest value at Heyuan station in the middle stream of the East River was 0.0183. The results of calculation mean that in the East River Basin the change of non-dimensional humidity degree was smaller in the river source region, moderate in the basin of lower stream and in the river delta region and larger in the basin of middle stream. Fig. 4.3 shows the changes of non-dimensional humidity degree in the major stations in the East River Basin. It can be seen that the annual changes of humidity degree at Xunwu Station were basically equilibrium or declined slowly, but the humidity degree at other stations rose in different degree and the risen tendency of the multiyear change of humidity degree at Heyuan and Huiyang stations was more obvious.

The analysis mentioned above shows that the basins of upper and middle stream in East River Basin were the regions of quickly changing in humidity degree and the regions of obviously rising of the humidity degree.

In order to show the change of humidity degree in various months, the changing in monthly mean humidity degree is shown in Fig. 4.4. It can be seen that beside the points, representing data at Shenzhen, the changing tendency of all points, representing data at other stations shows double peaks, that is, there were two months in a year circle, having higher mean humidity degree. However, in all stations there were lower mean humidity degrees in the duration from October to March, next year. The higher mean humidity degrees at Xunwu, Heyuan and Huiyang appeared in June and August and the lower mean humidity degree appeared in July. The first higher mean humidity degree at Zengcheng station appeared in the duration from March to April and the second higher mean humidity degree appeared in June. Fig. 4.4 also shows the common rule of humidity degree changing in East River Basin, that is, the lower mean humidity degrees appeared in Spring and Winter, and the higher mean humidity degrees appeared in Summer and Autumn.

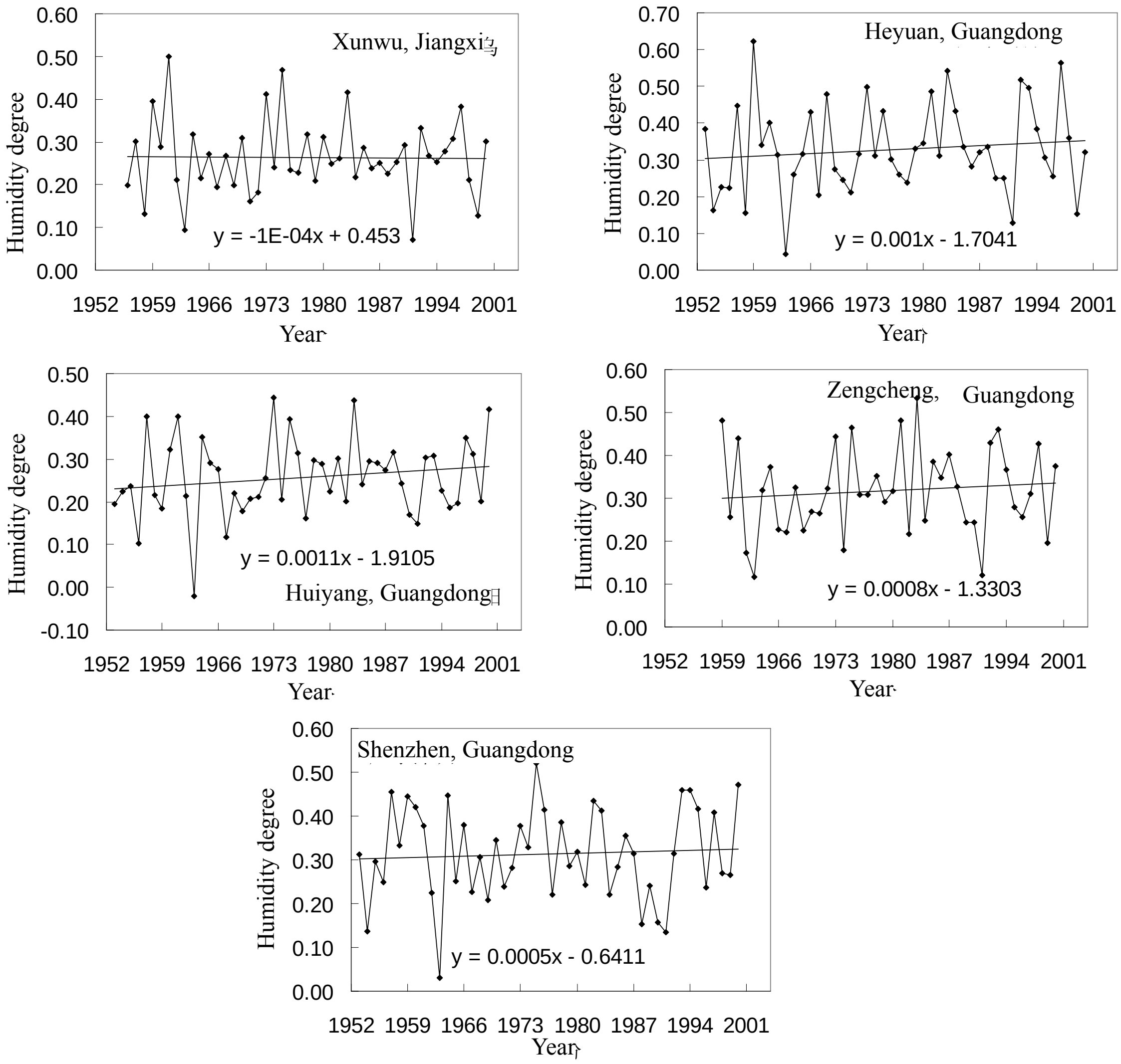


Fig. 4.3 Changes of non-dimensional humidity degree in the major meteorological stations in the East River Basin

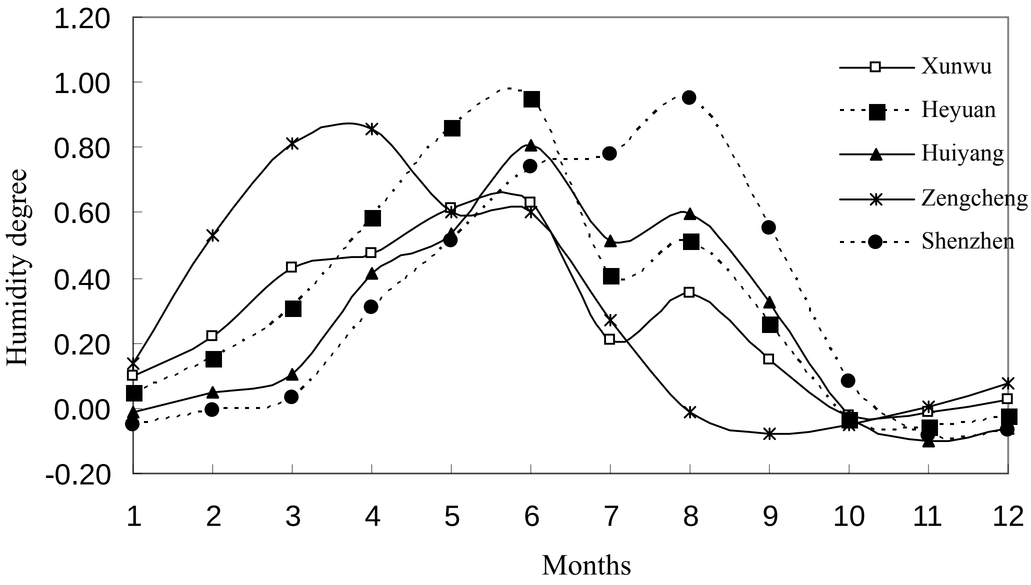


Fig. 4.4 Changing of monthly mean humidity degree in meteorological stations of East River Basin

4.3 Response of Climate in East River Basin to global climate change

4.3.1Climate change in river source region

Global mean temperature anomaly was –0.56oC to 0.70oC. In the source region of the East River it was –0.69°C to 1.09°C, much higher than the global mean. Fig. 4.5 shows the change of global annual mean temperature anomaly and the change of 5-year mean temperature anomaly at Xunwu Station in Jiangxi Province, indicating that the variation of temperature anomaly at Xunwu Station was larger than the global variation. Meanwhile, it also shows that the curve of Xunwu after 1970s was lower than the global curve. It means that the effect of human activities on climate change in the source region of the East River after 1970s was weaker than that of the globe.

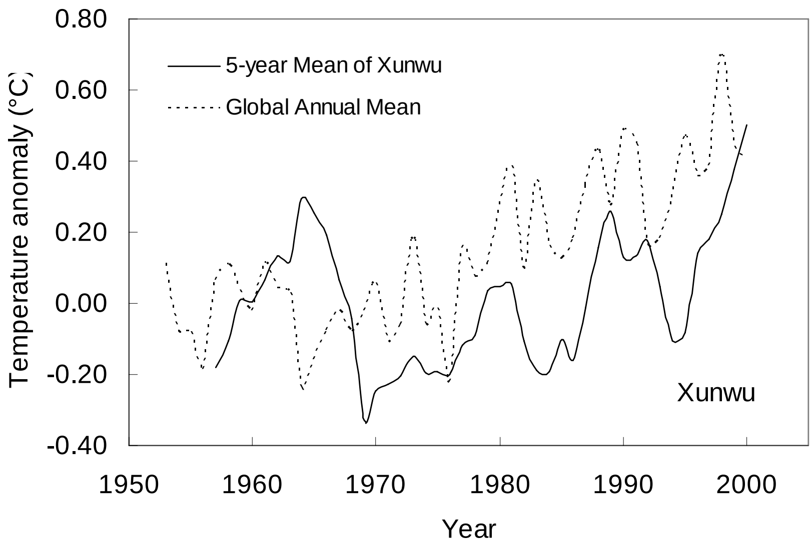


Fig. 4.5 Changes of annual mean temperature anomaly at Xunwu station and of the globe

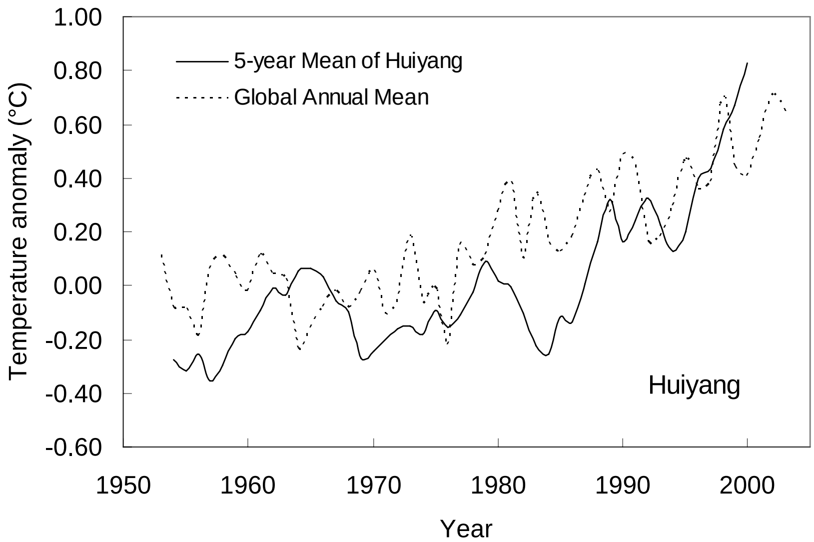


Fig. 4.6 Changes of annual mean temperature anomaly in Upper East River and of the globe

4.3.2 Climate change in Upper East River

The annual mean temperature anomaly in the Upper East River was –0.62°C to 1.22°C, higher than the global annual mean. It increased annually with the same tendency of the global annual mean (Fig. 4.6). Fig. 4.6 also shows that the annual mean temperature anomaly in the Upper East River was smaller than the global annual mean temperature anomaly in 1970s to 1980s, while it was larger after the 1990s. Such a situation manifests the change of human activities/human-induced stress on climate change in the Upper East River.

4.3.3 Climate change in Middle East River

The annual mean temperature anomaly at Huiyang Station on the Middle East River was –0.54°C to 1.09°C, higher than the global annual mean. Fig. 4.7 shows the variation at Huiyang Station, similar with the global variation. Only after 1990s the variation at Huiyang Station was larger than the global variation, indicating the effect of human activities/human-induced stress on climate change in the Middle East River being larger than that of the globe.

4.3.4 Climate change in Lower East River

The annual mean temperature anomaly at Zengcheng Station on the Lower East River was –0.65°C to 1.21°C. The variation at Zengcheng Station was smaller than that of the globe from the middle of 1960s to the middle of 1990s, but it was larger than that of the globe from the middle of 1990s (Fig. 4.8). It shows the same tendency of the effect of human activities/human-induced stress on climate change in various periods as in the other regions of the East River.

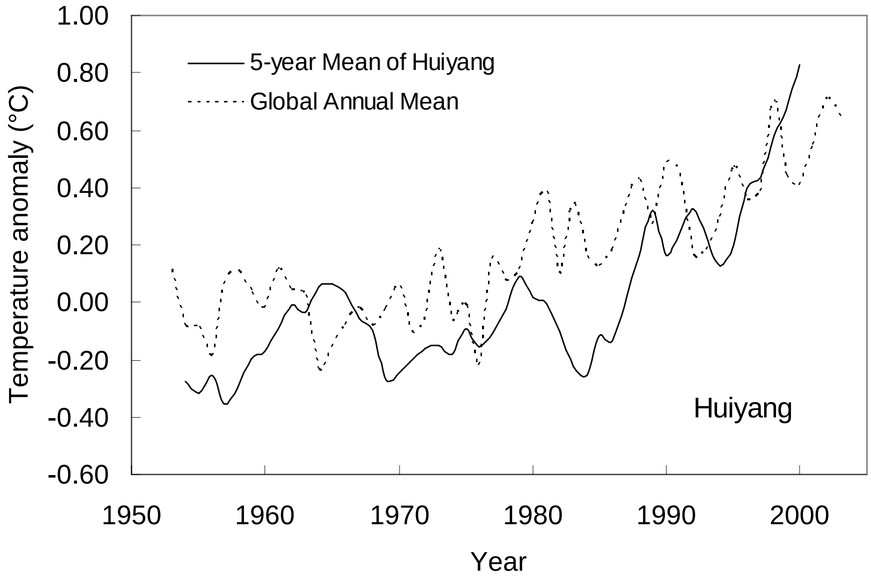


Fig. 4.7 Changes of annual mean temperature anomaly at Huiyang Station and of the globe

4.3.5 Climate change in East River delta area

The East River delta area is one of the most active areas of economic development in China and Dongguan and Shenzhen are the most active areas in the East River delta area. Since 1980s along with the rapid development of economy in those areas the effect of human activities has been increased correspondingly. Before the middle of 1980s the annual mean temperature anomaly at Shenzhen Station was smaller than that of the globe, while after the middle of 1980s it was larger than that of the globe (Fig. 4.9). This indicates that the effect of human activities on climate change in the delta area was stronger than that of the globe.

Figs. 4.5 to 4.9 show the effect of human activities on climate change in the East River Basin. In the river source region the ecological environment was better protected than other regions owing to persistence of keeping policy of protecting water source. Thus, the effect of human activities/human-induced stress on climate change in the river source region was smaller than that of the globe. In the Upper, Middle, Lower East River and delta region the effect of human activities on environment has been so strong since the middle of 1980s, that the mean annual temperature anomaly was larger than that of the globe.

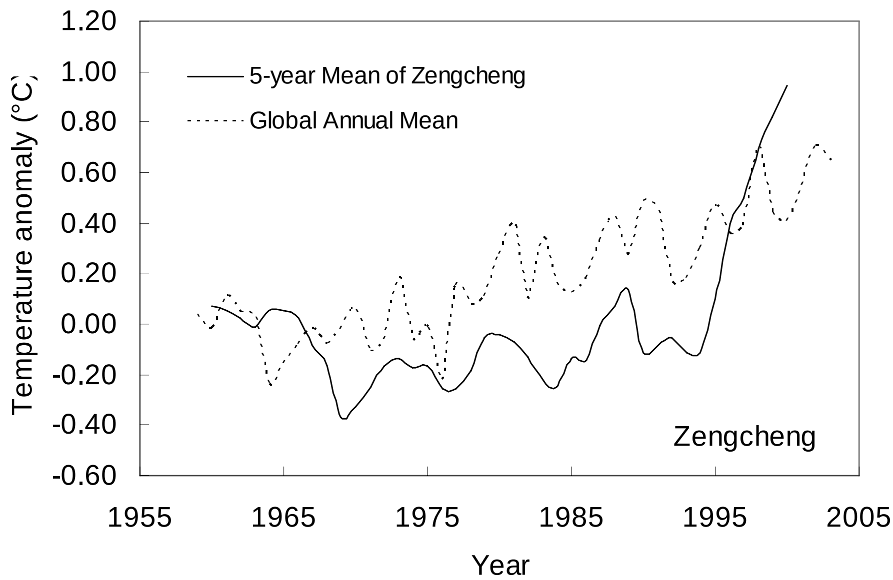


Fig. 4.8 Changes of annual mean temperature anomaly at Zengcheng Station and of the globe

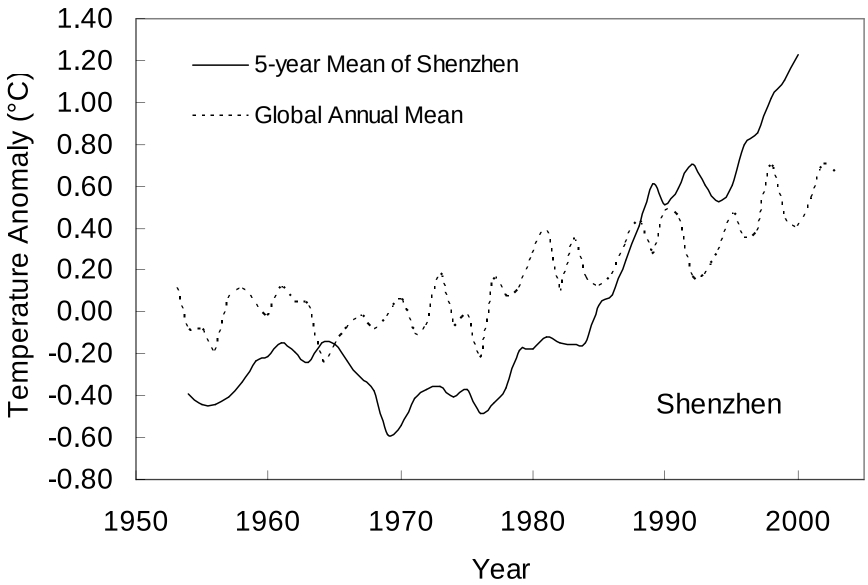


Fig. 4.9 Changes of annual mean temperature anomaly at Shengzhen Station and of the globe

4.4 Effect of ESNO on Climate Change in East River Basin

ENSO is abbreviated from El Niño and Southern Oscillation. El Niño is large-scale climatic fluctuation of the tropical Pacific Ocean. The El Niño itself is a warm surface current that usually appears around Christmas in the Pacific off Ecuador and Peru and disappears by the end of March, but every two to seven years it persists for up to 18 months or more as part of an ENSO. While the ENSO results from the dynamic and thermodynamic interactions among the atmosphere, oceans, and land surfaces, exactly what initiates an ENSO is unclear. Of the 29 ENSOs that occurred between 1700 and 1999, the 1982–83 El Niño was the strongest and most devastating. La Niña, a similar climatic fluctuation, involves the abnormal cooling of the waters off Ecuador and Peru. Penetrating westward, the cold current is believed to affect weather in areas in the middle latitudes in the western Pacific Ocean and to cause extremely hot summers in Japan.

The variation of temperature of sea surface of the tropical Pacific Ocean is closely related to the global atmospheric circulation, particularly to the tropical atmospheric circulation. The most direct link is the inverse correlation between the atmospheric pressure in the southeast Pacific Ocean east to the international date line and the atmospheric pressure in the west Pacific Ocean-Indian Ocean west to the international date line, i.e. the Southern Oscillation. In the period of La Nina the atmospheric pressure in southeast Pacific Ocean rises, while the atmospheric pressure in Indonesia and Australia drops. In the period of El Nino the situation is just opposite. Owing to the close relationship between El Nino and Southern Oscillation, they are called ENSO as a whole. Such a global-scale climate oscillation is called ENSO circulation. El Nino and La Nina are two abnormal states with different phases, El Nino is called the ENSO warm state, while La Nina is called the ENSO cold state.

The SST (sea surface temperature) index in the 3.4 region of Nino (5^oN-5^oS, 120^o-170^oS) is adopted as the index of ENSO. When the SST index in a month is larger than 0.4^oC, the month is in El Nino state; When it is smaller than -0.4^oC, the month is in La Nina state; when it is between -0.4^oC to 0.4^oC, the month is in normal state (NOAA/National Weather Service, 2005). From 1950 to 2000 there were 15 times El Nino states and 13 times La Nina (Table 4.2).

Table 4.2 El Nino/La Nina states in 1950-2000 (He, 2005)

State	Times	Period
El Nino	15	1951.8-12, 1957.4-1958.6, 1963.7-1964.1, 1965.6-1966.4, 1968.11-1969.5, 1969.9-1970.1, 1972.5-1973.3, 1976.9-1977.2, 1977.9-1978.1, 1982.5-1983.6, 1986.8-1988.2, 1991.5-1992.6, 1993.3-1993.7, 1994.4-1995.3, 1997.5-1998.4
La Nina	13	1950.1-1951.3, 1954.4-1957.1, 1961.9-1962.4, 1964.4-1965.2, 1967.10-1968.4, 1970.7-1972.1, 1973.5-1976.5, 1983.9-1984.1, 1984.10-1985.6, 1988.5-1989.5, 1995.9-1996.3, 1998.7-2000.6, 2000.10-2000.12

ENSO has global effect on climate. The strong El Nino in 1997/1998 induced climate abnormality in many regions of the world, resulted in a death toll over 20 thousand people and economic loss of 34 billion USD (Zhai, 2000). Although El Nino/La Nina take place in east Pacific Ocean, far away from China, they can affect the atmospheric circulation to influence climate change in China, which are strong signals of climate abnormality in China. But, their relationship with climate change in China is more complicated than that in tropical areas (Zhai, 2003). Temperature fluctuations and precipitation fluctuations in the Yangtze River Valley are closed related to ENSO events.

4.4.1 Effect of ENSO on atmospheric temperatures of East River Basin

Fig. 4.10 shows the monthly mean atmospheric temperatures in the East River Basin in various periods from 1950 to 2000. ENSO's effects on atmospheric temperature were different in various seasons. When an El Nino appeared, it made the mean monthly atmospheric temperatures higher than the mean annual atmospheric temperature in dry seasons from November to next April; but it made the mean monthly atmospheric temperatures lower than the mean annual atmospheric temperature in wet seasons from May to October. When a La Nina appeared, it made the mean monthly atmospheric temperature lower than the mean annual atmospheric temperature in dry seasons from November to next March; but it made the mean monthly atmospheric temperatures higher than the mean annual atmospheric temperature in wet seasons from April to October. In the years of occurrence of El Nino, the yearly average atmospheric temperature was 21.35^oC, higher than the mean annual atmospheric temperature, 21.25^oC; but in the years of occurrence of La Nina, the yearly average atmospheric temperature was 21.22^oC, lower than the mean annual atmospheric temperature. Meanwhile, In the years of El Nino, the ?(bianyi) variation coefficient was 16.8%, lower than the mean annual value, 27.2%; but in the years of La Nina, it was 28.0%, higher than the mean annual value.

4.4.2 Effect of ENSO on precipitation in East River Basin

Fig. 4.11 shows the monthly mean precipitation in various periods from 1950 to 2000. In the years of El Nino the annual precipitation, 1956.5 mm, was larger than the mean annual precipitation, 1832.4 mm; in the years of La Nina the annual precipitation was 1764.2 mm, smaller than the mean annual precipitation. In the years of El Nino the monthly precipitation was smaller than the mean monthly precipitation only in June, August, and September, while it was larger than the mean monthly precipitation in most other months. In the years of La Nina the monthly precipitation was larger than the mean monthly precipitation in May, October, and November, while it was smaller than the mean monthly precipitation in most other months. This indicates that the El Nino increases the annual precipitation and the La Nina decreases the annual precipitation. There is no obvious regularity of their effect on monthly precipitation.

The variation coefficients of monthly precipitation were 62.0%, 69.4%, and 69.1% in the El Nino years, La Nina years, and normal years, respectively; indicating that the El Nino and La Nina reducing the variation of monthly precipitation and the El Nino making the monthly precipitation more even.

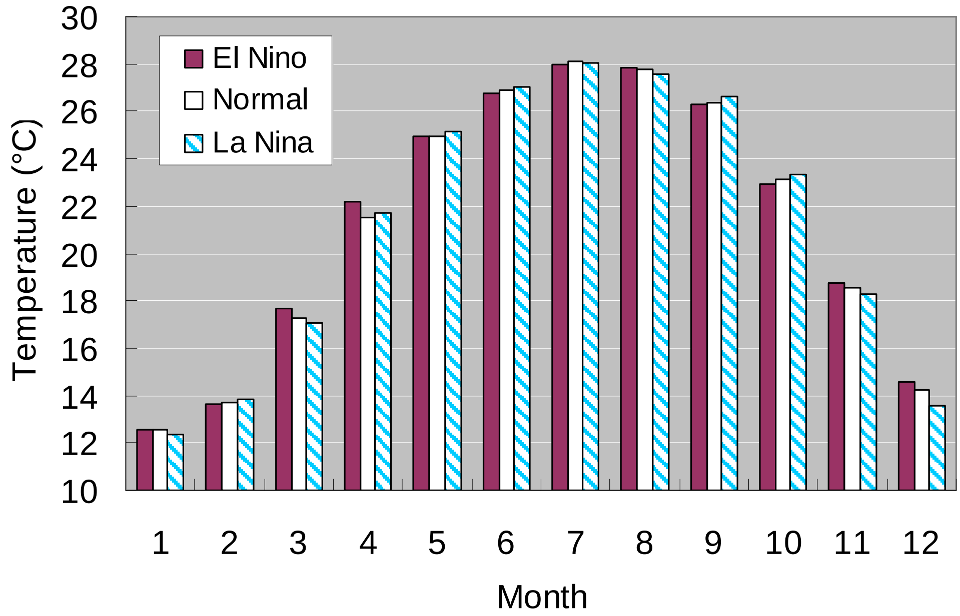


Fig. 4.10 Effect of El Nino/La Nina on mean monthly atmospheric temperatures of East River Basin

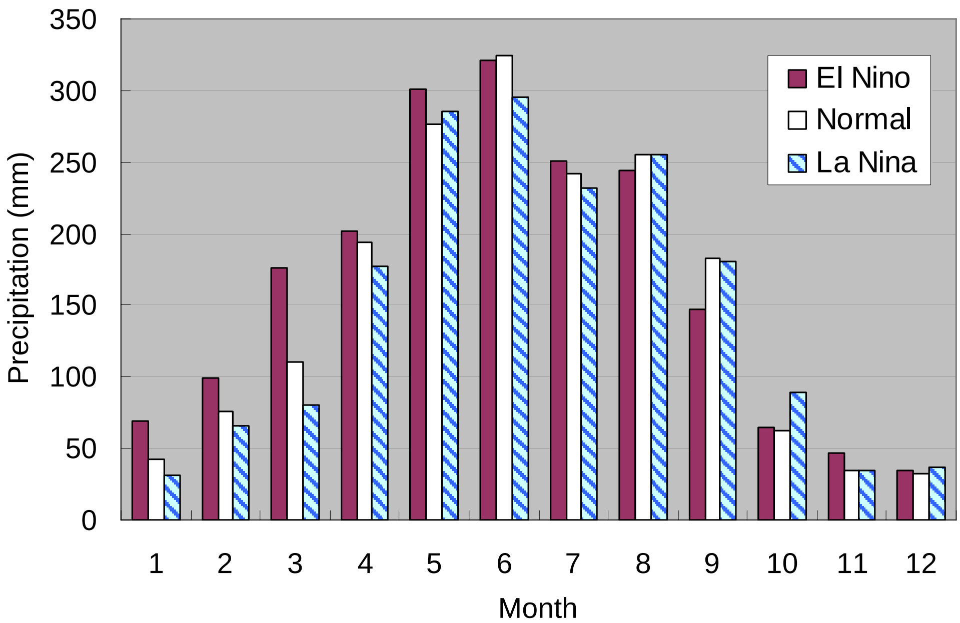


Fig. 4.11 Effect of El Nino/La Nina on mean monthly precipitation in East River Basin

5. HYDROLOGY, SEDIMENTATION AND FLUVIAL PROCESS

The runoff and sediment yield in a basin is determined by the mutual effect of its meteorology and ground cover. The meteorological factor is mainly the precipitation condition and the ground cover is the factor controlling the sediment transportation. The change of ground cover is controlled by two factors, one is the natural influence and the other is human activities. The natural influence includes land topography, land geomorphology, geology, soil and vegetation. The human activities are composed of water conservancy, soil and water conservation (such as, tree planting, slope control engineering, reservoir and dam construction etc) and unreasonable socio-economic activities (such as, mining, building road, land reclaim, destruction of forest and pasture, changing the source of sediment load and its transport process etc.) Fig. 5.1 shows the distribution of main hydrological stations in the East River Basin. This chapter will analyze the hydrological and sediment situations by use of the data, observed at these stations.

5.1 Basic Situation of Runoff and Sediment Load in the East River Basin

The Longchuan Hydrological Station is located at 60 km downstream from the Fengshuba Reservoir and is an important station in river source region. According to the statistical data from 1955 to 2002, the mean annual runoff was 6.35 $\times 10^9$ m^3. The maximum annual runoff was 12.2 $\times 10^9$ m^3 (1983) and the minimum annual runoff was 1.55 $\times 10^9$ m^3. The mean annual sediment load was 2.569 $\times 10^6$ t. The maximum annual sediment load was 3.91×10^6 t (1983) and the minimum annual sediment load was 0.28 $\times 10^6$ t (1999) .

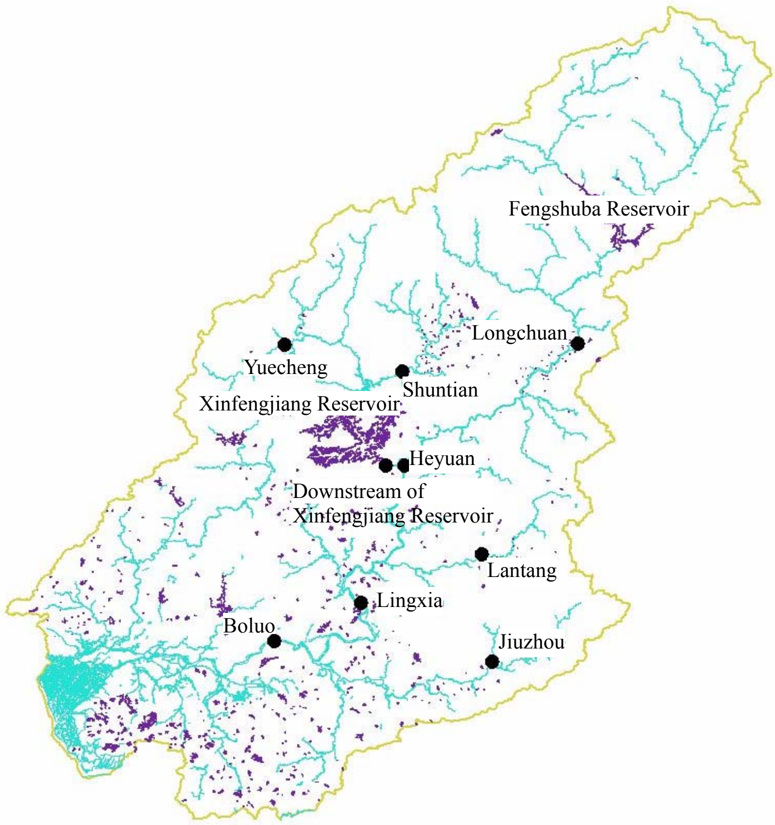


Fig. 5.1 Main hydrological stations in East River Basin

The Lingxia Hydrological Station is located in the middle stream of the East River basin. According to the statistical data from 1953 to 1988, the maximum and minimum annual runoffs were 37.5 $\times 10^9$ m^3 (1983) and 7.74×10^9 m^3 (1963), respectively. The distribution of runoff was non-uniform in a circle of a year and the runoffs were concentrated in the duration from April to September, which accounted for 70% of the annual runoff. The mean annual discharge was 602.2 m^3/s, and the maximum and minimum discharges in history were 10,900 m^3/s (1959) and 25.6 m^3/s (1995), respectively. The floods were conformed from large rainfalls, usually appeared in June and July, but also appeared in March and August. The exceptional large flood sometime occurred in September. The large rainfalls often occurred in the basins of middle and upper stream, so the flow discharge and water stage duration curves appeared as a multiple top curve, having some hydrologic features of mountain rivers.

Boluo Hydrological Station is located in Huizhou City, in the basin of lower stream and is an important river mouth station. The mean annual runoff was 23.46×10^9 $m^3$and the maximum and minimum annual runoffs were 41.3×10^9 m^3 (1983) and 8.94×10^9 m^3 (1963), respectively. The mean annual sediment load was 2.569 $\times10^6$ t and the maximum annual sediment load and minimum annual sediment load were 5.80 $\times10^6$ t (1959) and 0.325×10^6 t (1963), respectively. The mean annual sediment concentration was 0.117 kg/m^3 and maximum annual sediment concentration and the minimum annual sediment concentration were 0.170kg/m^3(1957) and 0.036 kg/m^3 (1963), respectively. The monthly mean sediment concentration in the flood season (from April to September) was between 0.09 kg/m^3 and 0.172 kg/m^3 and in the dry season (from October to March, next year) was between 0.016 kg/m^3 and 0.067 kg/m^3.

The Lantang Hydrological Station is located on the Qiuxiang River. According to the statistic data from 1958 to 1987, The mean annual discharge was 28.3 m^3/s. The mean annual runoff was $0.89\times10^9 m^3$ and the maximum and minimum annual runoffs were 1.60×10^9 m^3 (1983) and 0.368×10^9 m^3 (1967), respectively.

The Dongkeng Hydrological Station is located on the Xizhi River. According to the statistic data, the mean annual discharge was 36.1 m^3/s. The runoff was concentrated in the duration from June to September, which accounted for 66% of annual runoff.

5.2 Changes of Flow Discharge in East River System

5.2.1 Changes of monthly mean discharge in East River System

It can be seen from forementioned that the precipitation is the main meteorological factor to control the runoff in the East River System. It also can be seen from the climate situation graphs that the monthly mean precipitation has larger variation, and in accordingly that the monthly mean discharge also has larger variation. The Figs. 5.2 and 5.3 show the changes of monthly mean discharge at these hydrological stations on the stem of the East River and its tributaries, respectively. The monthly mean discharges at the stations from the Longchuan Station, located in the river source region, to the Boluo Station, located in the basin of lower stream, had the same changing tendency. The monthly mean discharges of different stations gradually rose in the duration from January to June, reached their own maximum in flood season and then fell down gradually in the duration from June to December. A litter rise appeared in August and September.

The monthly mean discharges on the main tributaries of the East River System show different changing tendency. Due to the Jiuqu River and Xunwu River Basins in the source region of the East River were slightly disturbed by human activities, so their discharges showed the natural situation. The monthly mean discharges rose gradually in the duration from January to June and reached the maximum in June, quickly fell down in the duration from June to July and then gradually fell down in the duration from July to December. The similar changes of monthly mean discharges appeared on the Chuntang and Xinfeng Rivers, the tributaries in the basin of its middle stream. But, the different changing tendency of monthly mean discharges appeared on the Qiuxiang and Xizhi rivers, the tributaries in the basins of its middle and lower stream. The obvious difference was appearance of double top curves in their graphs of monthly mean discharge, that is, the river discharges had two larger values in June and August.

It can be seen from Figs. 5.2 and 5.3 that the river discharge in East River Basin had larger value in duration from April to September and the maximum value often appeared in June.

5.2.2 Changes of mean annual discharge in East River System

According to the discharge data of the Longchuan Hydrological Station in the duration from 1952 to2002, the change of mean annual discharge in the basin of upper stream of the East River was drawn in Fig. 5.4.

It can be seen that the minimum mean annual discharge in the basin of upper stream, being 63 m^3/s, appeared in 1963 and its maximum mean annual discharge, being 387 m^3/s, appeared in 1983. The maximum value is 6 times greater than the minimum one, which means that the changing of mean annual discharge in the basin of its upper stream is obvious. It also can be seen that the mean annual discharges were relatively low in the duration from the end of 1960s to the beginning of the 1970s and high in the middle of 1980s. From the changing tendency of the mean annual discharges on the graph it can be seen that the mean annual discharges had fallen down tendency since the 1990s.

