DAM-BREAK FLOODING SIMULATION USING ONE-DIMENSIONAL AND TWO-DIMENSIONAL MIKE 11 HD AND MIKE 21 HD MODELLING

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Abstract

With the advent of digital information and remote sensing systems such as GIS and DEM production, greater speed and accuracy has been provided for Dam-Break data interpretations. The core analysis is performed by a hydrodynamic model and the input data as well as output presentations are provided by GIS. In this paper, input and output data have been analyzed using a mechanism for the transfer of data between the hydrodynamic models and the GIS tool. One dimensional MIKE 11 and two dimensional MIKE 21 hydrodynamic models are built upon the Saint-Venant equations for shallow water waves to estimate the maximum flood level down of the dam sites, these models have been combined to obtain river and floodplain flooding characteristics and Dam-break results have been developed using a GIS tool. The case of non Dam-Break flooding has also been studied for comparison Sefid-rud river basin has been used as the case study and the results are obtained for this case.

INTRODUCTION

By using a numerical modelling of dam failure a proper approximating of the amount of maximum discharge and water level in downstream area is accessible. Dam failure is an unstable Hydraulic Phenomena and the numerical simulation requires a strong mathematical modelling. Nowadays the different mathematical modeling such as BREACH, MIKE11, DAMBRK, and SMPDBK is available for dambreak simulation.

In this research one and two dimensional hydrodynamic models have been combined to obtain output flow hydrograph. The output hydrograph was routed in lower part in order to get the maximum speed amount, water height level and discharge during the time of reaching dam break wave to the lower parts points. For one dimensional modeling of dambreak output flow, MIKE11 hydrodynamic module was used. In this model, dam break development caused by overtopping with attention to damage was investigated using different methods like NWS-dam break or energy equation. In two dimensional modeling with attention to the Saint Venant equations by using the finite difference method, the propagation and transformation of the generated waves has been modeled using DHI´s MIKE 21 hydrodynamic module, which is based on the non linear shallow water equations. The effect of the Dam Break is modeled by forcing terms representing the dynamic vertical deformation of the bathymetry plus additional terms to represent the effect of the dam break due to viscous and inertia forces. Afterward, the obtained results from two dimensional models are combined to the corresponding one dimensional one using Mike flood and lateral link.

METHODOLOGY

DAMBREAK MODEL IN MIKE11

In MIKE11 implicit method and Finite Difference are used to solve the fluid equations in an unsteady state based on conservation of mass and Saint Venant momentum equations. The solution method to the above equations is 6 points Abbott scheme in which discharge and water level height are calculated at the nodal level namely H and Q.

Most dambreak setups consist of a single or several channels, a reservoir, the dam structure and perhaps auxiliary dam structures such as spillways, bottom outlets etc. The River channel description is based on a cross section data. However, due to the highly unsteady nature of dambreak flood propagation, it is advisable that the river topography be described as accurately as possible through the use of as many cross-sections as necessary, particularly where the cross-sections are changing rapidly.

Reservoir description

In order to obtain an accurate description of the reservoir storage characteristics,
The reservoir can be modelled as a single h-point in the model. This point also corresponds to the upstream boundary of the model where inflow hydrographs are specified. In this way the surface storage area of the dam is described as a function of the water level.

The dam

At the *Q*-point where the dambreak structure is located, the momentum equation is replaced by an equation which describes the flow through the structure which is sub critical or super critical. The spillway is described as a separate branch. Figure 1 illustrates typical setup for dambreak simulation.

