Progress and Pilot Practice of Flood Hazard Mapping in China

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China is undertaking strategic adjustment in flood control and disaster mitigation

- Preventing and controlling flood and waterlogging disasters is a pressing task in China.
- The core of strategic adjustment is to implement scientific flood management in accordance with the concept of harmonious coexistence of man and nature.
- The concept of ‘transfer from flood control to flood management’ is widely accepted by flood management administrations and the public.

How to analyze and evaluate flood risk for better avoiding and mitigating flood risk?

- In the “Eleventh Five-Year Development Plan for the National Water Sector”, a comprehensive plan for FHM was firstly brought forward.
- The objective is to complete FHM of important flood-prone areas, flood detention areas and cities along main streams of seven major rivers.
- FHM is expected to play an directive role for flood control plan, flood control works construction, land exploitation and awaking public consciousness etc.

Contents

1.General introduction of pilot practice of FHM in China

2.Outcome of pilot practice on FHM in Huaihe River

3.Problems encountered in process of FHM

4.Short-term Tasks and Suggestions on FHM

Progress on FHM in China

- In 2003, OSFCDRH sponsored a research project, for the purpose of drafting the guideline.
- In July 2005, tentative guideline for FHM was promulgated by OSFCDRH.
- 35 pilot regions from seven major rivers were selected to make FHM for acquiring experience.
- China Institute of Water Resources and Hydropower Research (IWHR) is responsible for technical support and training.

Pilot Regions for FHM in China

Sheet 1 Pilot Regions for flood hazard mapping

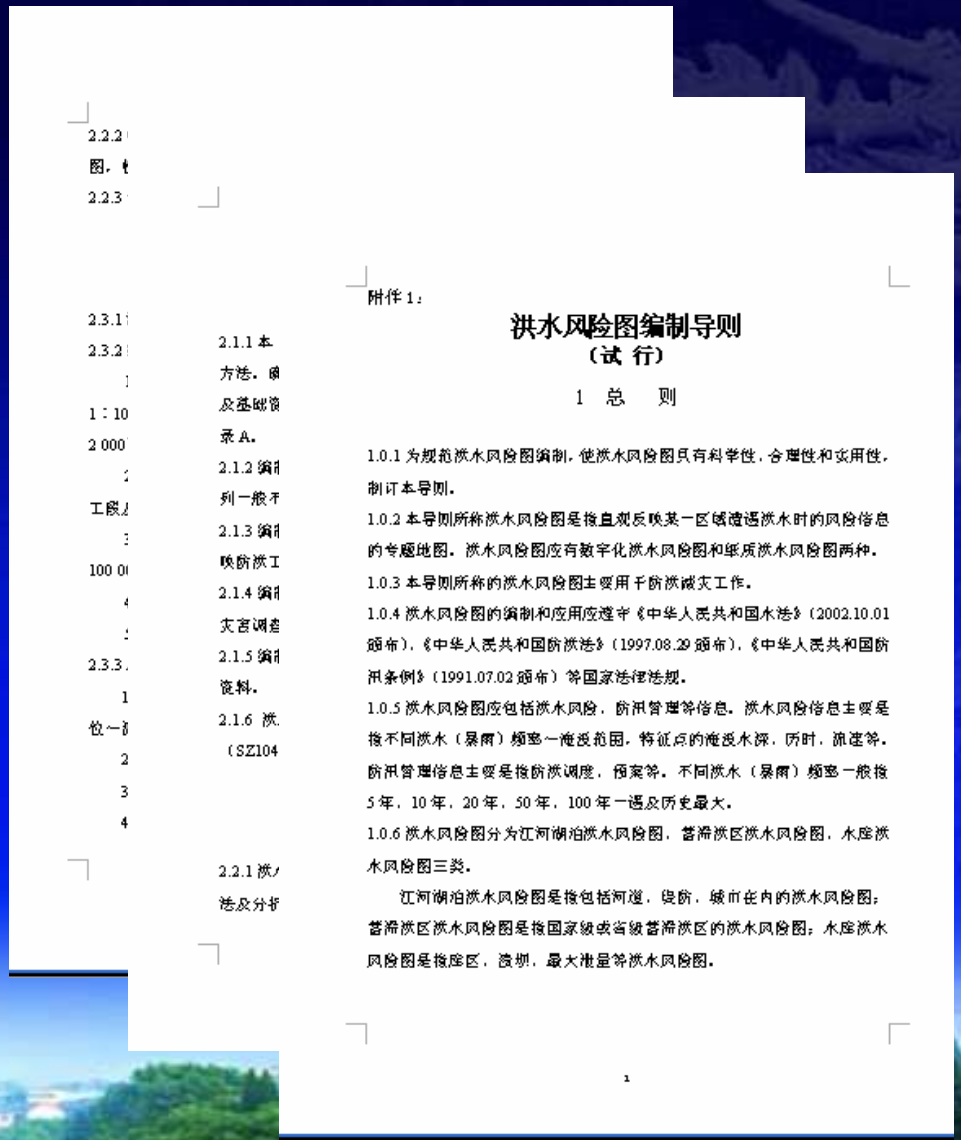
Region	River	City	Reservoir	Flood Detention Area
Total (35)	12	8	6	9
Songliao River Water Resources Commission	——	——	Chaersen	——
Heilongjiang Province	Lahai Reach of Nenjiang River	Haerbin	——	Pangtoupao
Haihe River Water Resources Commission	——	——	Yuecheng	——
Hebei Province	North bank of Zhanghe River	Baoding		Wenanwa
Yellow River Water Resources Commission	Floodplain of lower Yellow River	——	——	——
Shandong Province	Laowangmiao to Huojialiu Reach of Yellow river	Jinan	——	Dongpinghu Lake
Huaihe River Water Resources Commission	Left bank of Yi River	——	——	Chengdonghu Lake
Jiangsu Province	New Shu River	Lianyugang	Shilianghe	Huangdunhu
Yangtze River Water Resources Commission	Fuhe and Nanhe River of Chengdu City	——	——	Jingjiang
Hunan Province	Zijiang River	Yueyang	Zhushuqiao	Linan
Taihu Basin Authority	Dapu Sluice Gate	——	——	——
Zhejiang Province	Xixian Embankment of Dongzhaoxi River	Wenzhou	Qingshan	Gaohu
Pearl River Water Resources Commission	Hejiang River	——	——	——
Guangdong Province	Beijiang Dyke	Guangzhou, Foshan	Feilaixia	Pajiang
Guangxi Zhuang Autonomous Region	——	Wuzhou	——	——

- 35 regions from seven major rivers 12 rivers, 8 cities, 6 reservoirs and 9 flood detention areas
- Diverse types of flood control works included.
- sufficient basic information, explicit boundary, moderate task.

Objective of Pilot Regions for FHM

- To clarify thoughts, estimate rationality and availability of the tentative guideline.
- Expected to complete pilot practice within 2 years, and experience of pilot practice will be summarized.
- Hereafter FHM will be extended to seven major rivers and it aims to establish flood risk management system in China.

Briefing of Tentative Guideline for FHM



附件1：

洪水风险图编制导则
（试 行）

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1

- 4 chapters

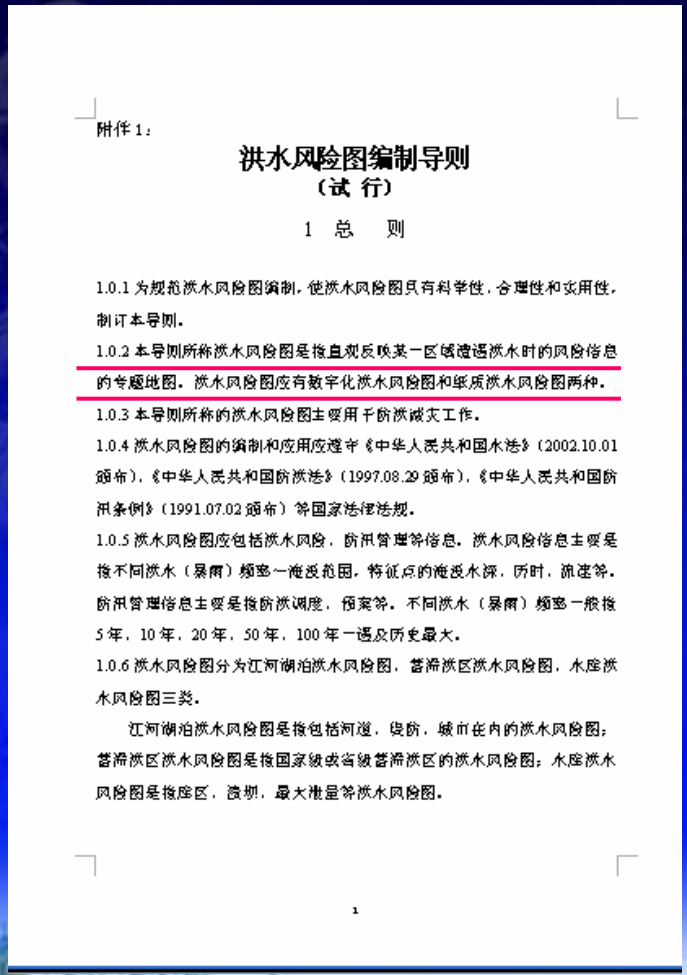
  general principle, flood risk mapping, flood risk computer system platform, outcome and supplementary principle.

Content of Tentative Guideline for FHM

（1）Definition

FHM is a series of special maps to show flood risk information clearly when a specific region is inundated in terms of different presumed scenarios.

It’s made by flood control administrations based on the actual need, categorized as digital and printed flood hazard maps.



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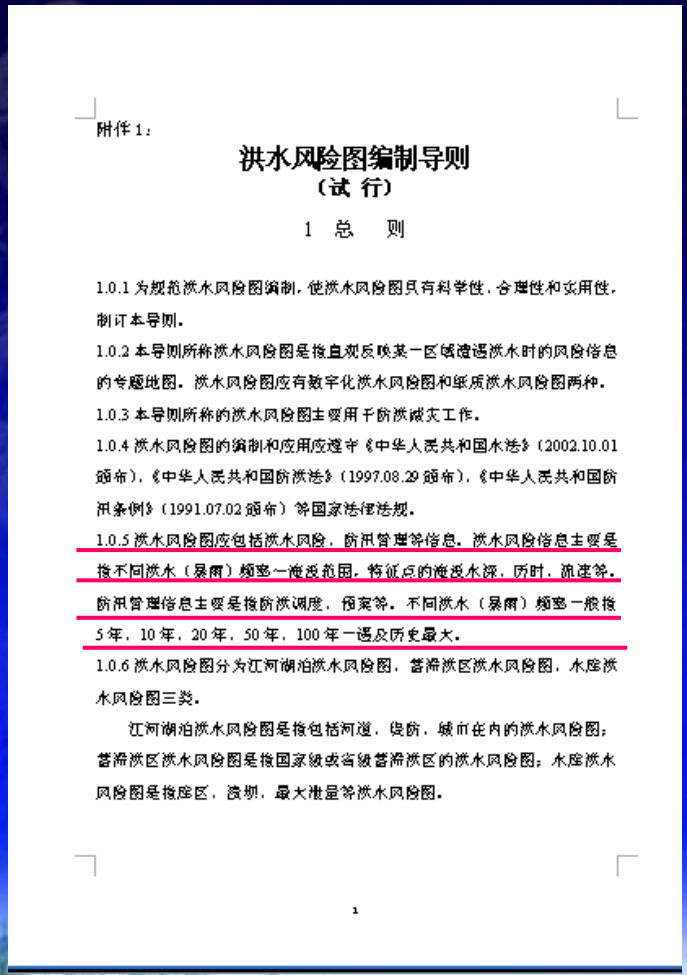
Content of Tentative Guideline for FHM

（2）Information

Flood risk information comprises inundation boundary, flood depth, velocity, inundation duration and arriving time, etc of different floods with return period of 5, 10, 20, 50 to 100 years.

Flood control scheme, evacuation routes and refuge shelters should be embodied in flood management information.



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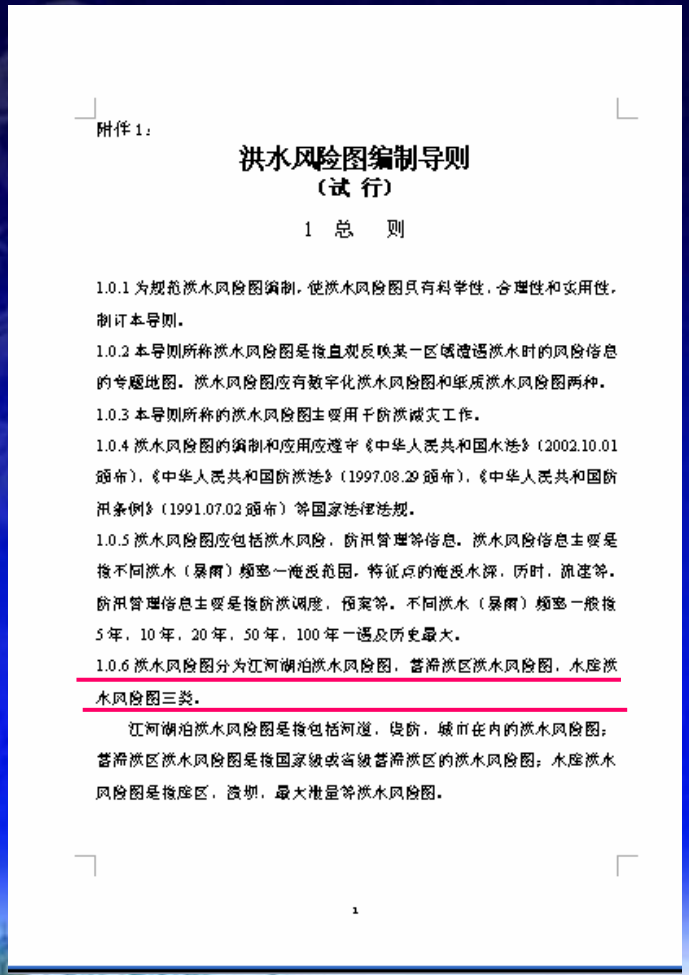
（3） Classification

Flood hazard map is classified into three categories

River and lake, flood detention area and reservoir. Each type of flood hazard map shows the flood risk of different flood control works separately.