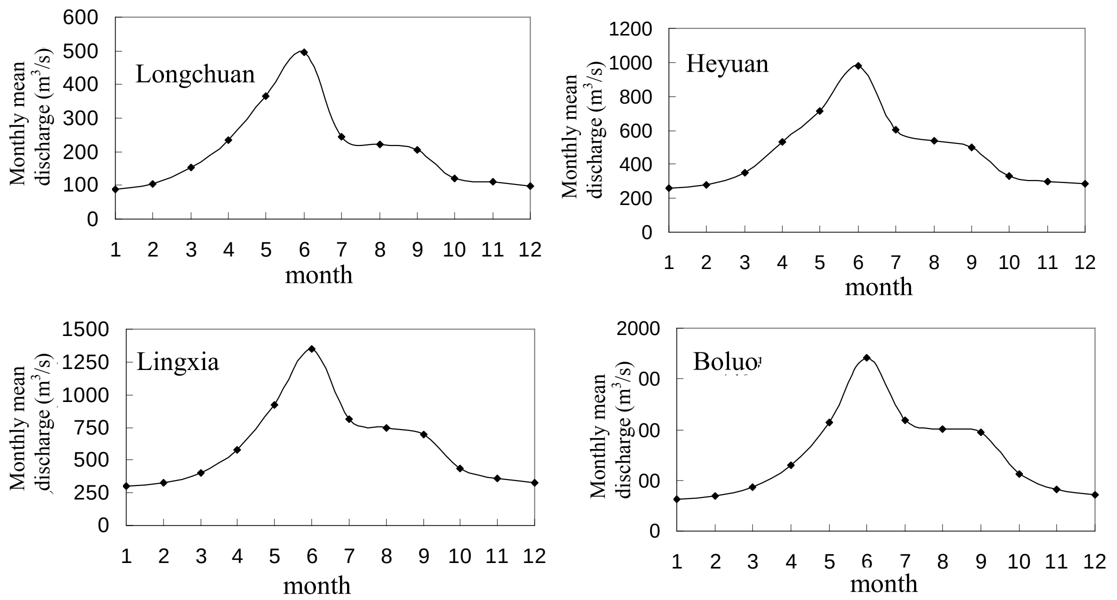


Fig. 5.2 Changes of monthly mean discharge on the stem of East River

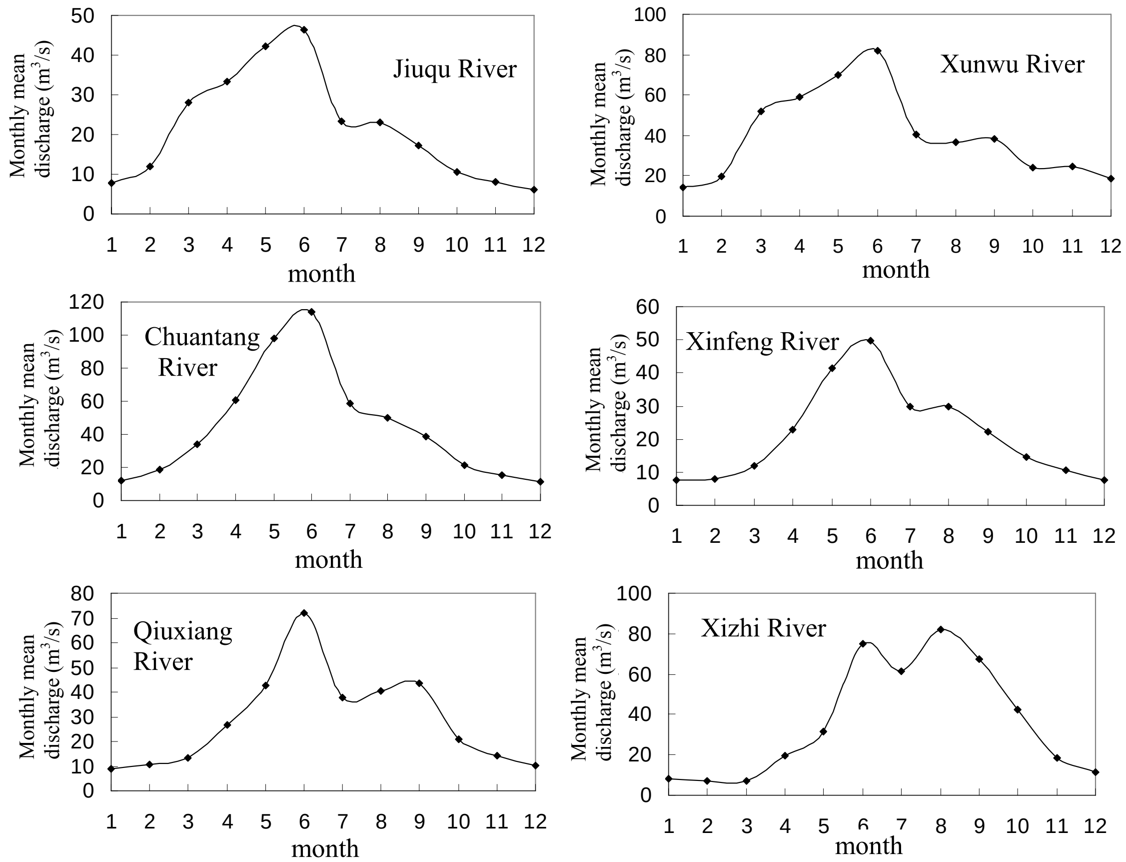


Fig. 5.3 Changes of monthly mean discharge on the main tributaries

The mean annual discharge at the Boluo Hydrological Station in the basin of lower stream was 738.5 m^3/s, the maximum and minimum annual discharges, being 1310 m^3/s and 283 m^3/s, respectively, appeared in 1983 and 1963. It can be seen that the changing of mean annual discharge at the Boluo Hydrological

Station was also obvious and the mean annual discharge had fallen down tendency, since the 1990s.

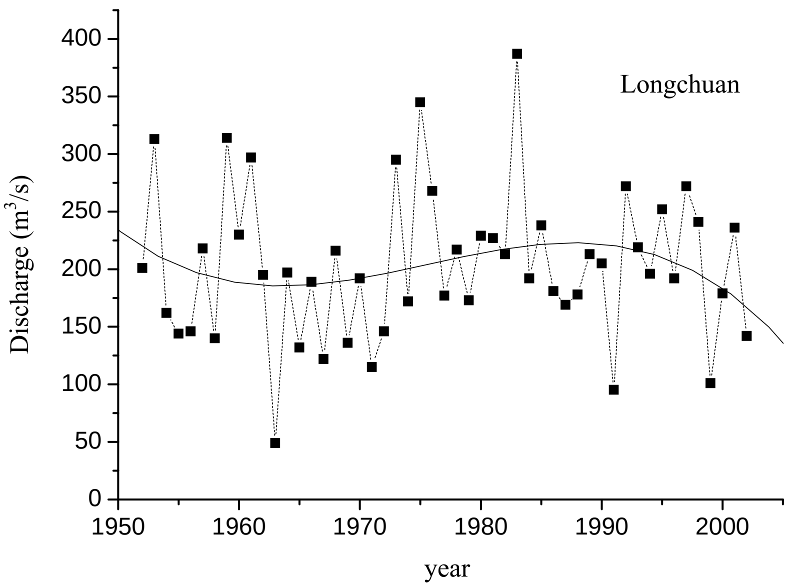


Fig. 5.4 Change of mean annual discharge at Longchuan Hydrological Station in basin of upper stream of East River

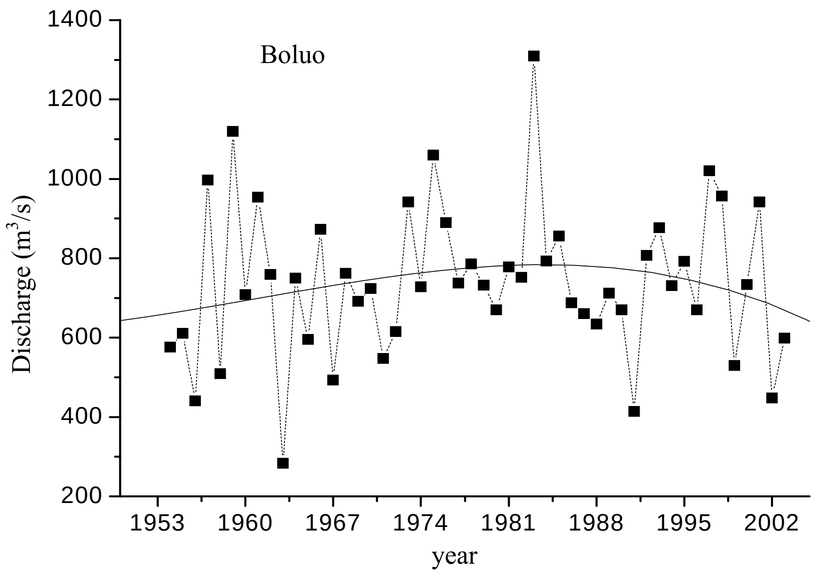


Fig. 5.5 Change of mean annual discharge at Boluo Hydrological Station in basin of lower stream of East River

5.2.3 Discharge fluctuation in East River Basin

The discharge can be expressed as the sum of the mean discharge, Q_m, and the fluctuated value, Q', as in Eq. (5.1).

$$Q(t) = Q_m + Q'(t) \tag{5.1}$$

Q_{rms} and Q_{s-rms} express the fluctuated discharge and fluctuated sediment load, respectively. Their expressions are as follows.

$$Q_{rms}=\left[\frac{1}{T}\int_0^T (Q(t)-Q_m)^2\,dt\right]^{1/2}=\left[\frac{1}{T}\int_0^T Q'(t)^2\,dt\right]^{1/2} \tag{5.2}$$

$$Q_{s-rms}=\left[\frac{1}{T}\int_0^T (Q_s(t)-Q_{sm})^2\,dt\right]^{1/2}=\left[\frac{1}{T}\int_0^T Q_s'(t)^2\,dt\right]^{1/2} \tag{5.3}$$

Flows in natural rivers are unsteady flows with unequilibrium transport of sediment; such flows have a definite tractive force on the riverbed. The relationship between the tractive force, Rs, and the fluctuated discharge is as follows.

$$R_s = k\sqrt{Q_{rms}} \tag{5.4}$$

K = 80 $(m/s)^{0.5}/a$ for the Huayuankou Hydrological Station on the Lower Yellow River (Wang, et. al., 2002). Eq. (5.4) shows that when the fluctuated discharge is small, the riverbed will be stable under a small Rs.

The fluctuation of discharges can be described by a pulsation coefficient, PC, which is expressed as in Eq. (5.5) .

$$PC=\frac{\left[\frac{1}{N}\sum_{i=1}^{N}(Q_i-\overline{Q})^2\right]^{1/2}}{\overline{Q}} \tag{5.5}$$

$$\overline{Q}=\frac{1}{N}\sum_{i=1}^{N}Q_i \tag{5.6}$$

in which $\overline{Q}$ is the mean discharge, Q_i is the mean discharge in the ith day, N is the number of total days, which must be over 1 year.

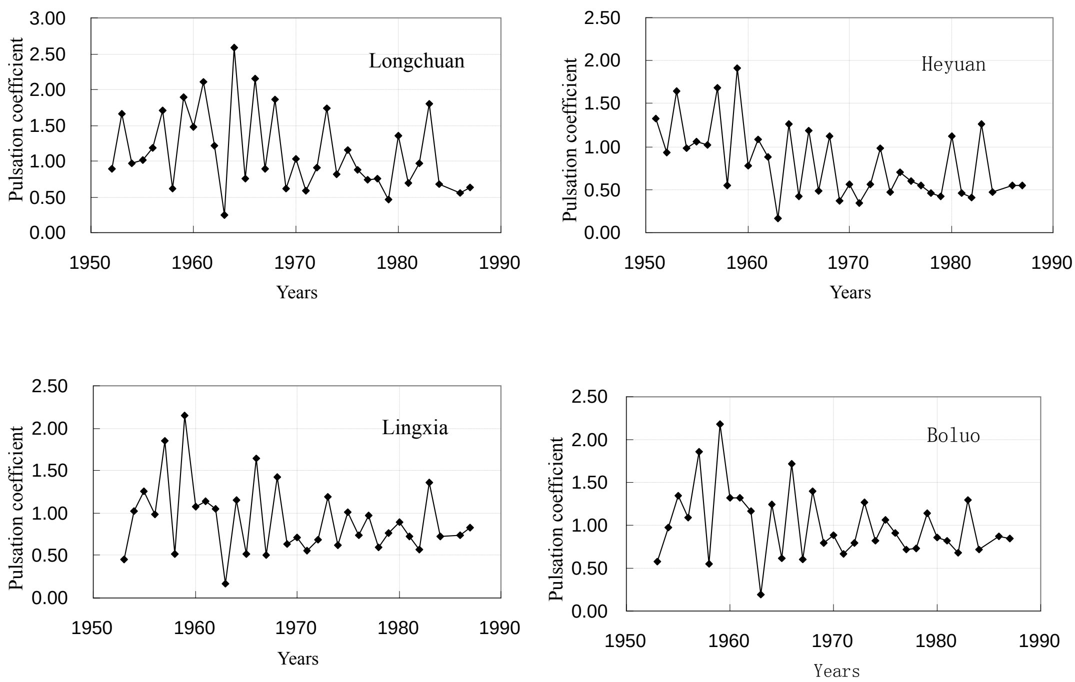


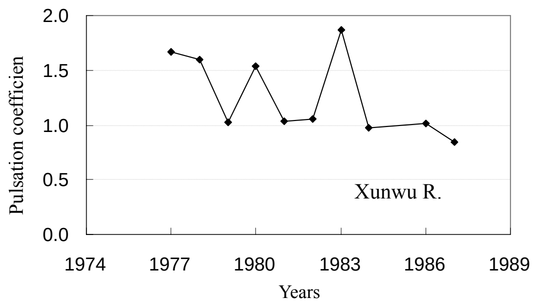
Fig. 5.6 Variation of pulsation coefficients of hydrological stations on East River

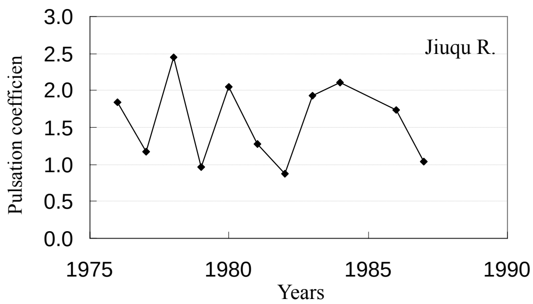
Fig. 5.6 shows that before 1970s the pulsation coefficients were high with a large annual oscillation, while after 1970s they became smaller with a small annual oscillation. Table 5.1 lists the average pulsation coefficients and their standard deviations of the hydrological stations. The reason of such changes is induced by the regulation of Xinfengjiang, Fengshuba, and Baipenzhu Hydroprojects, which diminished discharge fluctuation.

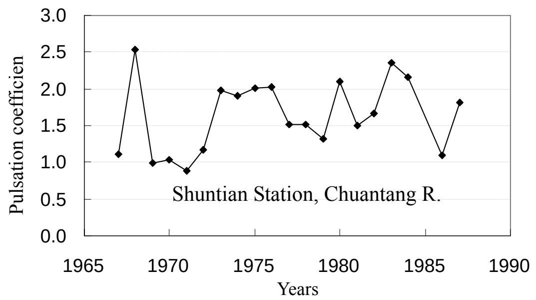
Table 5.1 Pulsation coefficients and their deviations of hydrological stations on East River

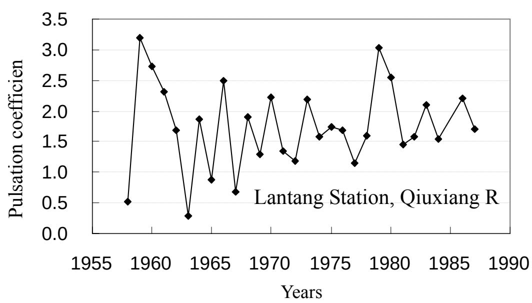
Station	Pulsation	Coefficient	Standard	Deviation
	Before 1970s	After 1970s	Before 1970s	After 1970s
Longchuan	1.27	0.94	0.62	0.40
Heyuan	0.97	0.61	0.46	0.27
Lingxia	0.99	0.83	0.52	0.22
Boluo	1.08	0.90	0.51	0.20

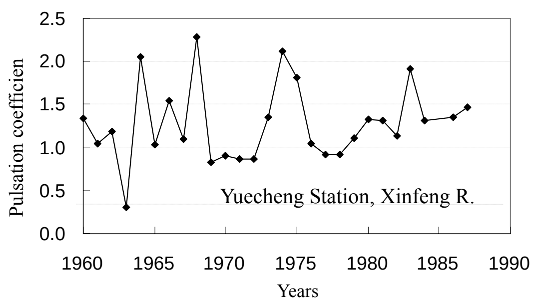
Fig. 5.7 shows the pulsation coefficients of hydrological stations on tributaries of East River. Most of the pulsation coefficients are in the range of 1.0-1.7; the pulsation coefficient of Baxia Station, located below the Xinfeng Hydorroject, is about 0.5, while it is 1.4 at Yuecheng station above the Xinfeng Hydroroject. This indicates the influence of hydroprojects on pulsation coefficients.

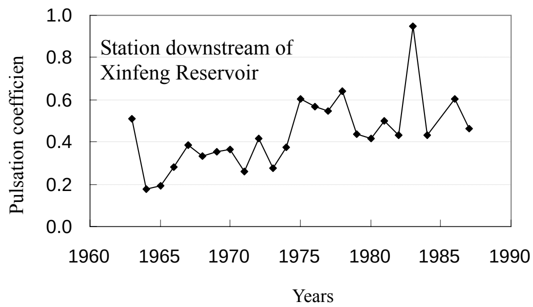












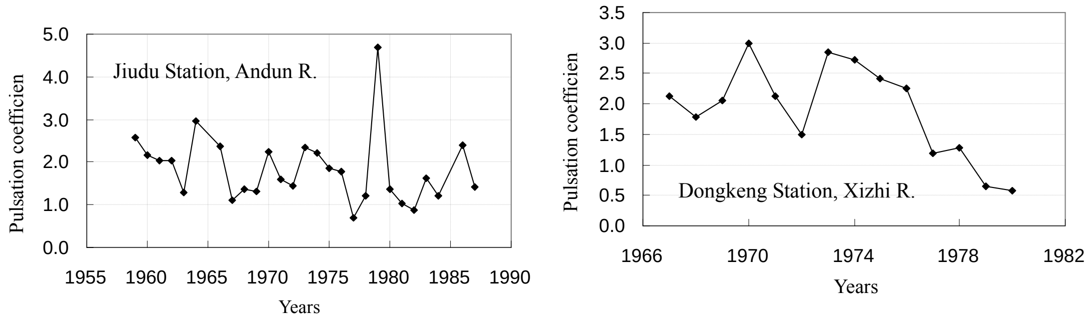


Fig. 5.7 Pulsation coefficients of hydrological stations on tributaries of East River

According to the above-mentioned data the pulsation coefficient of the East River under natural conditions is 1.450.

5.2.4 Discharge index of river health

When Gehrke, et. al. (1995), Ladson and White (1999), Landson (2000) developed their ISC evaluation systems, they adopted the discharge deviated from its natural state as the discharge index of river health. The expression is as follows.

$$R_a = \left(\sum_{i=1}^{12} \left(\frac{(c_{ij} - n_{ij})}{\bar{n}} \right)^2 \right)^{\frac{1}{2}} \tag{5.7}$$

in which R is the deviation index of river discharges, n is the mean monthly discharge. c_{ij} is the mean monthly discharge of the i^{th} month in the j^{th} year, n_{ij} is the discharge in the same month under natural conditions. The mean monthly discharge is changed to mean yearly discharge by the authors, thus, the expression of R_a is as follows.

$$R_a = \left(\frac{1}{n} \sum_{i=1}^{n} \left(\frac{C_i - \overline{C_n}}{\overline{C_n}} \right)^2 \right)^{\frac{1}{2}} \tag{5.8}$$

in which R_a is the deviation index of river discharges, C_{iI} is the annual discharge of the i^{th} year, C_n is the mean annual discharge of the river under natural conditions, n is the total years of statistics. According to Eq. (5.8) the values of R_a of various hydrological stations on the East River are listed in Table 5.2.

Table 5.2 Deviation indexes of discharge of hydrological stations on East River

River	Station	R_a
East River	Downstream of Fengshuba Dam	0.3011
East River	Longchuan	0.3676
East River	Heyuan	0.2925
East River	Lingxia	0.3404
East River	Boluo	0.2561
Xunwu	Lizhangfeng	0.2438
Jiuqu	Dingnan	0.3158
Beiling	Taoxi	0.2756
Chuantang	Shuntian	0.3198
Qiuxiang	Lantang	0.3420
Xinfeng	Yuecheng	0.2863
Xinfeng	Downstream of Xinfengjiang Dam	0.3304
Andun	Jiuzhou	0.3082
Gongzhuang	Honghuata	0.2424
Xizhi	Dongkeng	0.2685

Table 5.2 shows that the values of R_a in the East River Basin are about 0.30 and they vary slightly. Table

5.3 shows the values of R_a affected by reservoirs.

Table 5.3 Effect of reservoirs on values of Ra of main stem of East River

State/Station	Longchuan	Heyuan	Lingxia	Boluo
Natural state	0.3567	0.2715	0.2986	0.2994
Below Xinfengjiang dam		0.2566	0.2349	0.2587
Below Fengshuba dam	0.3751			
Below Xinfengjiang and Fengshuba dams		0.3314	0.4199	0.2411

5.2.5 Discharge fluctuation index of river health

Based on the variation range of river discharge fluctuation coefficients of the East River the discharge fluctuation index of river health may be obtained.

As large reservoirs, namely Xinfengjiang, Fengsuba, and Baipenzhu Reservoirs, have great influence on river discharge fluctuation, river discharge fluctuation coefficients under natural conditions are selected to determine the discharge fluctuation index of river health. For Heyuan Station it was under natural conditions before 1960, it was under the influence of Xinfengjiang Reservoir between 1960-1973 and was under the joint influence of Xinfengjiang and Fengshuba Reservoirs after 1973. For Longchuan Station it was under natural conditions before 1973 and was under the influence of Fengshuba Reservoir after 1973. Effect of reservoirs on other stations was also considered. The mean river discharge fluctuation coefficient under natural conditions was 1.518, which is adopted as a standard to differentiate the grade of river discharge fluctuation.

The deviation index of river discharge fluctuation coefficient, R_{pc}, is used to evaluate the river discharge fluctuation coefficient. Its expression is as follows.

$$R_{pc} = \left(\frac{1}{n} \sum \left(\frac{r_{pci} - \overline{r_{pc}}}{\overline{r_{pc}}} \right)^2 \right)^{1/2} \tag{5.9}$$

in which r_{pc} is the annual discharge fluctuation coefficient based on daily discharges, r_{pc} is the discharge fluctuation coefficient under natural conditions, n is the number of years.

Table 5.4 lists the deviation indexes of river discharge fluctuation coefficient. In the East River Basin the variation of deviation indexes of river discharge is not large, but the variation of deviation indexes of river discharge fluctuation is large. The large values of deviation index of river discharge fluctuation coefficient of the stations on the main stem of the East River (as Fengshuba, Longchuan, Heyuan, Lingxia, and Boluo stations) are induced by the regulation of Fengshuba and Xinfengjiang Reservoirs, reducing the fluctuation of river discharges. The largest value at Xinfengjiangbaxia Station was 0.7188, which measured directly the released discharges from Xinfengjiang Reservoir, reflecting human regulation of the reservoir. The large value at Dongkeng Station, 0.5475, reflects the effect of regulation of Baipenzhu Reservoir.

Table 5.4 Deviation indexes of river discharge fluctuation coefficient of East River Basin

River	Station	R_{pc}
East River	Fengshuba	0.5586
East River	Longchuan	0.4444
East River	Heyuan	0.5288
East River	Lingxia	0.4796
East River	Boluo	0.4300
Andun	Jiuzhou	0.5606
Jiuqu	Dingnan	0.3411
Xunwu	Lizhangfeng	0.2820
Chuantang	Shuntian	0.3250
Xinfeng	Yuecheng	0.3323
Xinfeng	Xinfengjiangbaxia	0.7188
Qiuxiang	Lantang	0.4797
Xizhi	Dongkeng	0.5445

Table 5.5 lists the deviation indexes of river discharge fluctuation coefficient of main hydrological stations on the main stem of the East River. Due to the effect of reservoir regulation the deviation indexes are increased. Under the effect of regulation of Xinfengjiang Reservoir the deviation indexes of Heyuan, Lingxia and Boluo Stations increased significantly; but under the joint effect of Xinfengjiang and Fengshuba reservoirs the deviation indexes decreased.

Table 5.5 Deviation indexes of river discharge fluctuation coefficient of East River

State/Station	Longchuan	Heyuan	Lingxia	Boluo
Natural conditions	0.4231	0.3067	0.3874	0.3389
Below Xinfengjiang Project		0.6547	0.5706	0.5072
Below Fengshuba Project	0.4784			
Below Xinfengjiang and Fengshuba Projects		0.6177	0.4853	0.4342

The deviation index of river discharge fluctuation coefficient under natural conditions was 0.3421 based on the analysis of situation of hydroprojects and field data, which is adopted as the standard.

5.3 Changes of Sediment Load in Basin of East River Basin

Fig. 5.8 is a graph of changing tendency of mean annual sediment concentration in the basin of upper stream of the East River. It can be seen that, in the general, the sediment concentration of the river had a fallen down tendency, and the sediment concentration in the duration from the end of 1950s to the beginning of 1960s was relative lower and their changes was also moderate. It reflected the natural sediment concentration situation in the upper stream of East River. But the sediment concentration in the river rose quickly in the middle of 1960s, which might be interpreted by the severe soil erosion, resulted by the severe destruction of natural plant cover in the end of 1950s. Because the East River Basin is located in the region of subtropical monsoon and has the mean annual temperature of 20℃ and mean annual precipitation of 1500mm, so the natural plant cover is easy to be restored. Besides, the Fengshuba Reservoir, constructed in1973 intercepted the sediment load, entering from the basin of upper stream. All these must decreased the sediment concentration of river in the end of the 1970s. In the beginning of the 1980s the sediment concentration of river again rose up, which resulted from the destruction of forest and plant cover at the beginning of carrying out the policy of Reform and Opening-up.

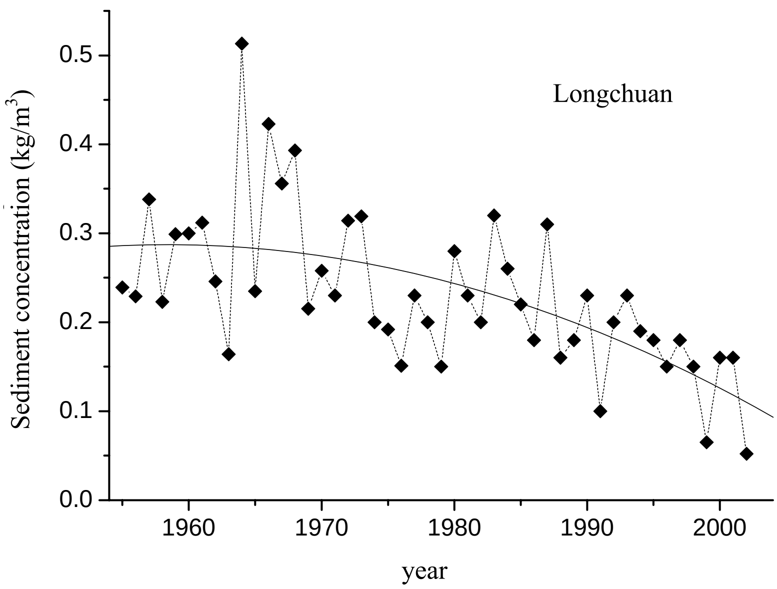


Fig. 5.8 Changing of sediment concentration at Longchuan Station on upper stream of East River

The mean annual sediment concentration at Boluo Hydrological Station was 0.11 kg/m^3 and its maximum and minimum annual sediment concentration were 0.17 kg/m^3 (1957) and 0.036 kg/m^3(1963), respectively.

It can be seen from the changing of mean annual sediment concentration at Boluo Hydrological Station (Fig. 5.9) that, in the general, the sediment concentration in the lower stream of the East River was gradually fallen down. Its sediment concentration in the duration from the end of 1960s to the beginning of 1970s fell down quickly, which might result from the decrease of sediment concentration in the upper stream of the East River.

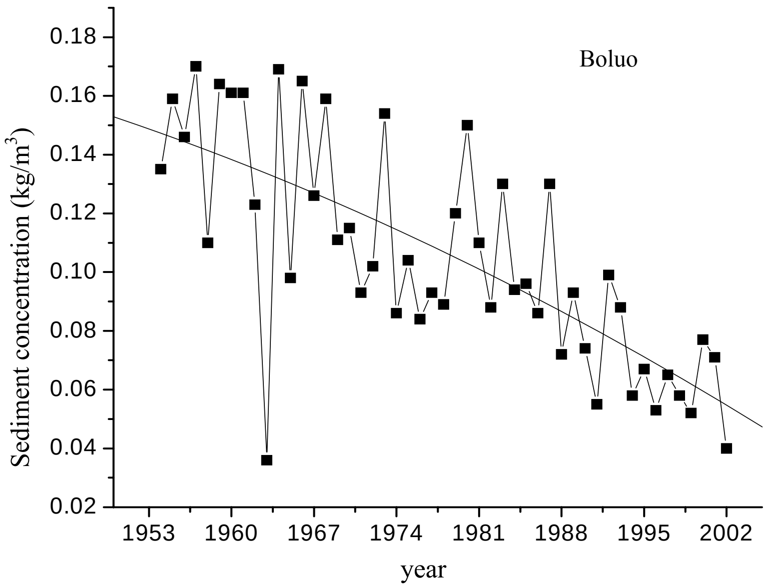


Fig. 5.9 Changing of mean annual sediment concentration at Boluo Hydrological Station on the lower stream of East River

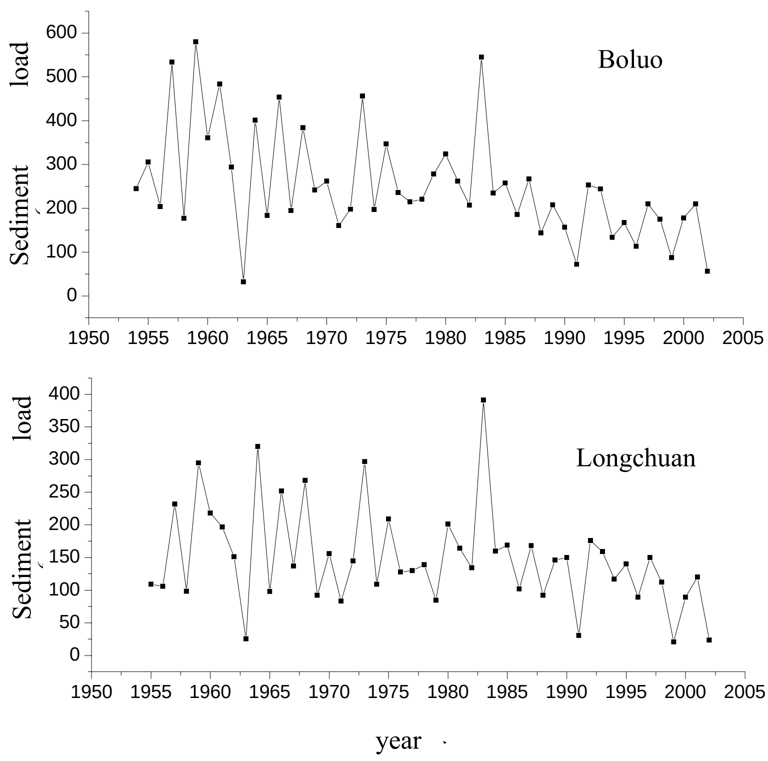


Fig. 5.10 Compression of mean annual sediment load at Longchuan Hydrological Station with that at Boluo Hydrological Station

Fig. 5.10 shows the mean annual sediment loads at Longchuan Hydrological Station and Boluo Hydrological Station. It can be seen from Fig. 5.10 that the changing tendency of the mean annual sediment load at Boluo Hydrological Station had the similar tendency with that at the Longchuan Hydrological Station. According to the statistic data the mean annual sediment load at Boluo Hydrological Station was 2.518 $\times10^6$ t and the mean annual sediment load at Longchuan Hydrological Station was1.497$\times10^6$ t, accounting for 59.5% of that at Boluo Hydrological Station. Fig. 5.11 shows the good linear relationship between the mean annual sediment loads of Boluo and Longchuan Hydrological Stations. Therefore, the source basin of the East River, the basin upstream of Longchuan, is the major source region of sediment load in the East River.

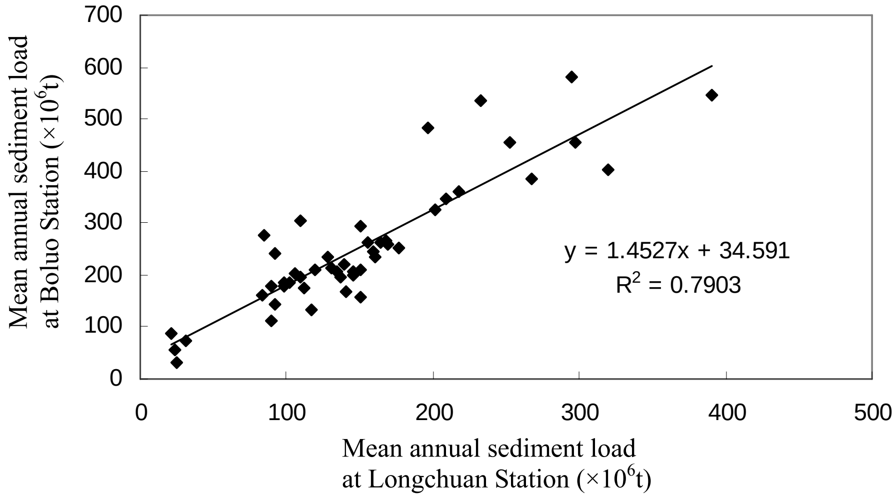


Fig. 5.11 Relationship between the mean annual sediment loads of Boluo and Longchuan Hydrological Station

5.4 Diagram of State Of Sediment Load of East River

Diagrams of state of sediment load are used to analyse the characteristics of spatial distribution of water flow and sediment load. The method of drawing the diagram is as follows. (1) The mean annual sediment concentration of Boluo Station, the exit station of the basin, is adopted as the equilibrium ratio of water and sediment, which is 0.11 kg/m^3. (2) The abscissa is time, years (1955-2002) in this paper. (3) The left ordinate is the annual runoff, and the right ordinate is the annual sediment load, they are correspondent to the equilibrium ratio of water and sediment. (4) Draw the curves of annual runoff and annual sediment load, respectively; where the former is higher than the latter, the area between them is plotted with light color; where the former is lower than the latter, the area is plotted with dark color. This diagram is called the diagram of state of sediment load.

The relative position of the two curves in the diagram indicates the states of water and sediment load. If the area between the curve of the annual runoff and the abscissa is larger than the area between the curve of the annual sediment load, it means that water is large and sediment load is small at this station and the basin above the station is a water source region; if the situation is just opposite it means that the basin above the station is a sediment source region.

Fig. 5.12 is the diagram of state of sediment load of Boluo Station. In 1950s and 1960s the curve of annual sediment load was just above the curve of annual runoff with little difference, which means that water and sediment load in the East River Basin were in quasi-equilibrium state in this period. From the middle of 1960s, particularly from 1980s, the curve of annual runoff was above the curve of annual sediment load. It means that the East River Basin has been changed from the quasi-equilibrium state to a water source region, i.e. a region of less sediment load and more annual runoff.

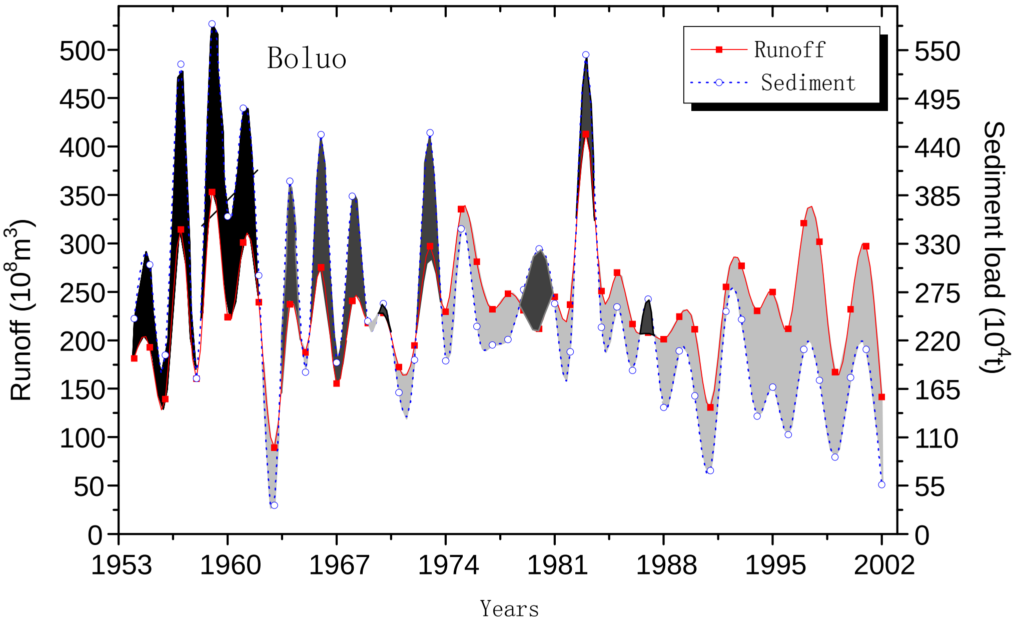


Fig. 5.12 Diagram of state of sediment load of Boluo Station

Fig. 5.13 is the diagram of state of sediment load of Longchuan Station. The curve of annual sediment load is above the curve of annual runoff. It means that the region above Longchuan is an important sediment source region in the East River Basin.

From 1990s the curve of annual runoff moves upward to surpass the curve of annual sediment load. It means that the basin above Longchuan has a tendency to be changed from a sediment source region to a water source region.

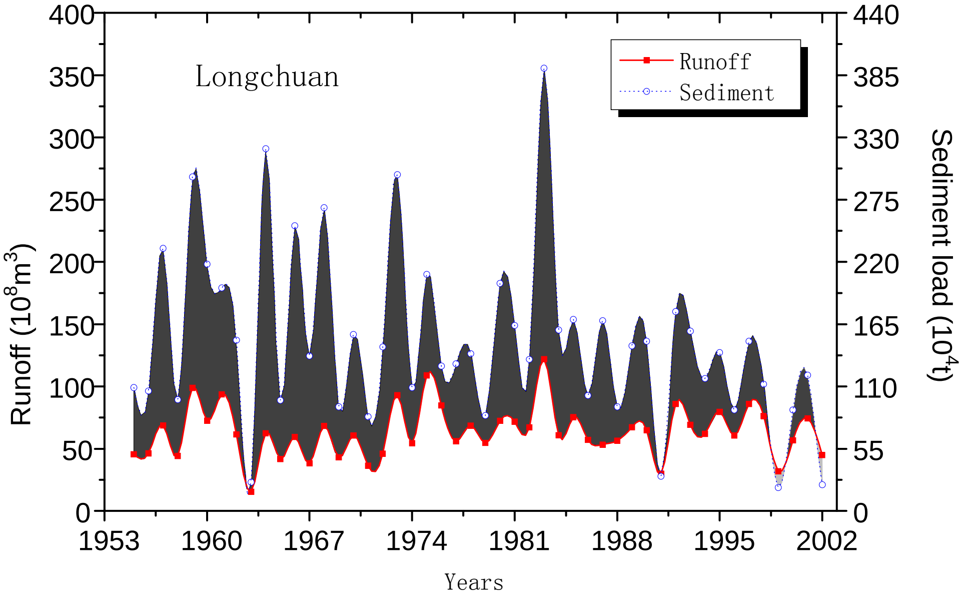


Fig. 5.13 Diagram of state of sediment load of Longchuan Station

5.5 The Intensity of the Fluvial Process

Rivers are the source of social development and the most active elements of geomorphologic evolution and ecological system. Erosion, transportation, and deposition of sediment particles are the basic agents of geomorphologic evolution. Water flow may change river channels and erode riverbanks. Alluviation of sediment particles may form plains and deltas in the sea. Various rivers have different characteristics, depending on their water flow, sediment load, and boundary conditions. The East River is a typical river of abundant runoff and scarce sediment load, its long-term annual average sediment concentration is only 0.11 kg/m^3.