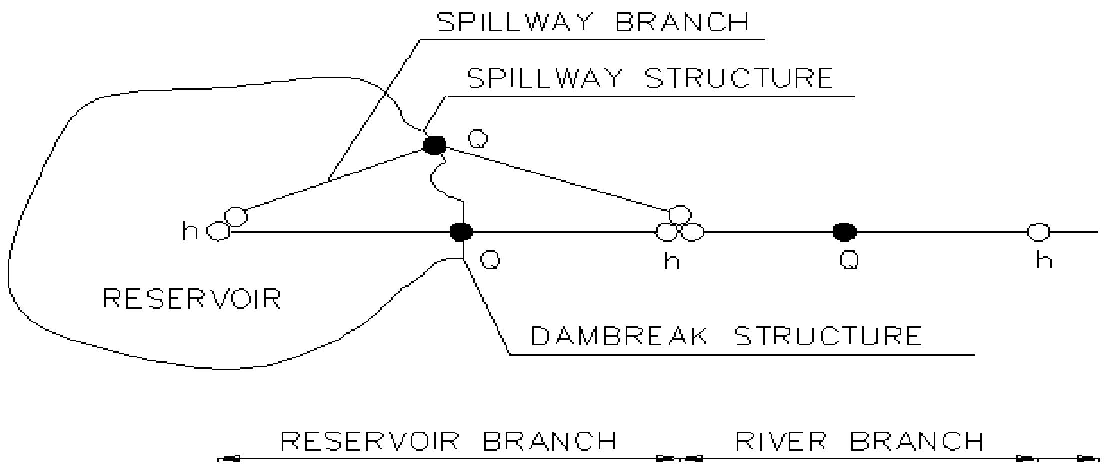


Figure 1: Typical setup for dambreak simulation

MIKE21

The propagation and transmit of the flood wave in flood plain is done using MIKE FLOOD21 which is based on shallow water nonlinear equation. MIKE 21 HD uses a uniform rectangular element by using a method so-called Alternating Direction Implicit (ADI) technique to integrate the equations for mass and momentum conservation in the space-time domain. The equation matrices that results from each direction and each individual grid line are resolved by a Double Sweep (DS) algorithm. The equations are solved in one-dimensional sweeps, alternating between x and y directions.
The dambreak effect appears as viscous and inertia forces in terms of equation and also by impact of dynamic forces which indicate the vertical changes of bathymetry.

MIKE FLOOD

MIKE FLOOD was used to integrate the one-dimensional model MIKE 11 and the two-dimensional model MIKE 21 into a single, dynamically coupled modelling system. A lateral link was used to allows a string of MIKE21 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, where flow over the river levee is calculated using a weir equation. Figure 2 described the application of lateral link in MIKEFLOOD.

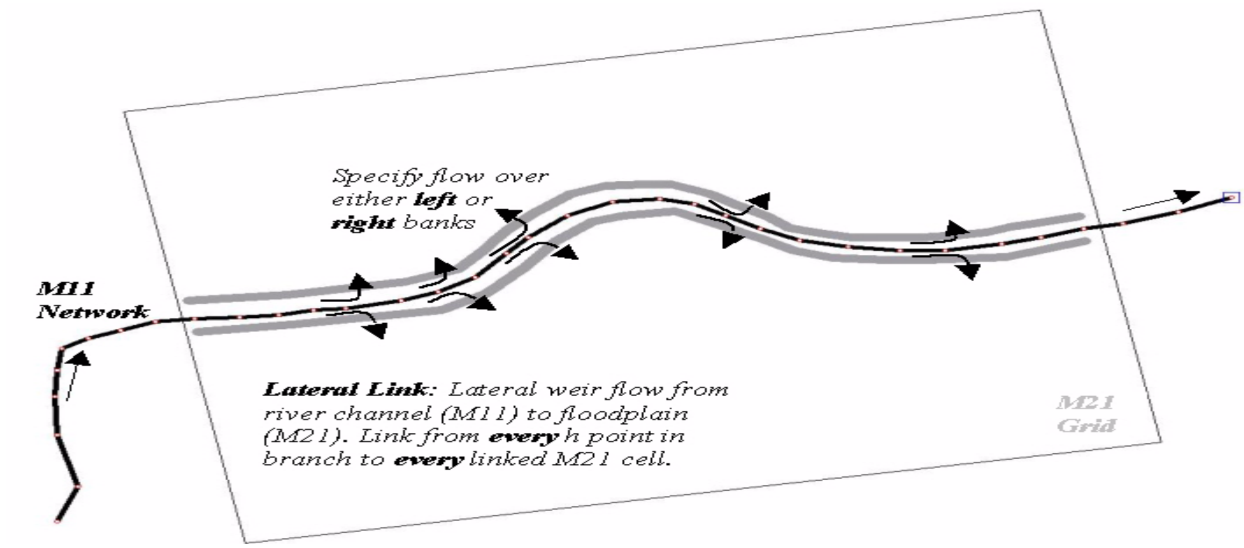


Figure 2: the application of lateral link

MODEL DESCRIPTION

Sefidrud dam

Sefidrud Dam which was Located on the Sefidrud River in north of the Iran; was completed in 1961 and is operated to provide flood control, irrigation, and hydroelectric generation. The dam created Sefidrud Lake, a 56 square kilometers reservoir. The dam data are presented in table 1.