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Content of Tentative Guideline for FHM

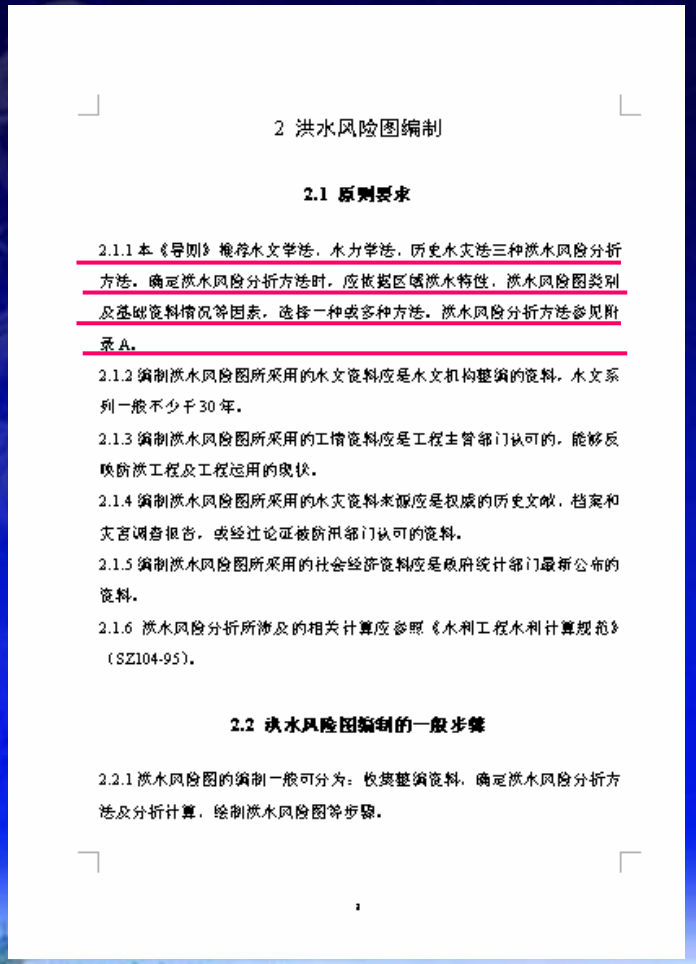
（4） Flood Risk Analysis Methodology

3 types of methods and models of flood risk analysis.

Hydrological method is used to analyze flood risk in the mountainous rivers.

Hydraulic method is used to calculate flood evolution process in the plain when embankments and reservoirs broken.

For these regions where historical flood datum and disasters can be obtained, historical flood disaster method will do work.



2 洪水风险图编制

2.1 原则要求

2.1.1 本《导则》推荐水文学法，水力学法，历史水灾法三种洪水风险分析方法。确定洪水风险分析方法时，应依据区域洪水特性，洪水风险图类别及基础资料情况等因素，选择一种或多种方法。洪水风险分析方法参见附录A。

2.1.2 编制洪水风险图所采用的水文资料应是水文机构整编的资料，水文系列一般不少于30年。

2.1.3 编制洪水风险图所采用的工情资料应是工程主管部门认可的，能够反映防洪工程及工程运用的现状。

2.1.4 编制洪水风险图所采用的水灾资料来源应是权威的历史文献，档案和灾害调查报告，或经过论证被防汛部门认可的资料。

2.1.5 编制洪水风险图所采用的社会经济资料应是政府统计部门最新公布的资料。

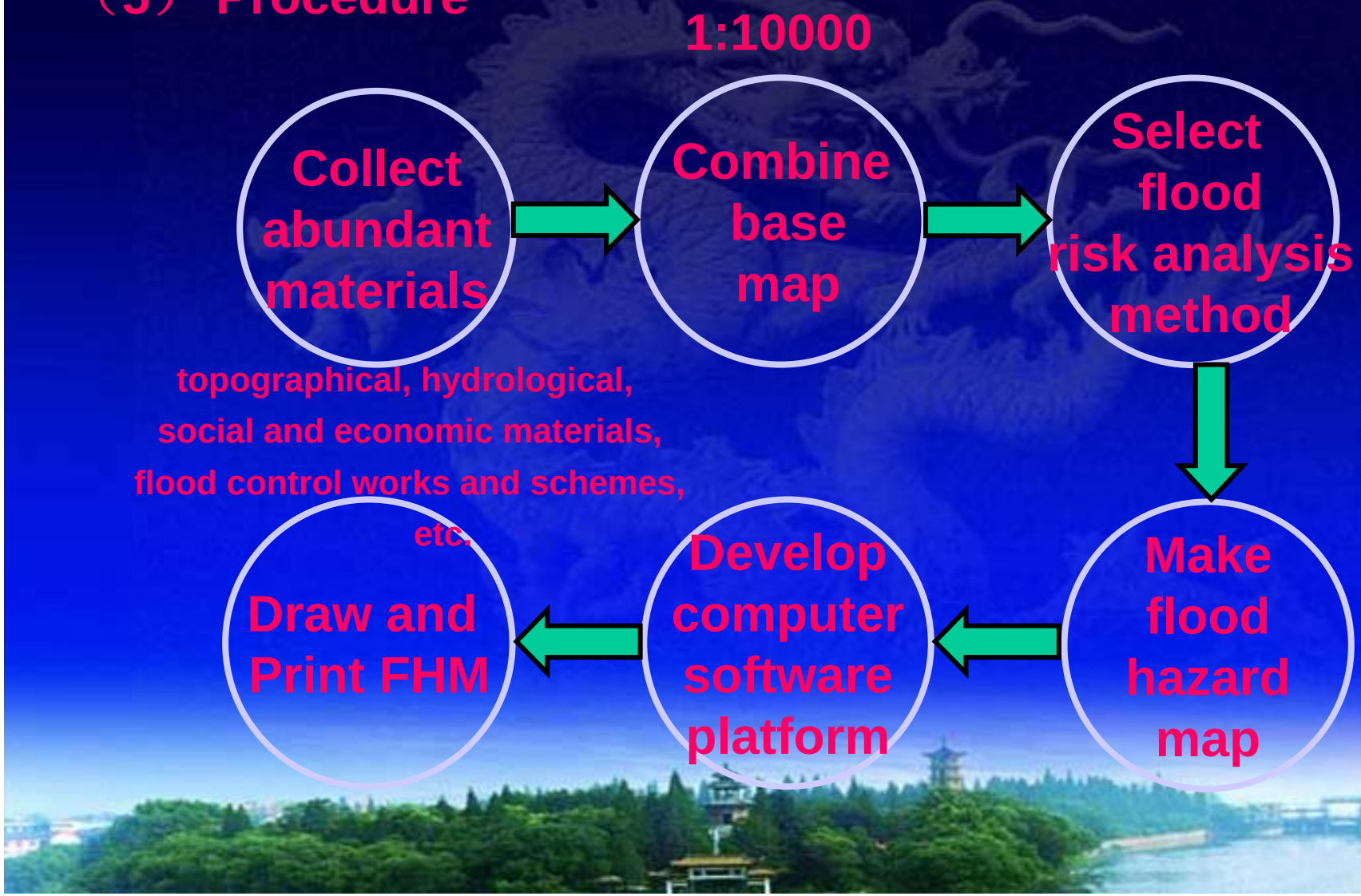
2.1.6 洪水风险分析所涉及的相关计算应参照《水利工程水利计算规范》（SZ104-95）。

2.2 洪水风险图编制的一般步骤

2.2.1 洪水风险图的编制一般可分为：收集整编资料，确定洪水风险分析方法及分析计算，绘制洪水风险图等步骤。

Content of Tentative Guideline for FHM

（5） Procedure

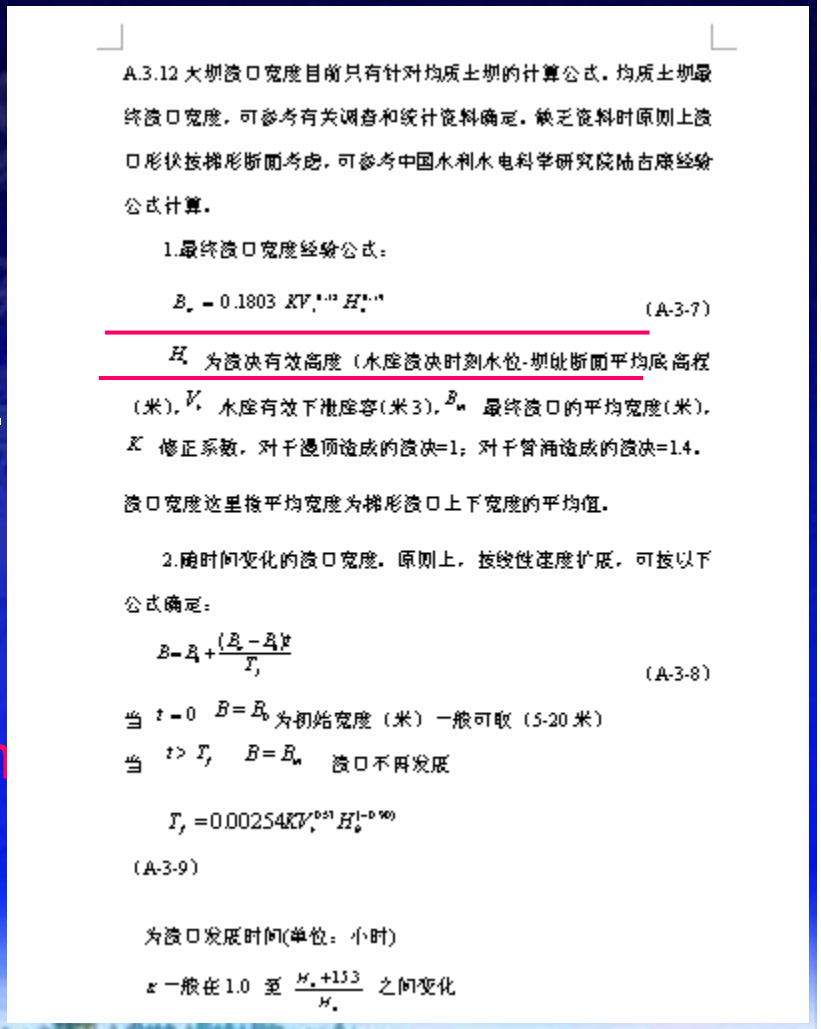


Content of Tentative Guideline for FHM

（6） Breach Supposition of flood control works

The breach spots of embankment and reservoirs are supposed according to experience.

In the condition of datum unavailable, embankment breach experiential formula in Korean Guideline for FHM and dam breach experiential formula summarized by Mr. Lu Jikang are suggested to analyze flood risk.



