

Simulation of Flood Inundation in Jilin City, Songhua River Project

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1 SCOPE AND OBJECTIVES

1.1 Scope

The study scope is to develop and calibrate 2D hydraulic models of Jilin City.

The key requirement of these models is the ability to predict areas of water inundation and flow patterns, timing and volumes in the above-mentioned cities and flood detentions areas in response to the following:

- Different return periods of design floods ranging from 100 year to 1000 year depending on different flood control criteria in different cities and historical flood events, namely year 1995.
- Different embankment layouts, namely no embankments, current embankments, and planned embankments from ADB projects.

1.2 Objectives

The developed hydrodynamic model will be expected to produce the following outputs over a range of flood flow scenarios in a GIS compatible format:

- Mapped flood extents
- Flood depth maps
- Spatial representation flood flow distributions
- Spatial representation of flood inundation

2 METHODOLOGY – MIKE FLOOD

MIKE FLOOD is a unique tool that integrates the one-dimensional MIKE 11 model and the two-dimensional MIKE 21 model into a single, dynamically coupled modelling system.

The combination of these modelling systems provides a software tool with unrivalled capabilities. A combined modelling system allows the best qualities of both systems to be utilised while at the same time avoiding many of the limitations of resolution and accuracy commonly encountered using the systems separately.

Special features of MIKE Flood include:

- The ability to model overbank areas in detailed 2D with the wider model domain and main river channels in 1D;
- The ability to model an extensive range of hydraulic structures including moveable structures;
- The ability to nest 2D grids at finer resolutions to obtain more detail in specific areas;
- Momentum transfer through 1D/2D links. This is a limitation of some linked model systems;
- Full ESRI ARCGIS Geographical Information System integration for ease of model preparation and result processing and presentation;
- Lateral links enabling accurate simulation of overbank flow from 1D channels into 2D floodplains;
- Standard DHI graphical user interface for data preparation and presentation including video animations;
- Available as a commercial hydraulic modelling software package; and
- DHI's continuing, long term commitment and support of the system;

The system is scalable and expandable so models developed now can be enlarged to take in wider areas of the river system, or changed to include added levels of detail in areas of specific interest at a later date.

2.1 Standard Links

This is the MIKE FLOOD linkage where one or more MIKE 21 cells are linked to the end of a MIKE 11 branch. This type of link is useful for connecting a detailed MIKE 21 grid into a broader MIKE 11 network. Potential applications are shown below in Figure 2.1.

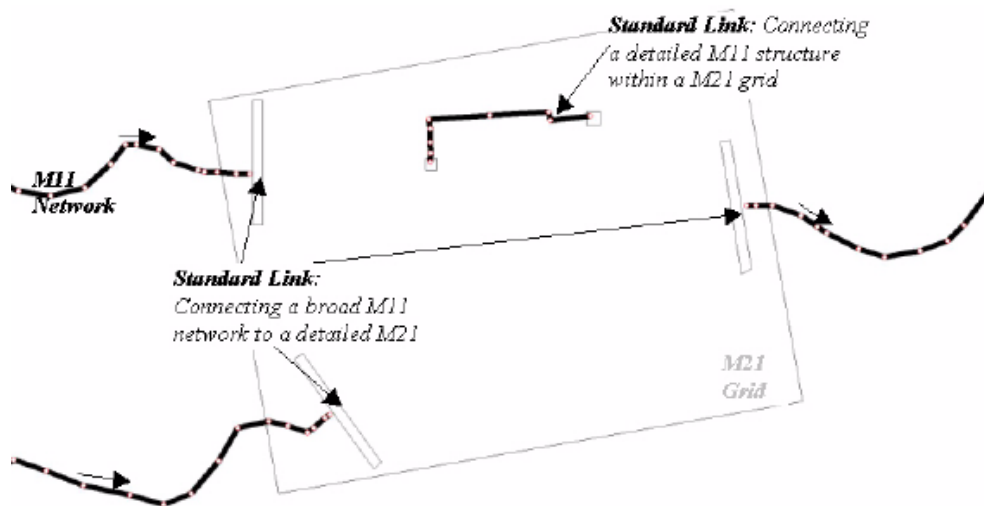


Figure 2.1 MIKE Flood Standard Links.

2.2 Lateral Links

A lateral link allows a string of MIKE 21 cells to be laterally linked to a given reach in MIKE 11, either a section of a branch or an entire branch. Flow through the lateral link is calculated using a structure equation or a QH table. This type of link is particularly useful for simulating overflow from a river channel onto a floodplain:

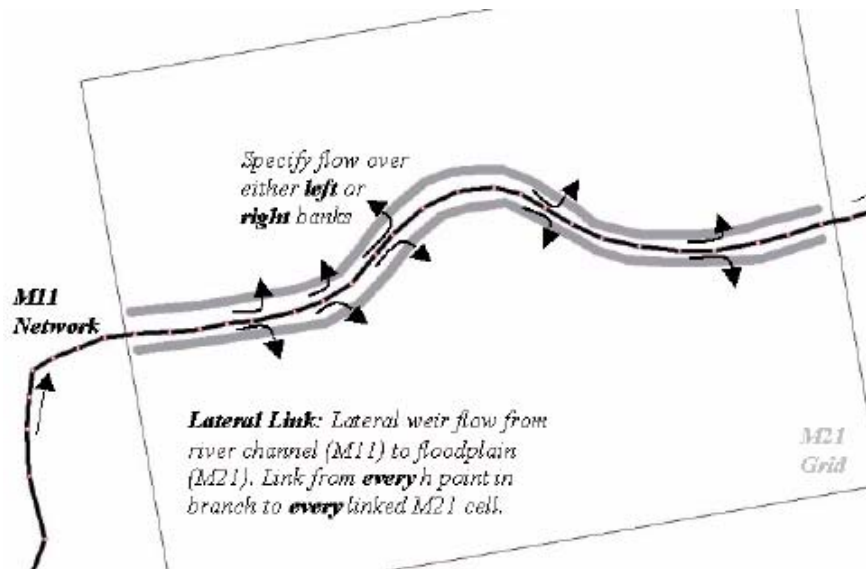


Figure 2.2 MIKE Flood Lateral Links.

3 JILIN CITY MODELLING

3.1 Hydrodynamic Model Development

In-bank Flow Model

Water levels and discharges in the Second Songhua are being modelled using the 1D MIKE 11 Hydrodynamic (HD) model. The 1D network has been adapted from the already established MIKE 11 model of the Nen/Songhua/Second Songhua Rivers, but with a mapping projection transferred from the conical Lambert Conformal Conic projection to the cylindrical Beijing_1954 projection. This transformation affects all geo-referred parameters i.e. river digitisation and cross-section coordinates.

Outflow hydrographs from the Fengman reservoir provide upstream in-flow boundary conditions while a depth/discharge (rating curve) formulation is assumed valid at the outflow boundary.

The MIKE 11 1D model of the Songhua/Second Songhua is calibrated to historical flow events by adjusting the Manning's friction number. This parameter was adjusted by an iterative procedure to determine the value producing the best model results.

If deemed necessary minor adjustments may be made to model characteristics or operations to improve simulations applying the 1D MIKE 11 model to the Jilin City sub-model.

As the 2D MIKE 21 model represents out-of-bank floodplain flow as described below these areas are excluded from the MIKE 11 cross-sections within the city area. Floodplains outside the 2D model domain are still represented in the MIKE 11 X-sections.

Flood Plain Modelling

Based on the given topographical data, a two-dimensional MIKE 21 flood plain model is being developed. This model will be applied to make detailed predictions of lateral flooding, split flows, bridge/road overtopping, flow in urban areas, etc.

MIKE 21 is a 2D finite difference model representing the floodplain topography using a grid based Digital Elevation Model (DEM).

MIKE Flood Modelling

Floodplain structures, such as buildings, road and embankments are represented either in the DEM or specified implicitly in the MIKE FLOOD parameter list.

Within the detailed 2D model domain the flood plain model is linked dynamically to the 1D in-bank channel flow model applying Lateral Links as described before. Links are being established from MIKE 11's chainage 0 to 53500 where actual spilling is supposed to take place are linked together.

3.2 Model Schematization

2D Model Bathymetry

As stated in Chapter 2, the latest topographical data with 1:10,000 and 1:5,000 scales are not well accommodating with each other, so under this circumstance, DHI decided not to include DEM data with scale 1:5000 for the two-dimensional model for Jilin City because it is not applicable here due to the discrepancies, instead, MIKE 11 map functionality is applied as an alternative to provide the river topography based on the cross-sections information to generate the bathymetry for Jilin City.

The 2D domain covers an area of about 20 times 26 km. After having investigated the various floodplain features and flow conditions we have selected a grid spacing of 20 meter. The key to this selection was the required resolution to accurately define specific hydraulic controls in the city area. Important hydraulic features such as levee banks and elevated roads must be adequately resolved by the model grid so that flow breakouts from the Second Songhua River can be adequate resolved and flow distributions on the floodplain and in the city correctly represented. Contradictory to these requirements were the need to develop a model suitable to run on today's computers considering available RAM, CPU requirements, etc.

It is imperative that ALL the physical features of the flood plains are adequately represented in the DEM. A thorough understanding of potential errors associated with the interpolation of grid surfaces from point and contour data is critical for producing a sound and reliable model. Likewise the quality of the raw data is forming the base of this interpolation. The timing of the spilling and the amount of water discharging into the city area depend to a very high extend on the location and height o the embankments and the roads forming these.

➤ Embankments

The elevations of embankments were supplied in the attribute table of the embankment layer and MIKE 11 GIS was applied in order to digitise the embankment levels accurately into the 2D model

bathymetry shown as green points as following, which ensured that each grid point has an elevation value of the embankments.