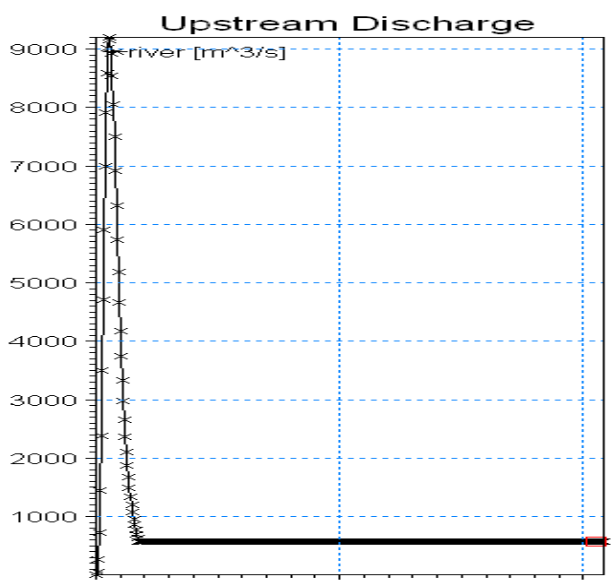
Table1-Sefidrud Dam specification:

Height from bottom	107 meter	Dam- Body
Elevation from bottom of the river	92 meter	
Crest height	277.06 meter	
Crest length	425 meter	
Reservoir area	$56*10^6$ cubic meter	Dam Reservoir
Reservoir volume in PMF flood	$8*10^8$ cubic meters PMF	
Weir Crest elevation	271.65 meter	Dam Weir
weir Design discharge	3000 m^3/s	

Cross sections
To obtain the better accuracy the cross section in desired code derive from the studied DEM in GIS from Sefidrud river. The Cross sections around 50 including the output data such as distance and height of each section was retrieved using cross section Editor, interpolation was used in order to obtain more section in other area. Manning Resistance flow coefficient considered 0.038 and addicted to each section. This factor is retrieved in Model calibration. One of the weaknesses of MIKE11 model is that if the height of water in a specified section becomes four times larger than the depth of the section, the calculation will be stopped. Occurrence of these phenomena is likely in dam failure modeling. Therefore the cross section should be developed as much as possible on 1:25000 topographic maps.

Boundary condition:

Upstream Boundary condition is resulting the hydrograph from dam failure which defined by time series function. Normal depth or Critical depth can be considered as a downstream boundary condition. But due to inappropriate rating curve in water-bathymetry station, slope of the corresponding normal depth was used as downstream boundary condition. Regarding to natural river profile and average ground slope at the end of the studied area was considered around 0/0022.
Figure 3 shows the upstream boundary condition in NWS-DAMBREAK model.



	Time	1:river [m^3/s]
0	1/30/2009 12:32:13 AM	4
1	1/30/2009 12:35:13 AM	48
2	1/30/2009 12:38:13 AM	270
3	1/30/2009 12:41:13 AM	728
4	1/30/2009 12:44:13 AM	1439
5	1/30/2009 12:47:13 AM	2381
6	1/30/2009 12:50:13 AM	3498
7	1/30/2009 12:53:13 AM	4703
8	1/30/2009 12:56:13 AM	5900
9	1/30/2009 12:59:13 AM	6994
10	1/30/2009 1:02:13 AM	7909
11	1/30/2009 1:05:13 AM	8593
12	1/30/2009 1:08:13 AM	9022
13	1/30/2009 1:11:13 AM	9202
14	1/30/2009 1:14:13 AM	9156
15	1/30/2009 1:17:13 AM	8920
16	1/30/2009 1:20:13 AM	8538
17	1/30/2009 1:23:13 AM	8051
18	1/30/2009 1:26:13 AM	7499
19	1/30/2009 1:29:13 AM	6913
20	1/30/2009 1:32:13 AM	6320
21	1/30/2009 1:35:13 AM	5739
22	1/30/2009 1:38:13 AM	5184
23	1/30/2009 1:41:13 AM	4662
24	1/30/2009 1:44:13 AM	4180
25	1/30/2009 1:47:13 AM	3738
26	1/30/2009 1:50:13 AM	3338
27	1/30/2009 1:53:13 AM	2977
28	1/30/2009 1:56:13 AM	2653
29	1/30/2009 1:59:13 AM	2364
30	1/30/2009 2:02:13 AM	2107
31	1/30/2009 2:05:13 AM	1879
32	1/30/2009 2:08:13 AM	1676
33	1/30/2009 2:11:13 AM	1496
34	1/30/2009 2:14:13 AM	1338
35	1/30/2009 2:17:13 AM	1197
36	1/30/2009 2:20:13 AM	1072
37	1/30/2009 2:23:13 AM	962
38	1/30/2009 2:26:13 AM	864
39	1/30/2009 2:29:13 AM	777
40	1/30/2009 2:32:13 AM	700
41	[illegible]	[illegible]