A.3.12 大坝溃口宽度目前只有针对均质土坝的计算公式。均质土坝最终溃口宽度，可参考有关调查和统计资料确定。缺乏资料时原则上溃口形状按梯形断面考虑，可参考中国水利水电科学研究院陆吉康经验公式计算。

1.最终溃口宽度经验公式：

$$B_m = 0.1803\ K V_s^{0.32} H_b^{0.19} \qquad \text{(A-3-7)}$$

H_b 为溃决有效高度（水库溃决时刻水位-坝址断面平均底高程（米），V_s 水库有效下泄库容(米3)，B_m 最终溃口的平均宽度(米)，K 修正系数，对于漫顶造成的溃决=1；对于管涌造成的溃决=1.4。

溃口宽度这里按平均宽度为梯形溃口上下宽度的平均值。

2.随时间变化的溃口宽度。原则上，按线性速度扩展，可按以下公式确定：

$$B = B_0 + \frac{(B_m - B_0)t}{T_f} \qquad \text{(A-3-8)}$$

当 $t = 0$ $B = B_0$ 为初始宽度（米）一般可取（5-20米）

当 $t > T_f$ $B = B_m$ 溃口不再发展

$$T_f = 0.00254 K V_s^{0.53} H_b^{(1-0.90)} \qquad \text{(A-3-9)}$$

为溃口发展时间(单位：小时)

ε 一般在1.0 至 $\frac{H_b+153}{H_b}$ 之间变化

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Pilot Regions for FHM in Huaihe River

Region	River	City	Reservoir	Flood Detention Area
Huaihe River Water Resources Commission	Left bank of Yi River	——	——	Chengdonghu Lake
Jiangsu Province	New Shu River	Lianyugang	Shilianghe	Huangdunhu
Total (6)	2	1	1	2

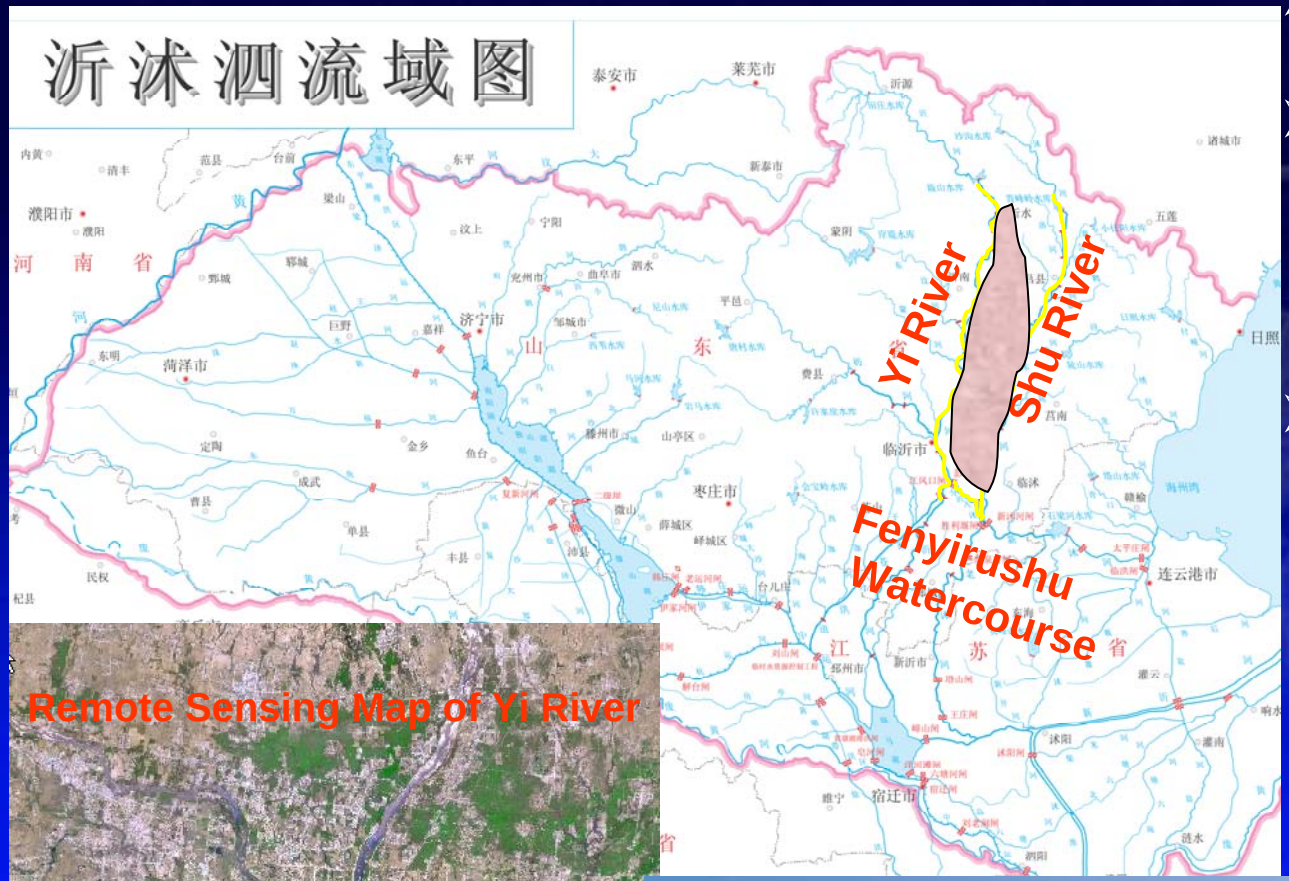
6 pilot regions in Huaihe River
2 rivers, 1 city, 1 reservoir and 2 flood detention areas

Pilot Regions for FHM in Huaihe River

Sheet 3 Brief Introduction of pilot flood hazard mapping in Huaihe River

Region	Type	Area (km^2)	Flood risk Analysis Method	Embankment (dam) breach spot	Embankment (dam) breach mode	Outcome
Left Bank of Yi River	River	480	Two-dimensional unsteady hydraulic method	2 breach spots	Experiential formula	8 scenarios FHM (different probability flood, embankment breach spots)
New Shu River	River	2000	Two-dimensional unsteady hydraulic method	2 breach spots	Korean Experiential formula	2 scenarios FHM of embankment breach at each bank
Shilianghe	Reservoir	2000	Two-dimensional unsteady hydraulic method	2 points at main dam and auxiliary dam	Lu jikang Experiential formula	2 scenarios FHM of main and auxiliary dam breach
Lianyungang	City	27.2	Hydrological method	Waterlogging	/	8 scenarios FHM of waterlogging hazard mapping
Chengdonghu	Flood detention area	378	Hydrological method	sluice gate	Diverting floods by sluice gate	FHM of 5, 10, 20, 30, 50-years floods, etc
Huangdunhu	Flood detention area	385	Two-dimensional unsteady hydraulic method	sluice gate and designated spots	Diverting floods by sluice gate	11 scenarios FHM of flood diversion ways combined with different water level in lake

2.1 Left Bank of Yi River

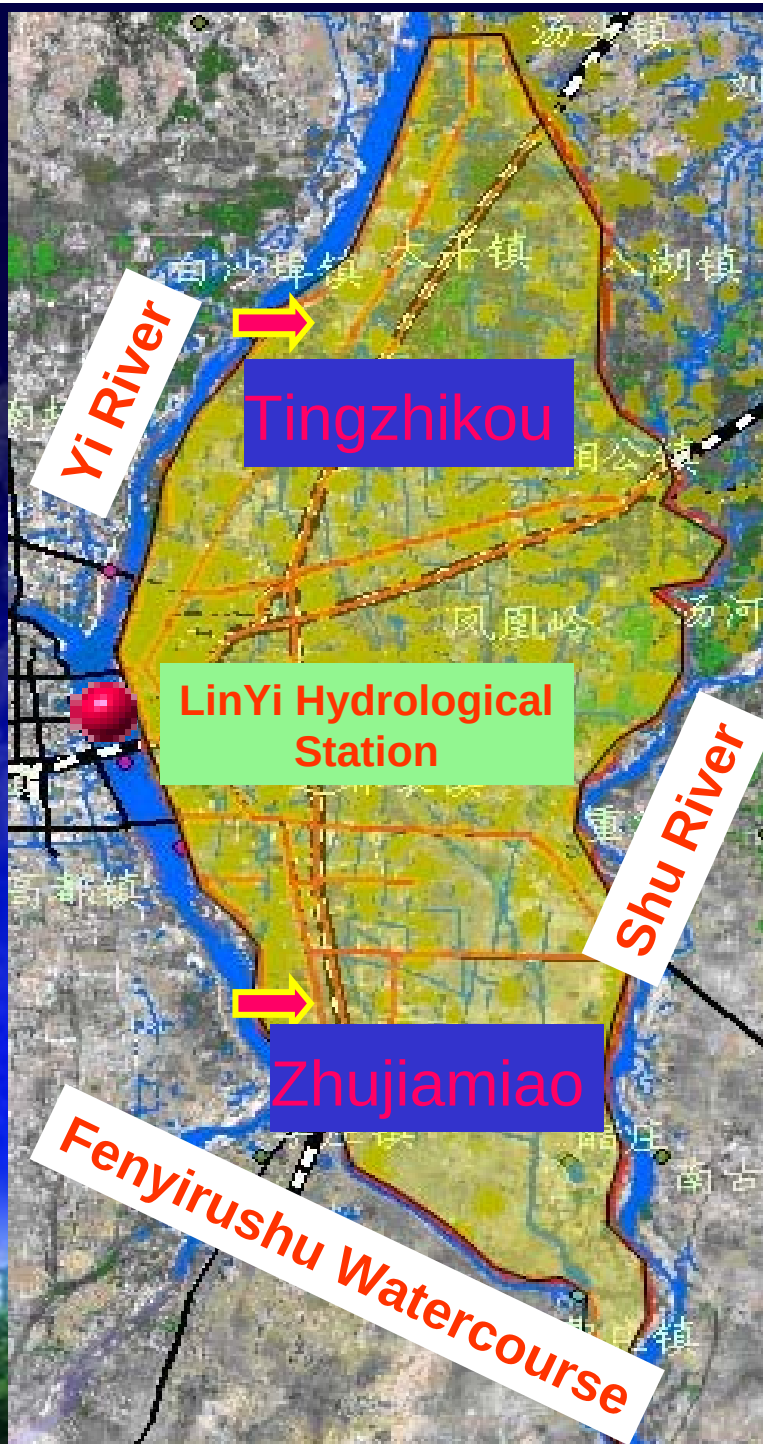


- 480km^2
- several severe floods occurred in year 1730, 1957, 1974 etc
- Embankments have been reinforced in recent years and can withstand floods with a return period of 20 years.

2.1 Left Bank of Yi River

Embankment breach Spots

- Tingzhikou, the weakest spot where embankment broke during floods of 1957 and 1974.
- Zhujiamiao, where embankment will be exploded to divert floods into left bank plain of Yi River, for safeguarding people's life when flood peak of LingYi Hydrological Station exceeds 13,000 m^3/s (return period of 20 years) according to flood control scheme.

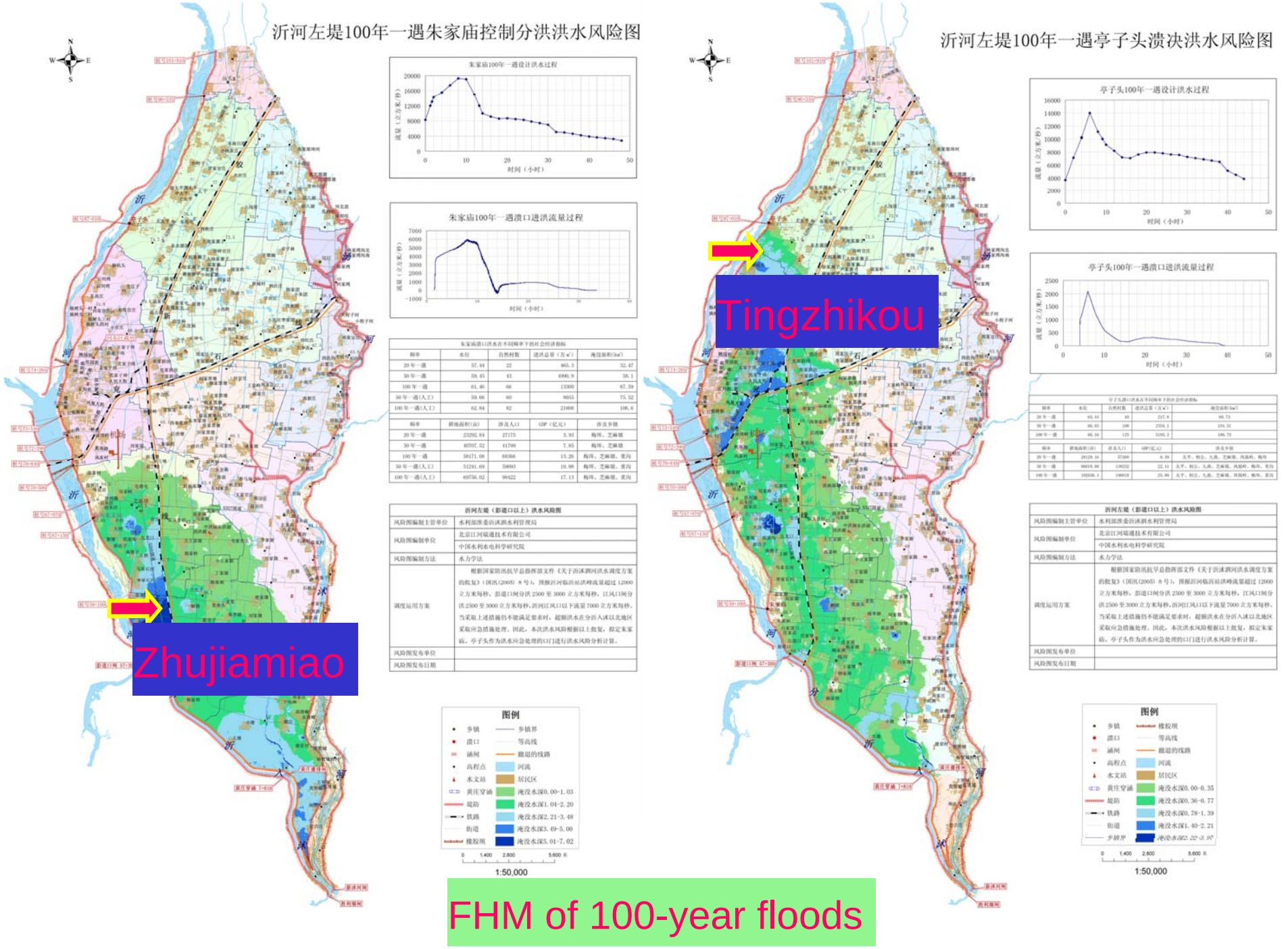


2.1 Left Bank of Yi River

2-dimension unsteady hydraulic calculation method

Sheet 4 Simulation Outcome of flood hazard mapping in Left Bank of Yi River

Scenario	Embankment breach spot	Flood magnitude (return period)	breach width (m)	breach process (s)	Flood diversion volume ($10^8 m^3$)	Inundation area (km^2)	Maximum water level (m)	Affected population (10^4)	Remark
1	Tingzhikou (natural breach)	100	300	30	0.52	180.72	3~4	22.59	
2	Tingzhikou (natural breach)	50	200	20	0.24	154.51	3~4	22.41	
3	Tingzhikou (natural breach)	20	100	10	0.02	60.73	1~2	8.39	
4	Zhujiamiao (natural breach)	100	300	30	1.33	87.59	>7	6.84	
5	Zhujiamiao (natural breach)	50	200	20	0.50	58.1	4~5	4.17	
6	Zhujiamiao (natural breach)	20	100	10	0.05	32.47	3~4	2.72	
7	Zhujiamiao (exploded)	100	650	65	2.18	106.6	>7	9.84	Reduce flood peak 6000 m^3/s
8	Zhujiamiao (exploded)	50	350	35	0.81	75.52	6~7	5.91	Reduce flood peak 3000 m^3/s