If a river section and sediment-laden flow within it are treated as a softe moving body, the deformation of the riverbed is then the mothin of the soft body, which is called river motion. The patterns of river mothin are aggradation, degradation, widening, translation, rotation, wandering, bifurication, and migration from one channel to another channel. Aggradation and degradation are vertical movement and the rests are horizontal movement. Migration is no-continuous motion and the rests are continuous motions. The movement speed of a river channel depends on the sediment-removing capacity of the flow. Sediment-removing capacity is defined as the capacity of the flow to remove sediment from per unit length of a river section to other places per time. The sediment-removing capacity is different from the well-defined sediment-carrying capacity. The sediment-carrying capacity is a feature of the mean flow, but the sediment-removing capacity is a feature of unsteady, non-equilibrium flow. The sediment-carrying capacity explains how much sediment load the flow can transport through the channel, while the sediment-removing capacity represents the capability of the flow to change the channel shape (Wang and Wu, 2001).

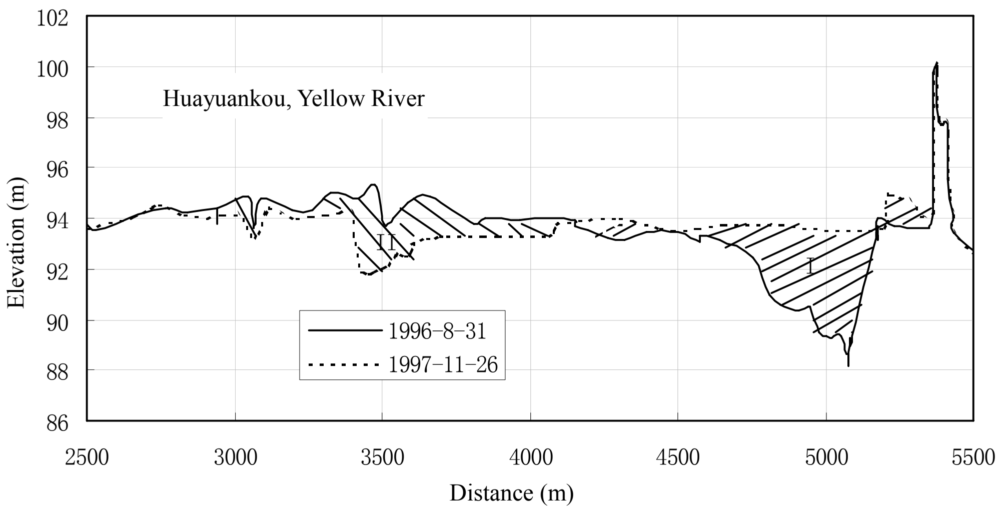


Fig. 5.14 Sketch map of method to calculate the intensity of the channel motion (using Huayuankou cross section of the Yellow River as an example)

Channel motion is a result of sediment deposition, bed scour, and bank erosion. The intensity of channel motion is defined as follows:

$$R_s = \frac{V_{scour} + V_{dep}}{LT} \tag{5.62}$$

where Rs is the intensity of river motion, V_{scour} and V_{dep} are the sediment volumes scoured from the bank or the bed and deposited in the channel in the time period of T, respectively, L is the length of the measured river section, and T is the time interval of the measurements. In many cases the cross sections of the Chinese rivers are measured once a year, thence T = 1 year. The measured R_s depends on the frequency of the measurement because the river motion in many cases is reciprocating. Fig. 5.14 exhibits the situation of fluvial process at Huayuankou cross section of the Yellow River during the period from August 31, 1996 to November 26, 1997. It shows that the river reach has shifted towards to left side about 1500m caused by the original channel ('I') deposited and the new channel ('II') eroded. Therefore, the intensity of river motion can be computed by summing quantities of erosion and sedimentation.

If the channel shifts towards to left side, the eroded area is formed by two boundary lines along left bank of the main channel, one is measured in the first time and the other is measured in the second time. Similarly, the deposited area is formed by two boundary lines along right bank of the main channel, one is measured in the second time and the other is measured in the first time. Thus, V_{scour} value can be calculated by average the two eroded areas of upper and lower cross sections of the river reach multiplied by the length of the river reach. V_{dep} can be computed by the average the two deposited areas of the upper and lower cross sections of the river reach multiplied by the length of the river reach. Thus, R_s the intensity of channel motion for any river reach between two cross sections can be computed by this way.

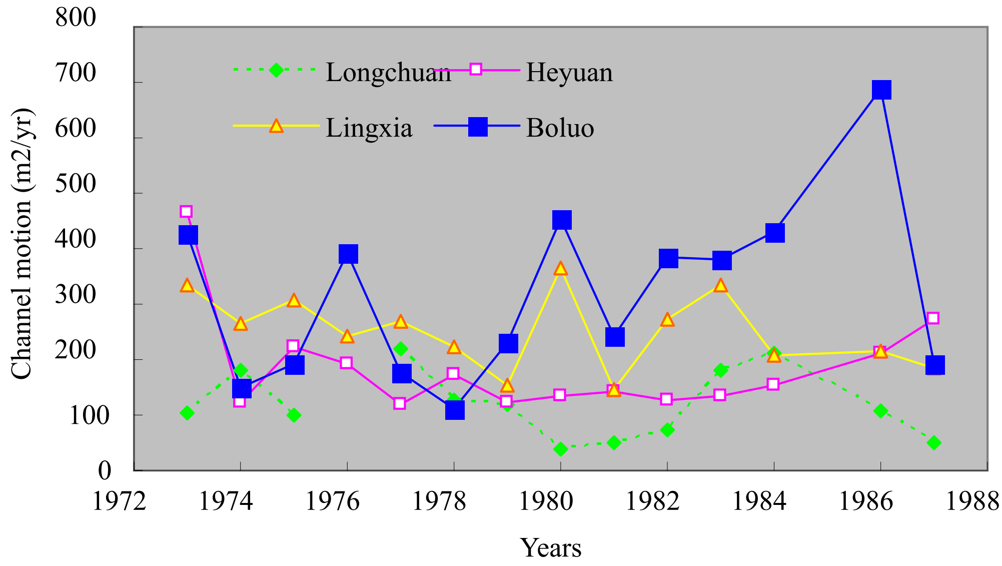


Fig. 5.15 Intensity of channel motion at cross sections of the main channel of the East River

Fig. 5.15 shows the intensity of channel motion at several cross sections of the main stem of the East River. It exhibits that the intensity of channel motion in the downstream is higher than that in upper and middle reaches. The averagy intensities of channel motion at Boluo and Lingxia sections are 282 m^2/yr and 236 m^2/yr respectively, while those at Heyuan and Longchuan sections are 155 m^2/yr and 115 m^2/yr respectively. It demonstrates that for the main stem of the East river, the upper reach is the most stable, the middle reach ranks the second, and the lower reach is the most unstable. If comparing the situation of the river with the Yellow River, it is regarded as relatively stable one.

6. FLOODS

Flood disasters are the most serious disaster in terms of economic and human loss among natural disasters. The UNESCO's survey shows that the loss by floods accounts for 40% of the total loss of natural disasters in the world. China is one of the countries with the most serious flood disasters. About 50% of the total population and 70% of the assets of China are located in the flood-prone areas. From 1993 to 1997 the direct economic loss by floods in China was 719.2 billion RMB yuan. Along with rapid development of modern economy and increase in hydroprojects flood disasters are aggravated. The data from the State Headquarters for Flood Control and Anti-Drought show that in 1998 a total population of 0.223 billion in 29 provinces were influenced by big floods with a direct economic loss of 166.6 RMB yuan and a death toll of 3004 people.

Since ancient time flood disasters have been the most frequent and serious natural disaster in the Pearl River Basin. Since the Han Dynasty there were more than 400 times basin-wide floods in the Pearl River. From 1915 to 1984 30 flood disasters with inundated farmland over 67 thousand hm^2 each time took place. In the 1990s 5 big floods occurred in June 1994, July 1994, July 1996, July 1997, and June 1998, among which the floods in July 1997 and June 1998 were 100-year flood. Such a situation was quite seldom in other large rivers in China. The main reasons were climate change, aggravation of soil erosion, construction of many bridges and piers, urbanization, and many human activities including sand mining.

Flood disasters are affected by many factors such as nature, social society, and economy. In recent years a new strategy of flood control was proposed based on historical experiences, i.e. flood management instead of flood prevention.

Flood risk is a description of the probability and uncertainty of disasters and adverse effect of flood events on human society and environment. Flood risk analysis is an important part of flood management. Zoning of flood risk is necessary for management of flood risk, prevention and reduction of economic loss to achieve the greatest benefit. Zoning of flood risk is a method of evaluation of spatial distribution of flood risk. At present the indexes for zoning include flood frequency, hydraulic parameters of a flood (water depth, flow velocity, duration of inundation, approaching time of the flood, etc), and possible economic loss, etc. Zoning of flood risk may effectively prevent flood damage and reduce economic loss of flood-prone areas and serve as the basis of planning of regional development. According to the zoning of flood risk the lower plain area and delta area of the East River belong to the most urbanized area in China and is the fourth grade area of flood risk in the Pearl River Basin; its standard of flood control is 50-100 year flood.

Flood disasters are the most serious disasters in the East River Basin, which is located in the low latitude region and near the sea. There are abundant rains with uneven distribution in time and space. Rains are concentrated in summer with high frequency of storms, which are mainly typhoon rains. There are three main storm sources in the basin, namely, Xinfeng River, Xizhi River, and Zengjiang River. The floods of the East River are mainly induced by storms.

6.1 Characteristics of Floods

Tables 6.1 and 6.2 are the characteristics of the floods in the East River. These values are based on published hydrologic bulletins and modified by historical records and literatures.

Table 6.1 Characteristics of floods in the main river

Frequency(%)	Dongchuan station		Heyuan station		Lingxia station		Boluo station	
	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)
1	9883	73.3	11500	42.0	12500	23.9	14400	14.2
2	8602	72.6	10400	41.3	11300	23.2	13000	13.5
5	6888	72.0	8800	40.3	10000	22.3	11200	12.6
20	4247	70.5	6500	38.8	7700	20.7	8060	10.0

In the process of calculation of water level the effect of downstream sand mining was considered. The calculated values may be a little bit higher than the real ones. The reasons are as follows. (1) The assumption of a same frequency of flood in the whole valley was adopted in the calculation, which was not the real situation. (2) When there was a levee break, the real water level was lower than the calculated. (3) A part of flood water might be impeded by dams and levees.

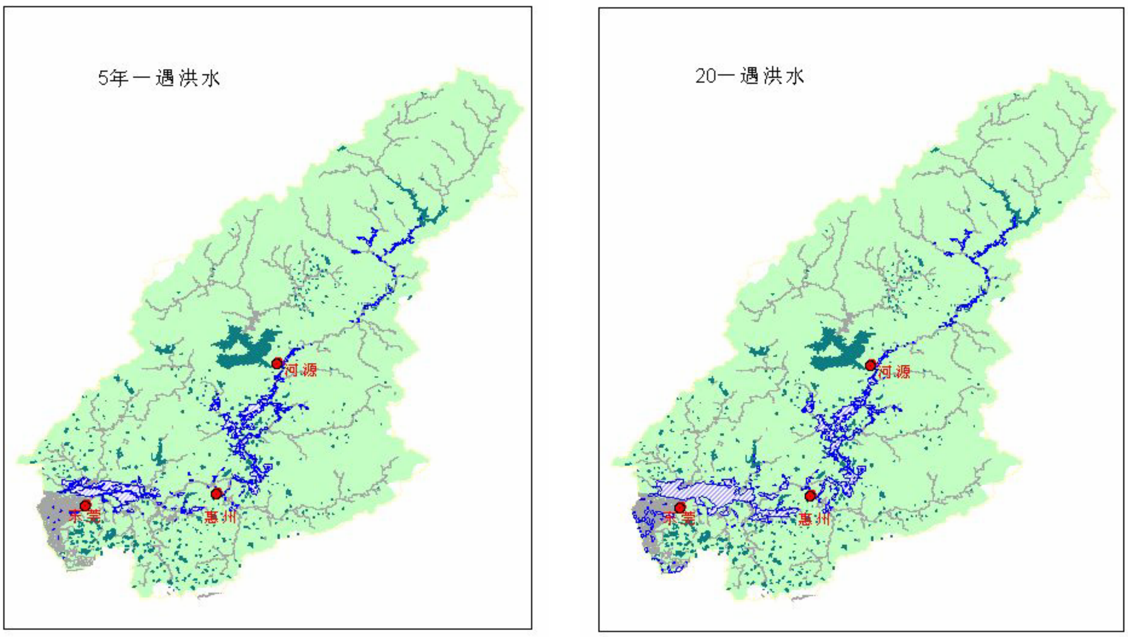
Table 6.2 Characteristics of floods in several tributaries

Frequency(%)	Lantang station		Jiuzhou station		Yuecheng station		Shuntian station	
	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)
1	1968	55.3	1500	44.7	1718	149.5	2000	118.3
2	1813	55.1	1300	44.2	1495	149.2	1800	118.0
5	1585	54.7	1120	43.6	1211	148.8	1600	117.4
20	1182	54.0	850	42.6	780	147.6	1200	115.5

According to the characteristics of floods in the East River Basin showed in Tables 6.1 and 6.2, combining DEM data collected, the zoning of flood –prone at different return period floods in the basin can be obtained shown in Fig. 6.1.

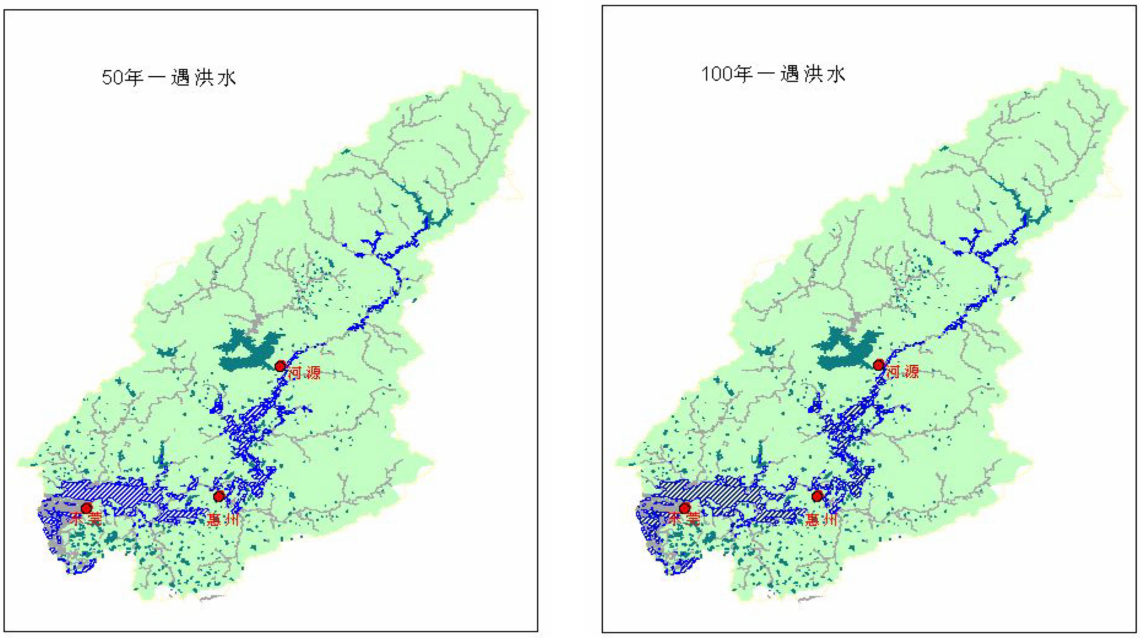
Fig.6.1 indicates that the zoning of flood-prone is located in the middle and lower reaches as well as estuary delta region. Limited by the data of topography and floods collected only from the main river, therefore, the calculating results can not reflect the situation of tributaries such as Xizhijiang watershed where floods occur frequently. In calculation, historical data has been used to compare and examine the results simultaneously. For example a 100- year return perid flood occurred in the middle and lower reaches of the East River in June, 1959, at that time the impact of reservoirs was less, all closing levee were broke, 1590 km^2 of farm lands was damaged which is closed to the simulated result.

According to inundated area exhibited in Fig. 6.1, the inundated area at different return period floods have been estimated and listed in Table. 6.3. It indicates that; when 5- year return period flood occurs, the inundated area along the main river is 742 km^2 accounts for 2.16% of the whole basin area; for 20-year return period flood, it is 1119 km^2 accounts for 3.25%; for 50-year return period flood , it is 1336 km^2 accounts for 3.88%; for 100-year return period flood, it is 1499 km^2 accounts for 4.36%. Those results mentioned above express that with the flood return period increases from 5-year level to 100-year level, the related inundated area increases 757 km^2; when 20-year return period flood increase to 50-year return period flood or even 100-year return period flood, the related inundated area increases 217km^2 and 380 km^2 respectively. Obviously, the total inundated area increases is not much. Therefore it can be considered that the area inundated by 20- year return period flood is the zoning of higher flood –prone.



(a) 5-year return period flood

(b) 20-year return period flood



(c) 50-year return period flood (d) 100-year return period flood

Fig. 6.1 Area inundated by foods in the main channel of the East River

Table 6.3 Situation of area inundated by different return period floods

Flood return period of the whole basin	Inundated area (km^2)	Ratio of inundated area along the main river and the whole basin (%)
5-year	742	2.16
20-year	1119	3.25
50-year	1336	3.88
100-year	1499	4.36

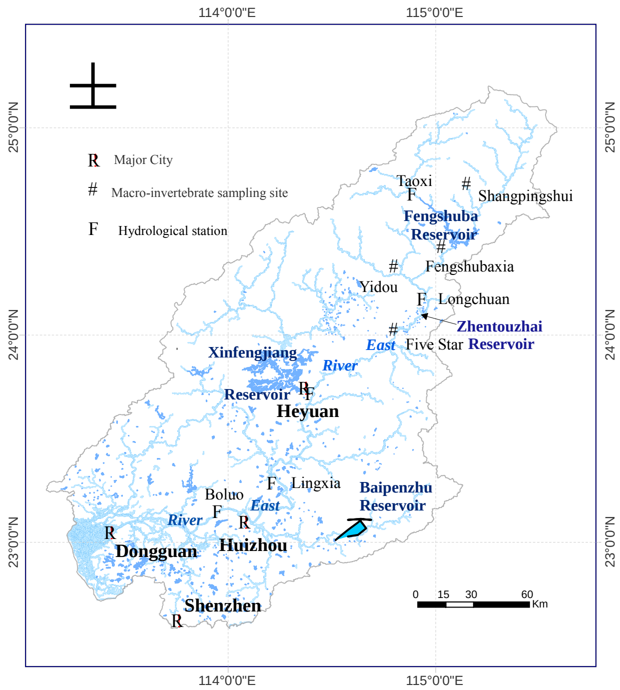


Fig. 6.2 Location of three reservoirs in the East River Basin

6.2 Reservoir Impacts on the Zoning of Flood-Prone in the East River Basin

After 1960s, a series of hydraulic projects such as water storing, water diverting, water pumping and closing levee etc have been built for comprehensive development and river management. Those projects and especially the measure of integrated operation of Xinfengjiang Reservoir, Fengshuba Reservoir and Baipenzhu Reservoir have played important role to reduce the zone of flood -prone greatly. Fig.6.2 is the location sketch of the three large reservoirs. Table 6.4 demonstrates the situation of floods peak discharge reduced, it is that for the 100-year return period flood, 20-40% of the flood peak discharge can be reduced; for 20-year return period flood, 20-30% of the flood peak discharge can be reduced; for 5-year return period flood, 10-20% of the flood peak discharge can be reduced.

Table.6.4 Analyzing results of regulated flood peak discharge by integrated operation of three reservoirs (Chen and Lin,1997)

Typical year	Frequency (%)	Xinfengjiang (m^3/s)		Fengshuba (m^3/s)		Baipongzhu (m^3/s)		Discharge at Buolou (m^3/s)		Water level of Huiyang (m)	
		Inflow	outflow	Inflow	outflow	Inflow	outflow	Natural	After regulated	Natural	After regulated
1959	1	3880	1729	1950	1286	970	526	14400	11969	18.46	17.52
	5	3190	1524	1610	1070	796	396	11200	9420	17.23	16.51
	20	2490	1340	1260	833	628	298	8060	7299	15.85	1545
1956	1	9810	2720	7250	6733	4670	1486	14400	8959	18.46.	16.30
	5	7272	1860	5120	2650	3390	650	11200	7407	17.23	15.56
	20	4950	1480	3240	1635	2220	504	8060	6250	15.85	14.80

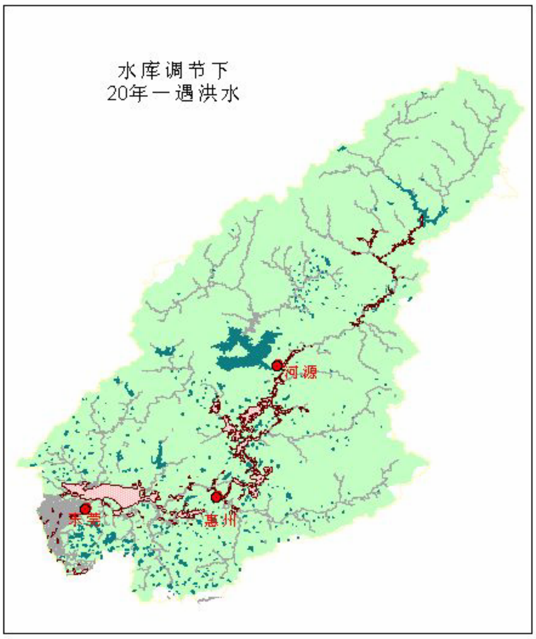
Combining previous operation, reservoir regulation can be estimated as follows: 5-year return period flood can be regulated as regular flood, inundated area calculation is no required; for larger floods occurrence, flood peak discharge at Longchuan Station can be reduced about 2000-3000 m^3/s regulated by Fengshuba Reservoir, the discharge at Heyuan Station can reduce 3000-4000 m^3/s regulated by Xinfengjiang Reservoir. For water level at each station downstream of Heyuan can be decided by average previous water level after integrated operation (Chen & Lin, 1997).

Based on the hydrological characteristics of floods after reservoirs built, the value of floods characteristics have been calculated and its results have been listed in Table 6.5. Take Buolou Station as example, by reservoir regulation, for the 100-year return period flood ,discharge of 14400 m^3/s can be reduced to 10400 m^3/s; for the 50-year return period flood, discharge of 1300m^3/s can be reduced to 9500m^3/s; for 20-year return period flood, discharge of 11200m^3/s can be reduced to 8400 m^3/s, water level corresponding to each flood can be decreased 12.1m, 11.3m and 10.5m respectively. According to characteristics of floods and combining topographical data, the inundated area caused by flood regulated is obtained, the results is listed in Fig. 6.3. It can be found that although the inundated area is decreased, but the zoning of high flood –prone is still in the middle and lower reaches and delta region of the river.

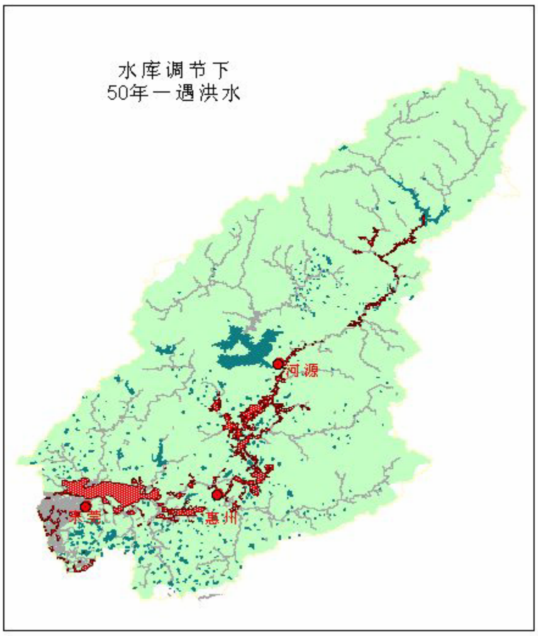
Table 6.5 Characteristics of floods after reservoir regulation

Frequency (%)	Longchuan station		Heyuan Station		Lingxia Station		Buolou Station	
	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)
1	6900	72.0	7500	39.4	8500	21.3	10400	12.1
2	6100	71.6	6900	39.0	7800	20.8	9500	11.3
5	4800	70.8	5800	38.2	7000	20.3	8400	10.5

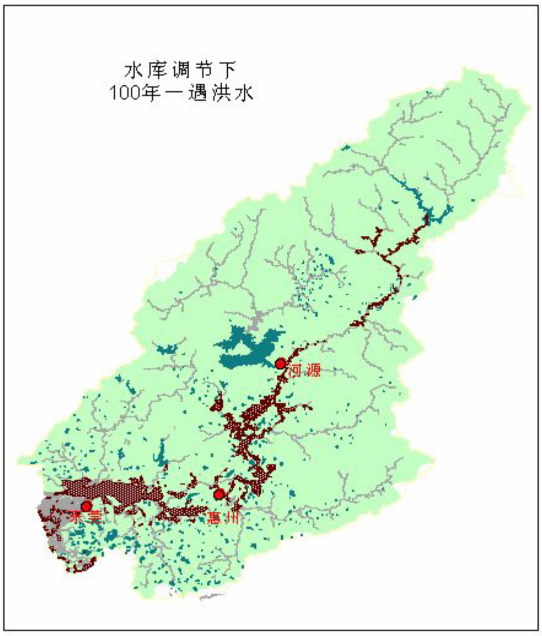
Overlap inundated areas before and after reservoir regulation for different level floods, the flood control benefits contributed by reservoirs can be observed obviously. In dealing with data, flood discharge and water level after regulated by reservoir have been returned to the situation without reservoir, than compare the discharge and water level returned with that of the same flood level without reservoir, the results of which is illustrated in Fig. 6.4. It can be seen from Fig.6.4 that the inundated area is reduced for different floods coming from the basin and the reduced inundated area manly concentrates in the downstream and estuary region of the East River.



(a) 20-year return period flood



(b) 50-year return period flood



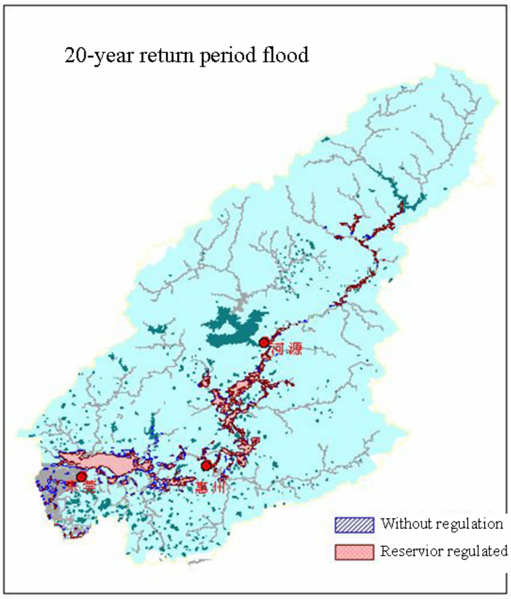
(c) 100-year return period flood

Fig. 6.3 Inundated area of different level floods after reservoirs regulation

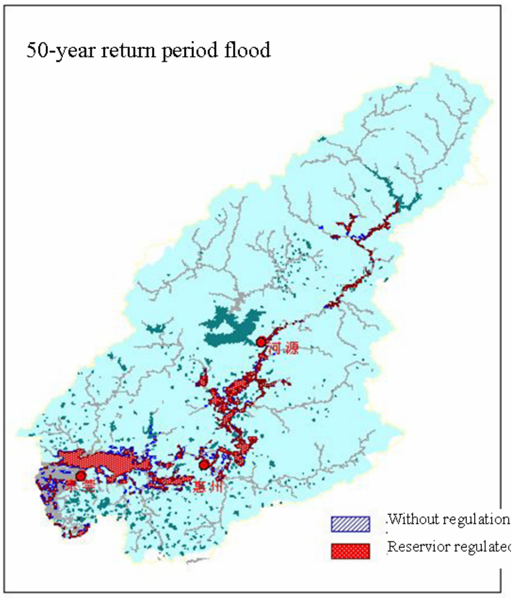
According to the information provided by Fig. 6.4, flood control benefits have been calculated listed in Table 6.6. The figures in the table indicate that the zoning of flood -prone along the main river is greatly reduced by reservoir integrated operation. For 20-year return period flood, 50-year return period flood and 100-year return period flood, the area of 259 km^2, 319 km^2 and 378 km^2 can get rid of inundation respectively.

Table 6.6 Flood control benefit contributed by reservoirs of the East River Basin

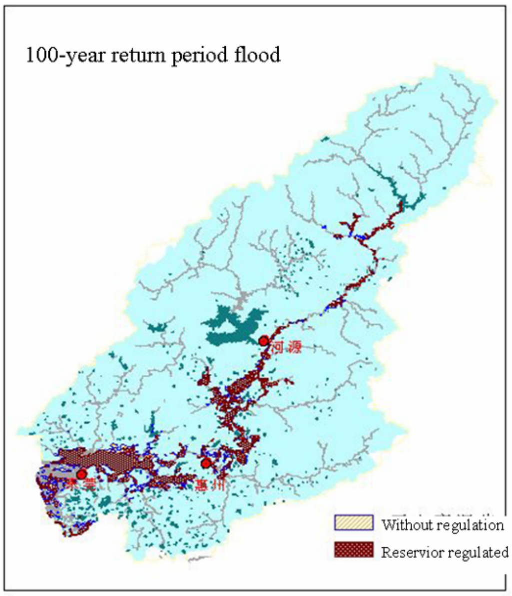
Frequency %	Inundated area (km^2)		Ratio of inundated area and total basin area (%)	
	No reservoir	Reservoir regulation	No reservoir	Reservoir regulation
1	1499	1121	4.36	3.26
2	1336	1017	3.88	2.96
5	1119	860	3.25	2.50



(a) 20-year return period flood



(b) 50-year return period flood



(c) 100-year return period flood

Fig. 6.4 Flood control benefit of reservoirs

7. WATER RESOURCES AND WATER ENVIRONMENT

The source of the East River is located to the south of Ganzhou city, Jiangxi Province. Two small rivers, Xunwu River in Xunwu County and Beiling River in Anyuan and Dingnan Counties are the main water source. The ecological environment of the river source area of the East River is important not only for the three counties, but also for the river basin and water supply to Hong Kong. The exploitation of water resources in the East River Basin must be considered in terms of the whole basin and the water in the Xinfengjiang Reservoir (which affects the middle and lower reaches of the East River) must be protected properly, thus the quantity and quality of the main river can be guaranteed. The water quality of the main river is Grade I above Heyuan, Grade II from Heyuan to Shilong, and Grade II or III below Shilong. There are more than 30 waterworks and 7 large water diversion works along the main river course. The water in the major tributaries in the southern region of the East River Basin, e.g. the Danshui and Guanlan Rivers has been seriously polluted, which eventually flow into the main river. Therefore, the water quality of the middle and lower reaches of the East River should be worried.

The followings are the features of the water environment of the East River Valley, summarized by Yuan Jishen (1999). (1) The principal pollutants are organic matters (COD first and volatilized phenol second) and waste water containing Cr, the former mainly comes from surface pollution and the latter from point pollution. (2) Seasonal variation of pollution is obvious, the organic matter pollution is more serious in flood seasons and the heavy metals pollution is more serious in dry seasons. (3) Pollution by Cr^{6+} has been getting worse yearly, pollution by volatilized phenol is not so stable with large amplitude, and the concentrations of other pollutants are stable. (4) The water quality in the upper and middle reaches is Grade I or II, the water quality in the main river is basically good. (5) With the increase in population and development in economy, water pollution in the East Rive will be aggravated.

7.1 Situation of Water Environment

The water environment is analyzed based on the *Surface Water Environmental Quality Standards* (GB3838-2002) of China. Table 7.1 shows several indexes of the Standard.

Table 7.1 Selected values of the *Surface Water Environmental Quality Standards* (GB3838-2002) of China

Item	Grade I	Grade II	Grade III	Grade IV	Grade V
PH value	6-9	6-9	6-9	6-9	6-9
DO ≥	7.5	6	5	3	2
KM_NO_4 ≤	2	4	6	10	15
COD≤	15	15	20	30	40
BOD_5≤	3	3	4	6	10
NH_3-N≤	0.015	0.5	1.0	1.5	2.0
P total≤	0.02	0.1	0.2	0.3	0.4
N_2 total≤	0.2	0.5	1.0	1.5	2.0
Cu(ug/L)≤	10	1000	1000	1000	1000
Zn(ug/L)≤	50	1000	1000	2000	2000
As(ug/L)≤	50	50	50	100	100
Hg(ug/L)≤	0.05	0.05	0.1	1	1
Cd(ug/L)≤	1	5	5	5	10
Cr^{6+}(ug/L)≤	10	50	50	50	100
Pb(ug/L)≤	10	10	50	50	100

7.1.1 Present situation of water environment

In July 2005, we organized a survey on the present situation of water environment of the East River. Water samples were collected at the locations shown in Fig. 7.1, which were almost located in the whole basin. In the past the river source area was not included in sample collecting. Through the survey a comprehensive understanding of the present situation has been gained. Just before the survey a basin-wide big flood took place at the end of June.

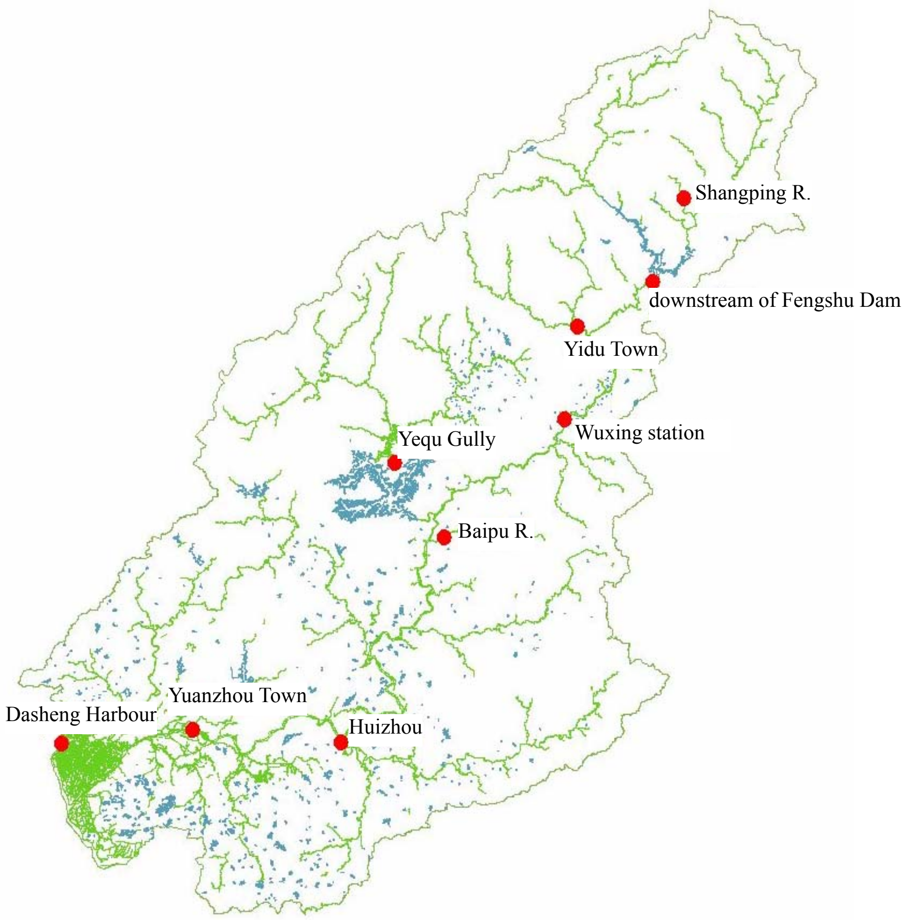


Fig. 7.1 Location of water sample collecting

Fig. 7.2 shows the longitudinal distribution of contents of N_2, P and Cl at several stations. As for NH_4^+-N the values at Wuxing and Yuanzhou were low, 0.85mg/L and 1.2 mg/L respectively; the values at other stations were over 2.0 mg/L, the highest was 6.68 mg/L at Huizhou Xizhi River. For NO_3^--N the highest was 1.08 mg/L at Dasheng Harbour and the lowest was almost zero at Huizhou Shizhi River. If adopting the sum of NH_4^+-N and NO_3^- -N as the total N the results are shown in Fig. 7.3. The highest was 6.68 mg/L at Huizhou Xizhi River and the lowest was 1.48 mg/L at Wuxing. Along the main river the content of NH_4^+-N was 0.85mg/L in the upper reaches and 2.86 mg/L near the river mouth, a gradual longitudinal increase in N and worsening in water quality.

As for Cl a longitudinal increase is obvious except Station downstream of the Fengshu Dam in the river source area, as shown in Fig. 7.2.

As for PO_4^{-3}-P the highest value, about 0.09 mg/L, appeared at Station 5, which is on a small tributary of Xinfeng River, a tributary of the East River and the lowest, 0.046 mg/L, at Yidu Town.

Based on Figs. 7.2 and 7.3 in the flood season the water quality of the main river was better than that of the tributaries and that in the upper reaches better than that of the lower reaches. In the flood season the content of total N in the river source area was high due to the surface pollution of agriculture.