Figure 3: Upstream Boundary condition in NWS-DAMBRK MIKE11 model

Manning factor in all sections for the main river channel was considered 0.038 using the results of studied area.
Time step was selected equal to 3 and time step for recording the output result was considered 20 minute which is based on the Sensitivity of one-dimensional model and two-dimensional modeling and how they connected. Δt and Δx values should be chosen in order to satisfy the linear change of the flow basic parameters.
For initial Condition using Hotstart file in a separate simulation, it was assumed that the dam reservoir is empty and the water elevation increase up to 277 /06 without

occurrence of the hydraulic dam failure. in this simulation the outflow discharge was assumed to be zero so that dam reservoir is filed faster, moreover to prevent numerical divergence, in the computational point after the dam, the small lateral discharge equal to 100 cubic meter per second was entered to avoid the drying of downstream computational points.

HYDRODYNAMIC SIMULAATION OF MIKE21 MODEL:

Creating flow network using GIS information

In order to create a proper region area and by using the available 10 m DEM, a proper cut raster was created in GIS. In bathymetry model, the text file of the desired area including x,y,z coordinates, was entered to the model using the suitable coordinate UTM39. Moreover the possibility to create the bathymetry is available by classifying the raster file and using the ASCII file which produced by Arctoolbox.
Figure 4 was shown the model Geometry which was stored as spatial series file in software. The polyline as boundary is used to describe the open boundary in tow ends of the model.