沂河左堤100年一遇朱家庙控制分洪洪水风险图
朱家庙100年一遇设计洪水过程
朱家庙100年一遇溃口进洪流量过程
朱家庙溃口洪水在不同频率下的社会经济指标
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风险图发布日期
图例
乡镇
溃口
涵闸
高程点
水文站
黄庄穿涵
堤防
铁路
街道
橡胶坝
乡镇界
等高线
蓄退的线路
河流
居民区
淹没水深0.00-1.03
淹没水深1.04-2.20
淹没水深2.21-3.48
淹没水深3.49-5.00
淹没水深5.01-7.02
1:50,000
Zhujiamiao
沂河左堤100年一遇亭子头溃决洪水风险图
亭子头100年一遇设计洪水过程
亭子头100年一遇溃口进洪流量过程
亭子头溃口洪水在不同频率下的社会经济指标
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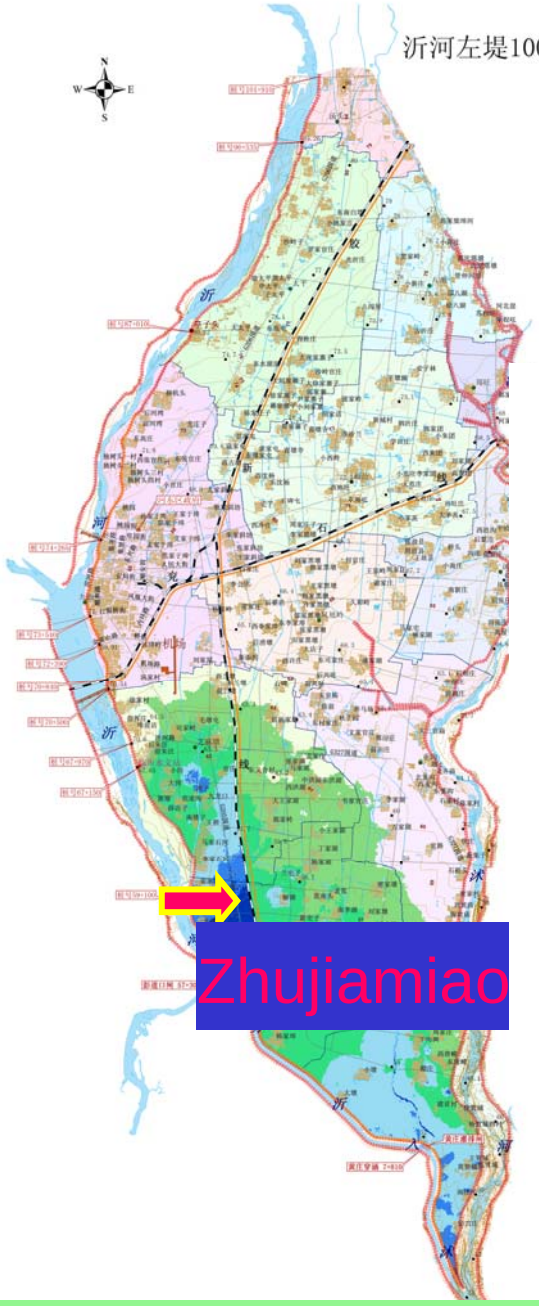
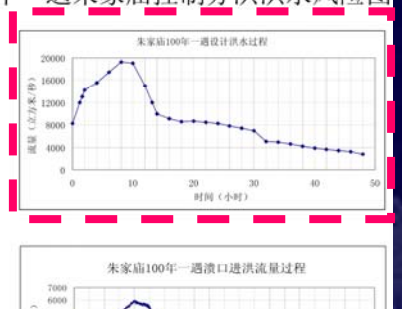
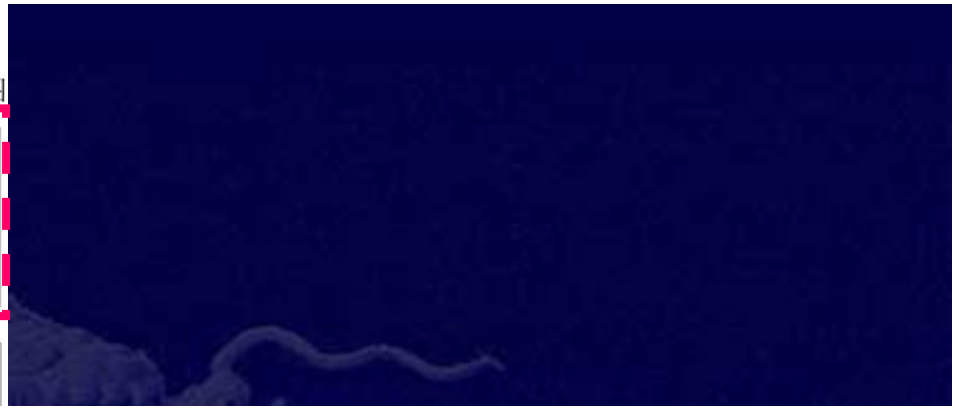
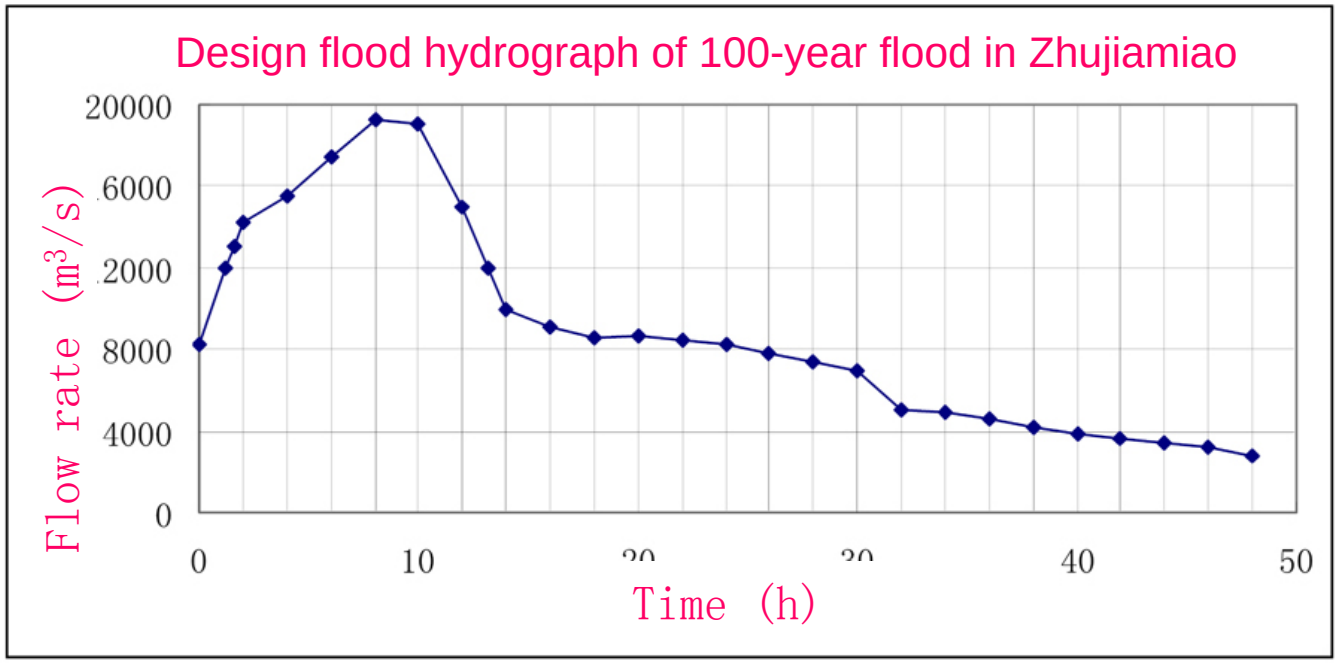
橡胶坝
等高线
蓄退的线路
河流
居民区
淹没水深0.00-0.35
淹没水深0.36-0.77
淹没水深0.78-1.39
淹没水深1.40-2.21
淹没水深2.22-3.97
1:50,000
Tingzhikou
FHM of 100-year floods

