

# Introduction to floodplain zoning simulation models through dimensional approach

Ahmad Shahiri Parsa\*, Netani Qalo Vuatalevu  
Civil Engineering Dept., Faculty of Engineering,  
University of UNITEN,  
Kuala Lumpur, Malaysia.

Mohammad Heydari, Noor Farahain bt Mohd Amin  
Civil Engineering Dept., Faculty of Engineering,  
University of Malaya,  
Kuala Lumpur, Malaysia.

**Abstract**— Since the most economic-agricultural activities in areas adjacent to the river is in flood plains, including a discussion on the management of these areas is the considerable, zoning map has an important effect on flood management, The right of the river bed, and the economic feasibility of development projects, forecast, warning and rescue operations and flood insurance could be included. Using computer models and using geographic information systems incorporating GIS as well as hydraulic and hydrologic models are the common methods of floodplain zoning maps. There are a variety of different performance capabilities and access to the data required by this model, so that we have to choose the best software related to that model. In this article, we try to introduce a few well-known models for floodplain zoning maps; some of the capabilities and applications are considered by some approaches. At the end, we express the factors that are affecting the accuracy of results.

**Keywords**— Computer modeling, floodplain zoning, MIKE11, HEC-RAS, GIS

## I. Introduction

Flood has always been considered as one of the natural catastrophes that accompanies with the huge losses and damages, which affect human beings' life. However, different methods of flood mitigation have been applied, but the fact is that the flood will not be fully controlled. Floodplain management and the use of science and knowledge can reduce flood damages. Management measures to reduce flood damage can be done in two parts: structural and non-structural measures. The nonstructural flood management approach includes eliminating the destructive effects of flooding without construction of physical structures. Structural flood management application involves damming, trenches, the diversion of river flooding and other physical flood mitigation structure constructions. Floodplain zoning maps and the river cross section boundaries are important to non-structural measures to planning and optimizing utilization of the areas around the river in order to reduce flood damage. The climatic conditions in different countries according to factors such as river basin, an expanse of rivers and flood plains, have developed a set of legal based on the return period of the flood volume and determining the limitation of the river bed.

The most common methods of floodplain zoning maps application involve observational methods, flood stage, and

comparing aerial photos, using manual calculations and computer models. Today, without the use of computer models based on mathematical calculations, engineering judgments are often more conservative and expensive. However, many computer models, will inevitably lead to an optimal model selection. The select applications should meet all criteria defined, compared and evaluated through its efficiency, accuracy, speed and many more. In this article, we're going to review the floodplain zoning simulation models in terms of their dimensions, advantages and disadvantages as well as the preference model to examine the situation. Below are some basic flood definition's implications used throughout this paper to better understanding and knowledge.

Some basic definitions:

**Flood:** The overload, inadequacy and raised the volume flow of river waters that fill the surrounding lands and damage properties and infrastructures. Usually this kind of flooding occurs during heavy rains or snow melting and ice flows.

**Flood plain:** land next to or along the rivers during the normal river flow and submerged in flood situations.

**Floodplain zoning:** The means to determine the ground water elevation and flow characteristics at different return periods.

## II. Floodplain zoning mathematical models

**One-dimensional (1D) models:** In these cases, the river is represented as a one-dimensional system by using the cross-section information, and the software models to solve the one-dimensional hydrodynamic St Venant equations for mass and momentum, for example; HECRAS, MIKE11 and ISIS.

HEC RAS: Bundles of river engineering are discussed in HEC-RAS (Hydrologic Engineering Centers-River Analysis System) model by the U.S. Army to simulate phenomena of the river and crossover structures. This model contains six sub-models for hydrological calculations, flow characteristics, reservoir storage, rivers' monthly flow simulation, management and operation of reservoirs composing with deposition morphological changes of the river bed.

HEC-RAS hydraulic system consists of three components: one-dimensional analysis for computing water surface profiles

in a steady flow (Time's terms are not in the energy equation); simulation of unsteady flow, and sediment transport calculations in a fluvial, respectively.

The three components are represented in a common geometrical data. The geometric and hydraulic calculations use the same process.

The basic information needed for floodplain zoning simulation can be modeled using HEC-RAS hydraulic data (Roughness coefficients, the river morphology...); topographic data (longitudinal & cross-section of the river and land borders) and hydrological data (flood inflow hydrograph, the discharge stage curve).

Annex HEC-GeoRAS is the bridge between GIS and hydraulic model HEC-RAS is the best feature of the surface on water and flood zones illustrations.

The simulation software is based on standard numerical method to calculate the surface flood level between the two sections. The method is based on the energy relationship that calculates the two ends of the interval (in sub critical flow, super critical flow, upstream and downstream) can start and this section continues to the next stage of the calculation. The constriction and the flow regime change (become critical to super critical flow and vice versa), the size of the equation of motion used.

The limits of the steady HEC-RAS model are as follows:

1. The variable flow is gradually because the energy equation, we assumed hydrostatic pressure distribution is at any cross section. In areas where the flow is varying (such as hydraulic structures like bridges, Calvert and overflow, etc.) the program uses momentum equation or other practical equations.