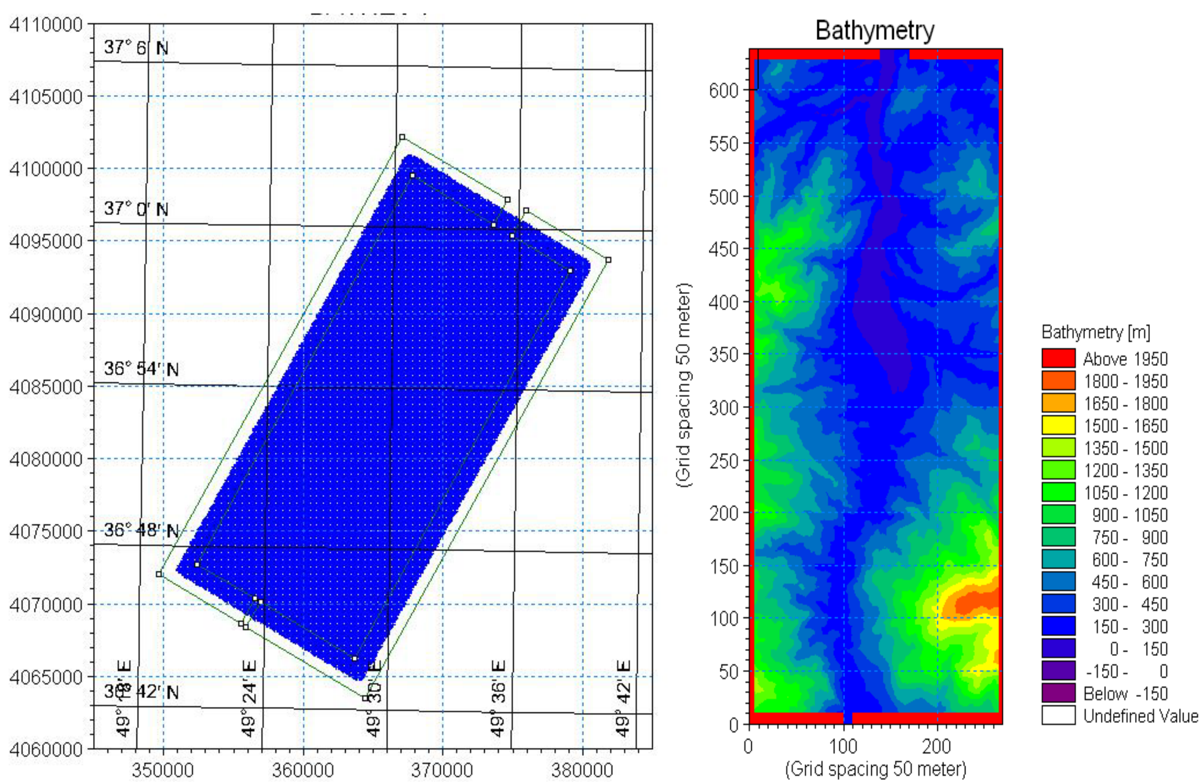


Figure 4: Bathymetry of studied area in MIKE21

Time interval due to dam failure modeling in flood plain, was considered the base time for inflow hydrograph. Calculating time step is equal to 3 in both MIKE11 and MIKE 21 models.

Since the MIKEFLOOD enters the overtopping flow from the main river channel as a lateral flow to flood plain, Needless to define boundary condition in MIKE21.
In MIKE21 initial water depth was considered Zero and the initial conditions of flood plains is dry bed.
In this model with choosing the time step equal to 3 second and spatial step equal to 50 meter and the gravity wave velocity equal to 5 m/s; while the maximum water depth in flood plain is 15 meter; the quadrant number is obtained less than 1.

INVESTIGATION OF RESULTS IN MIKE AND GIS

The peak of dambreak inflow hydrograph was considered 9202 m3/s. In this case with the inflow discharge to the downstream river, the initial flow section is filled at first and water flows to downstream direction. This causes the hydrograph to be stretched and the discharge becomes constant. The simulation is started at ، 13:07 2009/01/16 and get maximum in the beginning of the interval. Table 2 described water level In different distances from the dam location. Regarding to flood peak in desired distance, the time of reaching the flood wave is increased.

Table 2: output results of flood peak in time interval after dam failure

Water level (m)	Wave arrival time (hr)	Maximum flood discharge (m3/s)	Distance from dam (m)
243	2009/1/16 13:10	9112	45
236	2009/1/16 13:52	7824	1010
231	2009/1/16 14:02	6219	2005
223	2009/1/16 14:17	5119	3084
210	2009/1/16 14:47	3101	5364
159	2009/1/16 15:37	793	18550
141	2009/1/16 16:47	619	23962
137	2009/1/16 17:17	602	25238
120	2009/1/16 17:46	592	30938
96	2009/1/16 17:52	570	39750

The below figures introduces the flood water level, before dam failure and after the maximum flood water level, respectively,