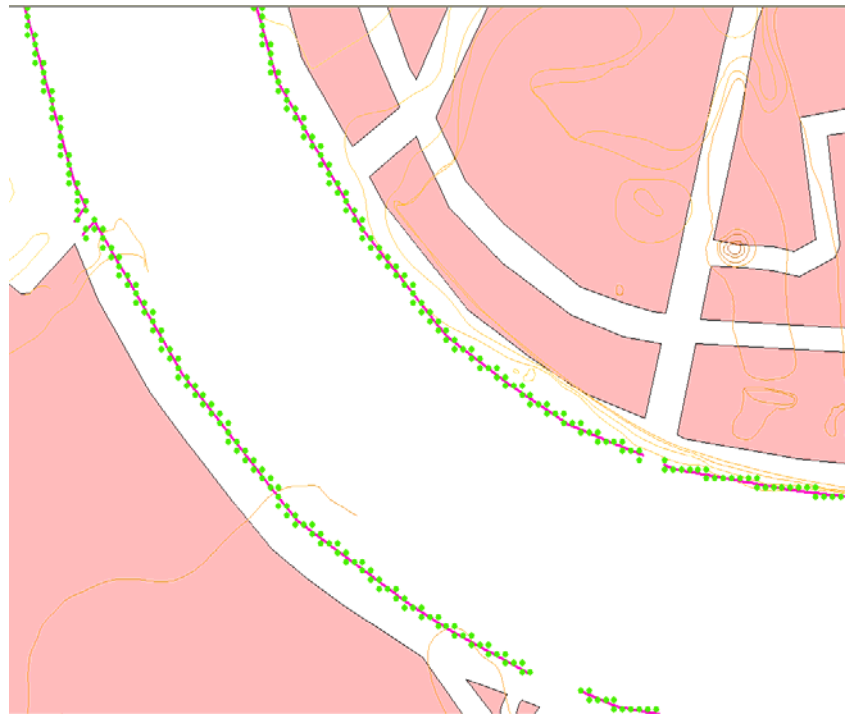


Figure 3.1 Schematization of embankment levels (Red line – embankment; green point – levels)

➤ Roads and Buildings

The elevations of main roads were given as a separate point layer, which has been used as one of the source to generate the final bathymetry.

After the site visiting and overview of the GIS data, the grid size of MIKE 21 model was cautiously determined as 20m with the consideration of accuracy of schematization as well as control of computational time.

When generating the Raster in ArcGIS, due to the cell size, some buildings and roads were inevitably bleached out or blocked. As shown in Figure 3.2, the left figure shown the Raster (blue blocks) and original building shape file (red polygons), it was clear that the small roads inside the buildings were blocked because of the too coarse grid size. Therefore, it is required to conduct carefully check on such roads and buildings in order to make sure the original look in the final bathymetry used in MIKE 21. The bathymetry is shown in the right figure, with red colour representing building and green colour standing for roads. Several cells were modified to road elevations so that the small roads are connected and able to convey flow in case of flood inundation.

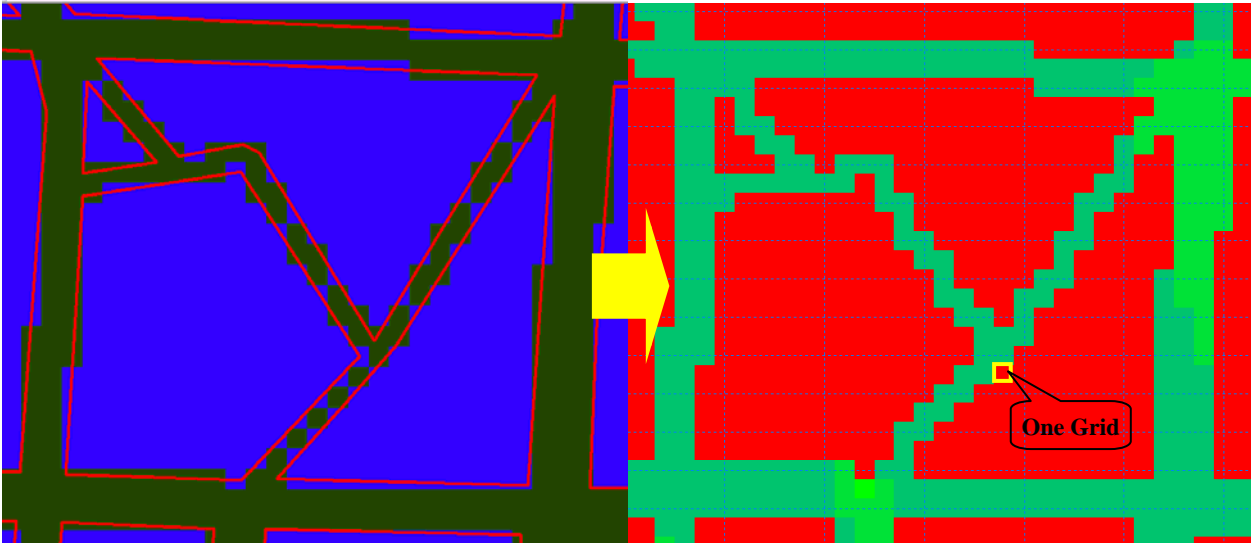


Figure 3.2 Schematization of roads

With the consideration of the above features in Jilin City, the final bathymetry looks like:

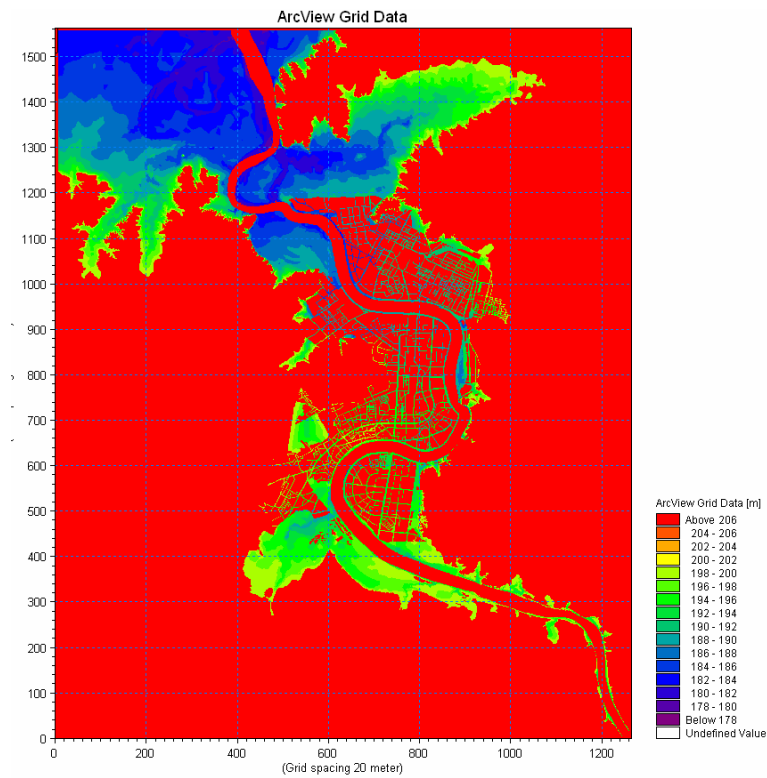


Figure 3.3 Jilin Bathymetry

Local drainage paths and urban drainage features are neither resolved in the 2D grid area nor in the MIKE 11 model.

Model Boundaries

The combination of inflow hydrograph and water level boundaries ensures conservation of mass within the model. The Mike Flood model solution scheme has been proven to conserve mass and

momentum for local areas in addition to globally conserving mass across the entire model domain. This provides the MIKE Flood system with a great advantage in terms of simulating the wetting and drying fronts of the flood wave over floodplain areas

The MIKE 11 model has its upstream inflow boundary at the Fengman Reservoir. The downstream boundary is being established as water level at 62420. This Chainage is located almost 20 km downstream the Jilin City Centre, more than 10 km downstream the northern outskirts of the city and 5 km D/S of the MIKE 21 model boundary. Sensitivity tests have shown that simulated levels and discharges within the city area are independent of this downstream boundary.

The flood hydrograph of year 1995 as well as the design flood discharge with 100 year, 500 year, and 1000 year return period were used as boundary conditions to the model.

Initial Conditions and Flood/Dry

Compared with estuary and inland water modelling, the floodplain modelling has its own features. In our study, the initial water level for the floodplain is assigned the minimum elevation in the floodplain, which is 125m. This also means that there is no water in the floodplain initially.

With regard to flood/dry, the default value for MIKE 21 set-up is 0.3/0.2 m, which means that if the water depth below the 0.2m, the grid cell is excluded from the calculation, and if the water depth is above the 0.3m, the grid can be calculated. While the default value is suitable for marine and estuary study, for the floodplain modelling, this value is too big. So, in this case, new flood/dry value of 0.1/0.05m is adopted, which can simulate the flood/dry more precisely.

Calibration of 2D Model

Theoretically, such a MIKE Flood model should be carefully calibrated against the historical flood (e.g. 1995 flood) in terms of inundation area and flood depth before it is applied for design flood simulation and any other production purpose. However, in practical, it is very difficult to collect the required information during the flood risk. Therefore, the roughness coefficient should be cautiously determined based on the local situation and past experience in the following section.

Model Roughness

It is technically difficult to collect information about flood inundation map due to the historical flood event; therefore, dedicated attentions should be paid to determination of the reliable and proper resistances for different surface like concrete, asphalt roads, grasslands, and farmlands, etc.

Extensive relative researches were referred in order to investigate different values for hydraulic resistance regarding to different surfaces. Hydraulic resistance is affected by different types of factors, and based on long term on-site monitoring, the grain size, curvature, bed forms, bed vegetations, human activities, and flow conditions (discharges and flow velocities) are all bringing profound influences to the hydraulic resistance.

Choice of different values will affect the flood peak time and to some extent the flow path within the city/floodplain, but has very limited impact on the inundation area and flood depth (for a given design flood event, within the given flood duration the total breach volume could reduce as the resistance in the floodplain increases). So for the present 2D modelling, choice of Manning numbers are important but not determinant when considering the modelling target.

DHI Water & Environment carried out MIKE Flood simulation focusing on urban area worldwide in the past decades, which allowed DHI collect some experiences on the determination of bed resistances for different problems.