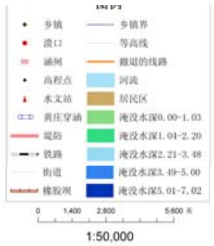


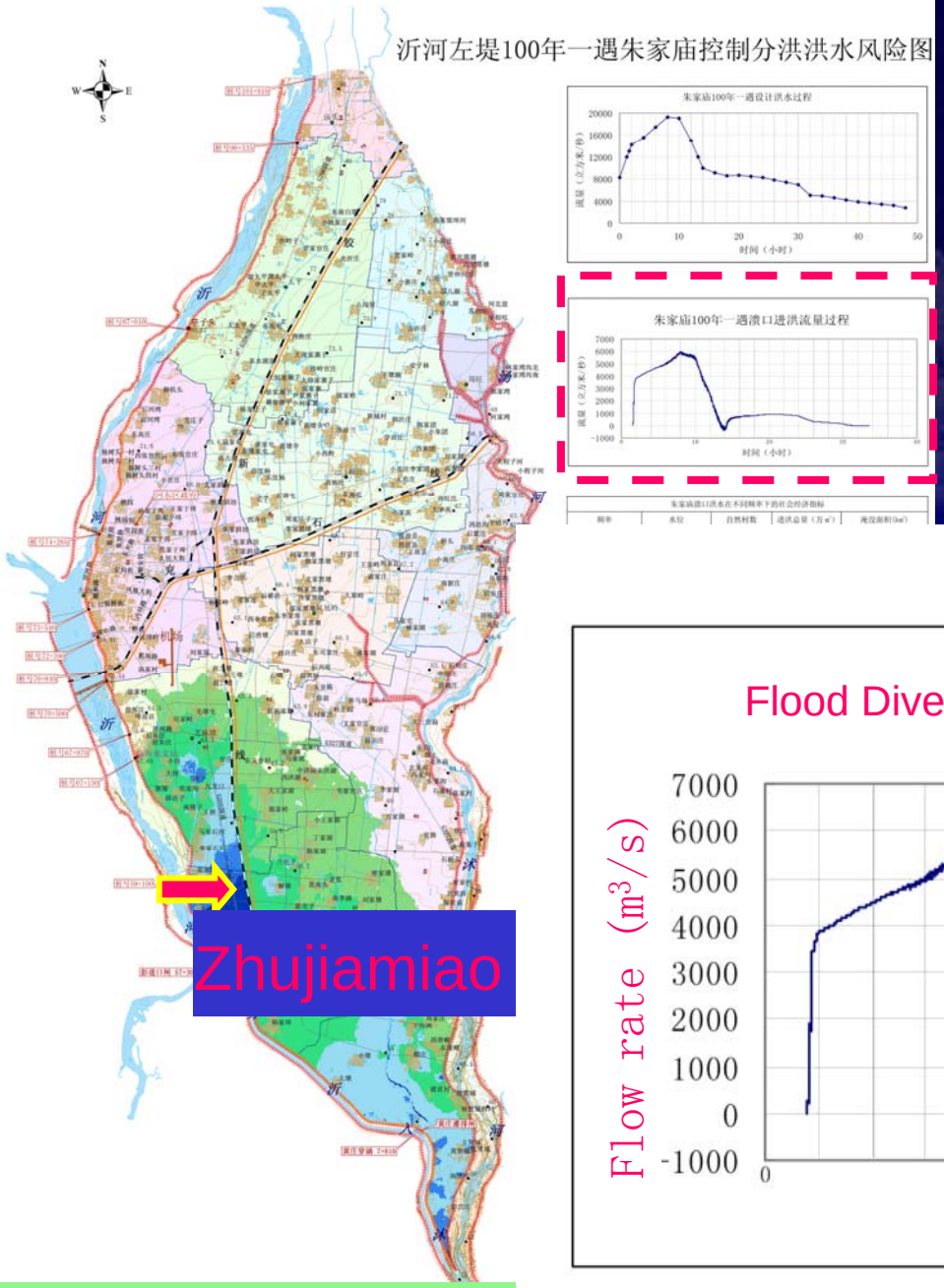
FHM of 100-year floods

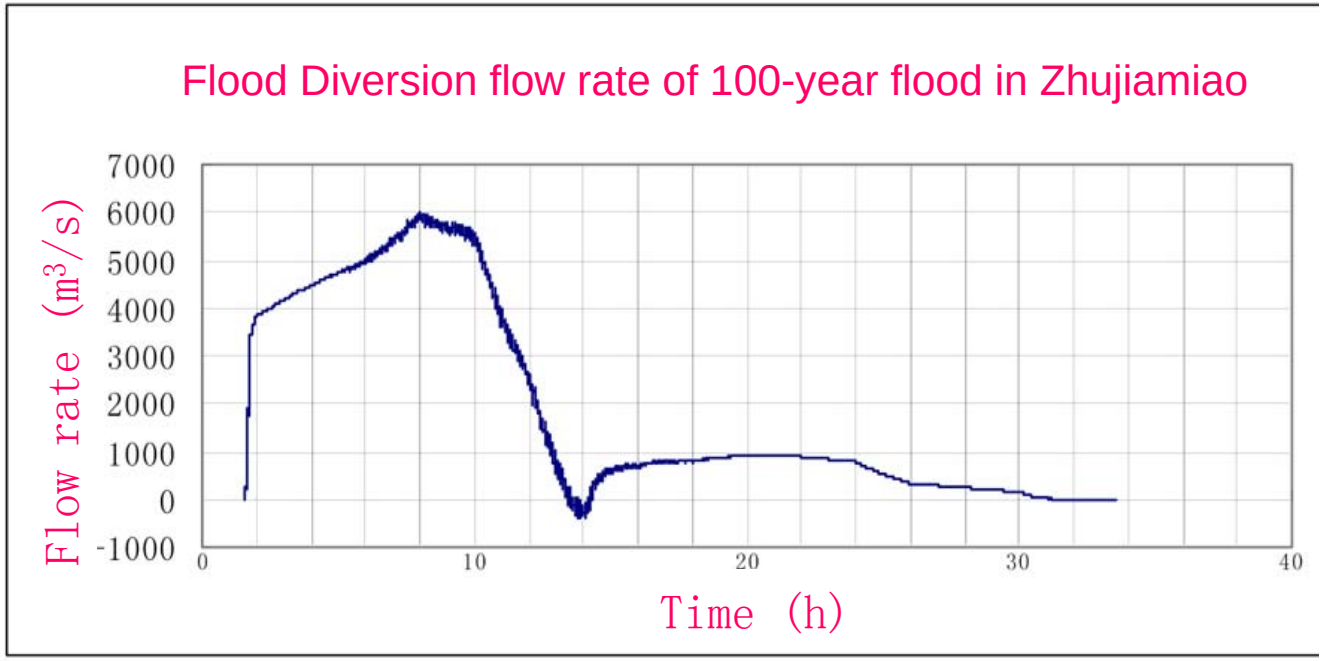




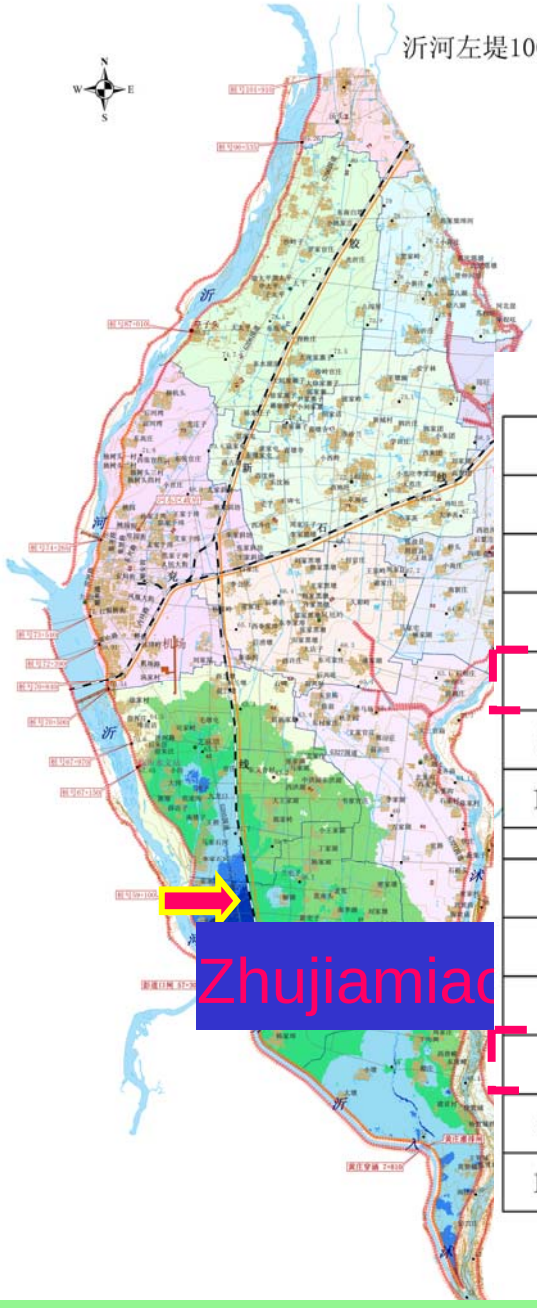


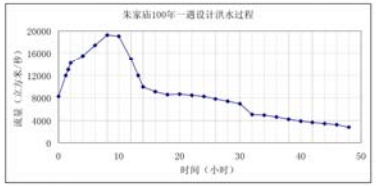


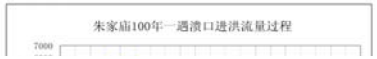


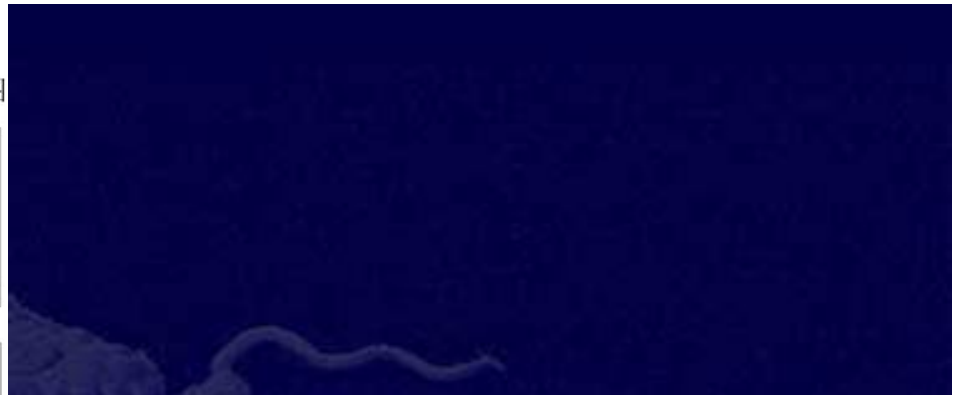


FHM of 100-year floods







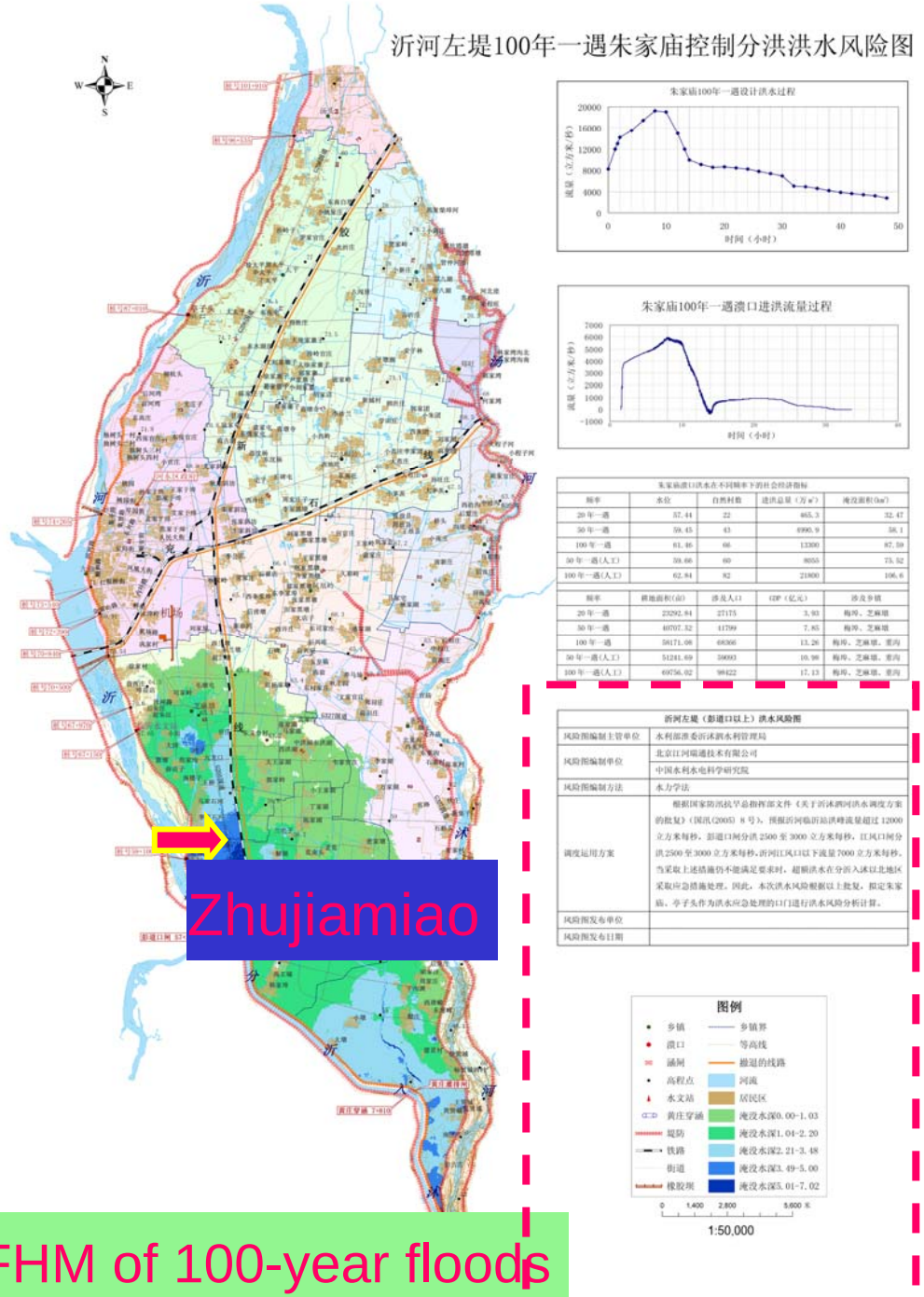


Loss and impact of different flood

朱家庙溃口洪水在不同频率下的社会经济指标				
频率	水位	自然村数	进洪总量（万 m^3）	淹没面积(km^2)
20 年一遇	57.44	22	465.3	32.47
50 年一遇	59.45	43	4990.9	58.1
100 年一遇	61.46	66	13300	87.59
50 年一遇(人工)	59.66	60	8055	75.52
100 年一遇(人工)	62.84	82	21800	106.6

频率	耕地面积(亩)	涉及人口	GDP（亿元）	涉及乡镇
20 年一遇	23292.84	27175	3.93	梅埠、芝麻墩
50 年一遇	40707.52	41799	7.85	梅埠、芝麻墩
100 年一遇	58171.08	68366	13.26	梅埠、芝麻墩、重沟
50 年一遇(人工)	51241.69	59093	10.98	梅埠、芝麻墩、重沟
100 年一遇(人工)	69756.02	98422	17.13	梅埠、芝麻墩、重沟

FHM of 100-year floods



FHM of 100-year floods

沂河左堤（彭道口以上）洪水风险图	
风险图编制主管单位	水利部淮委沂沭泗水利管理局
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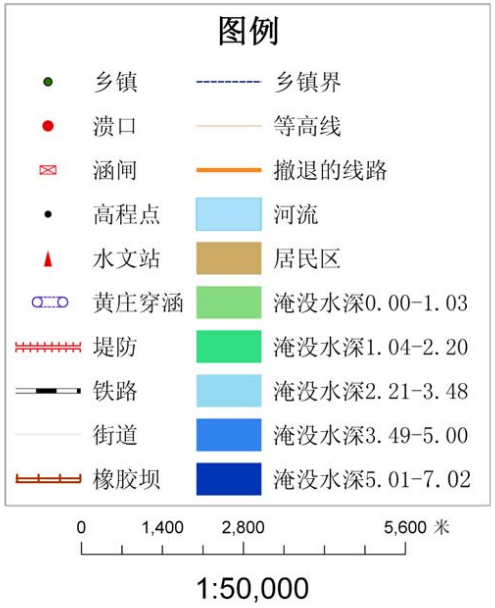
风险图发布单位	
风险图发布日期	

Legend and explanation



2.2 Shilianghe Reservoir

Storage capacity:

5.31×10^8 m^3

Main dam

22.0 m high, 5.2 km long

Two auxiliary dams.