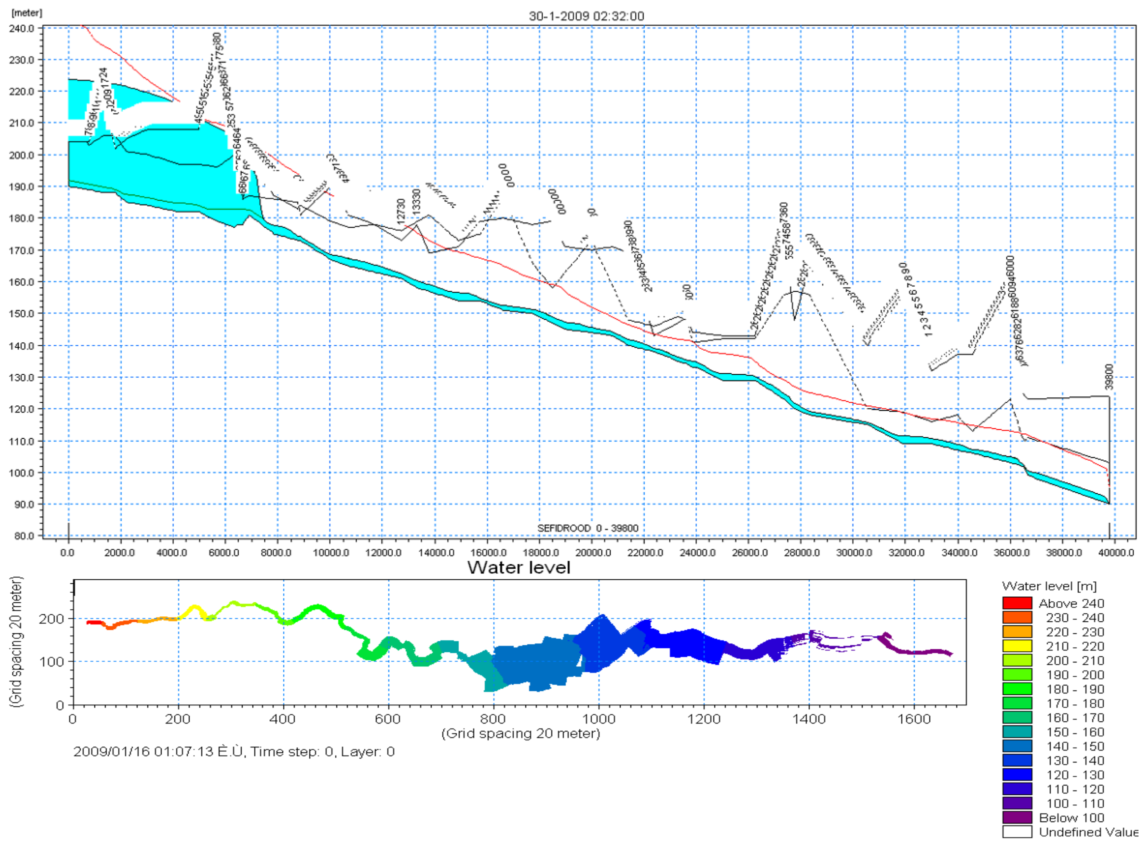


Figure 5: Flood water level before dam failure

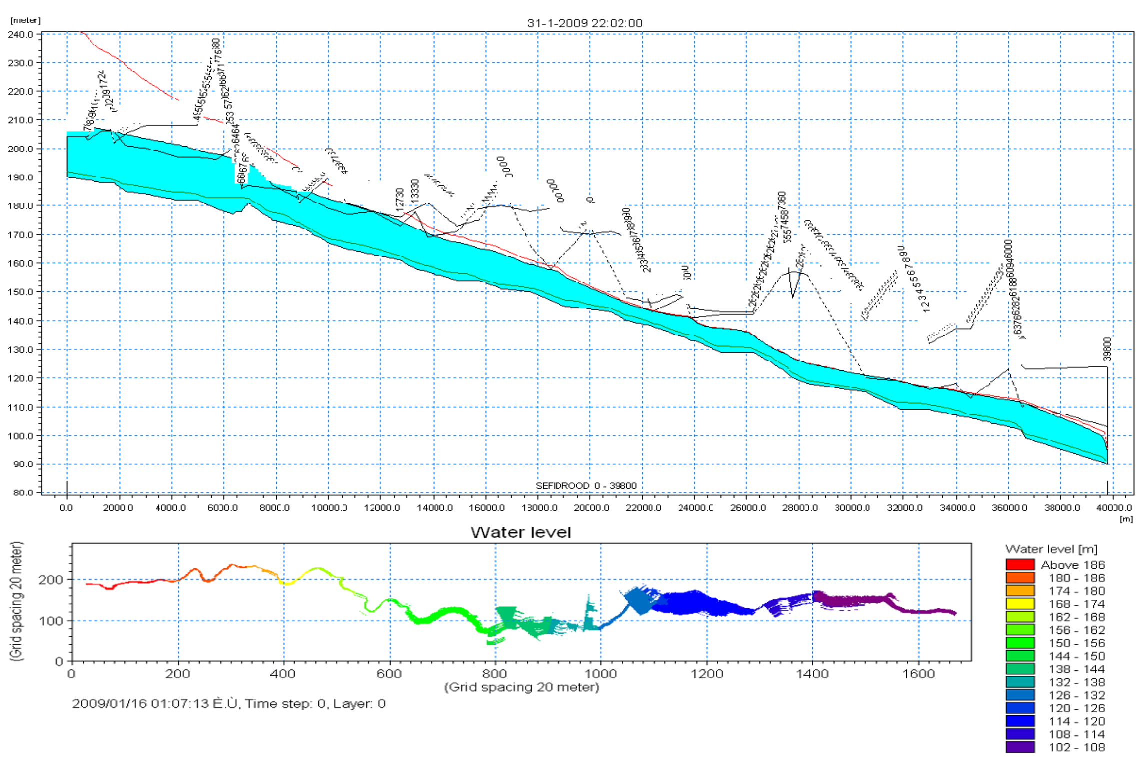


Figure 6: Flood water level after dam failure

“No amount value” represents the dry area in desired region which means that in lowest flood values, the water depth doesn’t exceed the dry area. The water depth value which is the difference between dry ground elevation and water surface level in the selected point is listed below.

Table 3: Water depth after the dambreak output hydrograph

Water depth (m)	Distance from dam (m)	Water depth (m)	Distance from dam (m)
17/113	5364	21/17	45
11/660	18550	20/275	1010
6/944	23962	19/879	2005
7/674	25238	17/550	3084

In MIKE11 the flood hydrograph in input points and water depth in different point of the river for output results can be displayed. The below flowcharts illustrates these value in specified points.