As for Cr the values at Stations 2, 6, 8 and 9 were the highest (in the range of 1.57-1.97 ug/L), but still much lower than the standard of Grade I (10 ug/L). As for Cu its values were low, the highest (5.29 ug/L) was at Station 9, still lower than the Standard of Grade I (10 ug/L). As for Zn the highest (14 ug/L) was at Station 4, still much lower than the standard of Grade (50 ug/L) As for Pb the highest (1.48 ug/L) was at Station 5, lower than the standard of Grade I (10ug/L). As for As the highest (1.05ug/L) was at Station 7, much lower than the standard of Grade I (50ug/L). The content of Hg in the East River was high; it was higher than the standard of Grade III at Stations 6, 8 and 9 and it was higher than the standard of Grade II at the other stations.

Compared with Table 7.1 the contents of heavy metals in the East River were at Grade I of the standard except the content of Hg, which was at Grade III or IV, even V.

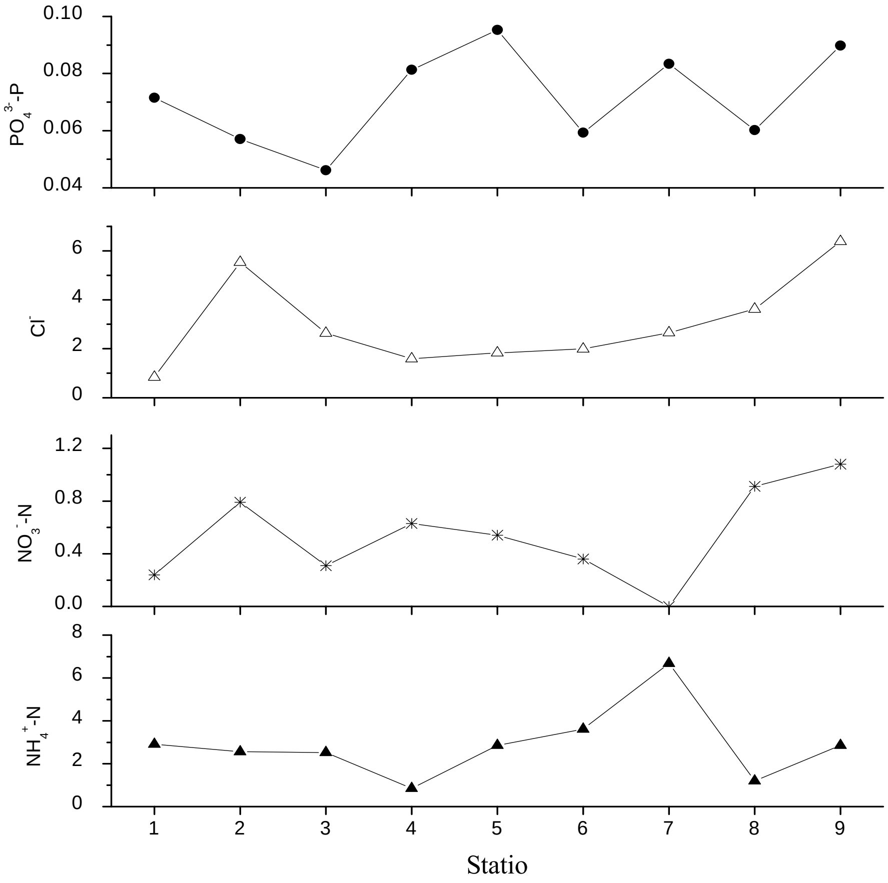


Fig. 7.2 Longitudinal distribution of contents of N, P, and Cl
Stations: 1.Shangping River, 2. downstream of the Fengshu Dam, 3. Yidu Town, 4. Wuxing Station on Helong Highway 5. Yequ Gully, 6. Baipu River, 7. Xizhi River at Huizhou, 8. Yuanzhou Town, 9. Dasheng Harbour.

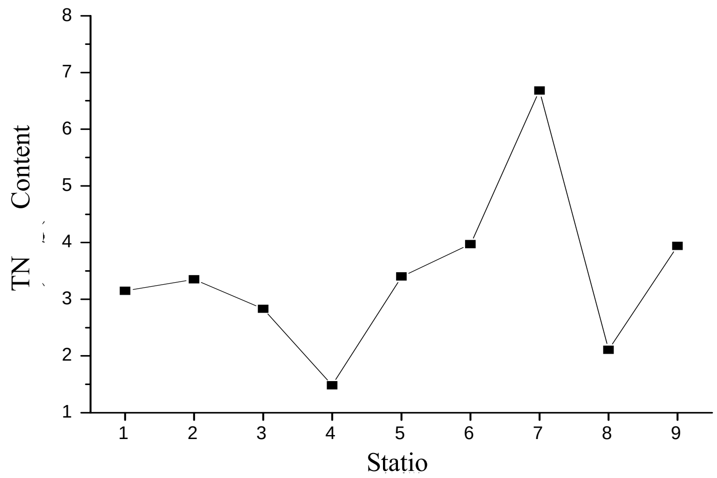


Fig. 7.3 Content of total N in June 2005
Stations: 1.Shangping River, 2. downstream of the Fengshu Dam, 3. Yidu Town, 4. Wuxing Station on Helong Highway 5. Yequ Gully, 6. Baipu River, 7. Xizhi River at Huizhou, 8. Yuanzhou Town, 9. Dasheng Harbour.

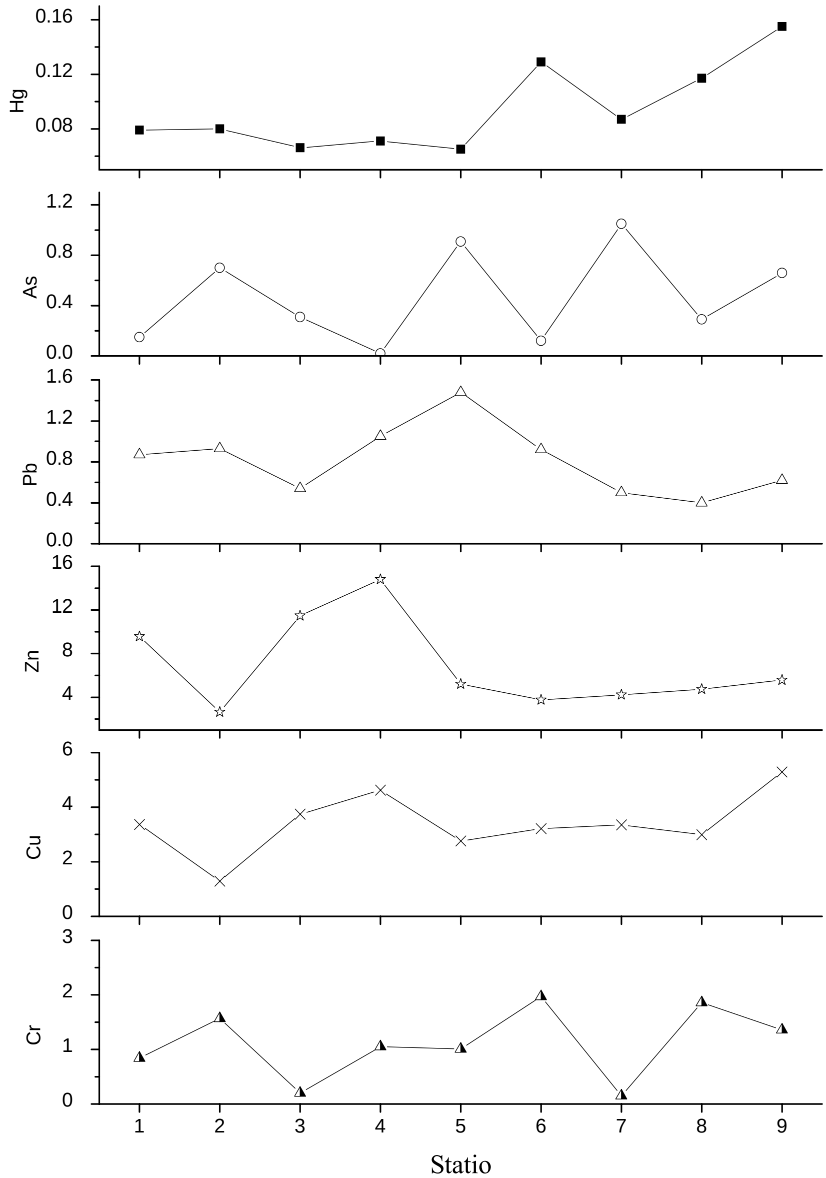


Fig. 7.4 Longitudinal distribution of contents of heavy metals in East River
Stations: 1.Shangping River, 2. downstream of the Fengshu Dam, 3. Yidu Town, 4. Wuxing Station on Helong Highway 5. Yequ Gully, 6. Baipu River, 7. Xizhi River at Huizhou, 8. Yuanzhou Town, 9. Dasheng Harbour.

7.1.2. Change of water environment in the source of the East River

The source of the East River is located in the poor area constrained by prominent problems of population, natural resources and environment etc. With the economical development, population growth, rapid process of urbanization and upgrading consuming standard, the demand of water resources and water quality is getting higher and higher. At present, the population there reaches 0.81 million, 6.8% exceeding that in 1998. The amount of the discharged domestic sewage is 296 million t, 5.89% exceeding that in 1998. The amount of pesticide usage is 106.35 kg/hm^2, 37.6% exceeding the average level of the whole Jiangxi Province. The amount of chemical fertilizer usage is 726 kg/hm^2, 60.58% and 53.77% exceeding the average level of the whole Jiangxi province and Ganzhou City respectively .The quantity of pesticide lost was 64.8 t in 2000, 63.2% exceeding that in 1999. The quantity of fertilizer lost was 21809 t in 2000, 3.41% exceeding that in 1999 (Zhang, 2000).

Seventeen indexes of pollutants have been monitored at Xunwu and Beiling rivers, it indicates that PH, hardness, volatile phenolic compounds, Cyanide, Hg, As, Cr^{6+} ,F, Cd ,Pb, Zn, Cu, $KMnO_4$, NH_4^+-N, NO_3^--N, NO_2^-N and SS are all meet the requriemnts of Grade I of the *Surface Water Environmental Quality Standards* (GB3838-2002) of China, which conform to the state standard of water utilization and protection in river source area. But, with social and economical development, especially irrational utilization of resources, the situation of water environment quality exhibits the degrading trend. Between 1999 and 2000, some monitored items exceeded Grade III at Beiling River. Coliform group was found much higher than the drinking water standards at upstream of Mati River and middle stream of Xunwu River in 2000, and the As concentration in the river nearby the water plant of Xunwu County was found 10 times higher than the standards. Hence, it is need to strength ecological environmental protection in the water source area urgently (Hu and Xiong, 2004).

7.1.3 Change of water environment in upper reach of the East River

From the change of NH_4^+-N and NO_3^--N content in the upper reach of the East river, it can been seen that N content have been increasing greatly since 1990, it means that water quality has been getting worse recently.

The change of N content in flood season in upstream of the East River is plotted by using the data from Jin et al.(2000) (Fig.7.5). As to the content of NH^+4-N, it was increasing about 4 times from 0.19 mg/L in 1995 to 0.85 mg/L in 2005. It expresses that the increasing trend of $NH4^+$ -N has emerged since 1990s. $NO3^-$N content has higher value also, which was 0.57 mg/L and 0.69 mg/L in 1994 and 1995 respectively, although, it reduced to 0.32mg/L in 1997; but it increased to 0.63 m g/L again in 2005.

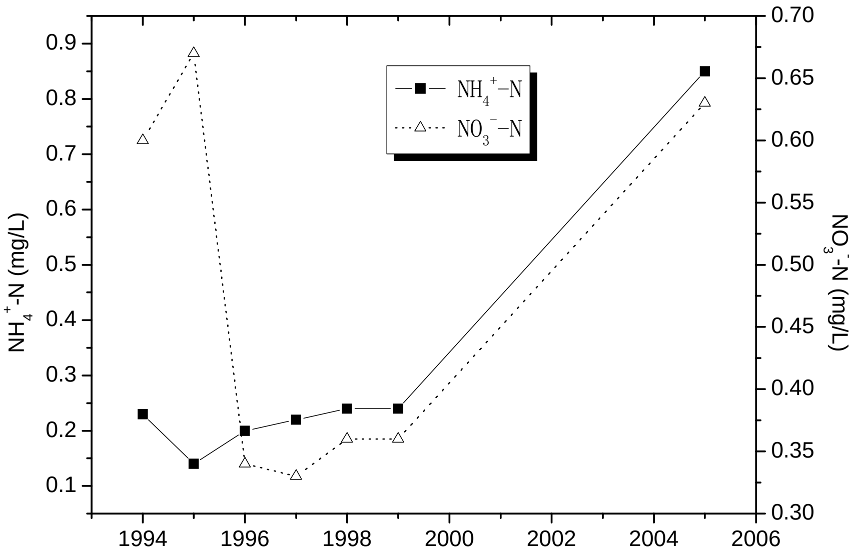


Fig.7.5 Change of N content in flood season at Heyuan Station, upper reach of the East River

Fig.7.6 demonstrates the variation of Cr^{6+} and As content with time in upstream of the East River. Curves in the Fig.7.6 indicate that both of Cr^{6+} and As content were keeping stable in 1990s. They reduced greatly in 2005 compare to that in 1990s. The fact has proved that the policy to protect water quality for upstream of the East River made by the related authorities and implemented strictly has obtained good achievement. At the same time, compare to the State Standard of Surface Water Environment Quality, both Cr^6 and As content are far less than the standard of grade I (Cr^6 10 ug/L and As 50 ug/L), it means that where the heavy metal content is less and conforms to the standard of grade I.

7.1.4. Change trend of water quality in middle reach of the East River

Fig.7.7 shows the change trend of COD in the main river of middle reach of the East River, the curve in Fig.7.7 illustrates that where COD is lower, even less than the standard of grade I (15mg/L) In 1980s, COD was keeping at the lower level. But the situation was changed in 1990s, especially , it increased abruptly to 3.6 mg/L and 3.15 mg/L in 1996 and 1997 respectively. It means that water quality was getting worse in the middle of 1990s, but it has decreased at lower level continuously after 1997.

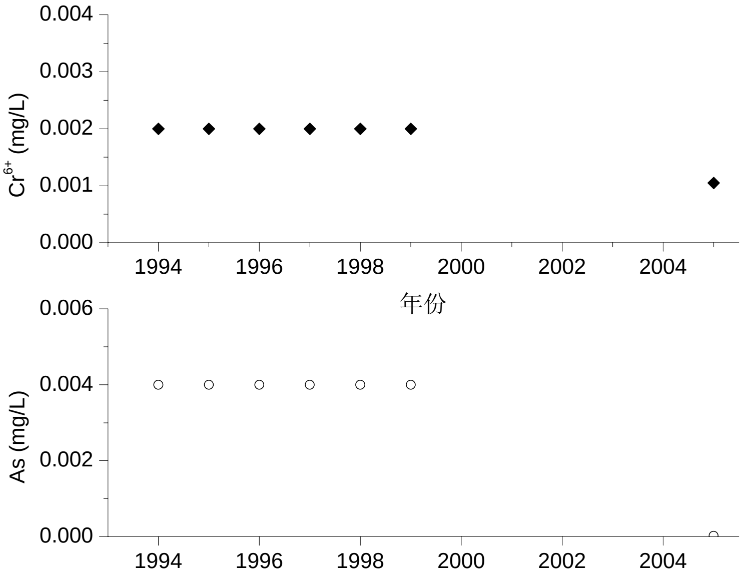


Fig.7.6 Change of Cr^{6+} and As content in flood season at Heyuan Station upstream of the East River.

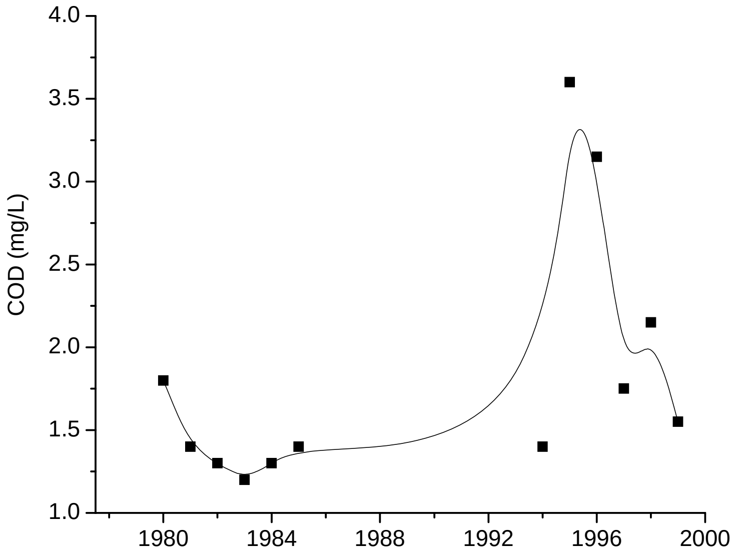


Fig.7.7 Change of COD in the main river of middle reach of the East River

Curves in Fig. 7.8 describe the change of heavy metal content in the main river of middle reach of the East River. It illustrates that Cr^{6+}, Hg, and As are varying in the range of 1-24ug/L, 0-0.55 ug/L, and 0-0.13 ug/L in order respectively. It also shows that heavy metal content was changed greatly in 1980s, and has getting stable since 1990s. At the same time, heavy metal content in 1990s was lower than that in 1980s slightly. Data of water and sediment of the river analyzed by Ho et al (2001), it found that water in the river have been polluted slightly by Cu, Pb, PCBs, PAHs and HCHs. But serious pollution has been found near Huizhou City. It reflects the situation that the worse trend of the water quality in middle reach of the river has emerged recently. Cr^{6+} content reached 24ug/L in some years over the standard of grade I and degraded to the standard of grade II; As to As content, it was low, even lower than the standard of grade I; Hg content reached 0.55ug/L over the standard of III in some years. Therefore, among them Hg was higher, the others was in the margin of the standard of grade I.

7.1.5 The changing trend of water quality in downstream of the East River

Downstream and delta region of the river is the most prosperous area with fast developed economy of the basin. Fig.7.9 reflects the change of N content in the main river downstream of the river. The NO_3-N content abruptly increased up to 7.06 mg/L in 2004. For other years, it kept round 0.4mg/L except that was 2.54 mg/L in 1996. The NH_4^+-N content varied in the range of 0.30-0.50 mg/L during 1994-2004, but it increased to 1.20 mg/L in 2005 suddenly, which increased more 3-4 times than before. It means that before 2004, water quality in downstream of Dongguan reached the standard of grade II-III, but it has degraded to the standard of grade IV in recent years

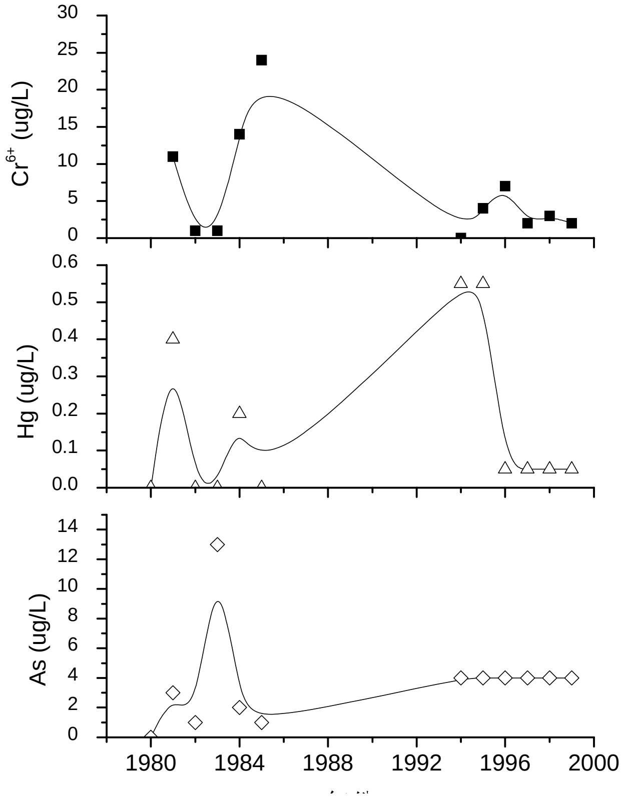


Fig. 7.8 Change of heavy metal content in the main river of middle reach of the East River

The COD content in downstream of Dongguan reduced clearly. Fig.7.10 shows that it decreased from 5.1 mg/L in 1983 to 1.62 mg/L in 2004. But it increased in 1990, especially in 1998 it reached to 2.85 mg/L. In view of time sequence, COD content appeared decreasing trend in downstream of the river and was less than the standard of grade I.

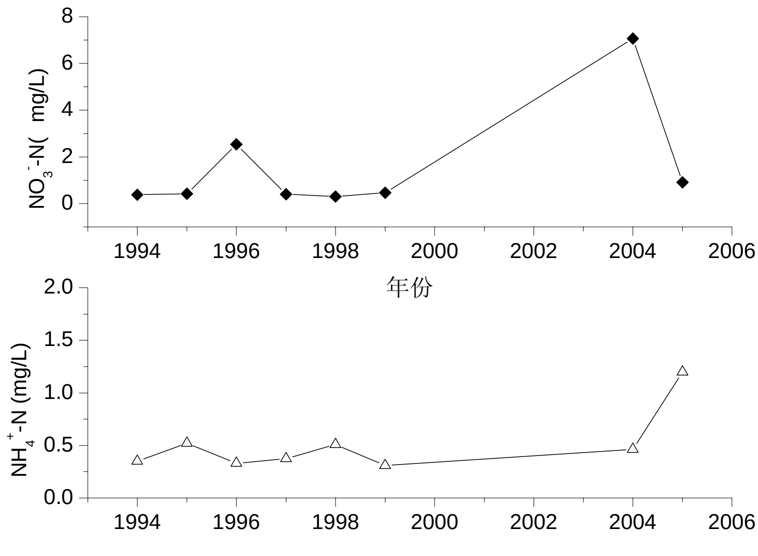


Fig.7.9 Change of N content at Dongguan Station, downstream of the East River

Fig.7.10 Change of COD in downstream of the East River

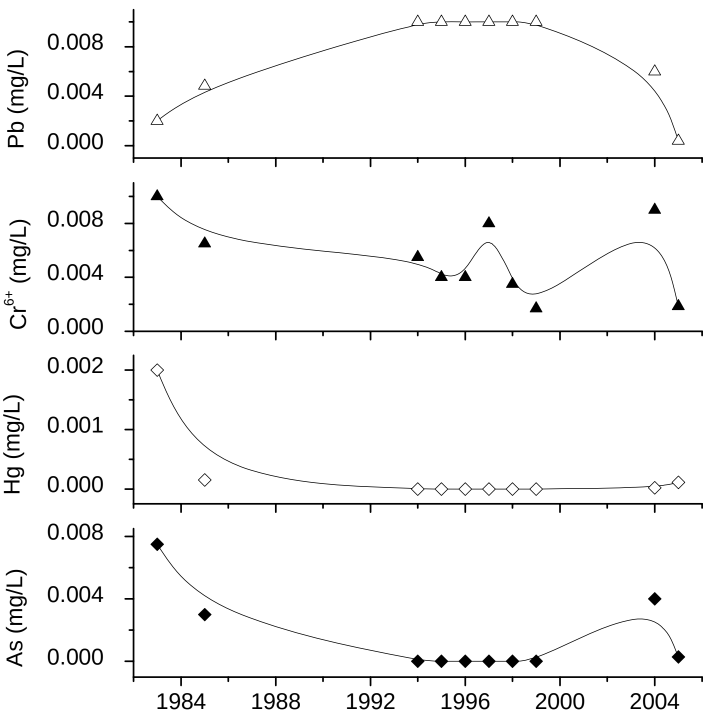


Fig.7.11 Change of heavy metal concentration in downstream of the East River

The lowest As content in downstream of the East River was near 0, while the highest value was 0.075mg/L; the Hg content varied in the range of 0-0.002mg/L, the max content was 0.002ng/L in 1983; the max content of Cr^{6+} was 0.009mg/L in 2004 which varied in the range of 0.001-0.009 mg/L; Pb varied in the range of 0.0004-0.01 mg/L. Compare the content in Fig.7.11 with the state standard of surface water quality in Table 7.1 , it is found that heavy metal content in the region is low and less than the State Stand of grade I , therefore water polluted by heavy metal in there was not serious. According to analysis by Jinhui (2001), water quality in the region reached the standard of grade II, except NH_3-N and petrol content over the state standard. From the whole view, water quality in there is getting worse.

Overview the situation of water environment quality of the river, it can be found that the river polluted by heavy metal is slight, the main pollutant is NH_3-N. Considering the fact that the East River is the main water resource and undertakes heavy responsibility to supply water to Hong Kong, Shenzhen, Dongguan, Guangzhou, and coastal region, therefore water environment quality is related to drinking water security .Undoubtedly, it should be paid great attention to the problem of water pollution caused by organic and inorganic pollutant. Cooperation between government of Hong Kong and main land should be strengthened in order to copy with the problem of water environment quality (Ho &Yan, 2003).

7.2 Water Required in the East River

7.2.1 Water Required for Ecology and Environment in the East River

Water required for ecology and environment includes water required for the zoning within the river channel and that for the zone beyond the river channel. Functions of of the ecology and environment that requires the water to maintain within the zoning of river channel are as follows: to maintain ecological environment for protecting aquatic community's habitat; self-purification; to transport sediment for maintaining the stable of river channel by equilibrium of erosion and sedimentation and to discharge necessary runoff for maintaining ecological equilibrium in estuary region. Therefore, the amount of water required within the zoning of river channel includes the water required for ecology; self-purification; sediment transportation and discharging necessary water into the sea simultaneously. As to the water required beyond the zoning of river channel is mainly for urban and rural water supply by withdrawal water from the river.

Sum up the water required for the river includes water required of ecology, self-purification, sediment transportation, and discharge runoff into the sea. For a river reach has to meet multiple purposes simultaneously, it can comply with the Maximum Principle , the maximum discharge among various water requirements can be selected as the minimum discharge of water required in order to meet various functions. As to the East River, according to its functions, water required can be classified into the following cases;

1). Water required for ecology: Among estimated methods, Montana method (Tennant, 1976) is usually adopted. The method assumes that river discharge can reflect the comprehensive characteristics of the basin including basin area, topography, climate, vegetable cover, and land utilization. Various ratio of average annual discharge is closely related to the environment quality. Therefore, a certain percentage of average annual discharge can be selected as recommended discharge of water required. Research result expresses that: 10% of average annual discharge is minimum for many aquatic community existence, 30% or more of that is safe value for aquatic community.

2). Water required for self-purification: Water required for self-purification means that a certain discharge is needed to provide the ability of diluting pollution by the river itself. In the study, the target is that water quality of the river can reach the state standard of the surface drinking water. It can be predicted by numerical simulation and field mearsurement.

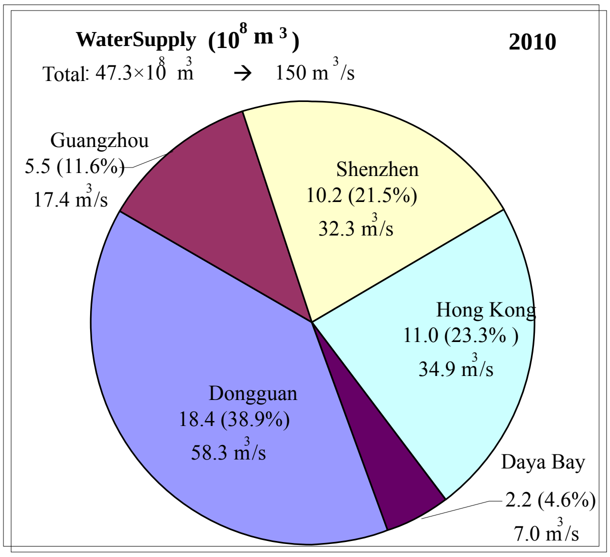


Fig. 7.12 Water withdrawals and its allocation downstream of Boluo Station of the East River

3). Water required for discharge runoff into the sea

The saline intrusion in the lower reaches of the East River became seriously in recent years, due to the runoff discharged into the see decreasing. It has brought impacts on economical development and people's daily life in the delta region downstream of Shilong. Therefore, it is needs for the river to discharge a certain amount of runoff into the sea to against the tidal flow intrusion. By analyzing data, at least 150 m^3/s discharge is needed for mitigating the impacts.

4) Urban and rural water supply: The East River is the main water resource of water supply to Hongkong, Shenzhen, Dongguan and delta region. Correspondingly, it is need that the river should have enough water to meet the requirements. Analyzing the situation of social and economical factors such as local population, and GDP increasing, the quantity of water required in downstream of the river is 4.73×10^9 m^3 converted to discharge of 150 m^3/s .

5). Water required for navigation: According to "The Plan of River Navigation Development in Guangdong Province" approved by local government of Guangdong province, RMB 5 Billion state investment is aviable for the infrastructure construction of navigable channel and should be fulfilled up to 2010, among which RMB 270 million is allocated for realignment of the navigable channel of 244 km from source of the river to estuary, RMB 150 million is expensed for realignment the river reach from the source of the river to Huizhou. After completion of those projects, the present navigable situation will be greatly improved, 500T ships will be able to pass through the navigable channel smoothly with the navigable guarantee rate P= 95%, corresponding to the river discharge is 210m^3/s.

Synthesis of the situation of the social, economical situation and population growth of the basin, the content of NH^3-N and BOD upstream of the Dongguan-shenzhen water intake has been calculated by applying mathematical model of HSPF. And refer to the standard of grade II of the water quality, the water required for self-purification has been determined.

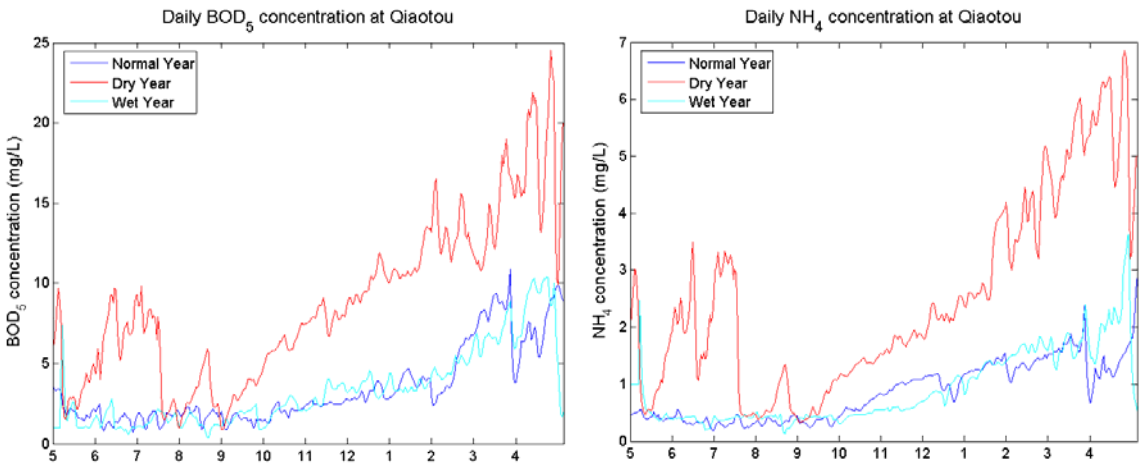


Fig.7.13 The content of $BOD_5$and NH_4 at the cross section of the Dongguan-Shenzhen water intake calculated by applying mathematical model of HSPF

Sum up the two indexes of water required in the two zones of within and beyond the river channel, the discharge of water required and its allocation for the downstream of the East River in 2010 can be obtained as follows:

Water supply: Qs = 150 m^3/s
Water required for self-purification: Q1 = 317 m^3/s
Water required for ecology: Q_2 = 76 m^3/s
Water required for navigation: Q_3 = 210 m^3/s
Water required for against saline water intrusion: Q4 =150 m^3/s

Consequently, the minimum discharge of water required withdrawal from the river can be calculated by sum up Qs and Max(Q1,Q2,Q3,Q4), which is equal to

$$150+\text{Max}(317, 76, 210, 150) = 150 + 317 = 467 \ m^3/s$$

7.2.2 Water supply security

General speaking, the East River is better one in terms of comprehensive utilization of water resources and water quality. Besides, it undertakes water supply to Heizhou, Dongguan cities for industrial, agriculture production and people's living requirements , and it also needs to supply water to Guangzhou, Shenzheng, Honhkong and Dayawan region etc. But the total volume of long term average water resource of the river is

$280x10^8$ m^3 only, among which, 224 $x10^8$ m^3 comes from April to September, about 5.6 $x10^9$ m^3 comes from October to March next year. The river basin has area of $2.82x10^4 km^2$ with $40x10^6$ populations, water resource per capita is 700 m^3 only which is less than the international evaluating standard, Obviously, The river basin is scarcity of water resources seriously

During dry season, Dongguan City is short of water 0.6 $\times10^6 m^3$ per day. Construction of water plants are accelerated by related local authorities. The second stage of The Forth Water Supply Plant has been constructed. The third stage of The Fifth Water Supply Plant is under constructing, and The Sixth Water Supply Plant is going to start soon. Up to 2015, the water supply ability required by Dongguan city will increase to 4.4 - 4.6 Million m^3/d, at that time the volume of water supply increased will be more than the total today. On the occasion, the total water supply ability will be increase to 8.68 Million m^3/d. Total volume of water required increased will withdraw water from the East River, therefore, the East River is the source of life. Shenzhen city is another big consumer of the river, at present, water withdrawal from the river is about 1.0 Billion m^3/yr and will reach 1.5 Billion m^3/yr in 2010according to plan.

At present, the rate of water resources utilization of the river is about 30%, it will be 40% up to 2010 by prediction. Compare to international practice that water withdrawal from river should be less than 20% of the total , the rate of water resource utilization should be less than 40% of the long term average discharge, obviously, it is necessary for the river to carried out research works on environment evaluation and to study on life and ecology health

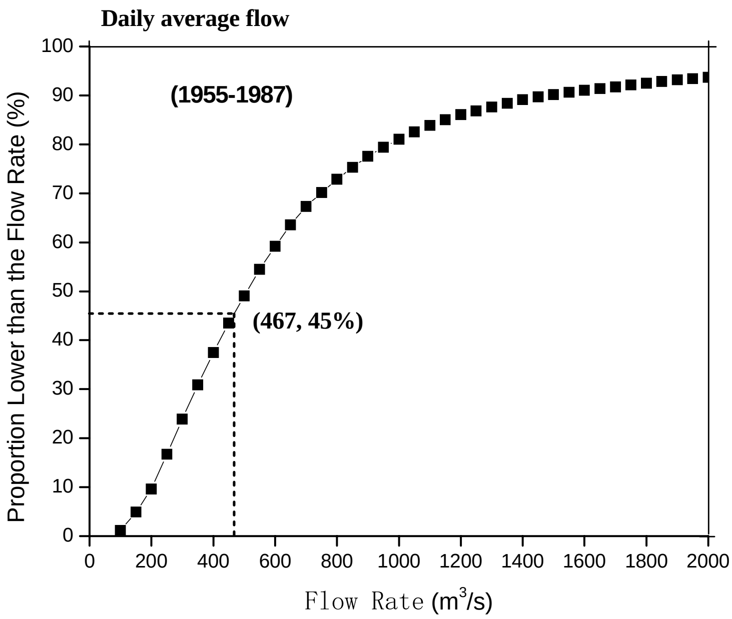


Fig. 7.14 Guarantee rate of river flow in downstream of the East River.

Fig.7.14 shows the change of flow rate with the proportion lower than the flow rate at Bolou Hydrological Station. It is obtained by data of daily average discharge measured in the duration from 1955 to1987. It exhibits that 80% of the daily flow discharge is less than 1000 m^3/s and the days of the discharge less than 467 m^3/s accounts for 45% of the total days. It expresses that the water supply security of the river will face serious situation.

8. VEGETATION DEVELOPMENT AND SOIL EROSION

8.1 Vegetation

The East River Valley is located in the subtropical monsoon climate region. The typical vegetation in this region is the subtropical evergreen broadleaf forest, which can be further divided into two groups. One is South Asia tropical evergreen broadleaf forest and the other is Middle Asia tropical evergreen broadleaf forest. The former is widely distributed in the East River Basin, which includes many types of trees, among which cassiabarktrees and evergreen chinquapins, belonging to the family of camphor trees are the principal types, the others include mulberries, madders, Japanese ardisias, legumes, and palms. When the South Asia tropical evergreen broadleaf forest was destroyed, ever green broadleaf bushes are formed. .

In 2000 the forest coverage in Guangdong Province was 56.9% (Zeng and Huang, 2001). Due to long-term effect of human activities, particularly large-scale reclamation and logging in 1950-1970, the primeval forest in the valley had been totally destroyed. The present forest was mainly afforested after 1985 (Zeng and Huang, 2001) and a part is secondary forest and secondary bushes (Huizhou Soil Conservation Station, 2001). The situation of forest in the East River Basin is similar with the whole province of Guangdong.

From May 2004 to July 2005 many field investigations of vegetation in most area of the basin were conducted. The results of the surveys are listed in Table 8.1.

Table 8.1 Situation of vegetation in East River Basin

Area	Forest coverage (%)	Vegetation coverage (%)	Arbor coverage (%)	Height of vegetation (m)
Dongguan	33.33			
Huizhou	59.9	69.34	58.08	1.46
Huizhou-Heyuan		64.32	38.53	1.34
Heyuan	72	68.32	36.98	1.98
Yequ Gully		82.22	66.11	2.31
Wanlu Lake	98.8	96.67	96.67	3.38
Heyuan-Baipuhe		50.40	16.11	1.01
Heyuan-Longchuan		65.43	45.54	1.59
Longchuan	71.3			
Heping	71.8			
Longchuan-Heping		65.75	29.97	1.37
Longchuan-Shangping		69.88	36.20	1.49
Longchuan-Fengshuba		70.68	36.8	1.52
Fengshuba-Shangping		69.31	37.05	1.52
Xunwu	78			

In Table 8.1 the data of forest coverage were downloaded from a network (the 2004 value) and the other three values were measured from the photos taken during the field investigation.

