Gis Approach Of Inundation Analysis In The Dongjiang(East River) Drainage Area*

Huaixiang Liu1,a,Yongjun Lu1, Zhaoyin Wang2

1State Key Laboratory of Hydrology-Water Resources and Hydraulic engineering, Nanjing Hydraulic Research Institute, Nanjing, Jiangsu Province, China
2Department of Hydraulic Engineering, Tsinghua University, Beijing, China
aliuhx@nhri.cn

Abstract

Flood has kept causing disasters to the east river basin. This paper developed an inundation risk model to estimate the economic loss in the scenarios of events with different frequency. A method was used to estimate the flooding area in the east river basin, using the digital elevation model (DEM), GIS spatial analysis, and hydrology calculation. Since the flow in East River is partly controlled by several reservoirs, the flooding area has been greatly reduced. The model was also used to estimate the flooding area in the case of reservoir control. Results indicated that there is a logarithm correlation between the flooding area and the flood frequency. The decrease in flooding area due to reservoirs will be about 25%. Some sediment problems that alter the fluvial process like sediment mining were also discussed with this model.

Keywords: East river, GIS, DEM, inundation risk.

1. Introduction

East river (Fig. 1) is a tributary of the Pearl River in southern China. Some of the most developed cities are located in the East River delta. In history flood has been the most destructive and frequent natural disaster in this basin. The geographical features, low latitude and seaside district, result in high precipitation, and 80% of which is concentrated in the period from May to August. The floods caused by this kind of intense rainfall have brought great losses to the East river basin. In 1959, with the discharge

* This work is partially supported by NSFC Grant #51009096.
at Boluo reaching 12800 m$^3$/s, the total flooding area was as much as 1.88 million mu (1267 km$^2$) because of the failure of most levees along the main stream. In 1979 more than 60,000 people lost their home because of the flood on a tributary Xizhi river. Even half of the Huizhou city’s urban area was inundated.

Inundation risk (Flooding risk) is the possibility of harm that the flood events will do to the human society and the environment. The flooding risk analysis is necessary for estimating the risk, predicting the flooding losses and for reducing the damage. The analysis adopts indices including flood frequency, some hydraulic parameters (depth, velocity, inundation time, etc.), the expect flooding losses and so on.

With the development of computer technology, especially some information technology such as GIS, RS and GPS (3S), GIS platform became an important tool in many flood analysis and flood control studies [1] [2]. Reference [3] integrated the flood flow calculation model with DEM and other feature themes for the simulation of flood scenarios and the computation of flooding losses. In ARCGIS reference [4] reclassified the flooding risk map of China by overlaying the GDP density distribution map with the flooding risk map generated in former study.

Fig. 1. The east river basin

2. The inundation risk model

The objective of this study is to develop the east river basin inundation risk model determining the flooding area for different flood events. The calculation process of this model is shown in Fig.2.
2.1. The estimation of flood discharge and stage

The hydrological frequency analysis assumes that the distribution of flood time series follow a probability model (e.g., P-III curve) [5]. And the parameters of this model can be determined by the series so that the whole distribution of the discharge-frequency correlation becomes available. This study took the flood time series as an input of the frequency analysis software and computed the flood discharge of different frequency directly. Then the flood stage was estimated by the stage-discharge relationship. The results of several hydrology stations were as follows in table 1.

2.2. The generation of flood surface layer

Although the stage value of stations were just some discrete dots in the space, a continuous flood surface layer could be simulated by these data in the Spatial Analysis module of GIS softwares such as Arcview.

TABLE 1 Flood discharge and stage at several stations

| Frequency | Longchuan | Heyuan | Boluo |
|-----------|-----------|--------|-------|
|           | Discharge (m³/s) | stage (m) | Discharge (m³/s) | stage (m) | Discharge (m³/s) | stage (m) |
| 1%        | 9883      | 73.3   | 11500  | 42.0     | 14400  | 14.2 |
| 2%        | 8602      | 72.6   | 10400  | 41.3     | 13000  | 13.5 |
| 5%        | 6888      | 72.0   | 8800   | 40.3     | 11200  | 12.6 |
| 20%       | 4247      | 70.5   | 6500   | 38.8     | 8060   | 10.0 |
2.3. The determination of flooding area

The flooding boundaries of different frequencies were identified by overlaying the DEM data of the whole basin with the flood surface layer generated above in Arcview (Fig. 3). Finally the flooding area were calculated in table 2.