In the project of South Boulder Creek, Colorado, USA, similar as most cases for the simulation of flood inundation, there was no any calibration data available, therefore best estimate based on local situation was required. The roughness values were applied in two distinct “land use types” – open space and developed areas. Developed areas comprised blocks where structures had been built, fences exist or where dense vegetation would act as a retardant to flow. These areas have a Manning M value of 12.5 applied; Open space constitutes land with grasses or light vegetation, which is what was seen in the high plains around Boulder. We also lumped streets and sidewalks into this open space category. Open space received a Manning M value of 16.667. These were numbers and land use classifications that kept the PREP group satisfied, but was not overly burdensome to the model development.

From DHI experience in Germany, the following Manning numbers are generally selected:

- Urban areas/roads/gardens: 15-25 (small roads must be modelled with high roughness to take cars etc into account)
- Vegetation: 5-20 (dense young forest app. 5 – open agriculture – 25)
- Other areas: 10-30

It is very seldom that Manning M value exceeding 30 was used in the real projects in Germany.

Therefore, based on the extensive literature review and DHI experiences, Manning M as 16.67 is selected as the roughness representing urban area such as roads, parking area, and narrow streets etc. while Manning 12 is used for the suburb area including grassland, gardens with heavy vegetation in the MIKE Flood model for Jilin. These Manning numbers are subject to calibration if required data is provided in time.

4 RESULTS

The MIKE Flood model of 1995-year flood produced the inundation maps shown from figure 4.1 to 4.3. The embankment layout in year 1995 was used in the MIKE Flood model, and two areas inside city were slightly inundated, namely Jiangbei area, and Longtan bridge.

Moreover, it was also found that with the planned embankment, the Jilin city was rarely flooded with 100 year and 500 year flood, as seen in figure 4.7 except that the upstream and downstream areas where there are no embankment layouts.

When 1000 year flood was used as the boundary condition, several places were inundated, as shown in figure 4.4 to 4.6, namely, Wende River and Longtan bridge.