The height of vegetation is defined as follows.

$$H_v = V_t x H_t + V_s x H_s + V_g x H_g \quad (8.1)$$

in which H_v is the height of vegetation, V_t, V_s, and V_g are the average height of arbors, bushes and herbs, respectively; H_t, H_s, and H_g are the coverage in percentage of arbors, bushes, and herbs, respectively. H_v is an index reflecting the condition of vegetation growth and its function; the larger the value of H_v, the larger the biological volume of the vegetation. Trees with large value of H_v are inclined to be arbors and have good function in soil conservation. Generally, the value of H_v of dense arbor forest is larger than 2 m, it is between 1.0 and 2.0 for dense bushes, and it is smaller than 1.0 m for grassland and wasteland.

In Table 8.1 the values of arbor covers measured from the photos are much smaller than that from the internet except Huizhou and Wanlu Lake (Xinfengjiang Reservoir); the values of vegetation coverages are a little bit smaller than that from the internet. The reasons may be as follows. The data from the internet include all kinds of trees, but the data taken from the photos only include arbors; the surveys were conducted along roads in the areas with intensive human activities; plain areas were not included in data analysis.

The vegetation coverage in the surveyed area was more than 65% except Heyuan-Baipuhe area (50.40%), where human activities, such as road construction, were intensive. The vegetation coverages in the areas of Wanlu Lake and Yequ Gully were high (96.67% and 82.22%, respectively). During survey storms occurred in the area of Yequ Gully, resulted in slope sliding and caving along the road, thus the vegetation coveratge was slightly reduced. The arbor coverages were about 30% to 40% and the heights of vegetation were 1.3 m to 2.0 m in most areas except Wanlu Lake and Yequ Gully areas with larger values. This is accordance with the real situation of the East River Basin. Most trees in the basin were afforested after 1985; therefore, the arbor cover was low and the height of vegetation was low.

8.2 Study on the Zone of Typical Watershed of the East River

Experiment on selection of tree species for soil and water conservation was performed at the Sanjiaolou village, Fengnian district, Longchuan County, where has the same climate and the purple red soil area. Nitrogen fixing plans such as *Acacia cunninghamia*, *Acacia holosericea* and *Acacia auriculaeformis* etc are selected as pioneer tree species for soil and water conservation forest in the purple red soil serious eroded area; the slow-growing tree species such as *CastanopsishystrLv*, *Ormosia pinnata* etc. are selected as partner of the pioneer trees; under the condition of applying fertilizer, the fast-growing species such as *Eucalyptus urophylla* and *Tristania conferta* are also selected as pioneer tree. Under the technical guidance, the mode of vegetation community consisting of pioneer trees, slow-growing trees and fast-growing trees and integrating arbor, shrub and grasses has been built, and has brought good achievement for soil and water conservation (Yang et al. 2001; Wang et al., 2004).

Shangyang Experiment Station, one of Huizhou Water and Soil Conservation Stations, is located at the range of the east longitude of 114°28′36″ to 114°29′41″ and the north latitude of 22°45′29″ to 22°46′03″, southeast of Danshui township, Huiyang County, near Dayawan developing area. Owing to the long term damaged by human activities, especially, deforestation for fuel in 1960s and 1970s, consequently, hundreds square kilometers of the hilly area from Huizhou to Aotou became into Barren Mountain covered by red soil, resulted in serious soil and water loss. For reforestation and harnessing soil and water loss, Shangyang was selected as experimental zone and Sahngyang Experimental Station of Soil and Water Conservation was set up by Bureau of Water Resources and Hydroelectric Power of Huizhou City in 1977. A series of soil and water conservation measures have been tested by Sangyang Station. First of all, it started to build engineering projects such as check dams, water ponds and dykes for storage water, than study on breeding nurse trees, planting and cultivating trees were performed. Through trial and error, the pioneer tree species such as *Acacia auricutaeformis* and *Acacia confusa* was bred successfully at last. Measures such as breeding nurse tree in a cup with nutrition soil, planting nurse trees in a cave for saving water and for upgrading the ability to against the adverse nature conditions as well as promoting the speed of root growing etc. have been created, Consequently, the tough problem of reforestation in the serious red soil erosion area has been solved. A series of successful experiences including breeding nurse trees, planting and cultivating trees for reforestation have been summarized. The modes of multiple species of vegetation community such as *Acacia auricutaeformis* mixed with *Pinus elliottii Engelm*, single species of *Acacia auricutaeformis*, *Acacia auricutaeformis* with *Acacia auricutaeformis* and *Eculyptus tereticornis*, as well as single species of *Acacia confusa* have been built as a model of reforestation. Based on the success of reforestation, study on planting forest and grass mixture community for soil amelioration, and introducing fruit trees as economic tree such as litchi, Longyan, Monguo and Orange etc for increase income to subsidize those projects have been developed. Up to now, the soil and water loss has been controlled and the rate reforested has been reached to 90%. Those experiences gained by Shangyang Station have been introduced to Beipengzhu Reservoir, Fengtian Water and Soil Conservation Station, Huiyang, quichang, and Xinxu etc. and has yielded good result to prevent soil and water loss in those area effectively.

8.3 Vegetation-Erosion Dynamics in the East River

Shangyang experimental research station is located in the south east of Huizhou City. The annual precipitation is 2,000 mm and annual temperature is 25^{o}C. There was high density of vegetation cover before the 1960s. In the 1970s and 1980s human activities and poor management resulted in severe deforestation and many hills became bared and the rate of soil erosion was nearly 8,000 ton/km^{2}yr. The Shangyang experimental research station was established in 1978 and experiments of reforestation were performed in the area. In selected experiment plots, trees were planted in the first 4 years and in the following years grasses, shrubs, liana and bamboos grow quickly. The vegetation develops with time and the rate of soil erosion reduces with time as shown in Fig. 8.1 a-d. An experimental plot is used as a comparison, in which no trees are planted and the plot is closed for natural development of vegetation. The variation in vegetation and erosion of the comparison plot is shown in Fig. 8.1 e-f.

The differential equations of vegetation-erosion dynamics are applied to the Huizhou area, and the parameters of *a, c, b, and f* are determined with the data from the experiment plots as follows:

$a=0.06(1/yr)$, $c=0.000005(km^2/t)$, $b=0.01(1/yr)$, $f=500\ (t/(km^2 \cdot yr^2))$ (8.2)

The vegetation and erosion chart for this area is worked out as shown in Fig. 8.2. The straight line E'=0 is steep and the Zone-C is very large. The point of the vegetation-erosion status in 1978 is in Zone-A. Planting trees and control of erosion moved the point into Zone-C. Thence, the vegetation develops automatically and the vegetation community develops from simple wood to a complex communities consist of different species, including grasses, shrubs, liana, woods and bamboos.

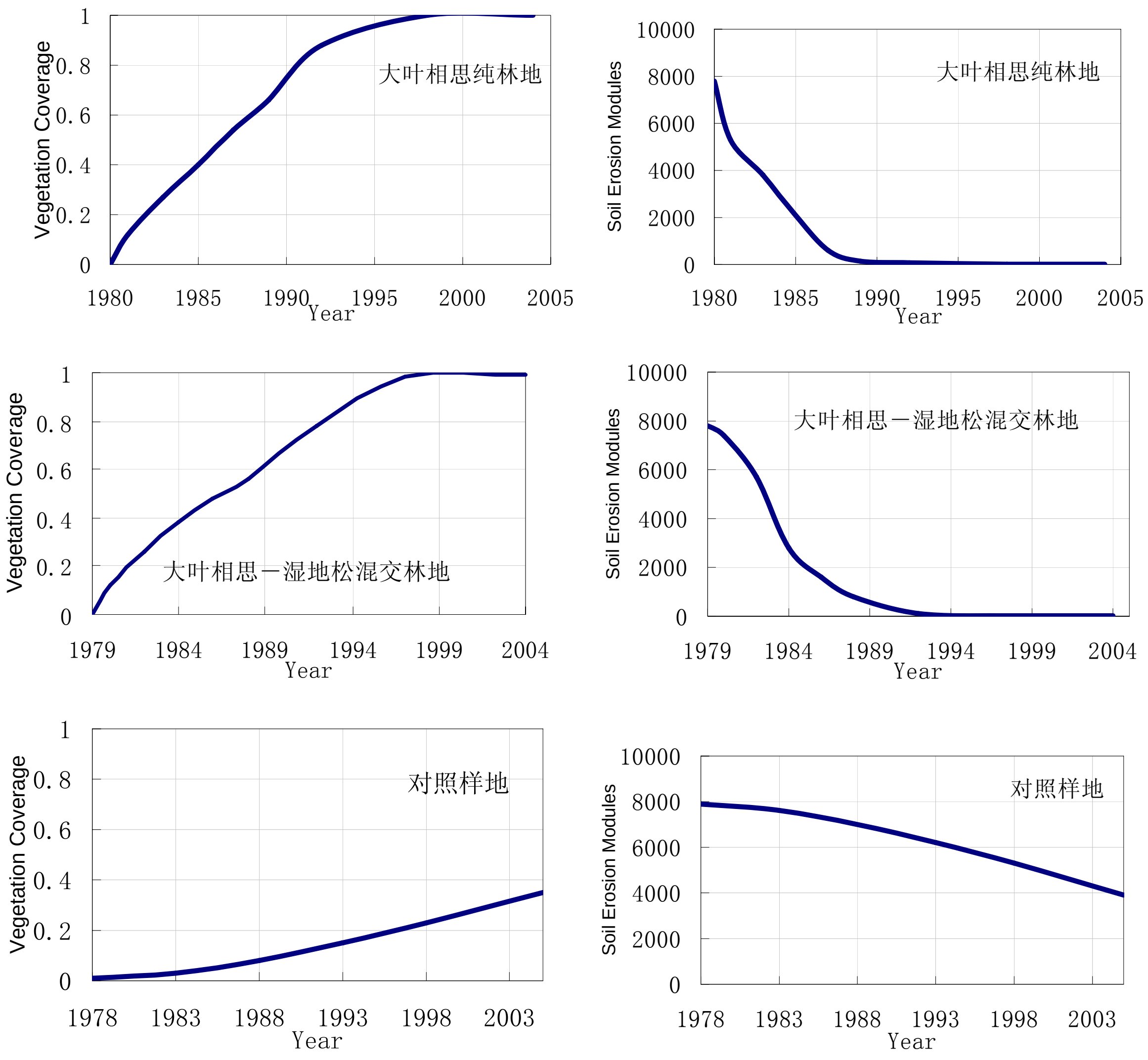


Fig. 8.1 Comparison of the vegetation development and the erosion reduction of reforested plots by planting *Acacia Auricutaeformis* (a) and (b) and *Acacia Auricutaeformis* and *Pinus elliottii Engelm* (c) and (d) with the plot, which is closed for natural development of vegetation (e) and (f) for Huizhou, Guangdong Province, south China.

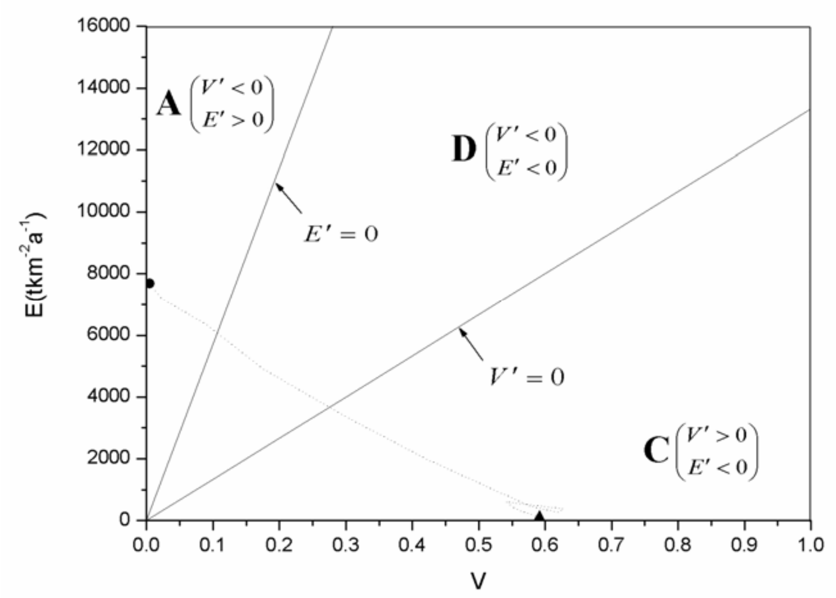
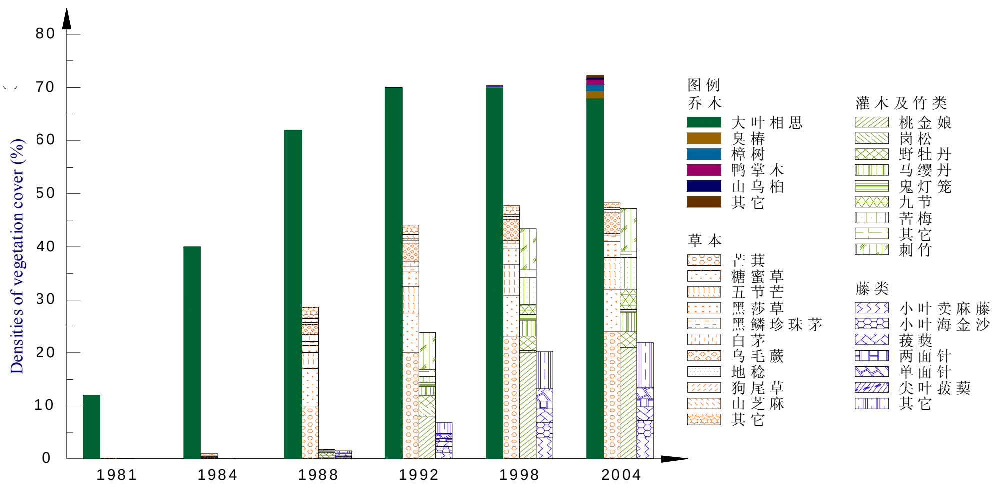


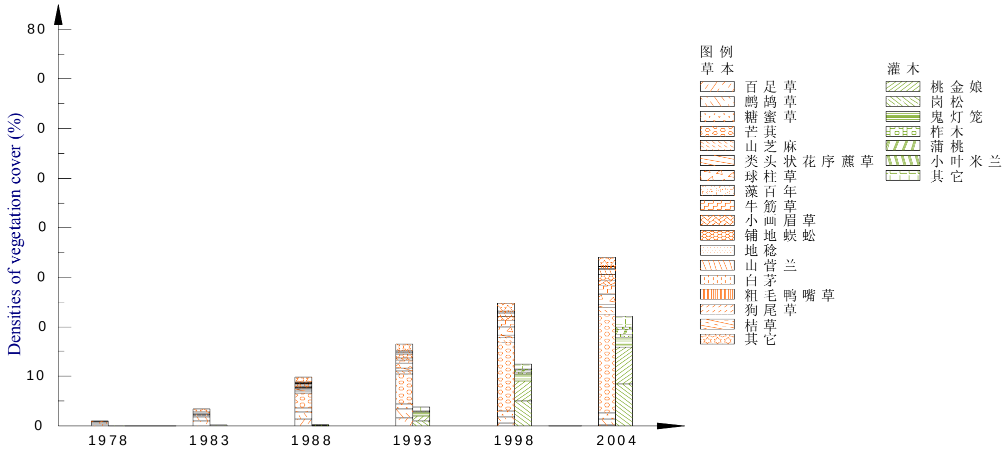
Fig. 8.2 Vegetation-erosion chart for Huizhou area in Guangdong Province, south China

The value of *a* is extremely high, which is 60 times and 2 times of the that for Anjiagou Watershed and Xiaojiang Watershed (Wang et al., 2003a, 2003b, 2003c). From Eq. (2.24) it can be calculated that the rate of vegetation development may be accelerated from dV/dt=0.002 (yr^{-1}) to dV/dt=0.014 (yr^{-1}) if the reforestation area is increased from 20% to 40% for erosion rate equals 2,000 ton/km^2yr. In other words, the rate of vegetation development may be increased by 7 times if the area of tree-planting is increased by 2 times. In general the vegetation succession from pioneer species well-adapted to bare soil and plentiful light to longer-lived species that can regenerate under more shaded and protected conditions takes about a century. Planting dominant tree species in the area accelerated the plant succession. It takes only 24 years to develop a vegetation consists of a complex plant community including long-lived wood species and grasses and shrubs which accustoms to shaded and protected conditions. The time of vegetation development is shortened by 75%.

Fig. 8.3a shows the development process of the densities of vegetation cover of woods, grasses, shrubs, liana and bamboos from 1981 to 2004. Only tree planting was performed in the beginning period from 1981-1984. In the following years, the vegetation cover and the species composition of the vegetation develop automatically. All species of shrubs, liana, bamboos and some wood species develop themselves. Fig. 8.3b shows the comparison of the closed plot, in which only herbaceous and some shrubs species, which are well-adapted to bare soil and plentiful light, have been developed.



(a)



(b)

Fig. 8.3 Comparison of the development process of vegetation cover consisting of woods, grasses, shrubs, liana and bamboos from 1981 to 2004 in the experimental plot by planting *Acacia Auricutaeformis*, which has accelerated the plant succession, with the closed plot, in which only herbaceous and some shrubs species have been developed.

Fig. 8.4 shows the pictures of the two cases, in the experimental plot the trees of Acacia Auricutaeformis have well grown and the natural species have also developed within the forest. In the comparison plot only some grasses and shrubs can grow under the conditions of bared soil and plentiful light after 24 years of closure and natural development.

Fig. 8.4 Comparison of the vegetation consisting of woods, grasses, shrubs, liana and bamboos in the experimental plot by planting Acacia Auricutaeformis with the vegetation in the closed plot consisting of only herbaceous and some shrubs species.

9. BIO-COMMUNITY

Biodiversity is the key part of the earth life supporting system and the base of human social existence and development. The 1992 United Nations Earth Summit in Rio de Janeiro defined "biodiversity" as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". This is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity.

Biodiversity, a shortened version of the term "biological diversity", can be defined simply as the variety of life and its processes. Usually it is considered in the four different levels, i.e., genetic diversity, species diversity, ecosystem diversity and landscape diversity (Forest Service, 1991). Genetic diversity refers to the variation of genes within species. Species diversity is the diversity and variation of species in a region. Ecosystem diversity denotes the diversity of habitats, communities and ecological processes within the biosphere. Ecosystem is a natural functional unit, as well as a dynamic function unit. When we talk about ecosystem diversity we generally consider its two levels, that is, communities and ecosystems. Landscape diversity means diversity and variation of different kind of sceneries in the space structure, function mechanism and time. Biodiversity is source and base of river bio-system production and bio-service. Varies of river ecosystem such as flood plain, wet land and river channel can provide not only places for biotic communities' breeding and living, but also the condition for biodiversity formation and evolution. At the same time, the river ecosystem also provides the gene storage of protecting nature high quality species and improving economic status.

River is the source of social development and the most active part of landform evolution and eco-system (Karr et al., 1986). It is widely used to evaluate river status by ecological status, because it has many advantages, of which, the first one is that ecological variation can reflect physical, chemical comprehensive impacts (Rosenberg and Resh, 1993; Reice and Wohlenberg, 1993). Species diversity can measure the complicated structure and function of biotic communities for further study the constitution, variation and development and reflect the protecting status of groups and environment. Study on biodiversity and ecosystem stability has become one of the focal points to be paid attention in the world.

Biodiversity index is expressed by integrated index which is deal with some information of group structure by mathematic model and is a simplify expression of community structure. Evaluation of biodiversity is usually expressed by the following three indexes; diversity, uniformity, and advantage (Meng et al., 2004). Shannon index and Simpson index are common used to evaluate the magnitude of biodiversity by many biologists as integrate index. Both of the species abundant and homogeneity are considered in the two indexes.

Shannon- Weiner biodiversity index is expressed as equation 9.1 as follows:

$$H = -\sum_{i=1}^{n} P_i \ln P_i \qquad (9.1)$$

in which: H is diversity index, P_i is the ratio between the number n_i of species i and the total number N of all species, that is $P_i = n_i/N$. Equation 9.1 express the species richness of a bio-community by the number of species and its relative richness. The Shannon –Weiner diversity index (H) usually is equal to 1.5-3.5, a few exceed 4. The index includes two meanings: One is diversity of species; the other is the uniformity of species. With the higher of the species number and the more uniformity of species, the diversity index is higher also.

Shannon- Weiner uniformity index is expressed by equation 9.2 as follows:

$$E = H/H_{max} \qquad (9.2)$$

in which, E is uniformity (0-1), H is Diversity index and H_{max} is Maximum biodiversity.

Let the total number of species is T, if all species exist as the same ratio (1/T), then biodiversity reaches the maximum, that is $H_{max} = lnT$; Uniformity of species in sampling site demonstrates the difference among the number of each species. Species diversity in sampling site is related to uniformity of species distribution.

Shannon- Weiner Dominant index is expressed as equation 9.3 as follows:

$$D = \ln T + \sum_{i=1}^{n} P_i \ln P_i \tag{9.3}$$

in which; D is the dominant index, T represents the total richness, that is the total number of species. Dominant index expresses the dominant species and its distribution.

The chapter is to study the vegetation development process and the changes of vegetation diversity, and to study the benthos and its diversity in the East River watershed.

9.1 Vegetation Diversity in the East River Basin

Vegetation is one of important resources, its characteristics and property can better demonstrate the nature condition of local place. The better vegetative condition is important condition to control soil erosion, to reduce soil and water loss. According to study of biology and river morphology, it shows that the riparian vegetative is important constituent part of alluvial river system. The roles are: to exert resistance on flow during flood flowing over the flood plain; to consolidate river banks by vegetative roots so that the river channel can be kept stable; to trap soil; to impact on the process of hydrodynamics by tree trunks and crotches; and to effect on river biological system and biodiversity etc (Hicken, 1984). Vegetative has been an important index to evaluate a river health.

The diversity index is an important index to evaluate the vegetative condition (Wang and Lee, 2004). The attention to evaluate vegetative status should be put on field investigation including vegetative communities, its evolving history, and present status. It is usually to consider the following three indexes including diversity index, uniformity index and dominant index. In practice, sampling site investigation method is always adopted for diversity investigation (Mao, 1998).

9.1.1 Analysis on the status of riparian vegetation in the East River basin

In the May and September of 2004 and July 2005, field investigations were made by the research groups including Prof. Zhao-Yin Wang, Dr. Cheng Liu, Dr. Dongsheng Cheng, Xiaobo Ma, Feixing Wang, Lincoln etc. Analysis on the status of riparian vegetation was mainly carried out by Dr. Xiaobo Ma. The detail of the investigation can be seen in the reference (Ma, et al. 2005).

Fig. 9.1 Field investigation on the riparian vegetation diversity in Meisizhou (May 2004)

Simeizhou is located on river branch 2 kilometer down stream of Bolou hydrological station Huizhou city shown in Fig. 9.2. The river channel is 40-50 m wide, it is straight and stable with gentle slope. In the relative stable alluvial channel, evolution of riparian vegetation is impacted by landform (Hack and Goodlett, 1960; Zimmermann and Thom,1982). Simeizhou is less impacted by human activities. The difference between elevation of low and high beaches is about 6-10 m. Low beach is submerged during flood season, high beach is only submerged during high flood coming. Plant on high beach evolves well. The clear layers of plant from high beach to low beach demonstrate the evolution status under nature condition, therefore it can represent the nature condition of the river basin.

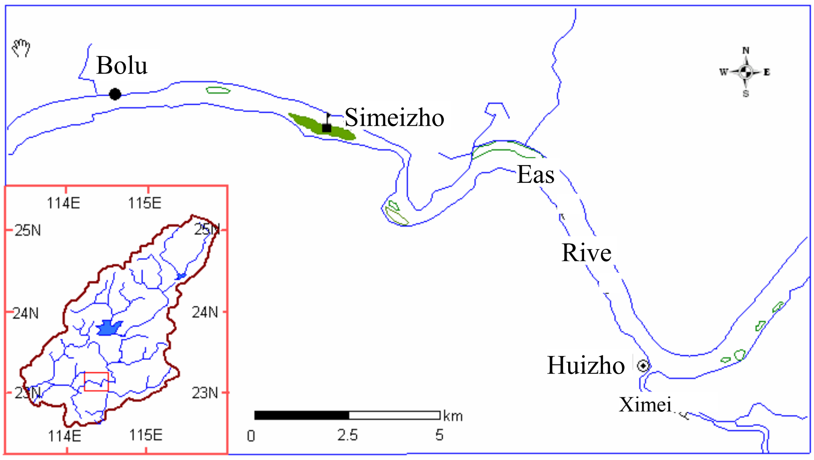


Fig. 9.2 Location map of Simeizhou

According to the distance and elevation from the river channel, diversity of riparian vegetation had been investigated for two times in May and September 2004 respectively. Seven investigating field sites are selected shown as Table 1. Among them, site No.1, 2, 3 and 4, were investigated in May, and No.5, 6 and 7,in September. The location of the sites is shown in Fig. 9.3.

Table 9.1 Location of investigating vegetative cover site in Simeizhou river banks

Plot	Area(m^2)	Elevation(m)	Distancefromriver(m)
1	5x5	5.0	10
2	5x5	5.7	25
3	7x7	10.0	35
4	10x10	12.6	60
5	1x1	5.7	29
6	1x1	5.9	32
7	5x5	10.0	37

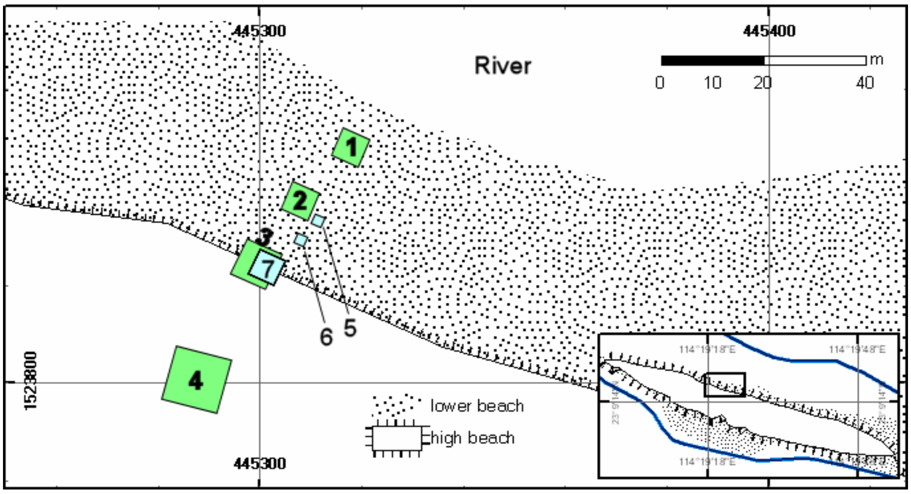


Fig. 9.3 Sketch of investigating plots for vegetative cover diversity on river banks.

Note: Plots No.1,No.2, No.3, No.4 are investigated in May 2004
Plots No.5, No.6, No.7 are investigated in September 2004

There are 14 species of herbaceous plant in sampling site No.1 includes Portulaca oleracea Linn (马齿苋), Mimosa Pudica (含羞草), Eupatorium catarium Veldkamp(假臭草), Paspalum paspaloides (Mithx.) Scribn(双穗雀稗), Borreria latifolia K.Schum(阔叶丰花草) and Rhynchospora rubra(Lour.) Mark(刺子莞) etc. There are nine species of Gramineae herb in the sampling site No.2, among them the Paspalum paspaloides (Mithx.) Scribn is the main species: For site No.3, plant species increases, but the main species is still herbaceous plant with species number of 23 which includes Solidago decurrens Lour.(一只黄花), reed(芦苇), Lonicera Macrantha Spreng.(大花忍冬), Palhinhaea cernua (L)A.Franco et Vasc(铺地蜈蚣),

Derris alborubra Hemsl.(白花鱼藤), Vigna marina (Burm.)Merr.(滨豇豆), Blechnum orientale Linn. (乌毛蕨), Paspalum paspaloides (Mithx.) Scribn and Borreria latifolia K.Schum, etc. For site No.4 shrub and arbor are the main species, with total 21 species are found include Distylium racemosum Sieb.Et Zucc(蚊惊树), Vaccinium carlesii Dunn (刺毛越橘), Symplocos cochinchinensis(Lour.) Moor(越南山矾) and Lantana camara Linn (马樱丹) etc.

Three sampling sites No.5, No.6, and No.7 are selected in September 2004. In the site No.5, there are only five species of plant with the main species of *Paspalum paspaloides (Mithx.) Scribn.* In the site No.6, six species of plant with the main species of *Panicum repens L.*(铺地黍) are found. There are 18 species are growing in site No.7 including *Panicum plicatum lamk*(狗尾巴草).

Field investigation indicates the distribution of plant on Simeizhou river banks shown in Fig. 9.4. The main species on lower beach near the river is herb. With the distance far from river, species gradually changes from herb, shrub to arbor. Different plants are growing on different landform: a certain species only can grow on a special landform such as arbor – *Distylium racemosum Sieb. Et Zucc* can grow on high beach, shrub such as *Lantana camara Linn* is found.

On high beach and lower beach where is far away from river, dry resisting grass such as *Paspalum paspaloides (Mithx.) Scrib* exist only on lower beach near river during high flood season. Some herb such as *Portulaca oleracea Linn* and *Mimosa Pudica* etc. are growing on the lower beach near river. Distribution of different plant species along river banks reflects restrained capacity of species from environment. It is the result of competition among species' and impacts each other with other index of river.

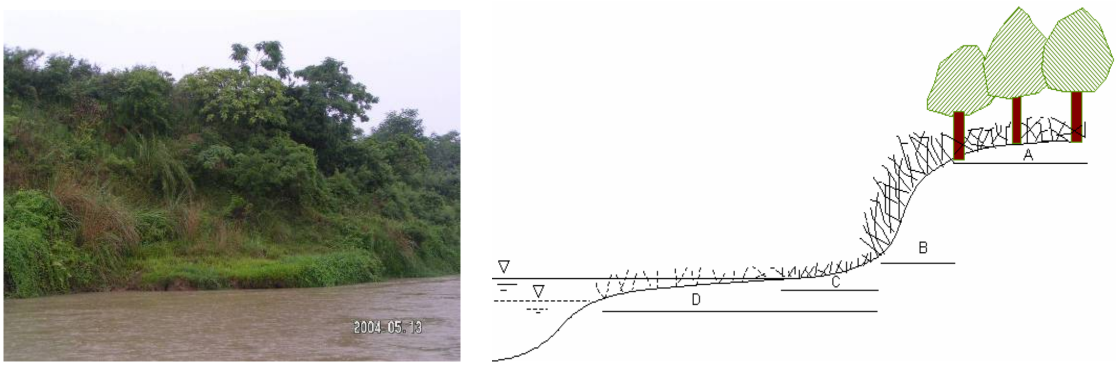


Fig. 9.4 Distribution of vegetative species along middle reach of East river bank

Because the complexity of species system e.g. the main species is shrub, arbor, or herb respectively, or all of them can exist on the same place. In the investigation, the number of plant species and their occupying space are adopted as a statistical unit and Shannon- Weiner evaluating method is used to evaluate plant diversity. Statistics is made by the number of species for sites No.1, No.2, No.5, and No.6. Both the number of species and its occupying space are used for sites No.3, No.4, No.7. The result of evaluation is listed in Table 9.2. It displays that adopting species occupying space as a statistical unit is more reasonable like the method using for No.3 and No.4. The result of evaluation is successive with the results of sites No.1 and No.2. Comparing to using the number of species as a statistical unit, the species occupying space is more reasonable, because the contribution rate of species to the stability of species system has been considered such as grass and arbor.

Table 9.2 Evaluation results of plant diversity at investigating sites

Plot	Number of species	Diversity index (H)	Uniformity index (E)	Dominant index (D)
1	14	1.01	0.14	6.0
2	9	0.90	0.50	8.67
3	23	1.95	2.56	2.09
4	21	2.23	0.40	3.29
5	5	0.11	0.07	9.11
6	6	0.13	0.07	9.10
7	18	1.74	1.19	6.01

The results of diversity, uniformity, and dominant indexes shown in Table 9.2 display that with the diversity index increase, the uniformity index increase ,but the dominant index decrease. It also shows that less species is on low beach, but dominant species is obvious such as herb *Paspalum paspaloides (Mithx.) Scribn*. Species is abundant on high beach, higher uniformity and plant species system is relative stable. The result of relative analysis between location and diversity of sites is shown as Fig. 9.5. It demonstrates that diversity of species is related with elevation, diversity index increase with elevation rising. The conclusion of evaluation for plant diversity change on Simeishou river banks is that plant changes from herb on lower beach into shrub and arbor on high beach. Diversity of plan species is related with elevation. It means that diversity index increase with elevation rising. The variation of water level is great impact on diversity of species: during flood season, abundant and uniformity decrease, but dominant species forms (the main species are herb and *Cyperaceae*).

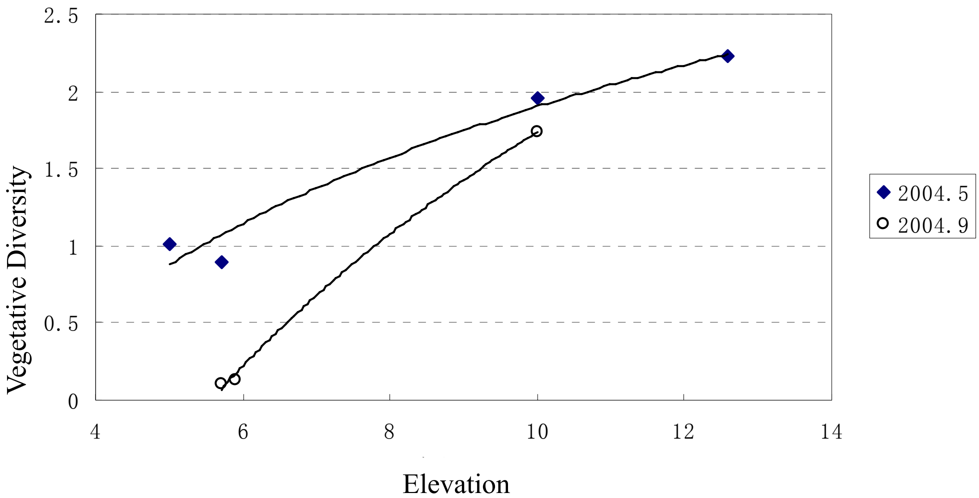


Fig. 9.5 Relation between vegetative diversity and plot elevation

9.1.2 Vegetation evolution in Shangyang Experimental Station

Due to the prolonged disturbing of human activities, in particular, hacking trees for the firewood in 1960s and 1970s, the vegetation cover on the hilly area along over 100 km from Huizhou to Aotou had been seriously destroyed. It led to heavy soil and water loss and appearance of red rock. In order to check the soil and water loss the Shangyang Experimental Station was established. A series of measurements, such as: check dames, small reservoirs, dikes and seeding forestry etc had been carried out. After several failures, according to site factors the pioneer species of tree, such as: *acacia auricutaeformis(*大叶相思*)* and *acacia confusa(*台湾相思*)* had been successfully selected in 1982. Shangyang Experiment Station summed up a series of experiences from seeding in nutritive cup to soil preparation for afforestation and brought up the afforestation modes of *acacia auriculaeformis-pinus elliottii engeim(*湿地松*)* mixed forest, *acacia auriculaeformis* pure forest, *acacia auriculaeformis-pinus elliottii* and *engeim-eucalyptus tereticornis* (小叶桉) mixed forest, and *acacia confusa* pure forest etc. The station also carried out the experiments of combining herbaceous plant and scrub. The soil and water loss in the area of this station had been checked and the greenery rate reached 90%.

In order to study the development of the vegetation cover in various afforestation modes and study its evolution process, the authors of this paper chose several blocks of typical afforestation for vegetation cover investigation.

There were two blocks of *acacia auriculaeformis* pure forest in the experimental station, dispersed in 1st and 10th blocks. The 10th block was located in the middle part of the station and was established in 1981. Its site factor was slope land of 5 degree, composed of red earth. The 1th block was located at south part of the station and established also in 1981. Its site factor was slope land, composed of red earth, some parts of which had the abrupt slope of 30 degree. The mingled forests of *acacia auriculaeformis* and *pinus elliottii engeim* were located in the 2nd, 7th and 11th blocks. The 2nd block of mingled forest of *acacia auriculaeformis* and *pinus elliottii engeimis*, located at east part of the 1th block of *acacia auriculaeformis* pure forest, was established in 1980 on the gentle slope with 6-10 degree, composed of red earth. The 7th

block of mingled forest of *acacia auriculaeformis* and pinus *elliottii engeimis*, located at east part of the 10 th *acacia auriculaeformis* pure forest, was established in 1980 on the abrupt slope of 30 degree, composed of red earth. The 11th block of mingled forest of acacia auriculaeformis and pinus elliottii engeimis, located at north part of10th acacia auriculaeformis pure forest was established in 1984 on the abrupt slope of 35 degree, composed of red earth. The burned area was a mingled(mixed) forest of *acacia auriculaeformis, pinus elliottii engeimis* and *eucalyptus tereticomis*, and partly was the mingled forest of *acacia auriculaeformis* and *pinus elliottii engelmis*. It was located at south-east part of the experimental station and at south-west part of 7 th block of *acacia auriculaeformis* and *pinus elliottii engeimis* mingled forest and was established on the slope land of 23-25 degree.

Fig. 9.6 *Acacia auriculaeformis* pure Forest (10th block)

The original site factor of 10th block of *acacia auriculaeformis* pure forest was gentle slope land, composed of red earth. In 1981 when the *acacia auriculaeformis* was planted, the slope land had been leveled into terraced field and the seeding in nutritive cup had been used for the young shoots. So, the young shoots (nursery stock) rapidly became the most heavy *acacia auriculaeformis* in the experimental station. The results of investigation showed that the *acacia auriculaeformis* could grow into a tree with its height of16-20 m, butt diameter of 25 cm and crown cover of 6-8 m^2. In addition, several plants were discovered in the forest, in which the arbors mainly were young trees and nursery stocks of *Ailanthus altissima*(臭椿), *Scheffera actinophylla* (鸭掌木)，*Cinnamomum camphora* (樟树)，*Sapium discolor*(山乌柏). The scrubs were Rhodomyrtus tomentosa *(*姚金娘)， *Melasoma candidum* (野牡丹)，*Cardiospermum halicacabum* (鬼灯笼) etc；the herbs were *Dicranopteris dichotoma (*芒其), *Miscanthus floridulus* (五节芒), *Melinis minutiflora*(糖密草), *Gahnia tristis Nees.*(黑莎草), *Scleria hookeriana Bocklr*.(黑鳞珍珠茅)；the vine were also plentiful, such as: *Lygodium japonicum（Thunb.）SW*.(海金沙), *RhizomaSmilacis Chinensis*(菝葜), *Smilax arisanensis Hay.*(尖叶菝葜), *Zanthoxylum nitidum (Roxb.) DC.*(两面针) and *Zanthoxylum nitidum*(单面针).