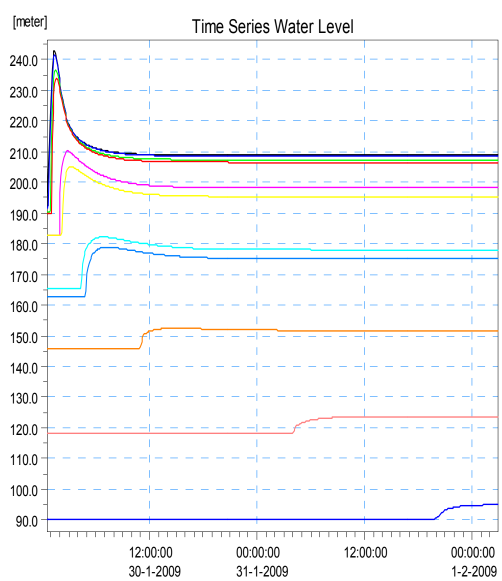


Figure 7: Water depth in different points

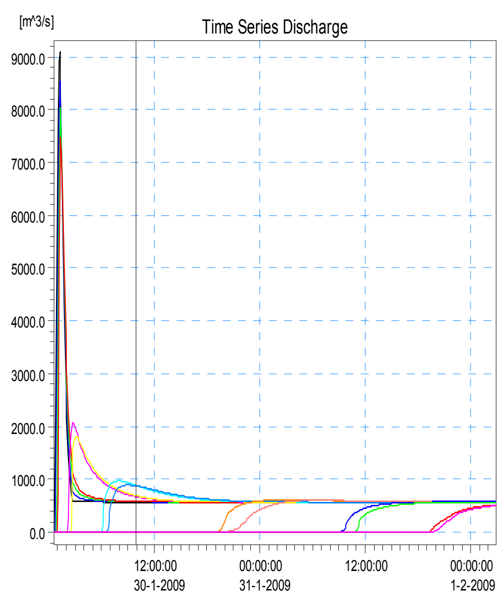


Figure 8: Dambreak output hydrographs

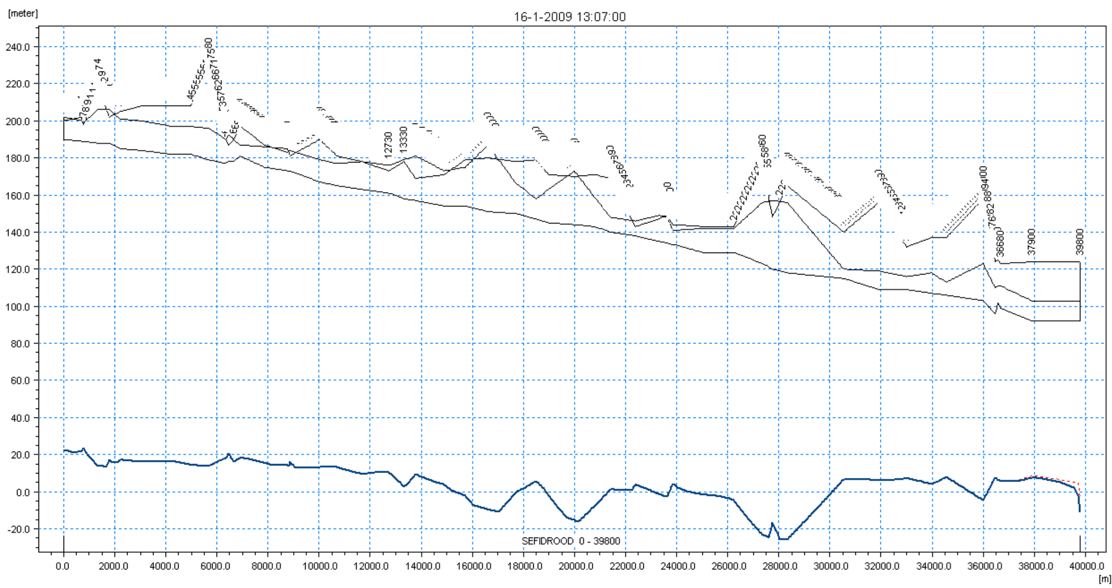
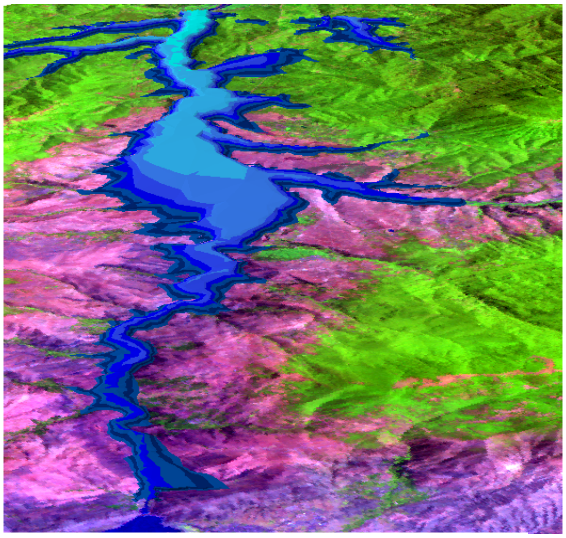


Figure 9: water longitude profile in river

The following figures show the depth and water level of flooded area which is produced by 1-D hydrodynamic model and transferred in ArcGIS to display the results in 2 dimensions. Floodplain is created as a water level elevation and is displayed in the cross intersection place. Using this elevation a TIN exchange file (capable of displaying the water flood level) is created and from combining the water level TIN with ground TIN the flood plain will be specified. With adding different layers like river banks layer and longitudinal and latitude structures, the flood are will be more clear and intelligible.



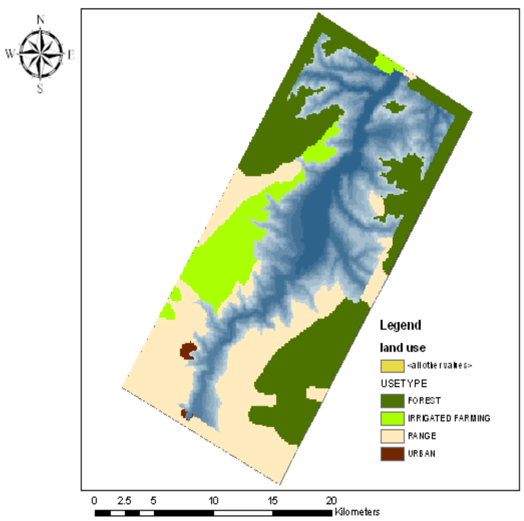


Figure 10 3-D model of floodplain in layer in ArcScene

Figure 11 overlapping landuse and floodplain in ArcMap

CONCLUTION

Model results indicate that due to the maximum discharge and short base time of dambreak hydrograph, flood velocity has a very dramatic rate specially in the early moments of dam failure and it decrease with advancement of the flood wave toward downstream. With Flood occurrence, at first the primary cross section was filled by water and the flood moves downstream. As can be seen from the output Hydrograph after the flood routing, the hydrograph is stretched with continuing much more flow in a base time around a few days and a constant discharge around 600 m3/s. The flood maximum in this area is almost equal and is a function of Hydrograph volume. The constant flow of 600 m3/s increases the dam failure losses. The flood characterization in two dimensions in flood plain is made in MIKE21 and the output results are transferred to GIS for a better display of flooded area in two and three dimensions.

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