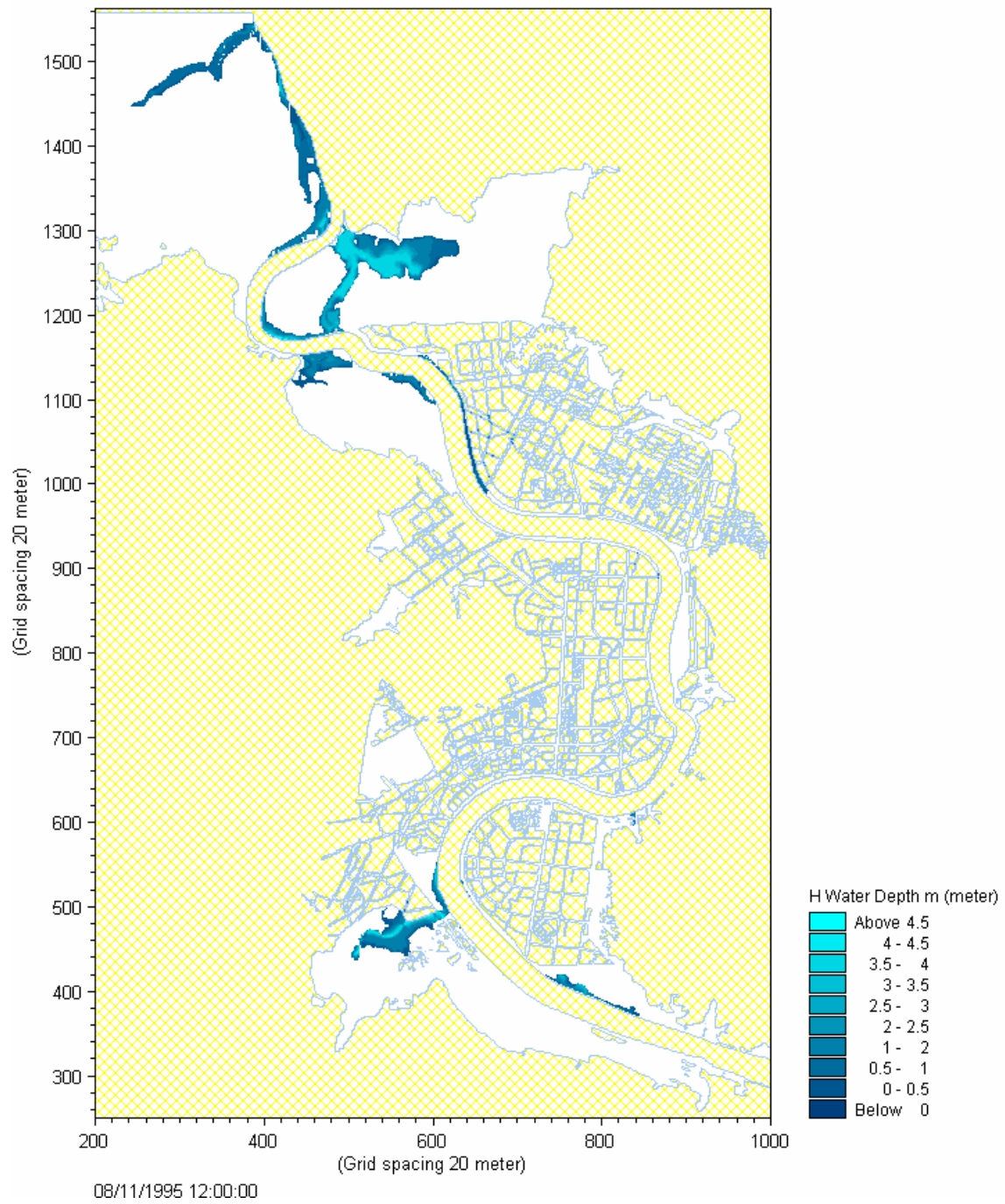


Figure 4.1 Overview of flood risk, 1995 flood

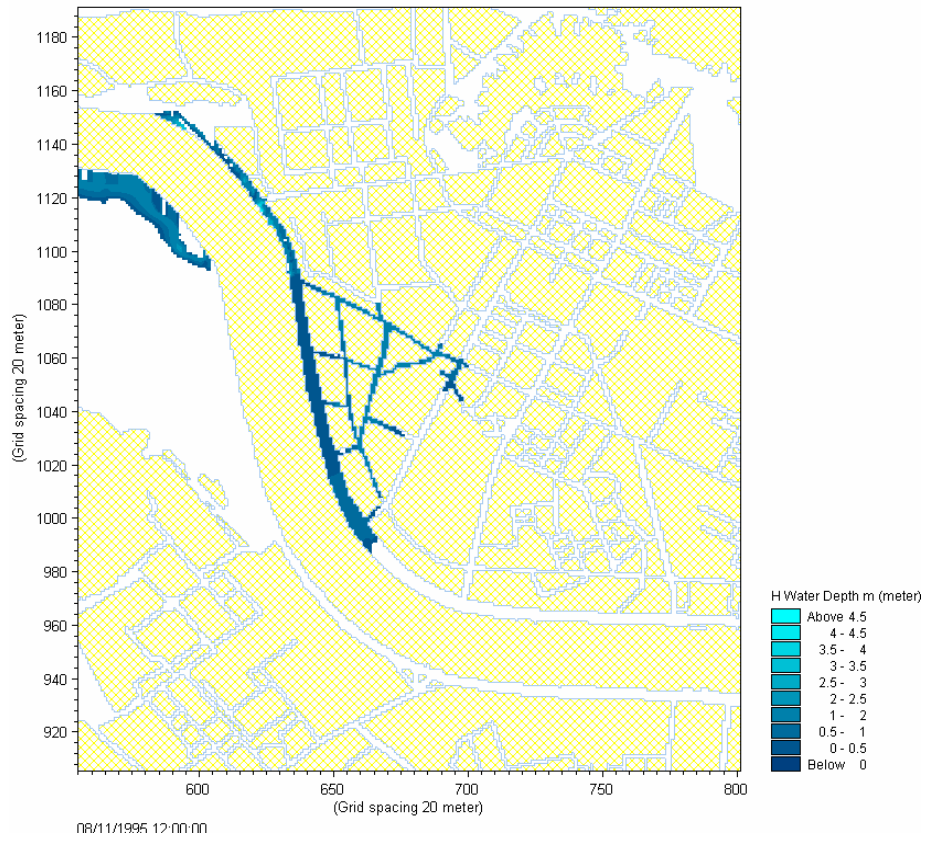


Figure 4.2 Flood risk map of Jiangbei area, 1995 flood

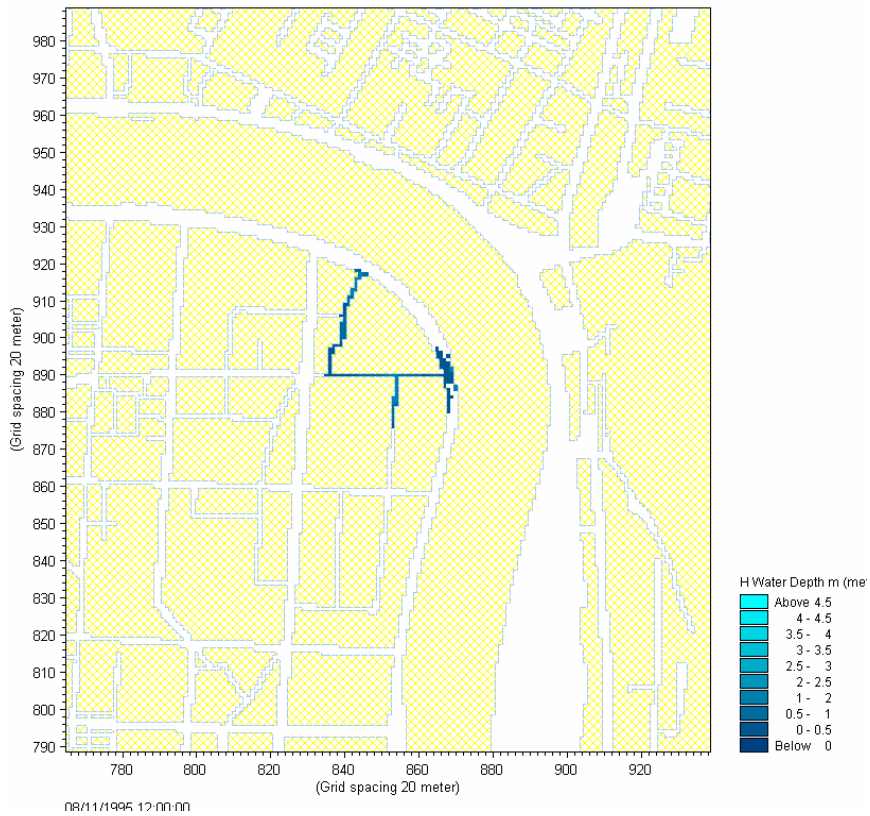


Figure 4.3 Flood risk map of Longtan bridge, 1995 flood

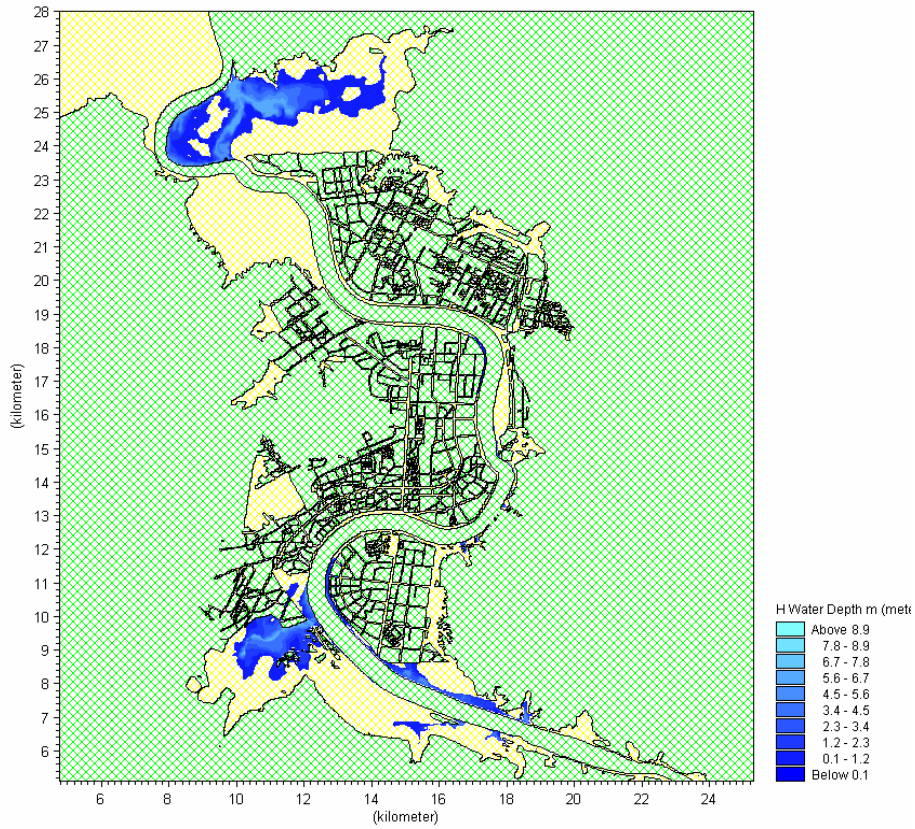


Figure 4.4 Overview of flood risk, 1000-year flood