The slope land in 1st block was difficult to reconstruct into level terrace due to the abrupt slope of 30 degree, so, the slope land had not be leveled. The development of vegetation cover in this a*cacia auriculaeformis* pure forest showed that its height was about 16-20 m, butt diameter was about 7-23.6 cm. In addition, there were less plant species, growing under its crown cover. The arbor included domestic tress species, such as: *ailanthu saltissima(*樟树*)*, *Ailanthus altissima*(臭椿) and *Scheffera actinophylla* (鸭掌木).The majority of scrub was *Rhodomyrtus tomentosa* (姚金娘). The herbaceous plant mainly was *Dicranopteris dichotoma (*芒其) and others were *imperata cylindrica*(白茅)，*Miscanthus floridulus* (五节芒) and *Blechnum orientale Linn.* (乌毛蕨). Besides, the *Phragmites australis (Cav.) Trin. ex Steud* (芦苇) was developed on the low swampy land at foot of slope.

Fig. 9.7 *Acacia auriculaeformis* pure Forest (1st block)

Fig. 9.8 Mingled forest of *acacia auriculaeformis* and *pinus elliottii engelmis* (2nd block)

The *acacia auriculaeformis* and *pinus elliottii engeimis* mingled forest was developed in 2nd, 7th and 11 th blocks.

Because the land of gentle slope had not been leveled for afforestation and the seeding in nutritive had also not used in the 2nd block, the development of pioneer species of tree and the vegetation cover under the crown cover of *acacia auriculaeformis* and *pinus elliottii engeimis* was greatly worse than that in 10th block. In addition, the plant species,growing in the forest were less, including only some *Rhodomyrtus tomentosa (*姚金娘) and *Dicranopteris dichotoma (*芒其).Some plant species, such as *Eremochloa ophiuroides*(百足草), *Lycopodium cernnum L(.*铺地蜈蚣) and *Pratia begonifolia (Wall)Lindl.(*地埝) could be discovered on the barren slope in this block. These species rarely appeared in the forest of the experiment station, beside at the joints of small beaten paths.

The investigation point in the 7th block of the mixed forest of *acacia auriculaeformis* and *pinus elliottii engeimis* was located at the top of slope, including 2/5 of level land on the top of slope. It had the obvious characters of transition area, because *Eremochloa ophiuroides*(百足草) and positive scrub, such as *Baeckea frutescens Linn.*(岗松) and *Melasoma candidum* (野牡丹) etc. grew here, which were also usual species on the barren slope in this block. The other part of the investigation point was on the upper part of abrupt slope, where the plant species, growing situation and distribution form were the same with that on the middle part of slope. The arbor was *acacia auriculaeformis* and *pinus elliottii engeimisin*, the scrub was *Rhodomyrtus tomentosa (*姚金娘) and the herbaceous plant basically was *Dicranopteris dichotoma (*芒其).

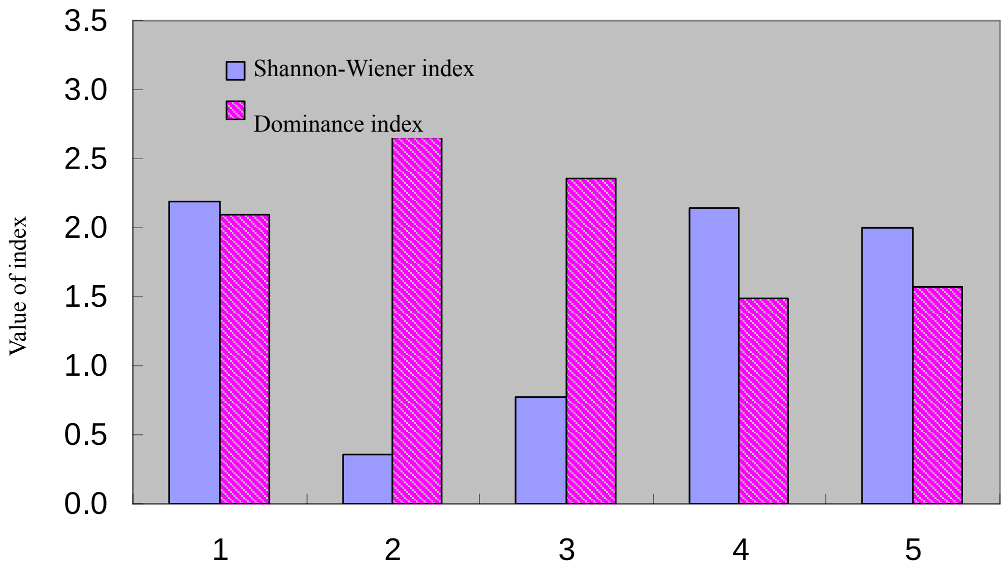
The investigation point in 11th block of mixed *acacia auriculaeformis* and *pinus elliottii engeimisin* was smaller and had narrow and long form. The lower part was connected with a pool, around which the *Eucalyptus spp, Leda,*(剥皮桉)，*Cinnamomum camphora* (樟树) were planted. The investigation site, having the area of 20m × 20m, contains the lower part of slope, so the investigation results showed that the arbor seem to grow very well. But, if the arbor, growing at the lower part was excepted, the development of *acacia auriculaeformis* and *pinus elliottii engeimisin* was worse in comparison with that in other three blocks. The *Rhodomyrtus tomentosa (*姚金娘) and *Baeckea frutescens Linn.*(岗松) developed under the mixed forest. The *Rhodomyrtus tomentosa* mainly grew at the middle and lower parts of slope. But the *Baeckea frutescens Linn.* spread at its upper part and between *Dicranopteris dichotoma (*芒其) and *Eremochloa ophiuroides* (百足草). The herbaceous plant contained *Dicranopteris dichotoma*and *Eremochloa ophiuroides*. The *Dicranopteris dichotoma* spread at middle and lower parts and grew luxuriantly. The *Eremochloa ophiuroides* mainly spread on upper part and top of slope. The mixed forest in the 11 th block was planted in1984 later than that in the 2nd and 7th blocks. The impact of human activities on it was obvious. It could be seen that part of acacia auriculaeformis and pinus elliottii engeimisin had been destroyed and some farmers cut off *Dicranopteris dichotoma* and planted *Litchi chinensis Sonn.*(荔枝) on the slope. In addition, the trace of early plant evolution process, caused by the afforestation could be seen from the top of slope to its foot. The positive plant, *Eremochloa ophiuroides,* grew at the upper part of slope, the *Baeckea frutescens Linn.*(岗松) grew at the next part, *Dicranopteris dichotoma* grew at the further next part again and *Rhodomyrtus tomentosa* occupied its bottom.

Fig. 9.9 Vegetaion development in the burned area

It can be seen from the investigation in burned area that the vegetation cover in burned area forest increased from zero to 60% after 5-7years of restoration, and the vegetation species reached 11-14 kinds, in which the scrub and herbaceous plant had 4 and 7 kinds. The scrubs and herbaceous plants basically were heliophilous species in which scrubs were mainly *Rhodomyrtus tomentosa (*姚金娘) and *Baeckea frutescens Linn.*(岗松), and herbaceous plants were mainly *Eremochloa ophiuroides*(百足草), *imperata cylindrica*(白茅), *Eriachne*(鹧鸪草) and *Dicranopteris dichotoma (*芒其). All of these plants were the pioneer species, which can grow in poor site in this region, such as poor slope under heavy soil erosion.

It can be seen from the investigation results in the comparative sites that a lot of scrub and herbaceous plant would be recovered and developed in this regions, if human ceased destroy in the duration of 20 years. But the bedrock, occupying 40% of the total area would still be exposed. The land with plentiful vegetation cover was covered with the scrubs and herbaceous plants. The scrubs mainly were the heliophilous plants, like as *Rhodomyrtus tomentosa (*姚金娘), *Baeckea frutescens Linn.*(岗松) and Clerodendron fortunatum L.(鬼灯笼). The herbaceous plants mainly were Eragrostis minor Host(小画眉草), *Melinis minutiflora*(糖密草)，*Eragrostis pilosa (Linn.) Beauv.*(珠牙画眉草), *Bulbostylis barbata (Rottb.) C. B. Clarke*(球柱草) and *Ischaemum bartatum Retz.*(粗毛鸭嘴草).

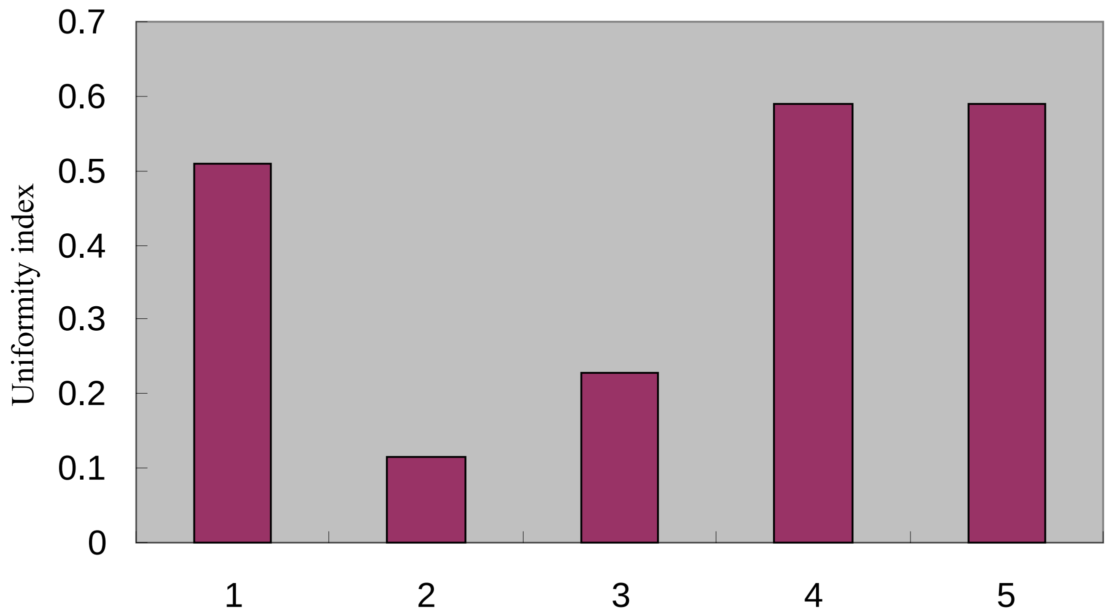
Fig. 9.10 Vegetation development in nature condition



1. *Acacia auriculaeformis* pure Forest (10th block), 2. *Acacia auriculaeformis* pure Forest (1st block), 3. Mingled forest of *acacia auriculaeformis* and *pinus elliottii engelmis,* 4. Burned area 5. Nature condition

Fig. 9.11 Comparison of vegetation diversity indexes of typical afforestation in Shangyang Experimental Station

The great difference between 10th and 1st block was the cultivation measures. The slope land in 10th block had been leveled and reconstructed into terraced land. The seeding in nutritive cup had been quoted and the fertilizer had been applied several times. So, the forest in 10th block grew plentifully and became the one of best forests in the aspect of vegetation cover recovery in the experimental station. It can be seen from Fig. 9.11 that both the Shannon-Wiener index and the dominance index were higher. It is shown that the arbor, represented by *acacia auriculaeformis* grew plentifully and the scrubs and herbaceous plants under their crown cover also were heavy. The slope land in 1st block was about 30 degree, which was difficult to level into terraced land. So, the land was not leveled during afforestation. It can also be seen from Fig. 9.11 that the Shannon-Wiener index was lower, but the dominance index was higher. The site investigation showed that the a*cacia auriculaeformis* and *pinus elliottii engeimis* mingled forest grew worse than the *acaci auriculaeformis* pure forest. Most of mingled forest became "small old tree" and the development of herbaceous plant was also worse than that in the 10th block. The burned area was a mixed forest of *acacia auriculaeformis, pinus elliottii engeimis* and *eucalyptus tereticornis*. But after the fire-disaster great amount of ashes and dry branches of tree were left on land surface, which gave beneficial condition for growing of plant. 5-7 years later scrubs and herbaceous plants grew plentifully. Therefore, the Shsnnon-Wiener index in burned area was higher and the dominance index was lower. According to the site investigation some scrubs and herbaceous plants can be gradually restored and developed, if human would not disturb them in the duration of 20 years. It shows that this region has the good possibility for restoring vegetation cover.



1. *Acacia auriculaeformis* pure Forest (10th block), 2. *Acacia auriculaeformis* pure Forest (1st block), 3. Mingled forest of *acacia auriculaeformis* and *pinus elliottii engelmis,* 4. Burned area 5. Nature condition

Fig. 9.12 Comparison of vegetable uniformity index of typical afforestation in Zhangyang Experimental Station

Fig. 9.12 shows the comparison of the uniformity index of typical afforestation in Shangyan Experimental Station. It can be seen that the uniformity index of Huoshaolin forest, developing in natural situation, and the nature condition was higher, but the uniformity index in 1st block was lower and the uniformity index in 10th block was near to that in the situation of natural evolution. It is concluded that the plant evolution in the 10th block is going toward to the natural evolution.

It is discovered by above analysis that the *acacia auriculaeformis* pure forest has higher vegetation diversity, the vegetation evolution is near to the natural evolution in this region. It is also concluded that the methods and measurements, adopted by the experimental station in *acacia auriculaeformis* afforestation are beneficial for the recovery of vegetation cover in this region.

9.2 Diversity of Benthic community

Benthic community, especially macro-invertebrate community has been widely used as an important index in comprehensive evaluating system of river. Based on the distribution with time and space of benthic community diversity on silt tideland Shenzhen Futian and combine with analysis on benthic species structure variation as well as organic etc. references, Cai Lizhe suggests that Shannon- Weaver benthic species diversity index (H') pollutant evaluating range can be divided into five stages as follows: H'<1 means serious pollution; 1<H'<2 less serious pollution; 2< H'<3 light pollution; H'>3, clean.

In July 2005, an field investigation was made in the East river for investigating river bio-environment status. Water and benthic samples were taken and analyzed. Samples were taken in the places including the source of east river, middle and lower reaches of main channel, and its important tributaries.

9.2.1 Algae diversity

Four sampling sites are selected in East river basin at Xinfengjiang (XFJ), Baipuhe (BPH), Simeizhou (SMZ), and Xizhijiang (XZJ) shown in Fig. 9.13. Algae samples on rock of river bed are taken in July and November 2004 respectively. At the same time, with samples taken, the water quality measurement and analysis were made in the field, including the measurement of water temperature, conductivity, value of PH, soluble oxygen, suspended load, total nitrogen, and total phosphorus.

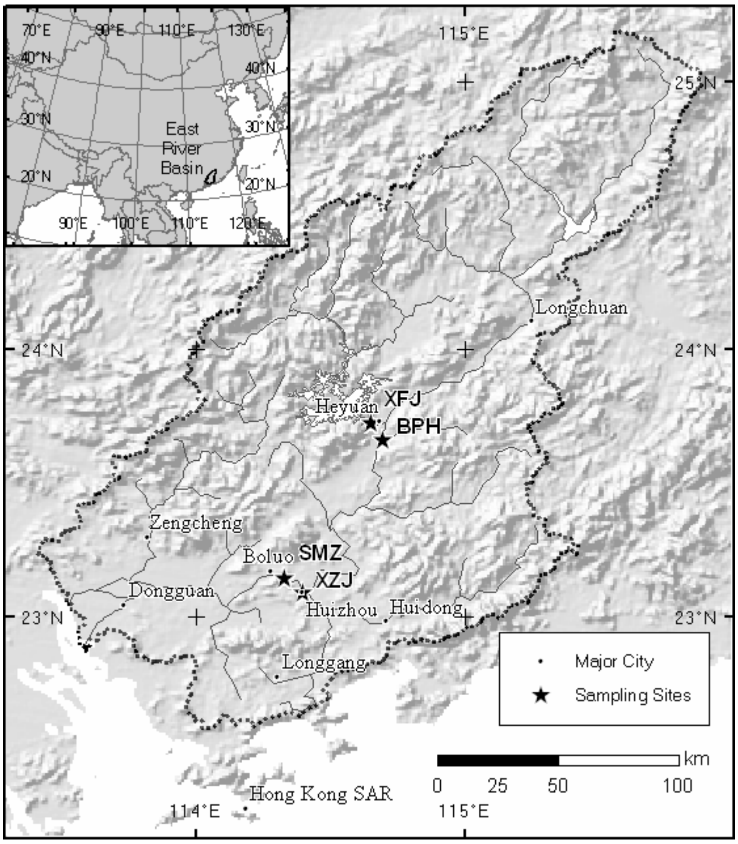


Fig. 9.13 Algae sampling sites in East river bed

The analysis results of algae are listed in Table 9.3. It is found that the abundance of Nitaschia even reaches 37.8%, therefore it is the tolerant species of pollution. At the same time, diversity analysis is made by diversity indexes: The Shannon- Weiner Index (H); Generic Index (GI); The Trophic Diatom Index (TDI); Diatom assemblage index of organic pollution (DAlpo). Water quality index applies references of water quality.

Relationship between water quality index and algae diversity index is shown in Fig. 9.14.

Fig. 9.14 displays that relationship coefficient between water quality index and Shannon-diversity index is only 0.34 which means the relationship between the two is not obvious. The relationship coefficient between water quality index and trophic diatom index and diatom assemblage index for pollution is 0.56 and 0.65 respectively, which indicates that the relationship between water quality index and the two biodiversity indexes is higher. The relationship coefficient between generic index of diatom (GL) and water quality index even reaches 0.83. Therefore generic index of diatom can be used as water environment healthy index of East river.

9.2.2 Diversity of benthic community

Samples are taken by especially making sampler（Fig. 9.15 and 9.15）. The sampling sites taken are shown in Fig. 9.17. Alive benthic fauna is selected one by one. Appraisal analysis of alive benthic fauna samples taken from sites on East river is shown in Table 9.4-9.10. The data listed in tables from 9.4 to 9.10 displays that the benthic fauna are quiet different with different river. The number of the benthic fauna found from the Yequgou is the most, and the number of the benthic fauna on the upstream of East River Longchuanyidu Township and Shangpingshui at the source of East river ranks the second.

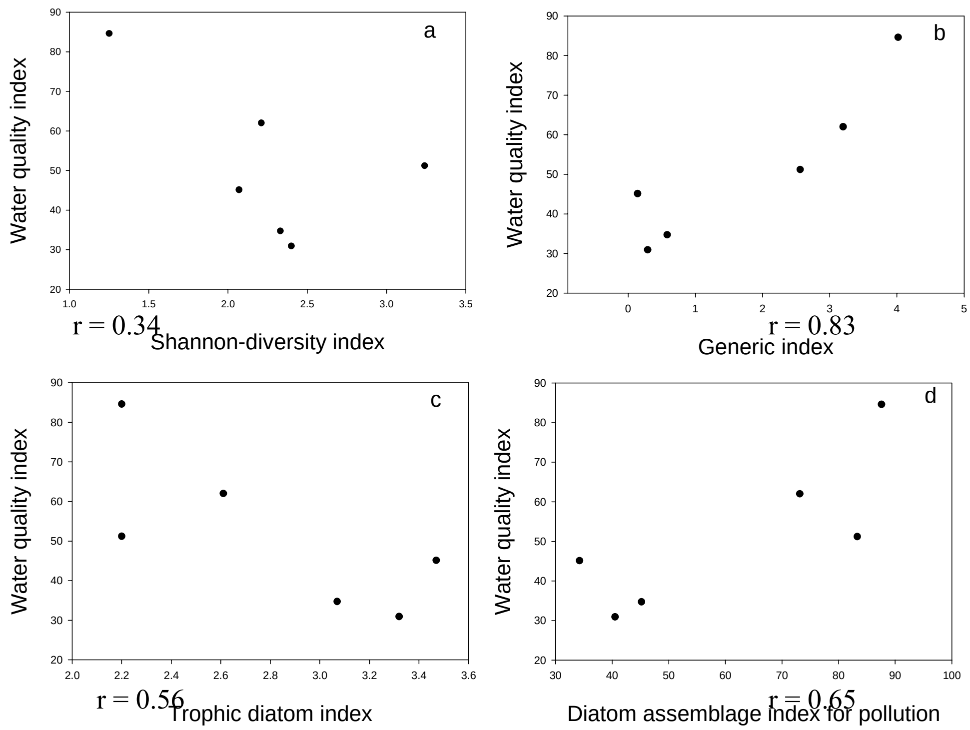


Fig. 9.14 Relationship between water quality index and biodiversity index
(a) Shannon-diversity index; (b) generic index of diatom; (c) tropic diatom index; (d) diatom assemblage index for pollution

Table 9.3 Richness of algae on East river bed (%)

Name of algae	July		November			
	Beipuhe	Simeizhou	Xinfengjiang	Beipuhe	Simeizhou	Xizhijian
Achnanthes	11.9	8.3	-	2.7	1.2	1.3
Achnanthidium	1.3	2.3	-	1.0	4.5	-
Amphora	3.8	-	-	1.8	-	-
Caloneis	7.2	-	-	-	-	-
Cavinula	-	1.4	-	-	-	-
Cocconies	7.8	11.3	1.5	5.0	2.4	4.9
Cyclotella	-	-	7.1	-	-	-
Cymbella	6.1	1.1	65.8	34.6	0.9	6.6
Diatoma	2.6	-	-	-	-	2.6
Eunotia	2.4	-	3.8	-	1.7	-
Fragilaria	8.9	4.1	-	-	-	7.3
Gomphonema	7.9	1.7	1.7	16.9	9.3	20.8
Lemnicola	6.4	1.7	2.3	3.5	3.3	-
Luticola	-	1.9	-	-	-	-
Navicula	8.4	2.3	16.7	11.9	4.3	2.3
Neidium	2.4	-	-	3.3	1.7	-
Nitsczhia	2.2	37.8	-	1.6	57.7	24.2
Nupela	-	-	-	-	-	2.6
Pinnylaria	15.1	6.6	1.1	1.1	2.7	5.0
Placoneis	5.6	0.5	-	-	-	2.2
Planothidium	-	3.6	-	1.7	-	-
Psammothidium	-	12.3	-	14.9	10.3	2.2
Rossithidium	-	3.1	-	-	-	-

Table 9.11 is the analysis result of invertebrate benthos. The biological difference of benthos in the East river is large: The density of benthos equal to zero at Dongguanyuan township, on the main stream of the East river; The number of benthos in per unit area varies from 0-17.093 g/m^2, among which the maximum is 17.093 g/m^2 at the source area of the East river, the minimum of that is also at Dongguanyuan township, on the main stream of the East river. Biodiversity index (H) displays that the highest one is at the source area and upper reach of the East river, e.g. Longchuan township on the upper reach of the East River,

Shangpingshui on the source area of the East River has the biodiversity index 1.823 and 1.822 respectively which reach the highest value of the basin. In the same case, biological index at the main stream between Heyuan and longchuan of the East River reaches is 1.482 belong to higher value. The higher biological diversity index at the confluence of Xizhijiang, Huizhou reflexes that where the water pollution is serious in Xizhijiang. At the lower reach of Fushuba, only Palaemonidae is found, it is perhaps that the sampling sits is on 50 m far from the lower reach of Fushu Reservoir, because the turbulent water is not suitable for benthos existence.

The benthic analysis of in the East River basin shows that the biodiversity of big invertebrate benthos on river bed at the source of the East River is higher, at Yeiqugou is lower, because where the water is muddy with higher velocity caused by flood.

It is lower at the lower reach of the river also. At the same time, it is found that the hydro-projects is impact on benthos, e.g. at the station below the Fushu Dam, the biodiversity index is equal to zero. The reason perhaps is that, before the investigation, a flood took place in the river,which is impact on the benthos distribution, nevertheless, the investigating result is still reflect the biological status on water environment of the East River basin.

Fig. 9.15 Samples taken from river

Fig. 9.16 Samples counting and analysis

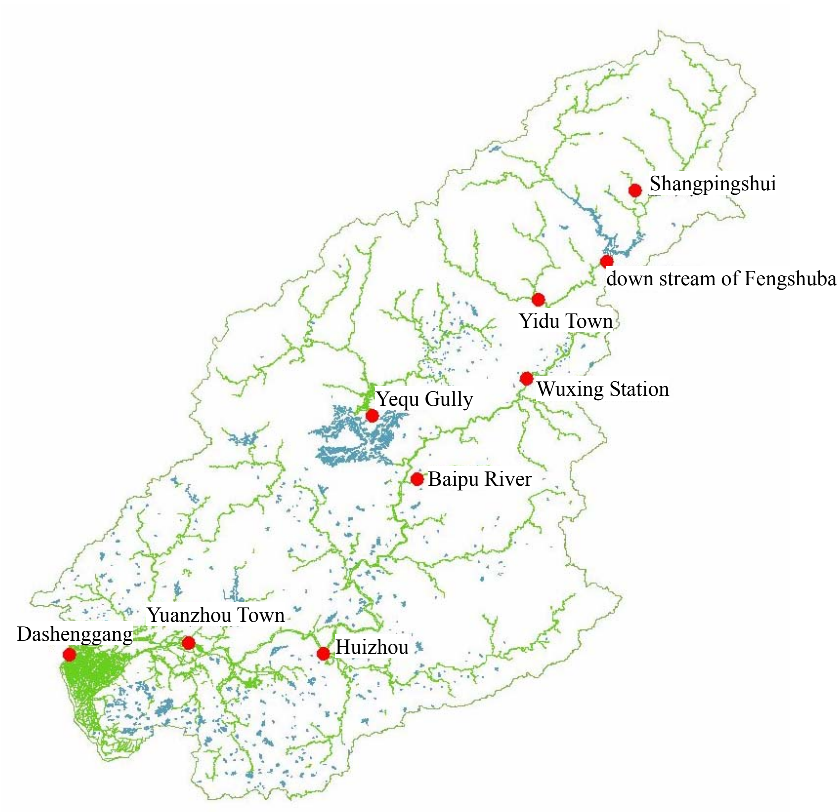


Fig. 9.17 Invertebrate community sampling sites in East river in July 2005

Table 9.4 Results of invertebrate benthonic sampling taken at confluence of Xizhijiang Huizhou

Name of invertebrate benthos		Number	Wet weight (g)
Decapoda	Paratelphusidae	1	1.5685
Oligochaeta	Tubificidae	5	0.0032
Diptera	Chironomidae	11	0.0077
Anisoptera	Libellulidae	1	0.0196
Zygoptera		7	0.0219
Gastropoda	Planorbidae	1	1.8576

Table 9.5 Results of invertebrate benthonic sampling taken at bottom of Baipu River

Name of invertebrate benthos		Number	Wet weight (g)
Odonata	Palaemon modestus	12	2.4379
	Aeschnidae	2	0.6480
	Corduliidae	2	0.6480
Gastropoda	Melaniidae	2	0.3157
Oligochaeta	Tubificidae	2	0.0375

Table 9.6 Results of invertebrate benthonic sampling taken at lower reach of Yequgou

Name of invertebrate benthos		Number	Wet weight (g)
Chironomidae		386	0.5436
Odonata	Corduliidae	1	0.0231
Hirudinea	Hirudinidae	2	0.0434
	Herpodellidae	2	0.0434
	Simuliidae	18	0.0270
	Psychodidae	1	0.0001
Ephemeroptera	Oligoneuriellidae	1	0.0001
Coleoptera	Dytiscidae	3	0.0002
Oligochaeta	Tubificidae	3	0.0001
	Lumbriculidae	1	0.0001

Table 9.7 Results of invertebrate benthonic sampling taken at Heyuan-Longchuan, main steam of East river

Name of invertebrate benthos		Number	Wet weight (g)
Gastropoda	Melaniidae	2	4.4958
	Viviparidae	10	4.8975
	Lymnaeidae	2	0.0800
Odonata	Agriidae	1	0.0285
Hemiptera	Nepidae	1	0.0053
Plecoptera		1	0.0035
Ephemeroptera	Heptageniidae	1	0.0036
	Leptophlebiidae	1	0.0036
Decapoda		44	3.6702
Lamellibranchia	Corbiculidae	1	0.2876
Coleoptera		1	0.0083
Oligochateta	Tubificidae	1	0.0133
	Tubificidae	2	0.0266
Hirudinea		2	0.1509

Table 9.8 Results of invertebrate community sampling taken at Lower reach of Fengshuba

Name of invertebrate benthos		Number	Wet weight (g)
Decapoda	Palaemonidae	9	0.4212

Table 9.9 Results of invertebrate community sampling taken at Yidu, Longchuan county

Name of invertebrate benthos		Number	Wet weight (g)
Plecoptera		3	0.0047
Ephemeroptera	Heptageniidae	11	0 .0546
	Leptophlebiidae	44	0.0500
	Caenidae	1	0.0042
	Libellulidae	1	0.0042
Odonata	Libellulidae	5	0.4822
Decapoda		2	0.1929
Gastropoda	Melaniida	1	0.1960
	Hydrobiidae	1	0.1960
Diptera	Chironomidae	21	0.0093
		1	0.0152
Hemiptera	Naucoridae	1	0.0275
Coleoptera		1	0.6851
Trichoptera	Hydropsychidae	4	0.0309

Table 9.10 Results of invertebrate community sampling taken at Shangping in source area of East river

Name of invertebrate benthos		Number	Wet weight (g)
Gastropoda	Melaniidae	23	4.5195
Lamellibranchia	Corbiculidae	2	0.1008
Trichoptera	Hydropsychidae	12	0.1385
	Baetidae	2	0.0231
Ephemeroptera	Oligoneuriellidae	27	
	Caenidae	3	
		1	0.0134
Hirudinea	Dytiscidae	1	
Coleoptera		3	0.0289
	Chironomidae	1	
Diptera		16	0.0066

Table 9.11 Analysis results of benthos in the East river watershed

Sampling site	Sampling taken area of river bed (m^2)	Number of benthos (n)	Quantity of benthos (g)	Quantity of benthos per area (g/m^2)	Density (n/m^2)	Biodiversity (H)
Dongguangou main stream of the East River	1	0	0	0	0	0
Confluence of Xizhijiang, Huizhou	1	26	3.4785	26	3.4785	1.593
Baipuhe	0.4	60	6.4292	150	16.073	1.046
Yequgou	2.5	418	0.6812	167.2	0.2725	0.393
Heyuan-Longchuan, the main stream of the river	0.8	70	13.6748	87.5	17.093	1.482
The lower reach of Fushu Reservoir	1.4	9	0.4212	6.4	0.300	0
Yidu, Lonfchuan county	1	97	1.9528	97.0	1.953	1.823
Shangyouping the source of the east river	1.5	91	4.8668	60.7	3.244	1.822

9.3 Ecological Assessment of the East River

The streams provide habitat for benthic macro-invertebrates, and on the other hand, the stream habitat can be rapidly assessed with benthic macro-invertebrates. The intent of the benthic rapid bio-assessment is to evaluate the overall biological condition, optimizing the use of the benthic community's capacity to reflect integrated environmental effects. Table 9.12 listed the examination results of the macro-invertebrates in the 12 samples. Shangpinshui in the upper reaches has a high taxa richness, which is defined as the number of species in the sample, and bio-diversity, which is defined in Eq. (9.4), demonstrating a good ecology system in the reaches. In the middle reaches, the taxa richness reduces along the course from Yidu, Wuxin, Baipuhe to Huizhou but remains at a high level. In the lower reaches only one species has been found from the samples at Yuanzhou and Dasheng. The bio-diversity index reduced to zero.

Shannon-Weiner bio-diversity index is used in the paper, which is defined by Krebs (1978):

$$H = -\sum_{i=1}^{S} \frac{n_i}{N} \ln(\frac{n_i}{N}) \quad (9.4)$$

in which S is the number of species (richness), N is the total number of individual animal of invertebrates, and n_i is the number of individual animal of i-th species. Shannon-Wiener bio-index reflects the taxa richness and the evenness of number distribution of species. The higher is the taxa richness, and the more uniform the number distribution of species, the larger is the H value. The Shannon-Wiener Index provides no information on the total abundance of the bio-community. Sometimes the Shannon-Wiener Index gives wrong results. For instance, Sample A has 3 species and each species has only one individual animal, the Shannon-Wiener Index equals to 1.1; on the other hand, Sample B has 9 species and 418 individual animals, but in which one species has 386 individual animals, the Shannon-Wiener Index for Sample B is only 0.38. Of course the conclusion is not correct. In general the higher is the number density, the larger is the taxa richness. Considering both the abundance and biodiversity, a bio-community index, B, is used (Wang et al., 2005):

$$B = -\ln N \sum_{i=1}^{S} \frac{n_i}{N} \ln(\frac{n_i}{N}) \quad (9.5)$$

Table 9.12 Result of species determination of benthic macro-invertebrates

Shang-ping-shui	*Baetidae (30); Melaniidae, S.libertine (23); Chironomidae (two species 16); Ceratopsyche sp.(7); Aphropsyche sp. (5); Elmidae (3); Corydalidae，Protohermes (3); Corbiculidae C.nitens (2); Polycentropodidae， Neureclipsis(2); Caenidae (1); Helobdella (1);*
Feng-shuba Dam	*Palaemonidae (9)*
Yidu	*Leptophlebiidae，Paraleptophlebia(42); Chironomidae (21); Gomphidae (5); Siphlonuridae (4); Hydropsychidae (4); Leptophlebiidae, Leptophlebia (2); Decapoda (2); Hydrobiidae (2); Semisulcospira (1); Tipulidae, Hexatoma (1); Naucoridae (1); Corydalidae (1); Caenidae(1)*
Wuxing	*Natantia (44);Bellamya (10); Branchiura (3); Radix (2); Melanoides (2); Nepidae (1); Limnodrilus (1); Coenagrionidae, Pseudagrion (1); Leptophlebiidae,Traverella (1); Heptageniidae (1); Leptophlebiidae, Paraleptophlebia (1); Corbiculidae C.nitens (1); Noteridae (1); Whitmania (1); Hirudinea Sp1.(1)；*
Baipuhe	*Palaemonidae Sp1.(40); Palaemonidae, Palaemon modestus (12); Gomphidae (2); Macromiidae (2); Semisulcospira (2); Branchiura (2)*
Huizhou	*Chironomidae (3 species 11); Coenagrionidae (two species 6)；Branchiura (4); Paratelphusidae (1); Ilydrolus (1);Gomphidae (1); Platycnemididae (1); Ampullariidae (1)*
Yuanzhou	*0 (first sampling); Palaemonidae (9) (second sampling)*
Dasheng	*0 (first sampling); Palaemonidae (5) (second sampling)*
Yequ Creek	*Chironomidae(386); Simuliidae (18); Herpodellidae(4);Dytiscidae (3); Branchiura (3); Lumbriculidae (1); Psychodidae (1); Corduliidae, Epitheca marginata (1); Baetidae (1)*
Zengjiang Bay	*Corbiculidae C.fluminea (113); Chironomidae (four species 44); Elmidae， Stenelmis (25); Ceratopogonidae Bezzia (25); Corixidae (21); Limnodrilus(23); Semisulcospira (20); Libellulidae (14); Ephemeridae (11); Bellamya B.Purificata (8); Macromiidae (6); Bellamya Sp1 (5); Branchiura (4); Coenagrionidae Pseudagrion (4); Gomphidae, Trigomphus (3); Ampullariidae (2); Psephenidae (2); Hydrophilidae Hydrobius (2); Tabanidae (2); Lepidoptera (1); Acariformes (1); Gomphidae, Sinictinogomphus (1)；Palaemonidae (1); Tricladida (1); Baetidae(1); Heptageniidae (1); Parafossarulus(1); Elmidae, Sp1.(1)*
Zhengguo	*0*
Xizhijiang Oxbow Lake	*Palaemonidae (13); Chironomidae (7); Hydrophilidae, Laccobius (2)*

* note: the Figures. within the parentheses is the number of individual animals of the species)

Fig. 9.18 shows the variation of the taxa richness *S*, number density of individual invertebrates, d_n, Shannon-Weiner bio-diversity index, *H,* and the bio-community index, *B,* from upper to lower reaches along the course. In general the richness, the density, and the bio-diversity of benthic invertebrates reduce from upper to the lower reaches. The Fenshuba Dam causes instantaneous fluctuation in flow discharge and velocity, which strongly impact the invertebrates. Therefore, only one species, *Palaemonidae*, which may survive the fluctuation, was found at the site downstream of the dam. The impact of velocity fluctuation becomes weak further downstream from the dam and exhibits no influence on the benthic invertebrates at a distance of 80 km from the dam.

In the lower reaches the channel has been regulated with relatively uniform width and the banks have been hardened with concrete and stones. Flow velocity in the channel is more uniform than the upper reaches and the substrate consists of only sand. Sand bed is compact, which provide no space for benthic animals to live and no shelter for the animals to escape current. The richness, number density, and biodiversity and bio-community indices in the lower reaches are very low or zero. Humans have reclaimed river bays, riparian lakes and wetlands, and sluggish and backwater zones, which caused loss of habitats and make diversified habitats very uniform and unitary. In general, the biodiversity and bio-community indices are proportional to the diversity of habitats. The habitat loss and low diversity of habitats result in low bio-diversity and bio-community.

9.4 Restoration Strategies

Ecological engineering has been defined as "the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both" (Mitsch, 1998). The main ecological stresses on the East River is loss of habitats due to reclamation, isolation of habitats by levees and hardened banks, fluctuation in flow discharge and velocity due to reservoir operation, and water pollution. In the lower reaches there are no good habitats and the biodiversity is zero. The lack of benthic invertebrates cuts off the food chain and, consequently, causes low bio-diversity of fishes. One strategy to restore the ecology in the lower reaches is to create multiple habitats for benthic invertebrates by engineering measures. A good habitat for benthic invertebrates should have stable streambed consists of boulders, cobbles, or gravel. Mud and aquatic plants are also good substrate for invertebrates. Typical habitats for benthic invertebrates include mountain streams with boulders and cobbles, bays by the river, riparian lakes and wetlands, and backwater and sluggish flow zones. Very few streams exist with substrate of boulders and cobbles in the lower reaches, and if any, are covered with a layer of sand. However, it is possible to create an environment for development of a mud layer in backwater and sluggish flow zones, or riparian lakes. Moreover, engineering measures may be taken to link the isolated waters, such as oxbow lakes, with the river, which may improve the ecological system.