Southern auxiliary dam

200 m long, 8.5 m high

Northern auxiliary dam

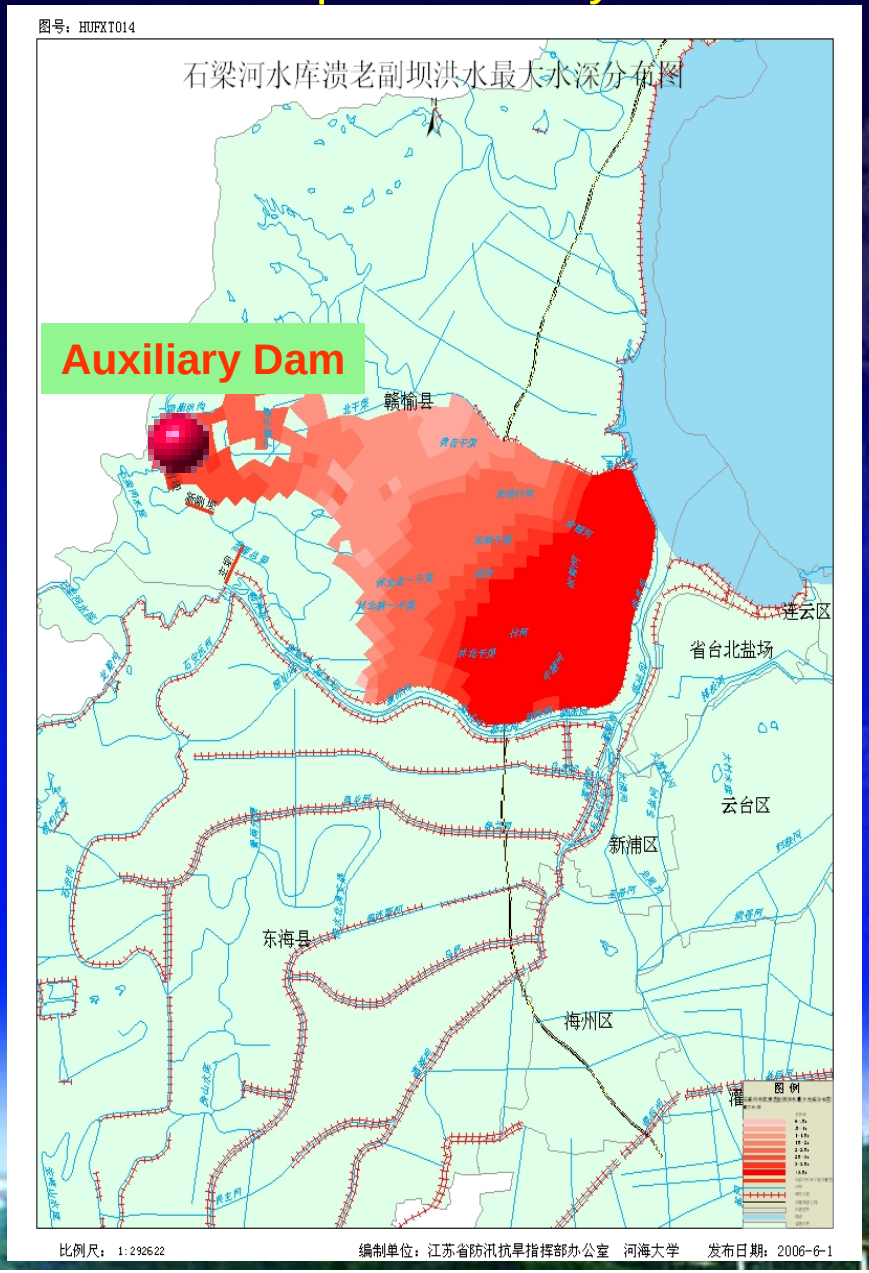
120 m long, 31.5 m high.

2 scenarios of main dam and north auxiliary dam breach separately are analyzed in FHM using two-dimensional unsteady hydraulic evolution method.

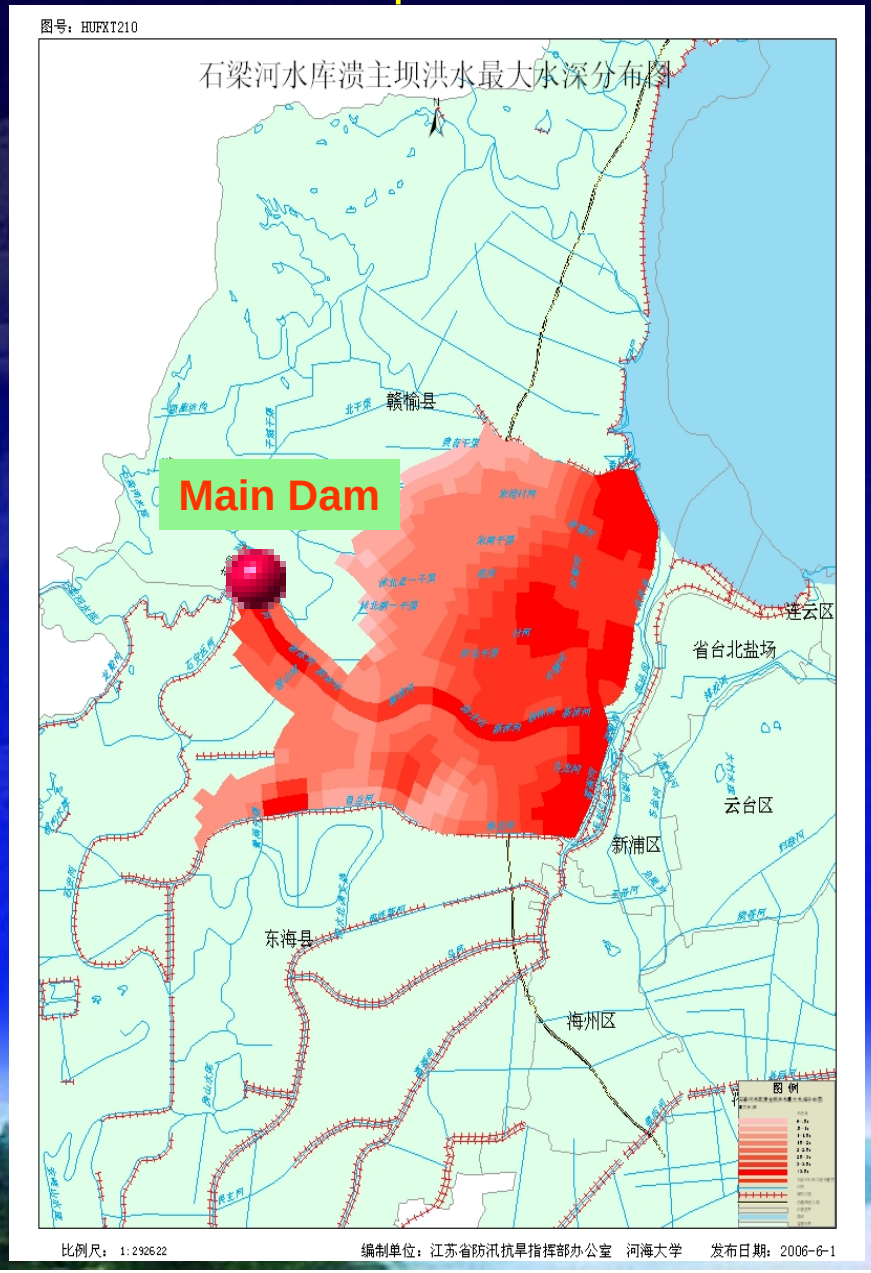
Dam failure width and process can be calculated according to dam breach experiential formula summarized by Mr. Lu Jikang suggested in the tentative guideline.

Flood risk information, inundation boundary, maximum water depth, arriving time and inundation duration etc, can be indicated in FHM separately.

Maximum inundation depth Distribution map of auxiliary dam breach



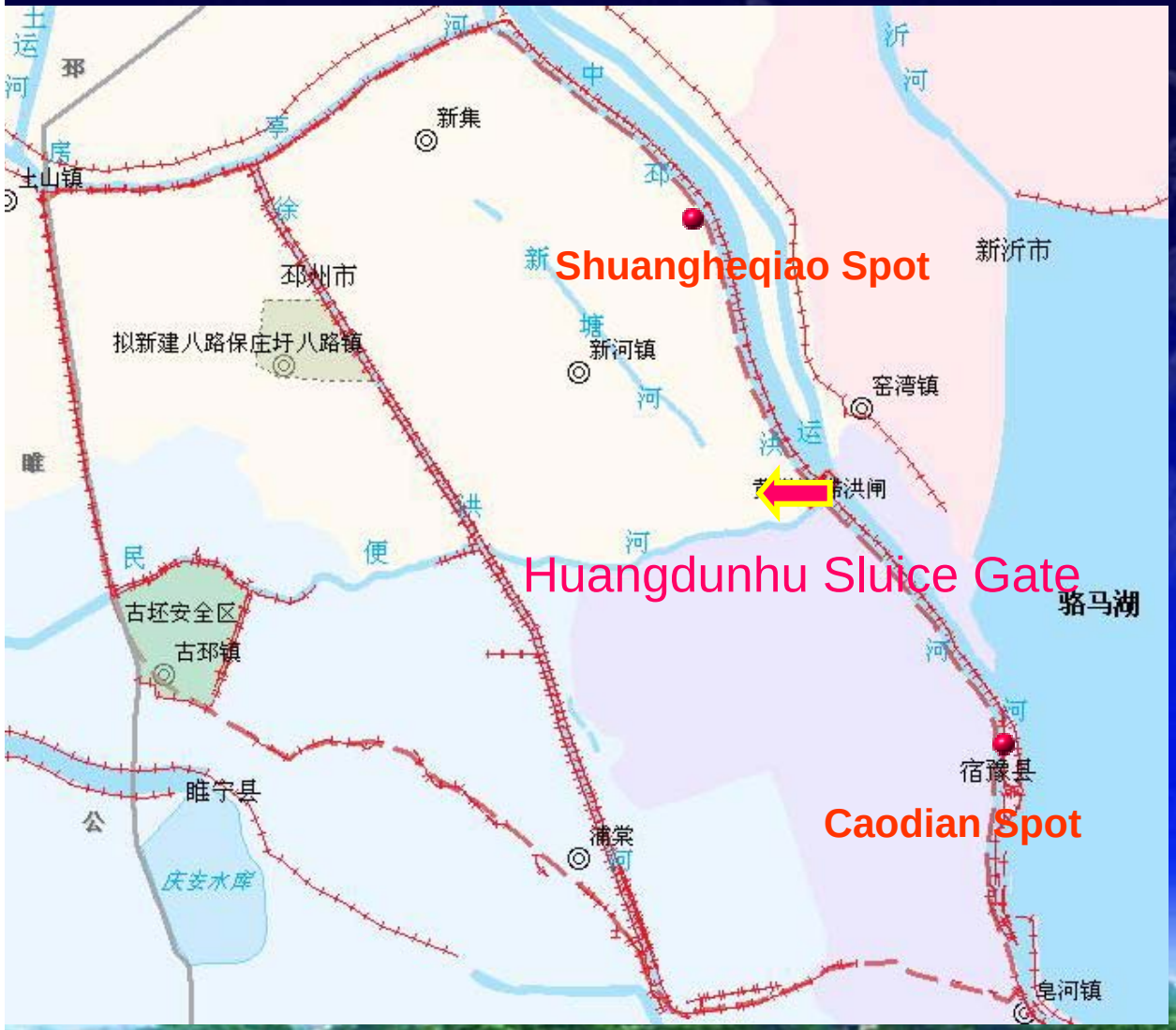
Maximum inundation depth Distribution map of main dam breach



2.3 Huangdunhu Lake

- 335.8km^2
- 14.7×10^{8}m^3 capacity
- 222,400 residents
- Floods will be discharged into Huangdunhu Lake when water level of Luomahu Lake rises up to 25.5 m and will exceed 26.0 m predicted

2.3 Huangdunhu Lake



Two ways of diverting floods into Huangdunhu Lake

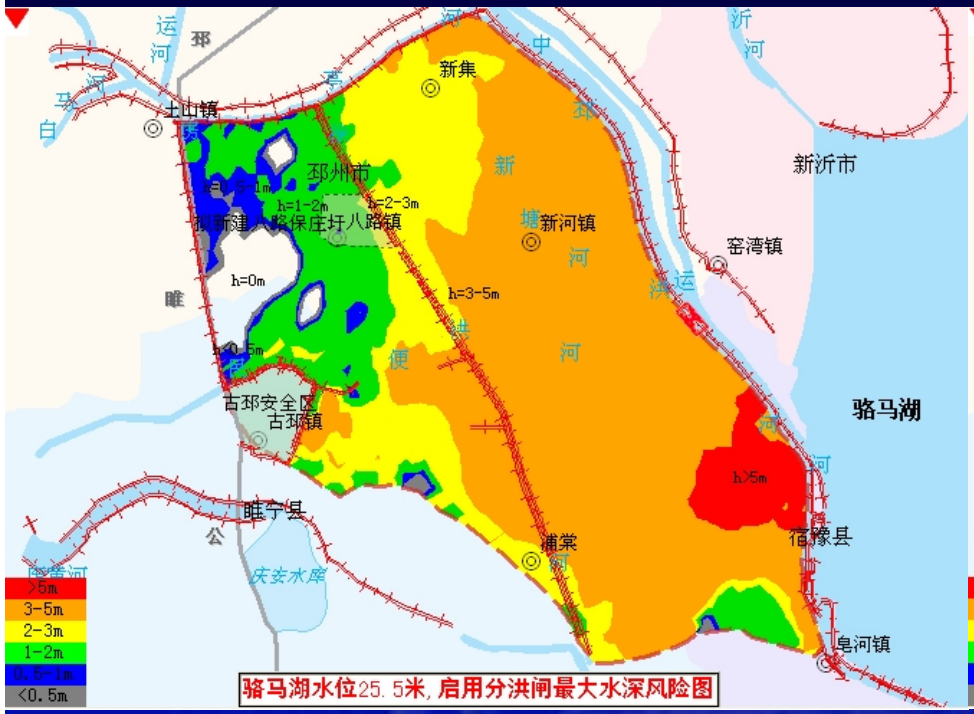
Huangdunhu Sluice Gate (design discharge is 2000 m^3/s)

Caodian and Shuangheqiao spots exploded when necessary (design width is 300 m).