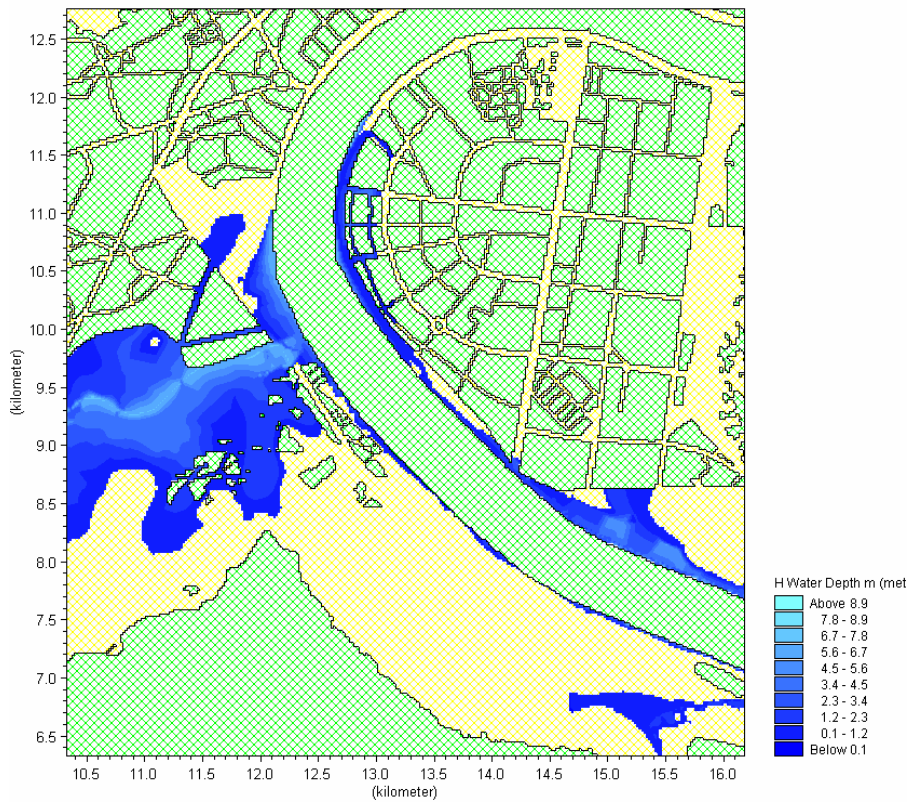


Figure 4.5 Flood risk map near Wende river, 1000-year flood

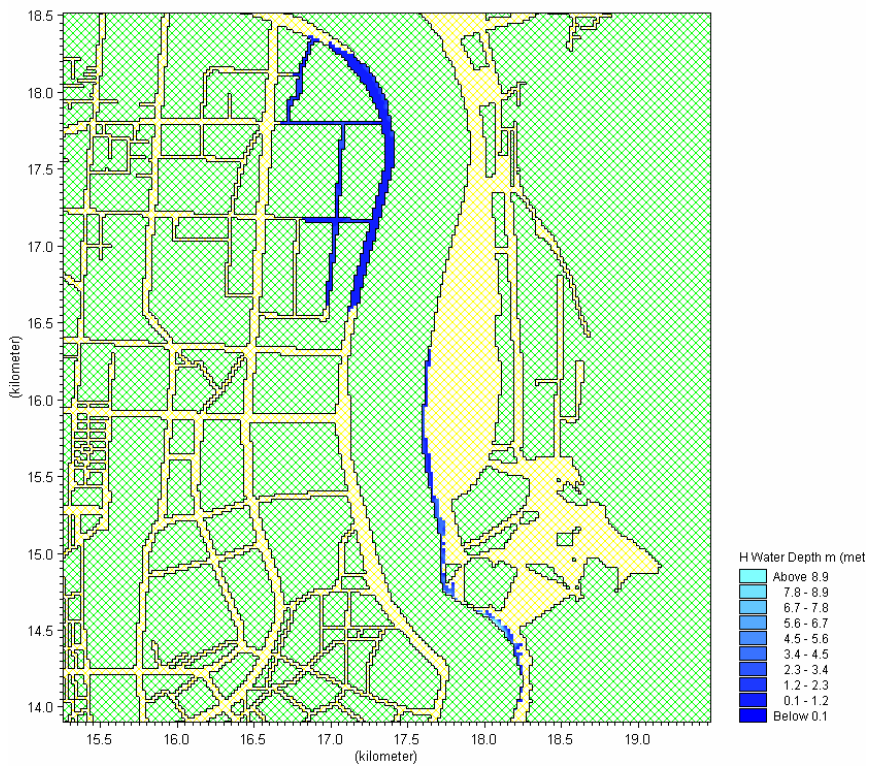


Figure 4.6 Flood risk map near Longtan bridge, 1000-year flood

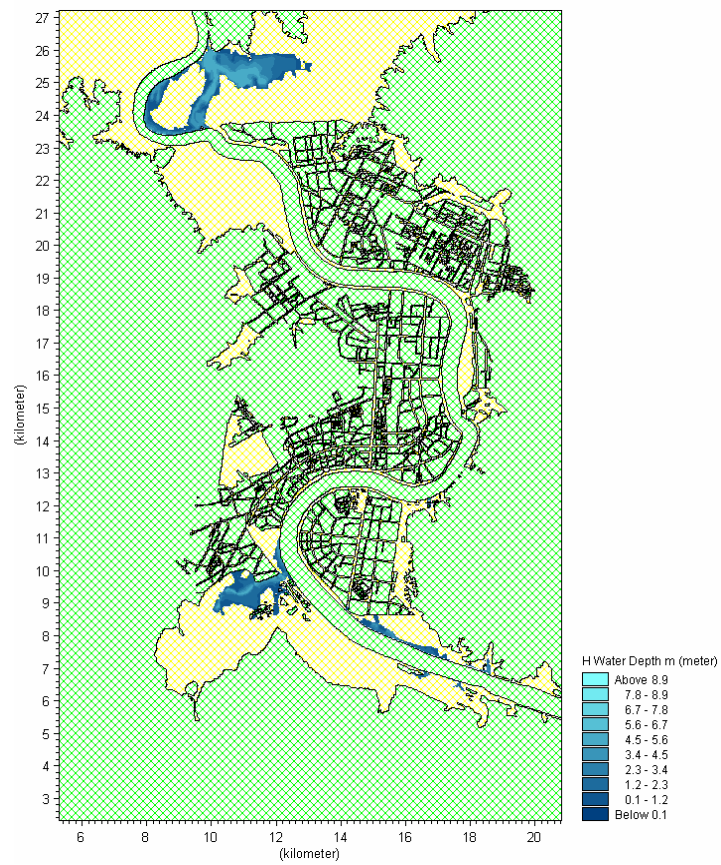


Figure 4.7 Overview of flood risk, 500-year flood

5 CONCLUSIONS AND RECOMMENDATIONS

As the widely-accepted and well acknowledged modelling tools, MIKE Flood has been extensively applied to numerous flood management projects worldwide. It approved that MIKE Flood is a feasible tool for similar applications here in China.

It is generally recommended that more flexible operation for adding the lateral links should be available in the newer version.

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