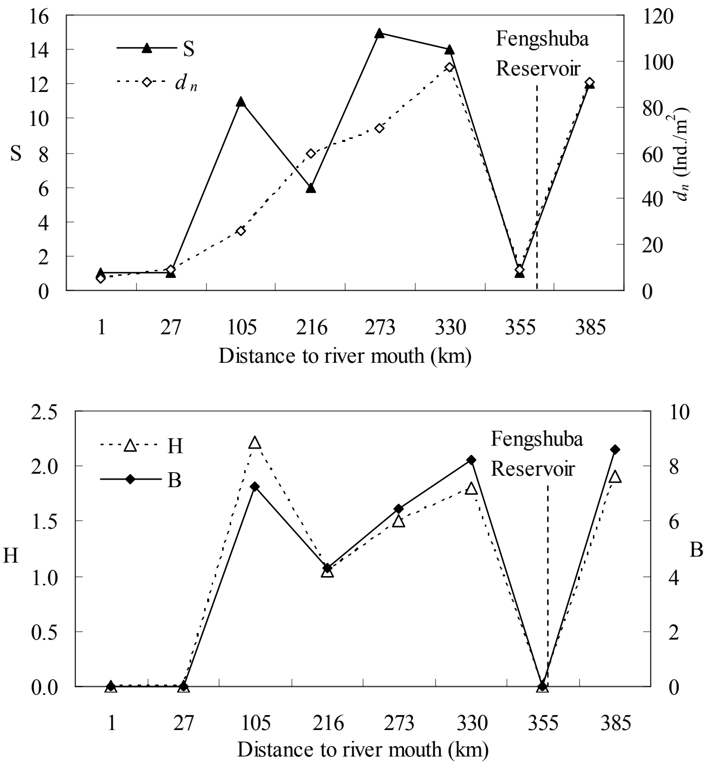


Fig. 9.18 Taxa richness, S, number density of individual invertebrates per area, dn, Shannon-Wiener Index, H, and the bio-community index, B, as a function of distance to the river mouth

Is it for sure that the taxa richness of benthic invertebrates, bio-community and bio-diversity indices are high in backwater and sluggish flow zones or river bays and riparian lakes? Is the linkage of riparian waters with the river effective for ecological restoration? A comparative study is performed to answer these questions with samples taken from Zengjiang Bay, Zhengguo, the Xizhijiang Oxbow Lake and Yequ Creek. Fig. 9.19 shows the geographical locations of Zengjiang Bay and the Xizhijiang Oxbow Lake. The Zengjiang River is a tributary of the lower reaches of the East River and the ecological conditions are similar to those of the lower East River. Substrate in the main channel of the Zengjiang River consists of sand. There is no benthic invertebrate in the sample from the river at Zhengguo.

Zengjiang Bay likes a riparian lake with a 100 m wide outlet connecting the river, as shown in Fig. 9.19. The river carries fine suspended sediment into the bay and deposit in the bay. A mud layer covers the most part of the bay, and some aquatic plants have colonized parts of the bay. The flow velocity and water depth in the bay varies in the ranges of 0–0.5 m/s and 0-3 m. Zengjiang Bay provides multiple habitats for benthic invertebrates. The taxa richness in the sample taken from the bay is 31, and the number density of individual invertebrates is 343 ind/m^2. The calculated biodiversity and bio-community indices are H=2.58 and B=15.05, both are the highest value in the East River. There are many fish species in the bay.

The Xizhijiang Oxbow Lake was the former Xizhijiang Channel, and had become an oxbow lake since an artificial cutoff in the 1980s. It is separated with the Xizhijiang River by a highway, as shown in Fig. 9.19. Now a part of the lake has been used as fishpond. Because of the separation there is almost no flow velocity in the lake. The separation also cut off fine sediment supply to the lake. The substrate, consists mainly of fine sand, remains unchanged after 20 years since the cut off. There is no mud layer in the lake. Analysis of sample from the lake indicates that the taxa richness is only 3 and the number density is 22 ind/m^2. The biodiversity and bio-community indices are H=0.89 and B=2.76, which are much lower than those for Zengjiang Bay. To develop the oxbow lake into a good habitat for benthic invertebrates, the lake should be connected with the river, allowing fine sediment to carrying into the lake and form a mud layer, the connection will increase the flow velocity and exchange of lake water with river water.

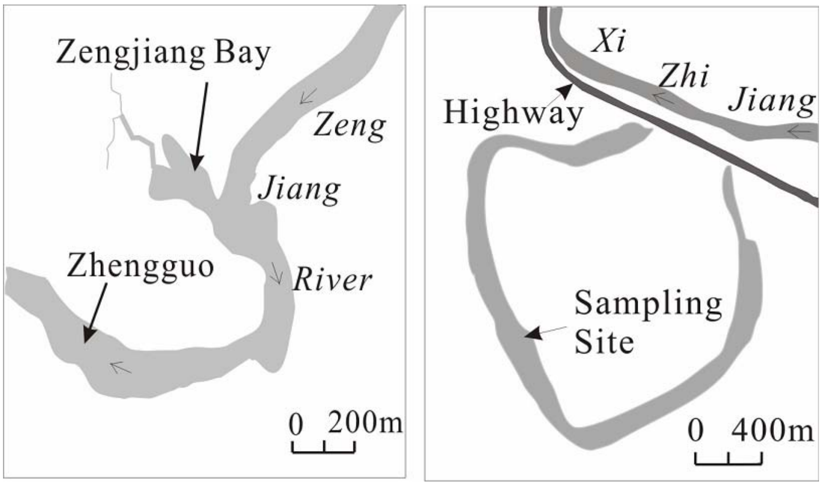


Fig. 9.19 Location and shape of the Zengjiang Bay and Xizhijiang Oxbow Lake

The physical conditions of stream habitat are mainly 1) the substrate; 2) water depth, and 3) flow velocity (Gorman and Karr, 1978). Different physical conditions support different bio-communities and diversified physical conditions may support diversified bio-communities. A habitat diversity index, H_D, has been proposed as follows (Wang et al., 2005):

$$H_D = N_h N_v \sum_i \alpha_i \qquad (9.6)$$

where N_h and N_v are numbers for water depth diversity and velocity diversity, and α is the substrate diversity, which is different for different substrates. If a stream has three water areas: 1) shallow water, in which the water depth is in the range of 0~0.1m; 2) mid depth water, in which the water depth is in the range of 0.1~1m; and 3) deep water, in which water depth is larger than 1 m, and each of the three areas is larger than 10% of stream water, N_h=3. If a stream has only shallow water and mid depth water, and each of them is larger than 10% of stream water, N_h=2. The value of N_h for other cases can be analogously obtained. If a stream has three water areas: 1) lentic area, in which the flow velocity is smaller than 0.3 m/s; 2) mid velocity area, in which the flow velocity is in the range of 0.3~1m/s; and 3) lotic area, in which the velocity is larger than 1 m/s, and each of the three areas is larger than 10% of stream water, N_v=3. If a stream has only lentic and mid-velocity areas, and each of them is larger than 10% of stream water, N_v=2. The value of N_v for other cases can be analogously obtained.

If the streambed consists of cobbles and boulders, water flows over the bed and also through the interstices, which provides the benthic macro-invertebrates diversified living spaces. Therefore, cobbles and boulders are associated with high habitat diversity. Stream flow over aquatic grasses has high velocity but the aquatic grasses generate a low velocity canopy, moreover, the aquatic grasses themselves are also habitat for some species. Thus, streams with aquatic grasses exhibit high habitat diversity. Some species may move and live within the fluid mud layer and consume the organic materials in the mud layer. The interstices in gravel and fine gravel bed are small but sufficient for some species. A sand bed is compact and the interstices between sand particles are too small for benthic macro-invertebrates to move and live within them. Moreover, sand particles are liable to be removed and the sand bed is not stable. Therefore, a sand bed is worst habitat for benthic macro-invertebrates. Based on the previous discussion and field investigations of 16 streams, the α -values for various substrates are listed in Table 9.13.

Table 9.13 α - values for different substrates

Substrate	Boulders and cobbles (D ＞ 200 mm)	Aquatic grass	Clay mud (D<0.02mm)	Cause gravel (20-200 mm)	Fine gravel (2~20mm)	Silt (0.02 -0.2 mm)	Sand (0.2 -2 mm)
α	6	5	4	3	2	1	0

If a part of the streambed consists of one substrate and another part consists of another substrate and both parts have areas larger than one tenth of the stream surface, the two α -values for the two kinds of substrates should be summed. If sand or silt fills the interstices of gravel the α -value should be taken as for the substrate of sand or silt. Only if different substrates cover different parts of the streambed, the α -values for different substrates should be summed. If a streambed has three parts with different substrates: boulders and cobbles, aquatic grasses, and fluid clay mud, and each of the three parts is larger than one tenth of the total stream area, the sum of the α -values for the stream is $\sum_i \alpha_i = 6 + 5 + 4 = 15$.

If the streambed is covered by sand or all interstices of gravel are filled with sand, the α -value is zero, or $\sum_i \alpha_i = 0$.

Fig. 9.20 shows the relation between the habitat diversity, H_D, and bio-diversity, H, and the relation between the habitat diversity, H_D, and the bio-community index, B. The higher is the habitat diversity, the higher is the biodiversity and the bio-community indices. The Shannon-Weaver biodiversity index, H, of the stream increases with the habitat diversity, H_D, but the points are rather scatter. The bio-community index, B, increases with habitat diversity, H_D, almost linearly and the points, including several measured points from the upper Yangtze River (Wang et al., 2005), are much more closely around the curve. The Zengjiang Bay has a high habitat diversity, because it has multiple substrates, therefore, has high biodiversity and bio-community index.

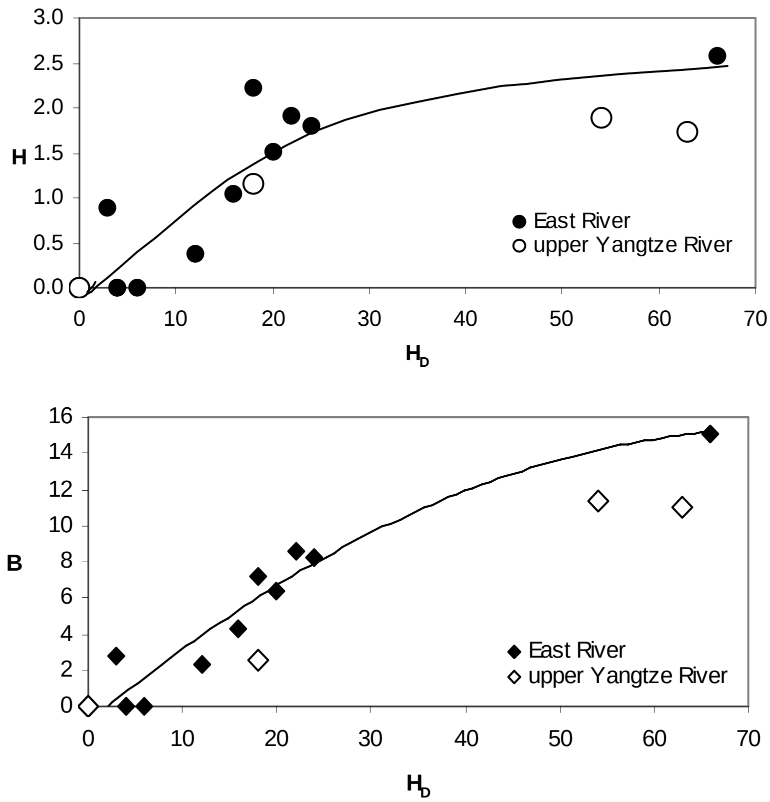


Fig. 9.20 Relation between the habitat diversity, HD, and bio-diversity, H (upper); and relation between the habitat diversity, HD, and the bio-community index, B (lower)

The results demonstrate that the ecology in the lower East River can be restored by creating habitats with high habitat diversity, like those in Zengjiang Bay. It is feasible to create riparian waters similar to Zengjiang Bay. One example is to connect the Xizhijiang Oxbow Lake with the river, and a mud layer may develop in the oxbow lake by allowing low velocity flow carrying fine suspended sediment into the lake and deposit in the lake. The lake water may exchange with the river water and fishes and invertebrates may spend a part of their life cycle in the lake and other parts of their life cycle in the river. Other engineering measures to create habitats may be construction of groins in wide river sections. Fine sediment may deposit in the backwater zones and aquatic plants may colonize the zones. Such habitats have high habitat diversity index and therefore support complex bio-community. Such engineering project must be designed integratedly with flood defense structures,

The restoration of the East River ecology should also include mitigation of the impact of instantaneous fluctuation of discharge from the Fenshuba Dam. The operation of the dam should be adjusted so to change the sharp increase and reduce in released water. Thus, a signal and a short period of time may be given for the animals to escape from the currents. Over time the animals may generally accustom for the non-natural changes in flow.

The Yequ Creek was gravel bed stream with good habitat conditions. A rain storm caused landslides and slope soil erosion in 2005. The vegetation on the steep bank slope was destroyed and coarse and fine sand deposited in the creek. A sample was taken from a 2.5 m^2 of the creek bed. The examination results are: there are 9 species in the creek but extremely dominated by *Chironomidae,* and the number density of invertebrates is 167.2 ind/m^2. The calculated bio-diversity, *H*, is 0.38 and bio-community index, *B*, is 2.31, which are much lower than Shangpingshui and Yidu, which are also gravel bed streams. It demonstrates that slope erosion may greatly reduce the bio-diversity and bio-community indices and the ecology is impaired by sediment deposition in streams. Restoration strategies are reforestation of the eroded land. A research on vegetation succession has proved that the vegetation succession process in the East River basin may be greatly accelerated by planting some selected species, such as *Acacia auriculaeformis* (Wang et al., 2006). The slope may be stabilized quickly by planting *Acacia auriculaeformis* and the aquatic ecology of the stream may be restored.

10. HUMAN- INDUCED ECOLOGICAL STRESSES

10.1 Impacts of Reservoirs on River Ecology and Environment

Reservoir operations seem to have considerable potential impact on the River ecology and environment. River damming exerts dramatic abiotic changes in the ecology of rivers, such as alterations in discharge and temperature, increased erosion as well as changes in the amount and composition of suspended material (Hynes, 1970; Petts & Calow, 1996). Flow regime largely contributes to how stable the environment is in streams, so streamflow regulation is one of the most extensive human disturbances occurring in flowing waters (Ward & Stanford, 1983; Petts, 1984). In some rivers, elimination of floods following impoundment has extirpated native riparian forest communities, subsequently reducing biodiversity (Molles et al., 1998; Nislow et al., 2002) and causing major changes in river food webs (Wootton et al., 1996). Physical habitat characteristics (water depth, current velocity, substrate) are important determinants for bio-habitats, and the change of habitat has influence on the stream fish community structure (Schlosser, 1985; Bovee, 1986).

The East River is the main fresh water sources for Hong Kong, Shenzhen, Dongguan, Huizhou, Guangzhou, so concerns for keeping its ecosystem health are growing. There are over 6000 reservoirs within the East River Basin. Among them, the Xinfengjiang Reservoir and Fengshuba Reservoir are the two largest reservoirs. The Xinfengjiang Reservoir was built in 1958, and completed in 1960, and the corresponding time for the Fengshuba Reservoir was 1970 and 1972. The Zhentouzhai Reservoir, 5 km downstream of the Longchuan hydrological station, was built in 1972, and in 1995 it was modified by increasing the water level from 64.5m to 67.0m. Flow and sediment regimes of Heyuan, Lingxia and Boluo hydrological stations can be affected by both the Xinfengjiang Reservoir and the Fengshuba Reservoir, however, both the Fengshuba Reservior and the Zhentouzhai Reservoir have impacts to the Longchuan hydrological station.

This chapter studies various effects of reservoirs on river ecology and environment over the East River Basin through field investigation, sampling, and data analysis. Physical habitat characteristics, such as streamflow, sediment transport, and stream morphology are analyzed, and benthic macro-invertebrates are sampled from the streams and examined.

10.1.1 Reservoir Index (RI)

The RI (Reservoir Index) is introduced to assess the impacts of the reservoirs over one basin, and it can be calculated as follows:

$$RI = (S/Q) \times 100 \qquad (10.1)$$

Where S is the total reservoir storage, and Q is the annual mean discharge.

Table 10.1 The criterion of reservoir index (RI)

Type	RI
Natural	RI≤10%
Semi-natural	10%< RI ≤40%
Semi-controlled	40%<RI ≤100%
Controlled	RI <100%

Based on the RI, rivers can be defined as natural, semi-natural, semi-controlled, and controlled types (Table 10.1). The Yellow River, the Colorado River, the Nile River, and the Mississippi River are the controlled rivers, and the Yangtze River and the Pearl River in the China are the semi-natural rivers (He, 2005). Fig. 10.1 shows the reservoir index (RI) of the East River basin. The RI increases step by step, which reflects the impact of the large reservoirs, such as Xinfengjiang Reservoir, Fengshuba Reservoir and Baipenzhu Reservoir etc. on the river system. And nowadays the RI of the Basin is over 70%, so the East River is a semi-controlled river.

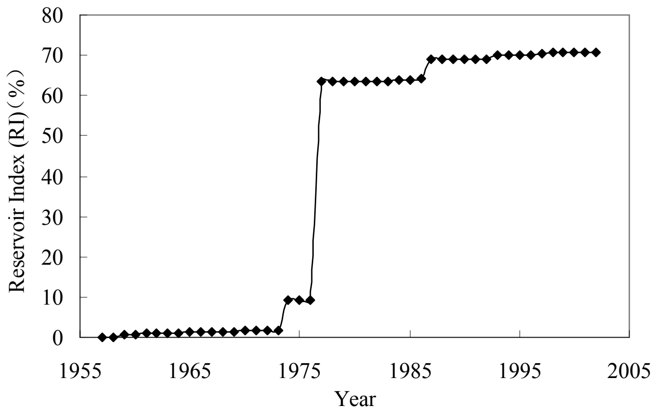


Fig. 10.1 Reservoir index of the East river basin

10.1.2 Impacts of reservoirs on water and sediment

Dams have major impacts on river hydrology, primarily through changes in the timing, magnitude, and frequency of low and high flows. Fig. 10.2 shows the monthly streamflow of some stations in different scenarios. For the Heyuan hydrological station, the variation coefficients are 78.8%, 50.9% and 31.5% for scenarios of natural, affected by Xinfengjiang Reservoir, and affected by Xinfengjiang and Fengshuba reservoirs respectively, and for the Boluo Hydrological stations, the variation coefficients for the corresponding scenarios are 89.0%, 66.7% and 44.3%. The same phenomena are found in the other stations. So reservoirs have increased the streamflow in the dry seasons, and decreased the streamflow in the flood seasons.

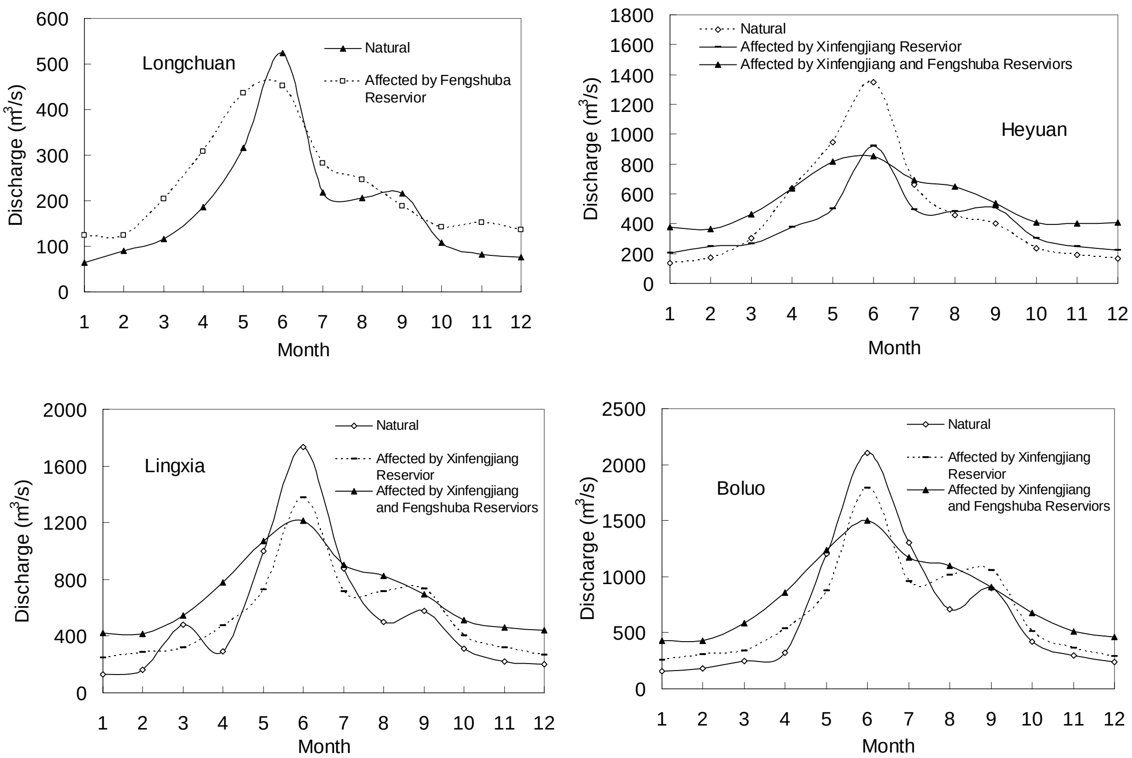


Fig. 10.2 Monthly streamflow at some stations in different scenarios

Another impact of reservoir on flow regime is to change the flow fluctuation. As we know, in order to meet the demand for power-generating, the instantaneous velocity is very high. In the Fig. 10.3, statistics of flow fluctuation coefficient are based on daily data. And the flow fluctuation can be calculated as follows:

$$F = \frac{\frac{1}{N}[\sum_{i=1}^{N}(Q_i - \overline{Q})^2]^{1/2}}{\overline{Q}} \tag{10.2}$$

Where F is the flow fluctuation coefficient, $\overline{Q}$ is the average discharge, Q_i is the ith daily runoff，N is the number of the days. Analysis has demonstrated that sediment removing capacity depends mainly on the fluctuation intensity of the stream flow (Wang, 1999, 2002).

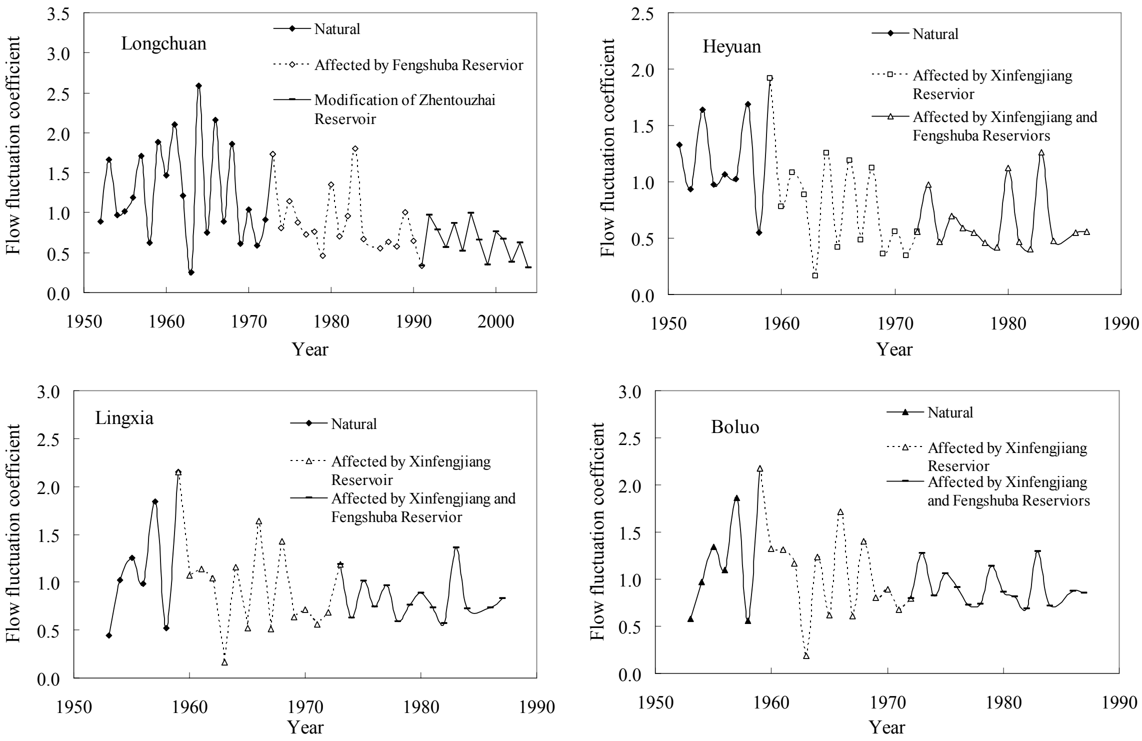


Fig. 10.3 Flow fluctuations at some stations along the mainstream

Fig. 10.3 demonstrates that reservoirs have reduced the flow fluctuation coefficients for these four stations, so the sediment removing capacity downstream decreases. The upper East River area controlled by Longchuan hydrological station is the major sediment-producing zone in the Basin. Reservoirs have changed the flow and sediment regimes in the Longchuan hydrological station. Owing to the reservoirs, sediment transport rate is much lower than that in the natural condition (Fig. 10.4). As a result, the amount of sediment transported downstream decreases, which will exacerbate the imbalance of sediment over the Basin. The river basin has experienced a fast economic development in the past decades, and demands for sediment for construction grow greatly, thus disorderly sediment mining was performed along the main channel. An analysis on the sediment budget over the Basin has shown that from 1988 to 1994, the mined sediment from the downstream channel of the Boluo is 57.23 million tons, and the contemporaneous sediment transported from upstream basin is only 12.11 million tons. Accordingly, the channel is deepening, and water level is lowering. And at some places, the ratio of width and depth ($\sqrt{B}/H$) decreased from 6.06 to 3.89 (Zhu, 2001). Problems, such as sea water intrusion, low water level for water abstraction, etc. occur often. Therefore for the water and sediment management in the East River Basin, it is very urgent to restrain disorderly sediment mining, as well as to maintain the water and sediment balance over the basin.

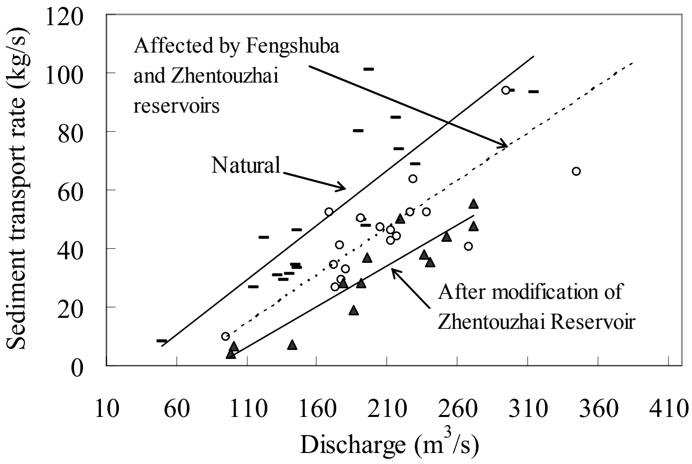


Fig. 10.4 Discharge-sediment relations at the Longchuan hydrological station

10.1.3 Impacts of Reservoirs on River Morphology

Reservoirs can result in chronicle changes in stream channel cross-sectional morphology, changes in channel planform or bed elevation downstream. And these geomorphic adjustments commonly contribute to the diminished ecological integrity of streams. The Taoxi hydrological station locates on the upstream of the Fengshuba Reservoir. Fig. 10.5 illustrates its cross-section change from 1977 to 1987. Owing to the impoundment of the reservoir, water level of the reservoir increases, and sedimentation occurs. With the fluctuation of the water level in different season, sediment scouring and depositing frequently occurs, so the channel is not stable.

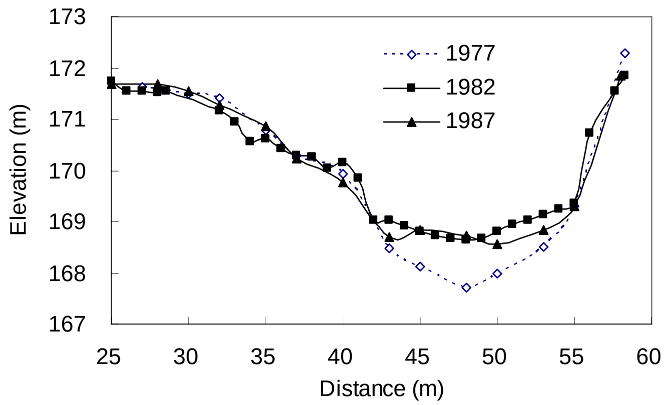


Fig. 10.5 Cross-section of the Taoxi hydrological station upstream of the Fengshuba Reservoir

River channel movement includes scouring, depositing, and shifting. In the East River Basin, transverse channel shift seldom occurs, and the main river channel movement patterns are sediment scouring and depositing. The channel movement intensity is introduced to assess the stability of the channel (Wang, 1999):

$$R_s = \frac{V_{scour} + V_{dep}}{LT} \tag{10.3}$$

Where R_s is the stream channel movement intensity; V_{scour} and V_{dep} are the sediment scoured and deposited during the time T; L is the measured channel length. In this study the Longchuan cross section is taken as a sample.

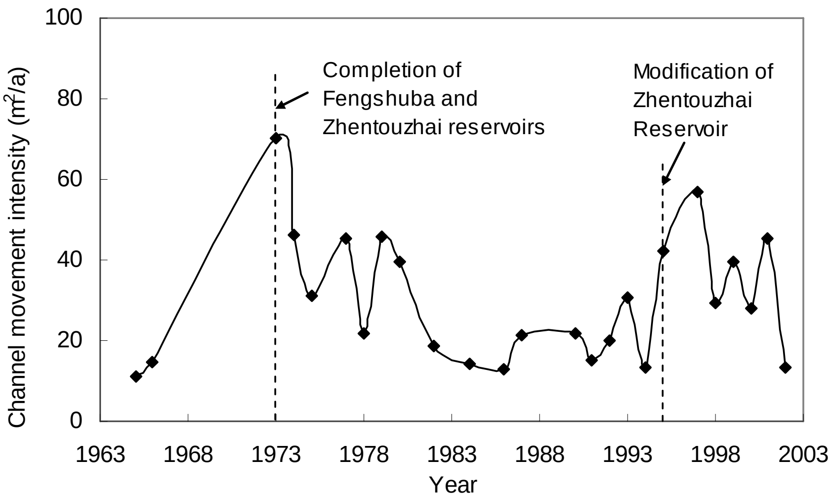


Fig. 10.6 Stream channel movement at the Longchuan cross-section

In the natural condition, the stream channel movement intensity is very low (Fig. 10.6). Fig. 10.6 also shows that after the completion of the Fengshuba and Zhentouzhai reservoirs, channel movement increased greatly in the following several years, then decreased to a formal level. After modification of the Zhentouzhai Reservoir in 1995, the channel movement intensity increased again, then after several years, it decreased. So it seems that if there was no further disturbance, the stream channel could keep stable through self-adjustment.

10.1.4 Impacts of Reservoirs on River Biota

Water depth, current velocity and substrate are the three fundamental physical habitat characteristics. Disturbances to the water depth, velocity and substrate have resulted in the negative impacts to the biota. Dams break off the transport of the fish, and building dams have resulted in 1/5 of fresh fishes in danger of extirpation (Ambasht, 1971, Petts, 1984). In 2004, a benthic macro-invertebrate survey over the East River basin was performed, and some sampling sites are shown in the Fig. 1. Benthic macro-invertebrates are sampled from the streams and examined. The biodiversity of the streams may be evaluated with the Shannon-Weaver Index, H, which is defined as follows (Krebs, 1978):

$$H = -\sum_{i=1}^{T} P_i \ln P_i \tag{10.4}$$

Where H represents the biodiversity; T is the number of species in the sample; Pi is the number ratio of the i-th species in the sample, Pi =ni/N, in which ni is the number of individuals of the i-th species, and N is the total number of individuals in the sample.

Table 2 lists the calculated values of species, density, density of biomass, and bio-diversity for the relevant sampling sites upstream and downstream of the Fengshuba Reservoir (Fig. 1). The sites with few impacts of the Fengshuba Reservoir have higher values of species, density, density of biomass, and bio-diversity. The Fenshuba Dam causes instantaneous fluctuation in flow discharge and velocity, which strongly impact the invertebrates. Therefore, only one species, *Palaemonidae*, which may survive the fluctuation, was found at the site downstream of the dam. The impact of velocity fluctuation becomes weak further downstream from the dam and exhibits no influence on the benthic invertebrates at the site of Five Star, which is 80 km downstream from the dam.

Table 10.2 Various biological indices for macro-invertebrate over the East River

Sampling Sites	N	Species	Density (ind/m²)	Density of biomass (g/m²)	*H*
Shangpingshui	91	12	97	1.953	1.91
Yidou	97	14	60.7	3.244	1.80
Fengshubaxia	9	1	6.4	0.300	0
Five Star	71	15	88.8	17.093	1.51

10.2 Urbanization

City is the concentrated area of population, capital, production and consumption. Urbanization increasing rate of 1.5% to 2.2% per year had been reached in China in several years since 1998. The urbanization rate of 40.53% had been reached until 2003 in China. The impact of urbanization on the river ecology and environment revealed the changes of river hydrology, sedimentation and aquatic ecology environment, which led to decrease of underground water supply, increase of flood frequency, intercept of sediment into river and destroy of dwelling for living creature (Wang&Tan, 2004) The circulation of population, production, energy, and information in many large cities was realized by city environment systems, such as buildings, road, water and electric networks etc. Therefore, about 80% of area in the center of city was occupied by buildings, roads and other fundamental installations and only 20% of area was maintained for the green land.

Some researchers (Blair, 2001; Czechetal, 2000; Denys&Schmidt,1998; Mackinetal,1988; Mclntyre,2000) consider that the decrease of vegetation cover, caused by construction of buildings, roads and other fundamental installations in the urbanization process is the main factor, leading to biological diversity decrease, because the abundance of creature species is positively related with the vegetation cover(Zheng, 1984; Czech et al.2000).

Urbanization, as a factor of underlying surface, has important impact on flood occurrence. Urbanization decreases the natural retention ability of city area and increases the speed of current confluence, so the runoff coefficient obviously increases. The process of runoff yield and confluence in urban area changes obviously. For an example, the Urbanization in Shenzhen City increased the speed of runoff confluence from Shengzhen River Basin, as well as confluence in river channels, decreased the duration of runoff confluence and increased flood discharge. For the flood of 1% frequency the duration of runoff confluence decreases 15.4%-21.7% and the flood discharge increases 11.8%-19.0%. (Gao et al, 2005)

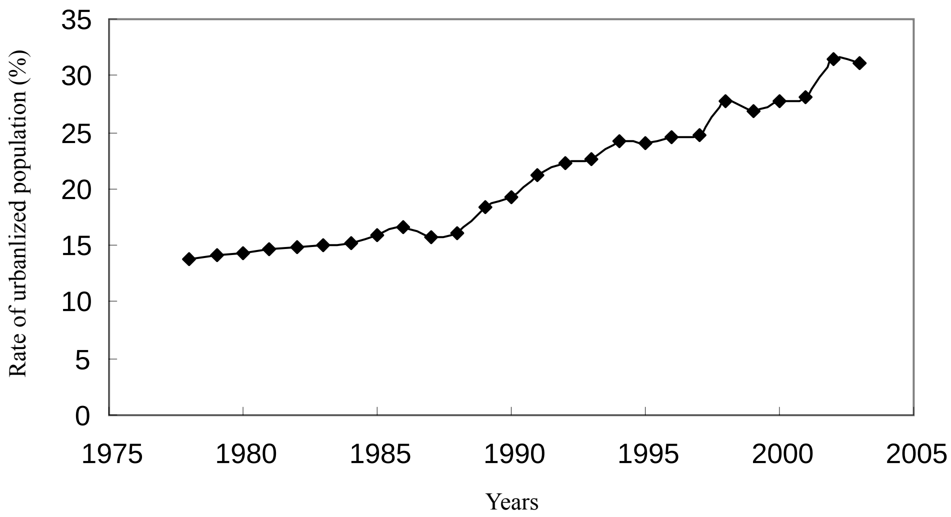


Fig.10.7 Urbanized population rate in Huizhou City

Fig.10.7 shows the changes of urbanized population rate in Huizhou City from1978 to 2003. The curve shows that the population rate in Huizhou City was steadily arising and had reached more 31.0% in 2003. Fig.10.8 shows the changes of urban area of the Huizhou City. Before the 1990s, urbanization in Huizhou City developed relative slowly, but it increased quickly after the 1990s.

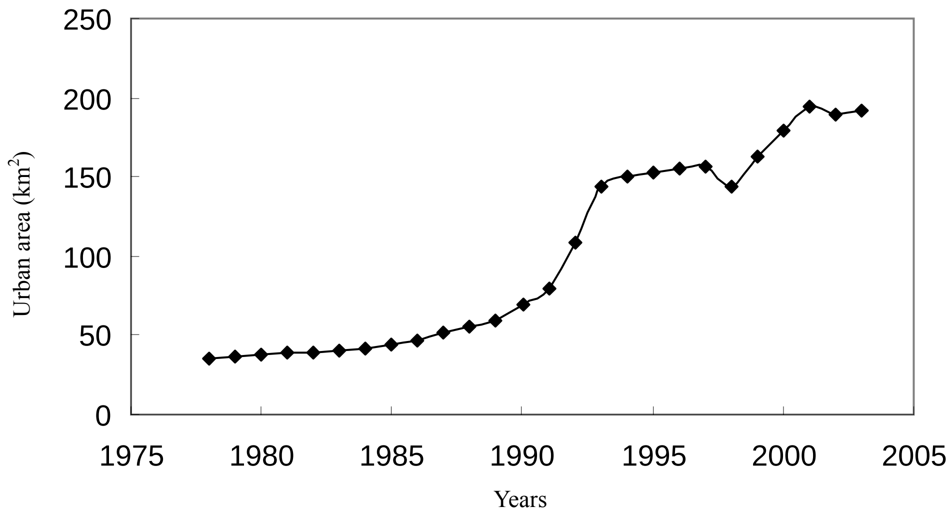


Fig.10.8 Urban area of Huizhou City

In order to quantitative analyze the impact of urbanization on the ecological environment of river basin this paper introduces a dimensionless index (urbanization index) to quantitative analysis of the impact of urbanization on the ecological environment of river basin. The urbanization index is defined as:

UI= urban area/ river basin area × 10000

The UI is larger, the urbanization rate is higher, and the impact of urbanization on the ecological system is also larger.