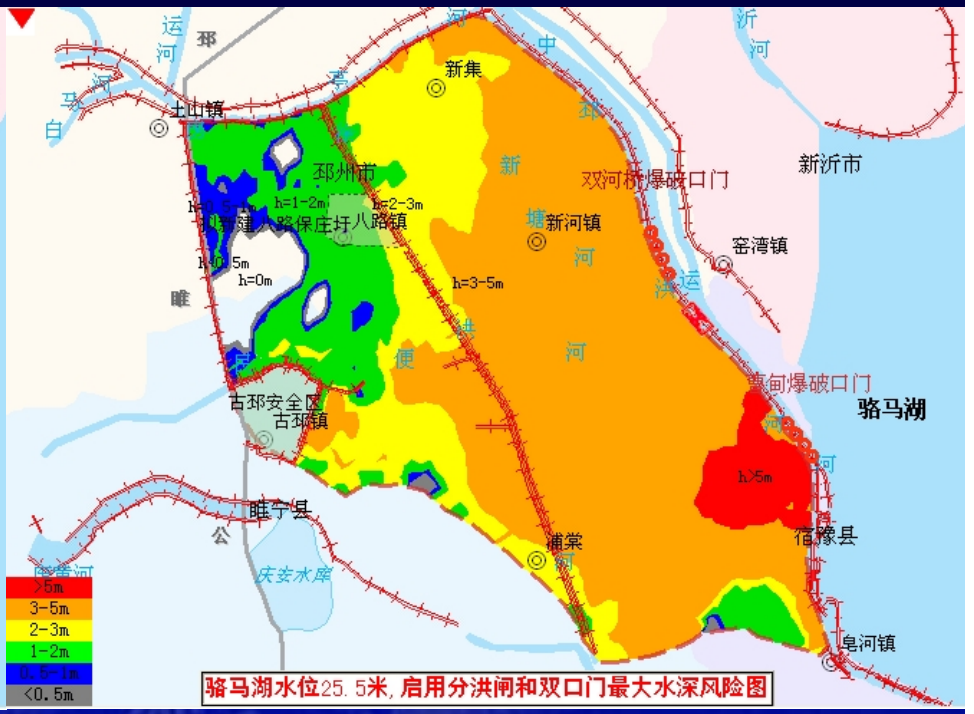
2.3 Huangdunhu Lake

Sheet 8 Flood Simulation Outcome of Different Scenarios in Huangdunhu Lake

No	Water Level of Luomahu Lake (m)	Flood diversion mode			Highest inundation level (m)	Corresponding flood diversion volume (10^8 m^3)	Time duration of diverting (h)	Remark
		Sluice gate	Shuangheqiao spot	Caodian spot				
1	25.5	√			25.68	12.34	185	
2	25.5	√	√		25.66	12.22	77	
3	25.5	√		√	25.66	12.27	72	
4	25.5	√	√	√	25.65	12.30	60	
5	26.0	√			26.29	13.92	193	
6	26.0	√	√		26.30	13.91	72	
7	26.0	√		√	26.36	14.01	71	
8	26.0	√	√	√	26.26	13.77	48	
9	/	1.5×10^8 m^3			22.26	1.5	21	Presumed flood diversion volume
10	/	3.0×10^8 m^3			22.76	2.96	42	
11	/	5×10^8 m^3			23.61	4.96	70	



FHM of Huangdunhu Sluice Gate diversion (scenario 1)



FHM of Huangdunhu Sluice Gate and two exploded spots diversion (scenario 4)

Sheet 8 Flood Simulation Outcome of Different Scenarios in Huangdunhu Lake

No	Water Level of Luomahu Lake (m)	Flood diversion mode			Highest inundation level (m)	Corresponding flood diversion volume (10^8 m^3)	Time duration of diverting (h)	Remark
		Sluice gate	Shuangheqiao spot	Caodian spot				
1	25.5	√			25.68	12.34	185	
2	25.5	√	√		25.66	12.22	77	
3	25.5	√		√	25.66	12.27	72	
4	25.5	√	√	√	25.65	12.30	60	

Contents

1.General introduction of pilot practice of FHM in China

2.Outcome of pilot practice on FHM in Huaihe River

3.Problems encountered in process of FHM

4.Short-term Tasks and Suggestions on FHM

3.1 FHM really reflect the actual flood risk?

Some of flood control administrations are unfamiliar with flood hazard mapping, question of “why, how and for whom to make FHM” exists commonly.

For a few simplifications and artificial suppositions are set in the process of FHM, such as certain spots in embankment and dams supposed to break, partition of finite element meshes etc, FHM only shows flood risk of one scenario supposed, actual flood risk status maybe differs from FHM.

3.2 Lack of laws support

Flood Control Law of People's Republic of China came into force as of January, 1998, but no such provisions about flood risk and hazard maps were stipulated in the law.

It's not an obligation for local governments to make FHM. If local flood control administrations are lack of enthusiasm or capital, it's hard to impel this work.

3.3 Incomplete basic datum, irregular data format, lack of technical specification

Some datum are outdated with low accuracy. Mass time, energy and capital are devoted into basic datum analysis and disposal.

The computer digital platforms to show flood hazard mapping differ with communities, and uniform technical criterion is in great demand.

3.4 Flood management information is ignored in FHM

Most work focus on two-dimensional unsteady hydraulic calculation to analyze flood risk. On the contrary, flood management information, such as evacuation routes, refugee shelter etc, is seldom indicated in FHM.

3.5 Dynamic flood risk simulation analysis systems haven't established

Mostly flood hazard map only shows several specific flood risk of supposed conditions, it's static. Dynamic flood simulation systems based on real conditions haven't been established.

3.6 Work of typhoon disaster risk mapping lags

Nearly Seven to eight typhoons land in China every year in average. Last year, 1522 people were killed by typhoon, 67% of death toll affected by flood and waterlogging disasters.

Typhoon can affect wide area and induce severe damage, it's urgent to make typhoon hazard mapping. Nowadays, corresponding research about how to make typhoon hazard mapping lags behind demand.

Contents

1.General introduction of pilot practice of FHM in China

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4.1 To promote pilot FHM project unceasingly

It's expected to finish the pilot project by the end of this year. Tentative guideline will be emended based on experiences achieved, detailed criteria and specification will be enacted, digital platform will be developed to show flood risk mapping uniformly, for the purpose of improving standardization level of flood hazard mapping.

4.2 To intensify early stage work of FHM

Proposal report for flood hazard mapping is being compiled by OSFCDRH, and it's hopeful to be approved by Ministry of Water Resources. And it's in the process of applying for national investment of Eleventh Five-Year Period.

4.3 To summarize function of FHM

Through 1~2 years practice, verify roles of flood hazard mapping in flood management.

4.4 To strengthen cooperation on typhoon disaster mapping

East and Southeast Asian countries suffer from heavy typhoons, and we hope to exchange information and experience about typhoon and tsunami prevention.


Thank you for your attention !

2.2 New Shu River

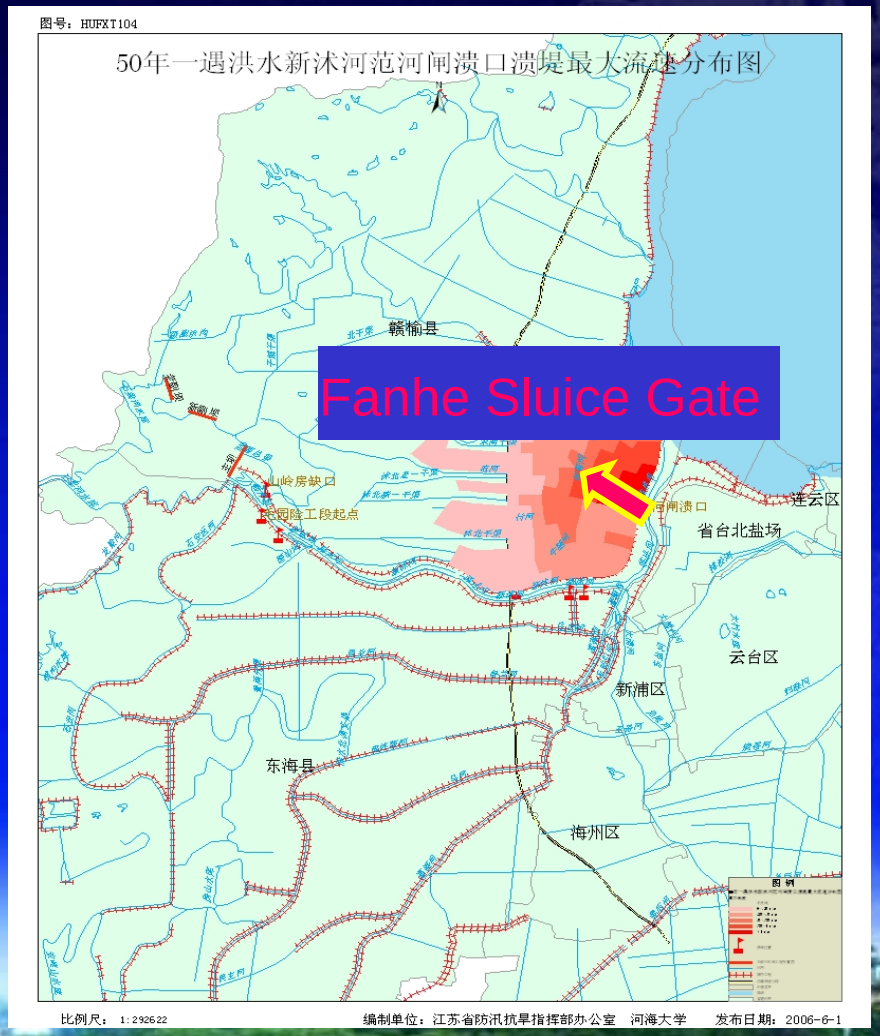
- 45 km long
- Embankments along both banks can withstand floods with a return period of 20 years, design flow velocity of 5000 m^3/s.

2.2 New Shu River

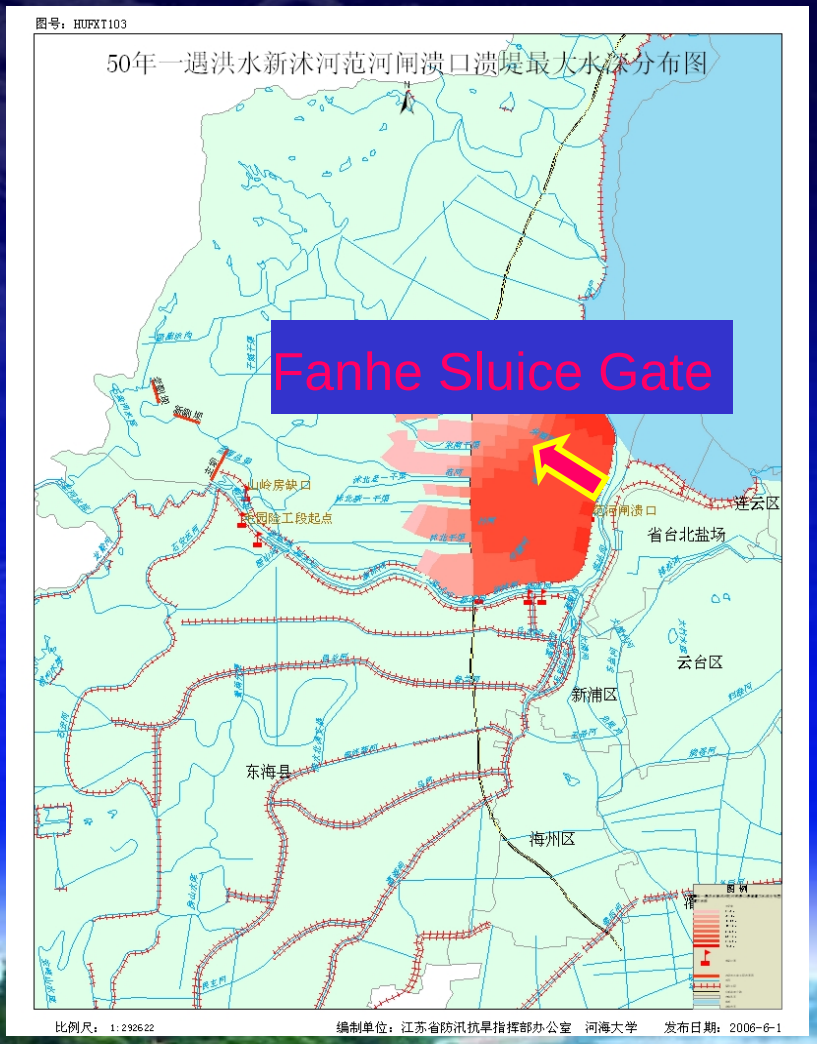
- Fanhe sluice gate and Maoyuan weak spot are supposed as levee breach spots for flood risk analysis.
- Based on two-dimensional unsteady hydraulic method, 2 scenarios of 50 years floods at left and right banks were calculated.