2. The flow is one-dimensional because it is assumed that energy head is the same for all points in along the river cross sections.

3. The slope of the river is low because the pressure head gradients in the energy equation represent the depth of the water (Maximum 1:10).

MIKE11: MIKE 11 is a dynamic bundle model that the Danish Hydraulic Institute (DHI) developed for one-dimensional river flow simulation, irrigation systems, water canals, and other fields (Hydrology and hydrodynamics, etc.) .It can simulate process modules for rainfall-runoff, flood forecasting, sediment transport, water quality, ecology, advection-dispersion, real-time operations, and dam break modeling, and the most inland water bodies. The St. Venant equations and modulus of continuity equations with nonlinear, are solved in all networking points at a specified time. Hydrodynamic models of the flood mitigation management of the water surface profiles were calculated and produced acceptable results, but are very expensive and complicated for users.

The MIKE11 model can be defined for each cross several roughness coefficient. The detailed floodplain image, sewer systems, watershed and coastal processes are clearly determined by integrating the proposed river and the

floodplain modeling. This engineering tool suggests the groundwater codes links, and its application consist of complex structure operation and other proposed forecasting projects.

HEC-RAS vs. MIKE 11: Some water surface profiles in HEC-RAS model cases are slightly higher than the MIKE 11 models. These different results in a non-steady flow, shows that MIKE11 is more consistent with the HEC-RAS model. In most cases, the highest sensitivity of water surface profiles in HEC-RAS model, depends mainly on the roughness coefficient and no other factors such as opening and narrowing the gradient energy coefficient.

With regard to access and free use of the HEC-RAS model and the ability to run in a windows environment and a graphical chart that displays the input and output and easy to use and other features compared to MIKE 11 complicated and expensive model to evaluate alternative models for good will.

ISIS: Integrated Services for Information Systems (ISIS) is one of the leading software packages for river modeling in the market place and its application worldwide, by consultants and public bodies. The main competitors are mainly HEC-RAS, Inforworks and Mike 11. The software originates from Russia by Konstantin Vasilyev (Kosta) - Generation Two of EuroAqua and ISIS currently located at the Water Engineering and Management Skill Group in Halcrow (Swindon). Upstream boundary, downstream boundary and at least two rivers, routing or conduit sections are the different hydraulic units connected together in the ISIS model. The hydraulic unit contains model data and more node labels that is functioned to locate and connect with other units. This software is used to model flows, floodplain and water level in rivers. Furthermore, culverts, bridges, weirs, sluices, pumps and other infrastructures are included in its applications.

**Two-dimensional (2D) models:** MIKE 21, Info Works 2D and JFLOW are examples of this software, a depth average form of the Reynolds-averaged Navier–Stokes equations (or RANS equations) are used, with suitable simplification to the turbulent development. The advantage of such models over the equivalent one-dimensional models is their ability to describe direction as well as magnitude in both river channel and flood plains.

MIKE 21: DHI Water and Environment, Denmark is the developer of MIKE 21 hydrodynamic model, and the 2D modeling tool application varies from free surface flow and sediment transport simulation. The software consists of a varying size mesh design with hydrodynamic and morphological technology. The bank lines to the hydrodynamic behavior of the river and bed topography of the proposed location can be identified from the dynamic response from the operating the model components at the same time. The MIKE 21 model application includes flow and sediment transport pattern in river channels and on flood plains; bank erosion and bend to scour in meandering channels; general erosion and deposition, constriction and confluence scour; development of new channels and bars; morphological impact of river training works.

InfoWorks 2D: InforWorks RS is a unique hydrology and hydraulic 2D modeling product from Wallingford Software, and the software is made by the combinations of advance ISIS Flow Simulation Engine, GIS function and database storage. The application of this software includes a wide range of the current engineering infrastructure problem solving areas such as detailed surface flooding analysis for overland flows, floodplains and hydraulic structures, and it is more stable than HEC-RAS on unsteady solution and data management. Also, the model can simulate the rainfall-runoff, and the animated geographic plan provides sectional views, identifying graphical data at any time and fully dynamic flood mapping. The error checking and warning of the InforWorks RS software is provided fast, free and fully documented online help system. The software is used in Europe and the US for complex modeling and forecasting flood situations.

JFLOW: JBA, United Kingdom is the developer of JFLOW-GPU solutions in the 2D hydraulic model package since 1995, and the GPU should be a G80 series machine supporting graphics card as the minimum recommended hardware specification. The 2D shallow-water equations solve the 2D diffusion wave equation of the flow driven by the balance between surface slope and bed friction on a Graphics Processing Unit (GPU). JFLOW model is designed to run problems using real-world depth and velocity data at one-minute intervals.

MIKE 11 vs. MIKE FLOOD: The results from the comparison between the two models, MIKE 11 and MIKE FLOOD, are the same for narrow and V-shaped river, as there is no difference in simulation results between these two models, but in the plain areas of water flow across the geographical range is higher, and a two-dimensional model MIKE FLOOD should be used to ensure the accuracy in the simulation results.