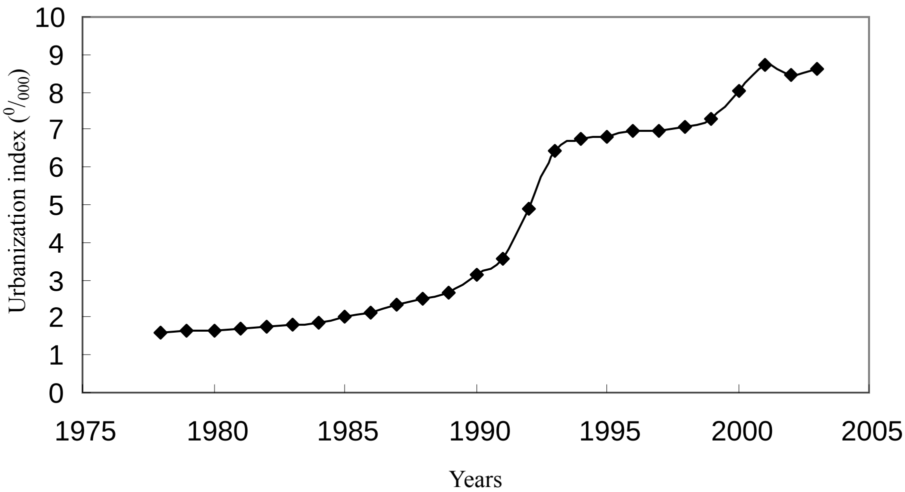


Fig.10.9 Urbanization index in Huizhou region

Shown as Fig. 10.9, the increase of urbanization index in the Huizhou region had the tendency of benched increase (Fig.10.9). The urbanization index in this district increased slowly in the duration from 1978 to 1991. It quickly arose from 3.5%% to 6.7%% in the duration from 1991 to 1994, but it again had a slow increase duration from1995 to1998. In the duration from 1999 to 2001 the urbanization index again had a quickly increasing period. After 2001 it arose in a slow speed.

10.3 Agricultural Production

The surface pollution in the agricultural production comes from the insecticides and fertilizers, which is used in agricultural measurement and comes into water environment together with the runoff. In addition, the nutrition and organic matters in soil are brought into the water environment together with the sediment during soil erosion. The surface pollution in the agricultural production is the main pollution factor of water environment. Using the great amount of nitrogenous and phosphate fertilizer and a little amount of potassium fertilizer, and non -equilibrium distribution between districts were the main causes. That led to hard-packed of soil, worse quality of cultivation, low effect of fertilizer, lose of soil and fertilizer, pollution of surface and underground water and enrichment of nutrition in lakes. Only 10%-20% of insecticide adhered to the agricultural plant, but its 80%-90% lost into soil, water body and air. According to the calculation of the Deportment of Agriculture the annual used amount of insecticide in China was about 0.8-1.0 million tons, in which the poisonous insecticide consisted of 95%。

With the quick development of animal husbandry in last several years the agricultural pollution, caused by animal excrement became serious. A lot of large and small animal husbandry had not the ability of treating animal excrements and discharged them into rivers and lakes, or put them everywhere. These animal excrements, entering into surface water body or underground water body would exhaust large amount of oxygen, that led to death of other microbes and caused serious organic pollution. According to the investigation data, the daily amount of discharged sewage for raising one cattle was more than daily amount of sewage for 22 men and the daily amount of discharged sewage for raising one pig was more than that for 7 men.

Agricultural activities destroyed riverbank and the natural vegetation covers on the terrace of riverbank. Agricultural activities also disturbed the soil and destroyed the soil structure, which led to serious soil lose.

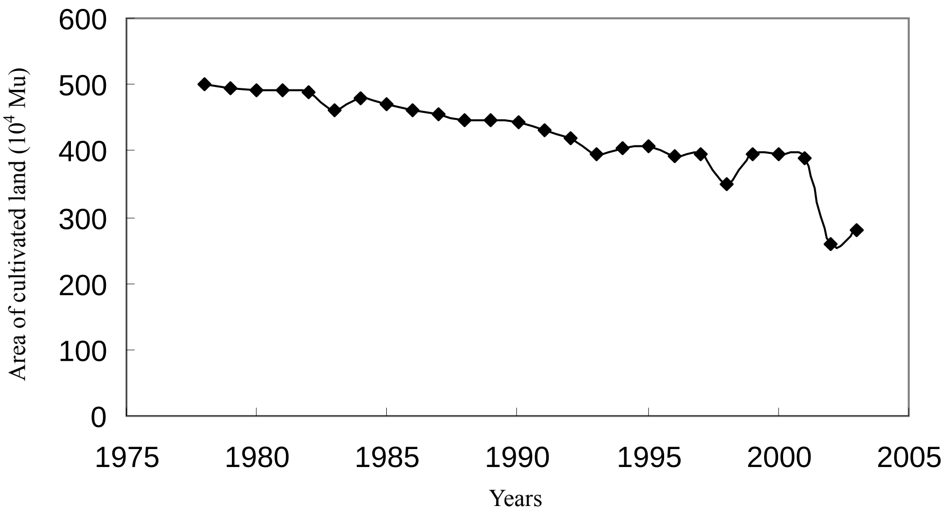


Fig.10.10 Change of area of cultivated land in Huizhou region

The main soil kinds in the Huizhou region are laterite, red earth and paddy soil. In 1998 the forest, cultivated land, orchard, herbaceous plant land, resident and other lands, road and waste land in the district occupied 70%, 14%, 2%, 2%,5%, 1%and1% of the total area, respectively. The main grain crops are paddy-rice, wheat, maize, sorghum and the main industrial crops consisted of peanut, soybean, tobacco, oil-bearing crops and tea. The vegetables consisted of white cabbage, mustard, kohlrabi and radish. The grain output was about 1.116×10^6 t, the meat output was about 96.3×10^3 t, aquatic product output was about 12.39×10^3. In1998 the population in the Huizhou region was 2,699,972 with the density of 242 person/km^2, in which population in countryside consisted of 34.4%. Fig.10.10 shows the change curve of cultivated land area from 1978 to 2003. It can be seen that the area of cultivated land in the Huizhou region was decreasing gradually. It is because of that many economic activities such as urban and road construction occupied the cultivated land.

It can be seen in Fig.10.11 that the increase of amount of chemical fertilizer consumption in Huizhou region followed the role of exponential function. Based on the data in 1998 it was found by simulation calculation on computer that the nitrogen amount, draining into the East River from Huizhou region was about 26300 t, in which 38% came from agricultural production. (Ma, 2005)

The Fig.10.10 shows that the area of cultivated land in Huizhou region was decreasing together with its development of urbanization and industry. So, the impact of agriculture on river ecology environment was also decreasing. But Fig.10.11 shows that in the same duration of time the consumptive amount of fertilizer in Huizhou region greatly increased. That led to the following inevitable results: the consumptive amount of fertilizer on unit area was increased; the utilization rate of fertilizer was decreased; a large amount of fertilizer entered into ecological system. All of these led to deterioration of soil, under ground water, river and lake, and other ecological environment.

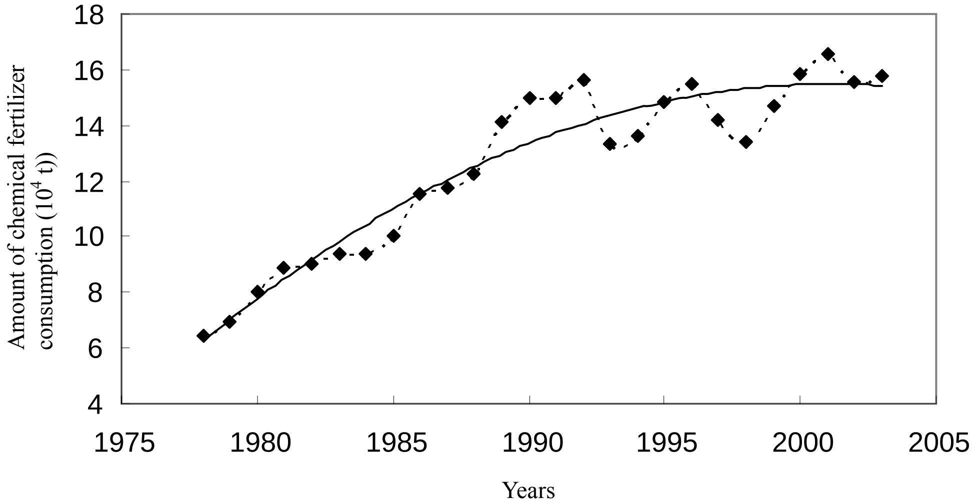


Fig.10.11Amount of chemical fertilizer consumption in Huizhou region

For quantitative study the impact of agriculture on river ecological system the authors of this report quote an agriculture development index. The agriculture development index is defined as:

$$AL = \text{agricultural area/basin area} \times 100$$

The value of AL is larger, the development rate of agriculture is higher and the impact of agriculture on river ecological system is greater.

The forestry development index is also quoted to quantitatively analyze the impact of forestry on river ecological system. The forestry development index is defined as:

$$PI = \text{forest area/basin area} \times 100$$

The value of PI is larger, the cover area of forest is higher, and the river ecological system is more healthful.

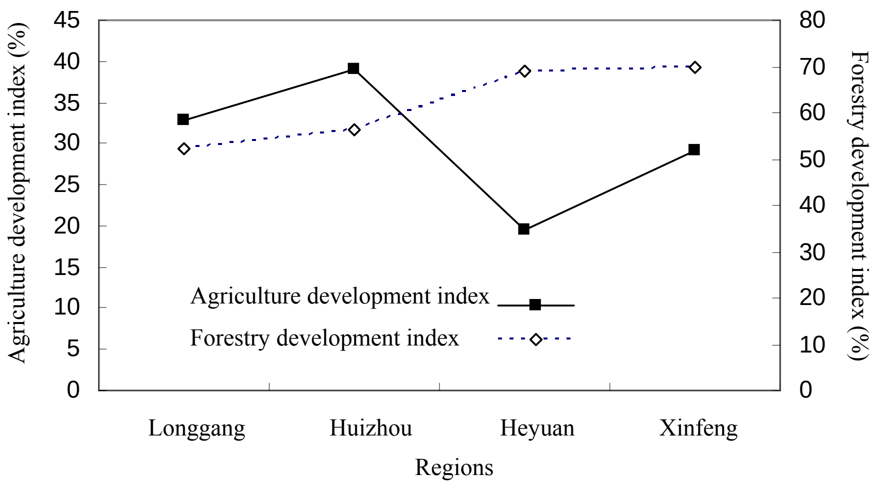


Fig.10.12 Agriculture and forestry development index in some regions of East River Basin in 1998

Fig.10.12 shows the agriculture and forestry development index in some regions of East River Basin in 1998. The lower agriculture development index in Heyuan region was 19.0% and the higher one in Huizhou was 39.1%. The lower forestry development index in Longang region of Shengzhen City was 52.2% and the higher one in Xinfeng County was 69.8%.

11. CONCLUSION REMARKS

11.1 Conclusions

In this report the East River is analyzed as an example to study the integrated management system of water, sediment, ecology, and environment. The following indexes of river health are analyzed: (1) climate, (2) hydrology and sediment, (3) floods and their risk, (4) water resources and water safety, (5) vegetation and soil erosion, (6) river patterns and river morphology, (7) biodiversity and diversity of bio-habitats, (8) human-induced stress. The following conclusions were derived:

1. Climate (1) Climate situation in the East River Basin is almost unitary, belonging to a warm-humidity type; (2) The Upper and Middle East River are in the region of sharp variation of humidity and of humidity increase; (3) In the source region of the East River the ecological environment is good owing to the persistent protection of water source. Human activities/human-induced stress have smaller effect on climate, thus the perturbation of human activities on climate is weaker than that of the globe. The economic development in the upper, middle, lower reaches and delta region of the East River has been active, particularly since the middle of 1980s. Thus, human activities has stronger effect on environment, particularly manifesting as the annual atmospheric temperature anomaly being higher than that of the globe, i.e. the perturbation of human activities on climate being higher than that of the globe; (5) In the years of El Nino El Nino makes the monthly atmospheric temperature in the dry season higher than the mean annual atmospheric temperature, while it makes the monthly atmospheric temperature in the wet season lower than the mean annual atmospheric temperature. In the years of La Nina it is just opposite. El Nino increases the yearly precipitation, while La Nina decreases the yearly precipitation. Their effect on monthly precipitation is still not clear.

2. Water and sediment (1) In the East River basin river discharges varies significantly within a year with a flood season from April through September. Yearly variation of annual discharges was quite large. In recent years the river discharges diminished; (2) The standard value of river discharge fluctuation coefficient of the East River Basin was 1.450; (3) The deviation indexes of river discharge fluctuation coefficient varied a little, but it was affected by reservoirs significantly. The standard deviation index of the East River Basin was 0.3421; (4) The diagram of state of sediment load shows that the basin above Longchuan is the main sediment source region in the East River Basin. In recent years the sediment load diminished based on the field data of Longchuan and Boluo Stations.

3. River channel (1) The East River channel is relatively stable, transverse shifting is not evident. Fluvial process mainly takes place within the river channel caused by the change of erosion and sedimentation ; (2) The main stem of the East River channel is regarded as relatively stable. The intensity of channel motion in the downstream is higher than that in upper and middle reaches. It demonstrates that for the main stem of the East river, the upper reach is the most stable, the middle reach ranks the second, and the lower reach is the most unstable.

4. Flood (1) Comparing the inundated area caused by different level floods, it is found that the zoning of high flood-prone for different level floods are concentrated in the middle and lower reaches and estuary region of the river covering the area of 1119 km^2 ; (2) Flood control installations have brought great flood control benefit. The zoning of flood –prone along the main river has been reduced effectively. By integrated operation of reservoirs, when 20-year flood, 50-year flood and 100-year flood comes from the basin respectively, the corresponding inundated area of 259 km^2, 319 km^2 , and 378 km^2 area can get rid of inundation.

5. Water resources (1) The situation of water quality in the East River is good. Heavy metal pollution in the river is minor, with their contents meet the requirements of the standard of grade I, except Hg content falls into the standard of grade III, IV, even V. The main pollutant in the river is Nitrogen. In flood season, water quality in the main river is better than that in its tributaries, it becomes worse along the river from upstream to downstream; (2) The minimum discharge at Boluo Station should reach 467m^3/s in 2010 in order to meet the amount of water required for ecology and environment; (3) Water supply security in downstream of the river is threatened seriously. By statistic daily average discharge from 1952-1987, it is found that the days with discharge less than 467m^3/s accounts for 45% of the total. At present, the situation is more serious, especially in dry seasons, its guarantee rate is lower, since the low runoff period of the river has been appeared recently.

6. **Vegetation and soil erosion** (1) The East River valley is located in the sub- tropical monsoon climate region in south Asia, humid warm climate is favorable for vegetation accelerating growth and ecological recovery ability. In recent 20 years, water and soil conservation projects have been carried out and has obtained great achievement. Soil and water lose in large area of the basin has been controlled. But water and soil lose in some local area is still prominent due to human activities such as irrational reclamation, quarry, and road construction etc. Gully erosion and landslide appears in upper and middle reach of the river such as Xunwu, Longchuan, Heping, and Huidong counties; (2) Climate, topography, soil, and vegetation are identical in the whole basin of the river. The parameters of vegetation -erosion dynamics determined preliminarily are: a=0.06, c=0.000005, d=0.01, f=500; (3) Compare to the situation of vegetation- erosion with other typical experimental zone, at present, ecological environment in the East River Basin is better one. Most area in the basin belongs to C zone, where vegetation has developed well and erosion modulus is decreasing in most area. Thence, the vegetation develops automatically and the vegetation community develops from simple species to a complex communities.

7. Biodiversity and diversity of bio-habitats (1) The vegetation cover changes from herbaceous plants on lower beach to scrubs and xylophyta on high beach. The diversity of vegetation cover is related with the elevation of their sites and increases with the arising of their sites. The change of water level has great impact on the diversity of vegetation species. In flood seasons abundant and uniformity decrease, but dominant species forms; (2) The10th blockof *acacia auriculaeformis* pure forest in the Shangyang Experiment Station has higher vegetation diversity and the vegetation evolution is near to natural evolution. So, the vegetation evolution is in good development. The *acacia auriculaeformis* pure forest and its afforestation methods and measurements are beneficial for recovery of vegetation cover in this region; (3) The taxa richness, biodiversity and bio-community indices of benthic invertebrates remain at a relatively high level in the upper and middle reaches of the East River but reduce to nearly zero in the lower reaches. The main ecological stresses are loss of habitats due to reclamation and separation of riparian waters from the river; (4) An important restoration strategy is to create multiple habitats with high habitat diversity, such as riparian lakes, wetlands, back water and sluggish flow zones and reconnect the separated oxbow lakes with the river; (5) A restoration strategy is to adjust the operation scheme and give signals and time for animals to find a shelter and escape from the currents. Slope erosion and landslides changed the substrate of streams and the biodiversity reduces as a consequence. Reforestation is the most effective strategy to control erosion and restore stream ecology.

8. Human-induced stresses (1) Reservoir operations have considerable potential impacts on the River ecology and environment. According to the reservoir index (RI), the East River is a semi-controlled river. In the East River basin impoundments have caused the decrease of variations in monthly discharge and average flow fluctuation downstream. The sediment transport rate is also reduced, which will exacerbate the sediment imbalance downstream. Deposition is found in the channel upstream, and channel movement intensity also increases downstream. The sites with few impacts of the Fengshuba Reservoir have higher values of species, density, density of biomass, and bio-diversity. And the study also reveals that if there are no further disturbances, the river ecology can be restored along the stream by self-adjustment; (2) A dimensionless coefficient, urbanization index, was introduced to quantitative study the impact of urbanization on the ecology environment. The increase of urbanization index in the Huizhou region had the tendency of benched increase; (3) An agriculture development index was introduced to quantitatively study the impact of agriculture on river ecological system and a forestry development index was also introduced to quantitatively study the impact of forestry on river ecological system. The agriculture development index in Heyuan region was lower (19.0%) and the higher one (39.1%) was in Huizhou (39.1%). The lower forestry development index (52.2%) was in Longgang region and the higher one (69.8%) was in Xinfeng County.

11.2 Integrated River Management Stratgies of the East River

"Integrated river basin management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems" (http://www.panda.org). The ideas of the modern integrated river basin management follows the principles of utilizing the natural law of river ecological system and realizing the sustainable development of both the social economy and environment protection. The integrated river basin management consists of the integrated project and administration for the long-term utilization of land and water resources on the scale of the whole river basin. The keys of integrated river basin management are: according to the envisages of possible distant prospect in utilizing natural resource the related departments and their leaders recognize the common benefits and unified actions, determine and carry out the common policy.

The East River, being a larger river in the Pearl River System, is an excellent river in the South China in its social and economic effects such as flood control, hydropower generation, water supply, navigation etc. The water resources are used in high efficiency, and the assurance of water quantity and water quality are also higher. The climate in the East River Basin is simple and belongs to warm humid type. The river channels are also stable and have little horizontal swing only. The East River Basin is rich in water quantity and has the excellent water quality. The concentration of sediment in the runoff is also decreasing. The flood-control facilities, consisting of reservoirs and dykes etc, reduced the flood risk in the main channels. Now, the ecological environment in the East River Basin is good and shows high biological diversity and diversity of bio-habitats.

According to the East River basin plans and the development and management projects of local governments, the water resources, channel regulation and drainage of sewage and wastewater will be developed in high speed in the coming years. The following integrated river basin management strategies for the East River are put forwarded aiming at the problems appeared.

11.2.1 Principles of the integrated river utilization and development be determined in the views of whole river basin

It is necessary to determine the principles of the integrated utilization and development of the East River in the views of whole basin when drawing the plans of the East River. Based on the principles of sustainable economic development and situation in the river basin the integrated utilization and development principles, such as water supply, flood control, hydropower generation, navigation, irrigation and aquatic production etc, can be determined.

With the developing of social economy, water supply in the downstream and delta reaches has become been increasing rapdily in the East River Basin. In addition to meet water requirement for its own river basin, the East River has the duty to supply water for the cities of Guangzhou, Hongkong and Shenzhen with population of about 11 million. So, water supply had the direct influence to the industrial and agricultural production and daiy life of these regions. Water supply with enough quantity and good quality is the first priority. The principle of the East River development should be giving priority to water supply and paying attention to flood-control, hydropower generation, navigation, irrigation and aquatic production etc.

11.2.2 Pressure of human activity on river ecological environment be reduced

Human activities intervene in river ecological environment of the East River. For example, with the construction of large reservoirs, the flow discharge in dry seasons in the main channel of East River and other tributaries obviously increases. Canalization of the river channel improved the navigation condition. But the cascade reservoirs destroy the continuity and interconnection of the East River, Canalized river and simplified river cross-section destroy the ecological environment of riverbanks and also threaten the life and ecological system of river, including the biodiversity and diversity of bio-habitats. Dams and dykes cut off the connection between main channels and floodplains, lakes and wetland, leading to decrease of flood-detention ability. Destroy of vegetation cover in upstream basin or tributary basins decrease the ability of lagging flood in these basins. The dams and dykes as well as the river regulation constraint the river morphology and increased the transferring speed of flood peak in river channel. Continuous rising of dams and dykes and continuous increase of population in floodplain led to larger flood risk.

The integrated river basin management consists of the Engineering measures and non-engineering measures. The reasonable project of hydro-projects and river regulation should not destroy the natural river system. The non-engineering measures should gave back the space of its own flow path to restore the natural hydrological specialty of the river, such as giving back the march land, increasing river resistance and the change extent of channel width, retaining the dried leaves and decadent wood block in mountainous tributaries，restoring the ecological environment of river bank and increasing the diversity of dwelling land for creatures. An important restoration strategy is to create multiple habitats with high habitat diversity, such as riparian lakes, wetlands, back water and sluggish flow zones and reconnect the separated oxbow lakes with the river. Slope erosion and landslides changed the substrate of streams and the biodiversity reduces as a consequence. Reforestation is the most effective strategy to control erosion and restore stream ecology.

11.2.3 Water resources be allocated rationally

The total volume of the long-term average annual water resource in the East River is about 28 billion m^3, but it is distributed unevenly around a year. The runoff from April to September is about 22.4 billion m^3 and about 5.6 billion m^3 from October to March of the next year. The East River is the main resource of water supply for the cities of Guangzhou, Shengzhen, Hongkong, Dongguan and Huizhou etc., serving population of about 40 million. The water volume per capita is only $700m^3$, which is severe water shortage region according to the international standard. In dry season the low-water flow discharge can not satisfy the necessary water volume for the ecological environment. The river pollution is originated from two resources: one is point and and line source pollution from industrial and urban regions, and the other is the non-point source pollution from farmland. Because the water in river is a continuous flowing body, so the polluted water in upper stream must be brought into the downstream. With the quick development of industry and agriculture some river reaches, such as Xizhi River, had been polluted seriously and became heavy lack of good qualified water.

Rational allocating water resource to achieve high water usage efficiency is main duties of water resource management. It is represented by the balance between various departments of water consumers and the balance between various regions in a river basin. The balance between various departments of water consumers means the coordination between industrial and agricultural water consumption, domestic water for cities and countrysides and others with the ecological water requirement. The balance of various regions means the coordination between water consumers of upstream and downstream basins. The water resource management also includes the transfer of water over several river basins.

The effect of water regulation by reservoirs should be studied and brought into play. The eco-environmental water demand of the East River Basin can be satisfied by water regulation of reservoirs. The regulation of water volume between various seasons (increasing the discharge in dry seasons) can satisfy the eco-environmental water demand, water supply and resisting salt water introsion. Increasing the fluctuation of river discharges can restore the natural characters of the river. The water quality of East River Basin must be protected in the strengthening the supervision and management on the draining

11.2.4 Tendency of river deformation be restricted

The excessive extraction of river sand causes cutting down of channel bed and descending of water level in the down stream and delta reaches of the East River. Channel bed descending also increases tidal current. The upper boundary of salted water on the delta continuously moved upstream along the river channel. The wastewater in the river reach at Dongguan City can not be drained away. The wastewater, discharging from the lower reach of the East River canal, flows upstream together with the incoming tidal flood current and directly threatens the water entrance of water plant. The lower water level at the water entrance of Dongguan-Shenzhen water supply works reduces continuously due to the extraction of river sand. The lowest water level reduced to 0.41m in December 1995, which could not satisfy the necessary water level for the water pump station.

In order to change the situation of serious river deformation, it is necessary to stop the extraction of river sand under the support of governments.

References

Amy Jansen, Siwan Lovett. 2004. Development and application of a method for the rapid appraisal of riparian condition. http://www.rivers.gov.au/publicat/guidemanual.htm

AWPPF, Assessment &Watershed Protection Division Office of Wetlands, Oceans, and Watersheds US EPA Watershed Protection: A Project Focus. August 1995.

AWPSA, Assessment &Watershed Protection Division Office of Wetlands, Oceans, and Watersheds US EPA Watershed Protection: A Statewide Approach. August 1995.

Blair RB. 2001. Birds and butterflies along urban gradients in two ecoregions of the U. S . In :Lockwood JL ,eds.Biotic Homogenization[C] . Norwell (MA) : Kluwer , 33～56.

Brierley, G.J., Cohen, T., Fryirs, K. and Brooks, A. 1999. Post-European changes to the fluvial geomorphology of Bega catchment, Australia: implications for river ecology. Freshwater Biology, 41: 839-848.

Chessman, B. C., Growns, J. E. and Kotlash, A. R. 1997. "Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: application to the Hunter River system, New South Wales." Marine and Freshwater Research 48: 159-172.

Chutter FM. 1998. Research on the Rapid Biological Assessment of Water Quality Impacts in Streams and Rivers. WRC Report No. 422/ 1/ 98. Water Research Commission , Pretoria.

Cooper, S.D., Diehl, S., Kratz, K. and Sarnelle, O. 1998. Implications of scale for patterns and processes in stream ecology. Australian Journal of Ecology, 23: 27-40.

Covich A. 1993. Water and ecosystems. In:P. Press, New York, New York, USA., H. Gleick, ed. Water in crisis: A guide to the world's fresh water resources. Oxford University

Czech B ,Krausman PR ,Devers PK. 2000. Economic associations among causes of species endangerment in the United States. Biol . Sci . ,50 :593～601.

Denys C ,Schmidt H. 1998. Insect communities on experimental mugwort plots along an urban gradient. Oecologia,113 :114～116.

Dodds WK, Jones JR ,Welch EB. 1998. Suggested classification of stream trophic state : Distributions of temperate stream types by chlorophyll ,total nitrogen ,and phosphorus. Water Res ,32 :1455-1462.

Downes B., Lake P.S. and Schreiber E.S.G. 2000. Habitat structure, resources and diversity: the separate effects of surface roughness and macroalgae on stream invertebrates, Oecologia, 123: pp.569-581.

Eloranta P. 1998. Applications of diatom indices in Finnish rivers. In : Prygiel J ,Whitton BA ,Bukowska J eds. Use of Algae to Monitor Rivers Ⅲ. Douai : Agence de l'Eau Artois2Picardie. 138～144

Fan K.W. , L. Fok, X.B. Ma, P. Yeh, D.S. Cheng, J.H.W. Lee, Z.Y. Wang & F. Chen. 2005. Field Investigation on Biodiversity in the East River (Dongjiang) (submmited).

Ferreira J G. 2000. Development of an estuarine quality index based on key physical and biogeochemical features. Ocean and Coastal Management, 43(1): 99-122.

Frissell, C.A., Liss, W.J., Warren, C.E. and Hurley, M.D. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management, 10: 199-214.

Gehrke, P. C., Brown, P., Schiller, C. B., Moffatt, D. B. and Bruce, A. M. 1995. "River regulation and fish communities in the Murray-Darling river system, Australia." Regulated Rivers: Research and Management 11: 363-375.

Gerald E., Galloway M. 1997. River basin management in the 21st century: Blending development with economic, ecologic, and cultural sustainability. Water International, 22(2): 82 – 891.

Hack, J. T. and Goodlett, J. C.1960. Geomorphology and forest ecology of a mountain region in the central Appalachians. US Geological Survey Professional Paper, 347.

Hansen, J.E., Ruedy R., Sato, M., Imhoff, W., Lawrence, W., Easterling, D., Peterson, T. and Karl T. A closer look at United States and global surface temperature change. J. Geophys. Res. 2001, 106, 23947-23963.

Harper, D. and Everard, M. 1998. Why should the habitat-level approach underpin holistic river survey management?

Aquatic Conservation: Marine and Freshwater Ecosystems, 8: 395-413.

Harper, D., Smith, C., Barham, P. and Howell, R. 1995. The ecological basis of the management of the natural river environment. In: Harper, D.M. and Ferguson, A.J.D. (eds.) The Ecological Basis for River Management. John Wiley and Sons, Chichester. pp. 219-238.

Heinrich Walter. 1985. Vegetation of the earth. 3d ed. New York: Springer-Verlag.

Hicken, E.J. 1984. Vegetation and river channel dynamics. Canadian Geographer, 28 111-126

Ho K. C., J. T. S. Yau. 2003. A comparative study of chemical contamination in sediments of East River (Dongjiang) and selected reservoirs in Hong Kong. Chemical Speciation and Bioavailability, 14, 19-23.

Ho K.C., K.C.C. Hui. 2001. Chemical contamination of the East River (Dongjiang) and its implication on sustainable development in the Pearl River Delta. Environment International, 26, 303±308.

James R K, Chu E W. 1999. Restoring Life in Running Waters : Better Biological Monitoring. Washington DC: Island Press.

Karr J. R., Chu E. W. 2000. Sustaining living rivers. Hydrobiologia , 422/ 423: 1-14

Karr JR. 1981. Assessments of biotic integrity using fish communities. Fisheries (Bethesda) , 6 : 21～27

Karr JR. 1999. Defining and measuring river health. Freshwater Biol , 41 : 221～234

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication No. 5.

Kate Rowntree and Gina Ziervogel. 1999. Development of an Index of stream Geomorphology for the Assessment of River Health. Prepared for the River Health Programme, January 1999. Department of Geography, Rhodes University

Kelly MG,Whitton BA. 1998. Biological monitoring of eutrophication in rivers. Hydrobiologia ,384 :55～67

Kemper NP. 1999. RVI : Riparian Vegetation Index. Draft report to the Water Research Commission. WRC.

Kleynhans CJ . 1999. The development of a fish index to assess the biological integrity of South African rivers. Water SA , 25 : 265～278

Kwandrans J , Eloranta P , Kawecka B , et al . 1998. Use of benthic diatom communities to evaluate water quality in rivers of southern Poland. J. Appl. Phycol., 10 :193～201

Ladson AR ,White LJ ,Doolan JA , et al . 1999. Development and testing of an index of stream condition for waterway management in Australia. Freshwater Biol ,41 :453～468

Ladson, A. R. 2000. A multi-component indicator of stream condition for waterway managers: balancing scientific rigour with the need for utility. Dissertation for Doctor degree. The University of Melbourne.

Leung, Alan Sze-lun, 2007, Epson Pearl River Delta Scoping Study, WWF Hong Kong, Hong Kong SAR, China

Mackin Rogalska R ,Pinowski J ,Solon J , et al . 1988. Changes in vegetation , avifauna , and small mammals in a suburban habitat. Polish Ecol . St udies ,14 :293～330.

Maddock, I. 1999. The importance of physical habitat assessment for evaluating river health. Freshwater Biology, 41: 373-391.

Marsden MW, Smith MR , Sargent RJ . 1997. Trophic state of rivers in the Forth catchment ,Scotland. A quat Cons ,7 :211～221

Martin Griffiths. 2002. The European Water Framework Directive: An Approach to Integrated River Basin Management. European Water Management Online, Official Publication of the European Water Association (EWA).

McIntyre NE. 2000. Ecology of urban arthropod :A review and a call to action. Ann. Ent . Soc. Am., 93: 825～835.

Montgomery, D.R. 1999. Process domains and the river continuum. Journal of the American Water Resources Association, 35: 397-410.

Muhar, S. and Jungwirth, M. 1998. Habitat integrity of running waters – assessment criteria and their biological relevance. Hydrobiologia, 386: 195-202.

Norris, R.H. and Thoms, M.C. 1999. What is river health? Freshwater Biology, 41: 197-209.

Parsons, M, Thoms, M and Norris, R. 2000. Review of Physical River Assessment Methods—A Biological Perspective. http://www.deh.gov.au/water/rivers/nrhp/protocol-2/chapter1.html

Pavluk TI , et al . 2000. Development of an index of trophic completeness for benthic macroinvertebrate communities in flowing waters. Hydrobiologia ,427 :135～141

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. EPA444/ 4-89-001. U.S. Environmental Protection Agency, Washington, DC.

Rankin, E.T. 1995. Habitat indices in water resource quality assessments. In: Davis, W.S. and Simon, T.P. (eds.) Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. CRC Press, Boca Raton. pp. 181-208.

Rapport D. J. 1999. On the transformation from healthy to degraded aquatic ecosystems. A quatic Ecosyst. Health Manag., 2: 97～103

Raven, P. J., Holmes, N. T. H., Dawson, F. H., Fox, P. J. A., Everard, M., Fozzard, I. R.and Rouen, K. J. 1998. River Habitat Quality: the physical characteristics of rivers and streams in the UK and the Isle of Man. The Environment Agency , Scottish Environment Protection Agency, and Environment and Heritage Service, Northern Island. Bristol.

Reice, S.R. and Wohlenberg, M. 1993. Monitoring freshwater benthic macroinvertebrates and benthic processes: measures for assessment of ecosystem health. In: Rosenberg, D.M. and Resh, V.H. (eds.) Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York. pp. 287-305.

Resh VH , Jackson J K. 1993. Rapid assessment approaches to biomontoring using benthic macroinvertabrates. In :Rosenberg DM , Resh VH eds. New York :Chapman & Hall.

Rosenberg, D.M. and Resh, V.H. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates. In: Rosenberg, D.M. and Resh, V.H. (eds.) Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York. pp. 1-9.

Rowntree K.M. and Wadeson R.A., 1999. A hierarchical framework for categorising the geomorphology of selected river systems. Water Research Commission Report.

Roy P S, Williams R J, Jones A R, et al. 2001. Structure and function of South-east Australian Estuaries. Estuarine, Coastal and Shelf Science, 53(3):351-384.

Sale, P.F. 1998. Appropriate spatial scales for studies of reef-fish ecology. Australian Journal of Ecology, 23: 202-208.

Schamberger, M., A.H. Farmer, and J.W. Terrell. 1982. Habitat Suitability Index models: introduction. FWS/OBS-82/10. U.S Department of the Interior, U.S. Fish and Wildlife Service, Washington, DC.

Schumm, S.A. 1977. The Fluvial System. John Wiley and Sons, New York.

Sládecek V. 1986. Diatom as indictors of organic pollution. Acta Hydrochim Hydrobiol ,14 :555～566

Smith MJ , Kay WR , Edward DHD , et al . 1999. AusRivAS :Using macroinvertebrates to assess ecological condition of rivers in Western Australia. Freshwater Biol ,41 :269～282

Stalnaker C., Lamb B.L., Henriksen J., Bovee K. and Bartholow J., 1994. The instream flow increamental methodology: a Primer for IFIM, National Ecology Research Center, Internal Publication, National Biological Survey.

Townsend, C.R. and Hildrew, A.G. 1994. Species traits in relation to a habitat templet for river systems. Freshwater Biology, 31: 265-275.

United States Fish and Wildlife Service (USFWS). 1981. Standards for the development of Habitat Suitability Index models (ESM 103). U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Uys, M.C., Goetsch, P_A. And O'Keeffe, J.H., 1996. National Biomonitoring Programme for Riverine Ecosystems: Ecological indicators, a review and recommendations, NBP Report Series No 4. Institute for Water Qulaity Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Wang Zhao-yin and Joseph H.W.Lee, 2004. Integrated river management. Textbook for Ph.D students, Tsinghua University.

Wang Zhao-Yin and Wu Yongsheng, 2001, Sediment-removing capacity and river motion dynamics International Journal of Sediment Research, Vol.16, No.2, pp. 105-115.

Wang Zhaoyin, Li Changzhi, Guo Yanbiao and Wang Feixin, 2003c, Vegetation–Erosion chart and its application in typical watersheds in China, …

Wang Zhaoyin, Wang Guangqian and Gao Jing , 2003a, A dynamic model of vegetation–erosion process, , Journal of Environmental Sciences, Vol.23. No.1, pp.98-105 (in Chinese).

Wang Zhaoyin, Wang Guangqian, Li Changzhi and Wang Feixin, 2003b, Preliminary study on the Vegetation –erosion dynamics and its application, Sciencia Sinica, Series D, No. 8, pp. 1-11.

Wang ZhaoYin. 2000. Experimental study on scour rate and channel bed inertia, Journal of Hydraulic Research, IAHR, No.1, pp.27-47.

Waterway and Floodplain Unit, 1997. An Index of Stream Condition: Reference Manual. Department of Natural Resources and Environment, Victoria.

Weins, J.A. (1989) Spatial scaling in ecology. Functional Ecology, 3: 385-397.

Wright J F , Armitage PD , Furse MT. 1989. Prediction of invertebrate communities using stream measurements. Regul Rivers : Res Manag ,4 :147～155

Zimmermann, R.C. and Thom, B.G. 1982. Physiographic plant geography. Progress in physical Geography, 6, 45-59.