Fig. 3. The extraction of flooding boundary
| Flood Frequency | 20% | 5% | 2% | 1% |
|-----------------|-----|----|----|----|
| Flooding area (km²) | 742 | 1119 | 1336 | 1499 |

### 3. The impact of reservoirs

In the east river basin there are several big reservoirs (Xinfengjiang, Fengshuba, etc. as shown in Fig.1) which have got great impact on reducing flood discharge and flooding economic losses. Reference [6]’s data about reservoir control in east river basin were summarized in Fig.4. This graph displayed the relationship between the original discharge and the adjusted discharge by reservoirs at different stations. A rough linear relationship could be drawn.

With the application of this linear correlation to the data in Table 1, Fig. 5 was obtained by estimating the adjusted flood discharge at every station.

![Fig. 4. The effects of reservoirs on discharge](image)

![Fig. 5. Adjusted discharge at different stations](image)
The flooding area with reservoirs control was calculated by the input of the adjusted discharge into the inundation risk model. We plotted both the flooding area values with and without reservoirs as a comparison in Fig. 6. The data from two real floods in the year 1959 and 1964 (before and after the construction of Xinfengjiang reservoir) were also plotted in this figure as a verification. It showed that about 25% losses were saved due to the reservoir control.

4. Sediment mining

Since 1990s the rapid economic development in the east river basin has resulted in a soaring demand of the construction sediment. So there was a sediment mining boom in the lower reach of the east river. The sediment transportation equilibrium was severely damaged because of the overmining and meanwhile the main channel was incising. Correspondingly the water stage value of the same discharge
became lower and lower. A decrease of about 1~1.5m at Boluo was resulted from the year 1995 to 2002 [7].

The study of reference [8] indicated that the stage at Boluo would be lowered by another 1.4m from the year 1999 to 2007 if the sediment mining remained uncontrolled. As shown in Fig.7, the flooding area will decrease by 150km² around for every reduced 1m flood stage at Boluo.

Although the direct effect of sediment mining was the degradation of flood stage, the incised channel would approach the levee feet and weaken the levee defence. For example there are 23 sections of Dongguan levee in danger due to the incision. The cities and vast farmlands are commonly protected by levees so that the real economic losses will greatly increase if the levees fail. Therefore the flooding risk might be acturally increased by sediment mining.

5. Conclusions

In this paper the result has revealed that:

1) The downstream of the east river basin, especially the east river delta, is the high inundation risk zone. There is a logarithm correlation between the flooding area and the flood frequency. When a 100-year flood (frequency 1%) occurs the flooding area will reach about 1500 km².

2) The reservoirs has got great impact on controlling the flood discharge and on reducing the flooding losses. The decrease of flooding area will be 25%.

3) The downstream channel is incising gradually because of sediment mining activity, leading to the degradation of water stage. the flooding area will decrease by 150km² around for every reduced 1m flood stage at Bolu. But as channel incises the levees were endangered and the flooding risk rose up.

6. Acknowledgment

The authors are grateful to the Scientific Research Institute of Pearl River Water Resources Commission (PRWRC) for their very useful data and Dr. Dongsheng Cheng from IWHR for his help in analysis.

References

[1] G. Gambolati and P. Teatini, “GIS simulations of the inundation risk in the coastal lowlands of the northern Adriatic sea,” Mathematical and Computer Modelling, 2002, 35: 963-972.
[2] A.T. Philip and J.W. Stephen, “Modeling floodplain inundation using an interated GIS with radar and optical remote sensing,” Geomorphology, 1998, 21: 295-312.

[3] C.C. Zhang, X.W. Chen, and H.L. Guo, “Calculation method of flood disaster losses based on GIS,” Engineering Journal of Wuhan University, 2004, Vol.37. No.1, pp. 7-14.

[4] J.F. Liu, X.N. Zhang, Z.W. Tang, and Q.Z. Geng, “Spatial distribution of flood hazards in China,” Journal of Hohai University(Natural Sciences), 2004, Vol.32. No.6, pp. 25-31.

[5] J.D. Wang, Hydrological Statistics, China Hydraulic and Hydropower Press, beijing, 1993, pp.165 - 174.

[6] D.Y. Chen and Z.X. Li, “The retrospection of water resources integrated utilization in east river basin,” The hydraulic programming, 1997, Vol.1, pp. 72-82.

[7] H.Q. Chen, H.X. Huang, and Z.F. Zhou, The analysis of sediment mining impact on hydrologic feature of boluo section in the east river, GuangDong Water Resources and Hydopower, 2004.

[8] L.X. Han, W. Li, Y.J. Lu, and S.P. Mo, “Impact of artificial sand excavation on hydrodynamics and water environment of dongjiang River network,” Journal of Hohai University(Natural Sciences), 2005, Vol.33. No.2, pp. 62-69.