In the mountain areas that the width of the valley is narrow (V-shaped valley) is a less difference between the two simulations, MIKE 11 and MIKE FLOOD. The high cost of two-dimensional modeling and the need for more information, one-dimensional model MIKE11 can be used. On plain areas, there is much difference between the two simulations models, and MIKE FLOOD is currently the best available software and very high accuracy.

### III. Geographic Information Systems (GIS):

GIS is a powerful tool in Water Resources Engineering studies and in case where the use of models and simulators are necessary for solving problems, it features its ability efficiently. Providing geometric data streams, including flow lines, the Manning coefficient and cross-sectional data from topographic maps are time consuming, but if Geographic Information Systems are used this can easily be done with high speed and accuracy.

Today, there are a number of GIS supported hydrodynamic numerical software products available, which can be applied effectively by experienced consultant engineers. An adequate

topographic data basis and reliable calibration data are provided, then the existing tools can be used to obtain information about the flood depth and flow velocity with a high temporal resolution.

Briefly, the benefits of geographic information systems in floodplain zoning maps can be stated as follows:

- Making changes and update maps based on the new data, it is simple as possible.
- Ability to display the depth of flooding at each point of flood.
- Changes in the geographic effects and their possible implications beyond the scope and depth flood will be considered.
- Connection with mathematical models and Flood Forecasting and Warning System (Real Time) could be provided.
- Archiving and storage and retrieval, and distribution maps are more reliable, easy and simple.

Combining GIS and arithmetic models facilitate the calculations and improve the results of the River floodplain zoning. Incorporating ArcView and models like MIKE 11 leads to gain powerful tools for planners and decision-makers to calculate zoning floods with different return periods in a short time and with high accuracy. By using the results, they can plan to control the flood efficiently.

### IV. Result

The most essential tool to prevent the risks of float in rivers in order to optimize the surrounding lands is to determine their boundaries and also the riverbeds. The river zoning maps are certainly one of the most basic, and important information needed in studying on civil projects, and it should be taken into consideration before any investment or operating any development project. Since the river zoning maps give valuable information such as the depth and area of flood prevention in flood zones, it is crucial to provide the maps at first place. The pointed factors would considerably improve the accuracy of results.

1 - One of the most important hydraulic parameters for calibration of the model is to determine the roughness coefficient. The roughness coefficient depends on the length, density, distribution, vegetable species and also the river bed's material and sizes. The engineering experience and the use of riverbed's material tables give a clear criterion to choose the best roughness coefficient.

2- To estimate the flow characteristics of a particular interval on a river, the boundary condition adaptation is required. Boundary conditions are used to determine the input and output stream in the given upstream intervals. Obviously, the exact specifications bring up better results. The number of intervals also which have been studies increase the accuracy.

3- When there is no data for water flow, software could be utilized for simulation. As a matter of fact, rivers are always subjected to abrupt changes continuously; therefore, the water

flow may change from under critical situations to super-critical or in the other way around. The boundaries should be defined within their upstream and downstream, and this may happen to come with a good approximation by allocating the normal slope and depth of the corresponding river as the boundary conditions.

4- Geometry of rivers is also important as they are used for hydraulic calculations and studies on riverbeds. Topographic maps are used to show natural and man-made features of rivers in detail and accurate graphic representation. Hence, the sampling should be done for the main parts and also flood plains surrounding the sides of the river. This consideration would be usually between 100 to 400 meters.

5- The behavioral features of rivers, the basic elements of design such as balance width, slope width, control width (optimized), and also social and hydro-logical water flow considerations to normalize the condition should not be forgotten since they are important.

6- The basics and professional studies, frequent visits to the field, paying adequate attention to the necessary interactions in the river, software simulations, and ultimately, the engineering experiences are significantly effective for the best water flow limitation results in a particular river interval.

7- It is also essential to determine the river bed through water flow limitation within a particular width by utilizing embankments (hydraulic models) in wide and broad rivers, and the reason is the water flow decreases at the final intervals of wide rivers, so it acquires this kind of embankment to be optimized. This plan could be applicable by the selection of correct river width.

8- Another factor in the result of floodplain zoning maps is choosing a suitable return period to match the proposed design and area. The most significant factors that can affect any area of flood return periods are: volume and surface runoff to the upstream of the river or flood conditions, and its physical characteristics (surface morphology, etc.).

9- Construction of mechanical structures has a significant role in changing the scope of the flood zone. The bridge is one of the obstacles on the path of water flow in rivers, canals and the general changes' expansion and contraction process in the flow or water current. Although the forces exerted by the flow on the basis of comparison with other structural forces that are going to be negligible, but what is important here, and the issue is significant, increasing water depth ( $\Delta y$ ) is based on the upstream of the area where the bridge comes down.

10- It is proposed to simulate a two-dimensional model where the fields are used.

11- Damage assessment will be evaluated with different return periods.

12- Using the right hydraulic models and terrain, the level of the river bed can be determined.

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