2.2 New Shu River

Maximum Flood Velocity Distribution map



Maximum inundation depth Distribution map



2.3 Lianyungang City

- Xinpu district, urban area of Lianyungang City, 27.2 km^2
- Dapu River, flowing through Xinpu district, greatly influences waterlogging in Xinpu district.
- The drainage capacity of Dapu River totals 108 m^3/s (48 m^3/s by gravity drainage, 60 m^3/s by pumping stations)

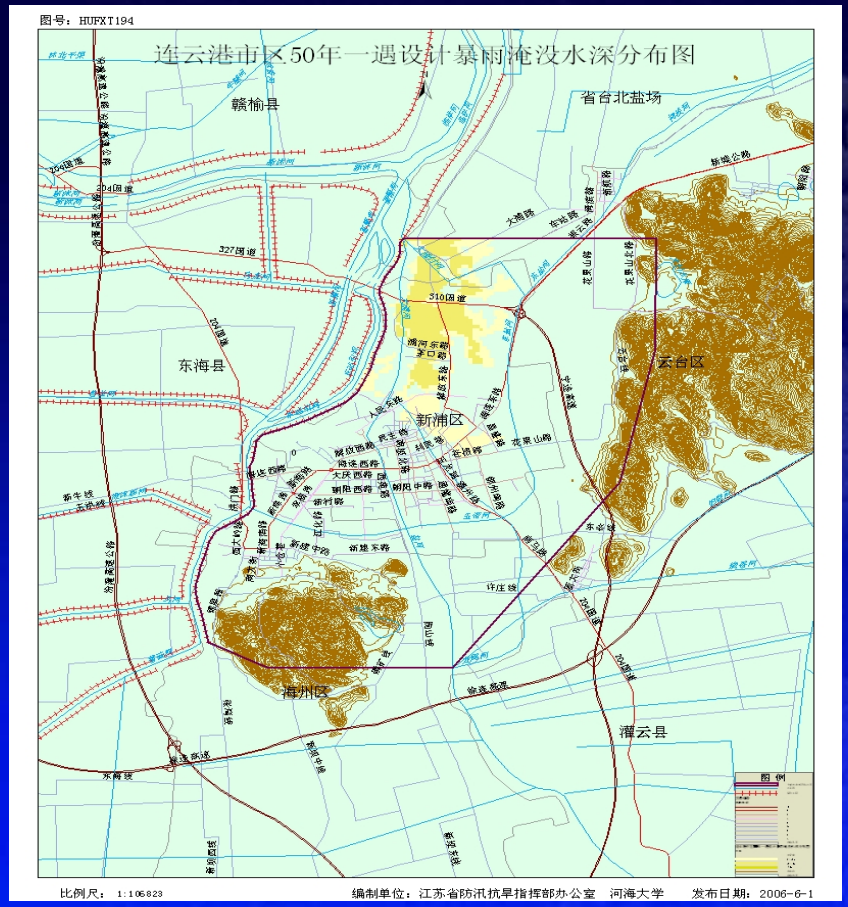
2.3 Lianyungang City

- The pure precipitation and residual water quantity are calculated using hydrological method. As the topography is flat at equivalent elevation, waterlogging depth can be obtained in terms of residual water quantity distributed even in the district.
- 8 scenarios of 20, 50, 100, 200-years floods can be obtained in FHM

Sheet 5 Outcome of Flood Hazard Mapping in Lianyungang City

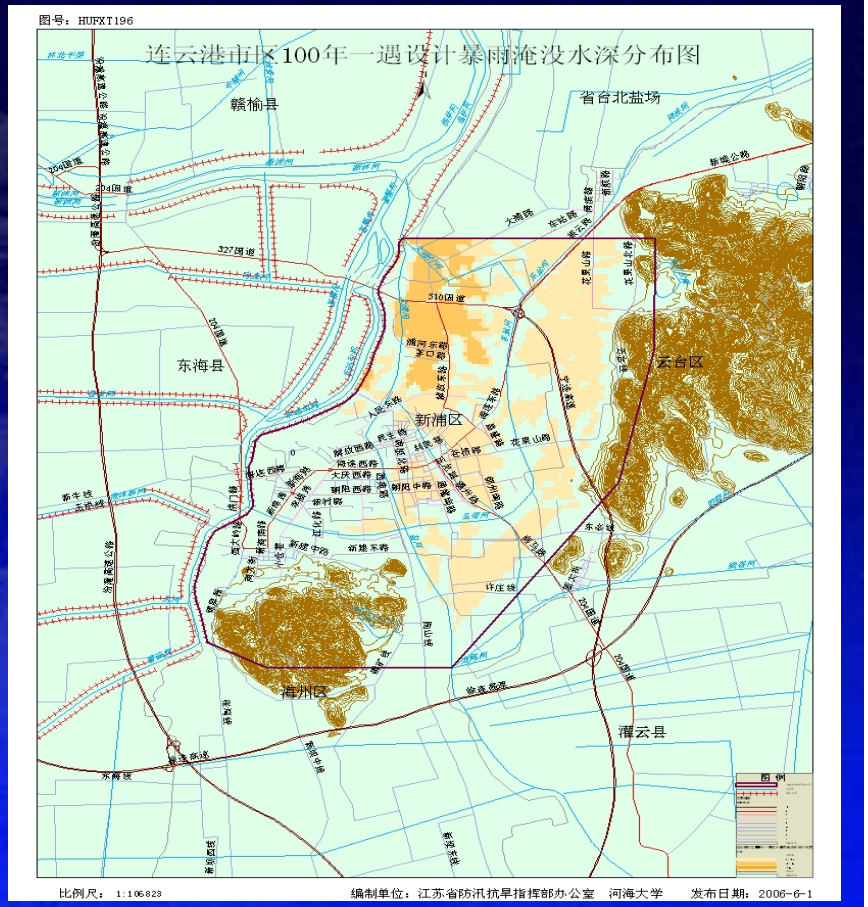
No	Flood (Return Period)	Total pure water quantity of 3 days (10^8 m^3)	Drainage water (10^8 m^3)	Residual water (10^8 m^3)	Water Depth (m)	Remark
1	20	0.26	0.28	0	0	
2	50	0.33	0.28	0.05	3.49	
3	100	0.38	0.28	0.10	3.67	
4	200	0.43	0.28	0.15	3.79	
5	20	0.26	0.12	0.14	3.75	Only Gravity drainage
6	50	0.33	0.12	0.21	3.89	Only Gravity drainage
7	100	0.38	0.12	0.26	3.98	Only Gravity drainage
8	200	0.43	0.12	0.31	4.06	Only Gravity drainage

2.3 Lianyungang City



Maximum inundation depth

Distribution map of 50-year flood



Maximum inundation depth

Distribution map of 100-year flood

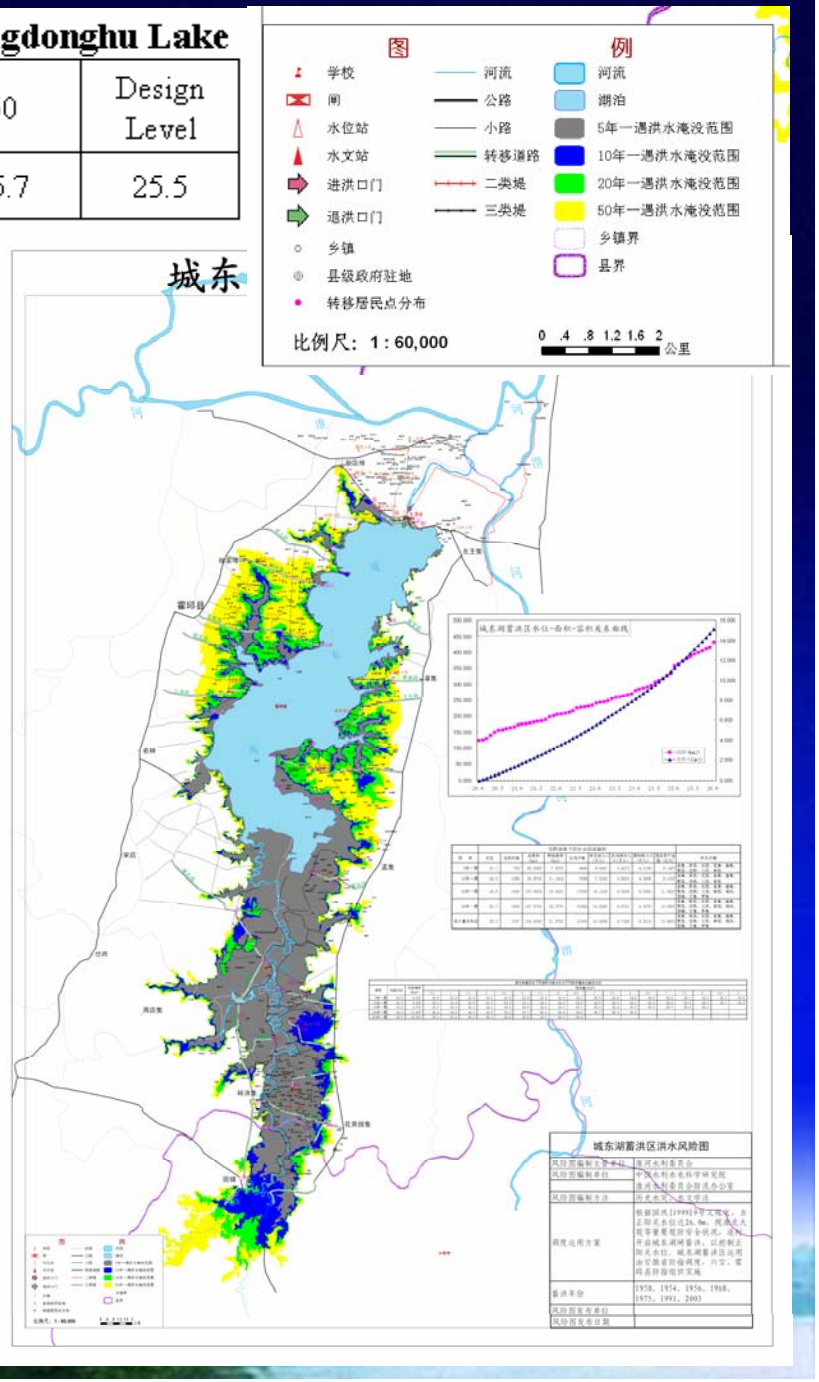
2.5 Chengdonghu Lake

- It is a natural lake isolated by Cross-lake Dam and Chengdonghu Sluice Gate from Huaihe River, and has a catchment area of 2170 km^2
- Low-level mountains and depressions are encircled around the lake.
- Capacity 15.9×10^8 m^3
- Area: 380 km^2
- total population of 132,600

Sheet 6 Flood level of different probability floods in Chengdonghu Lake

Probability (Return Period)	5	10	20	30	50	Design Level
Water Level (m)	23.1	24.0	24.8	25.2	25.7	25.5

- According to highest flood level sequence from year 1954 to 2003, using hydrological probability analysis method, flood levels of varied flood probability, such as 5, 10, 20, 30, 50-year flood can be achieved. For flood level is even in the lake, therefore inundation area can be marked according to water level~capacity~area curve from topographical map



- In the meantime, scenarios of different flood diversion quantity ranging from 0.5×10^8 m^3 to $9\times10^8 m^3$ combined with the lake water level ranging from 22.3 m to 24.7 m are analyzed in FHM.

Sheet 7 Highest flood level of varied diversion quantity combined with varied water level in the lake (m)

Probability (Return Period)	Water level in lake	Initial capacity (10^8 m^3)	Flood diversion quantity (10^8 m^3)																
			0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9
5	22.3	6.670	22.5	22.8	23.0	23.2	23.4	23.6	23.8	23.9	24.1	24.3	24.5	24.6	24.8	24.9	25.1	25.2	25.3	25.5
10	23.0	8.259	23.2	23.4	23.6	23.8	24.0	24.1	24.3	24.5	24.6	24.8	25.0	25.1	25.2	25.4	25.5	25.6	25.7	25.9
20	23.6	9.763	23.8	24.0	24.1	24.3	24.5	24.6	24.8	25.0	25.1	25.2	25.4	25.5	25.6	25.7	25.9	26.0		
30	23.9	10.561	24.1	24.3	24.4	24.6	24.7	24.9	25.0	25.2	25.3	25.4	25.6	25.7	25.8	25.9				
50	24.2	11.407	24.4	24.5	24.7	24.8	25.0	25.1	25.3	25.4	25.5	25.7	25.8	25.9						
100	24.7	12.921	25.0	25.0	25.1	25.3	25.4	25.5	25.7	25.8	25.9