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Research Article

INVESTIGATION OF EARTH DAM FAILURE AND ZONING OF RESULTING FLOOD USING HEC-RAS SOFTWARE (CASE STUDY OF DALAKI DAM)

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ABSTRACT
It must be taken into account that due to reservoir dam failure, downstream areas will face irreparable damages. Therefore, dam failure hydraulic simulation is vital for damage estimation, proper planning and provision of assistance activities in the area. Bushehr's Dalaki earth dam is considered as the case study in the present research. About 20 thousand hectares of groves, irrigation networks and their facilities, as well as the cities of Dalaki, Vahdatiyeh, Sadabad, and etc., are located in the downstream of Dalaki dam and on the Dalaki riverbank. If Dlaki dam collapses, the cities will suffer severe casualties, industry and agriculture damage. In this study, by utilizing of one-dimensional hydraulic simulation of Dalaki dam failure due to overtopping and piping, water level and flow discharge hydrographs, velocity tables and flood zoning maps were derived from dam failure hazard analysis. Finally, by using drawn hydrographs, flood wave arrival time at any downstream spot and the rate of increase in water surface at that particular spot were specified.

Keywords: *Dam Failure, Flood Zoning, HEC-RAS Model, Dalaki Dam*

INTRODUCTION
Constructing dam benefits societies in great extent has an essential role in economic, agricultural, rural and urban development, supply of drinking water, generation of hydroelectric power, control and regulation of river flows. Despite of the high confidence applied to the phases of dam's design, construction, and utilization, there has always been the possibility of dam failure like other human manufactures (Vafaian, 1996). According to the statistics from 10 2nd issue of ICOLD, as a result of overtopping and occurrence of piping in dam body, more than 80% of failed earth dams in the world were collapsed (Schnitter, 1979).
The analysis of the risk of dam failure is done by the use of numerical models in order to estimate the output current leaking from the crack resulted from dam break, and to simulate flood spread in downstream areas (Singh, 1988). Thus, modeling of dam failure using HecRas model, running the model and extracting the obtained results, supplying downstream river model using GIS, extracting river spots and related constructions (bridges, water reservoirs and etc.) using Hec Geo Ras software, analysis of unsteady current in downstream river (Wahl, 2001). The present study examines various possible scenarios that would lead to Dalaki dam failure, and deals with modeling of the dam break, tracking flood and extracting the spread of resulting flood in downstream river and plains.

MATERIALS AND METHODS
Geographical Location of the Studied Area
Dalaki dam construction is located on Dalaki River in Bushehr province, 90 km from Bushehr port, and 30km from Dashtestan city. It is an earth dam with maximum 320 m above sea level, 360 million cubic m of reservoir capacity and height of 105 munder constructions to supply water for 13000 hectares of palm trees.
There are lands and irrigation networks, and also cities of Dalaki, Vahdatie, Sa'adAbad, along with several villages which are located in the downstream of Dalaki Dam and on the bank of Dalaki River. On the event of Dalaki Dam break, casualties, and severe damages to industry, agriculture in the downstream cities and villages would be indispensable (Jafari, 2012).

Methods and Materials

Using HEC-RAS model, this research investigates the implications of Dalaki dam break under two conditions of: a) Overtopping andb) Creating piping phenomenon on the body of dam for lands, installations, residential downstream and bank areas with the use of flood zoning and extracting flood's transverse sections in various cross sections**.**

*Introduction of HEC-RAS software***:** HEC-RAS software pack was developed by Hydrologic Engineering Center 'HEC', an affiliate to the United States army's engineering corps. Clear enough is the face that to be provided with the model, physical data related to the current and one of the data on current to be introduced based on the type of analysis.

This software has been in use in the development of many projects in Iran, and as a result of availability and superb graphic capabilities, it has become popular and favorite software among engineering society. It also enjoys connect-ability to ArcGIS software via an adaptor called HEC-GEORAS to perform pre- and post-processing in geographical information system (GIS). HEC-RAS software supports special capability to correct waterway and computing necessary ground-related operations (Brunner, 2010). This research employs version 4.1.0 of this software. It is necessary to add that a variety of studies and research papers have attempted to ratify output data of HEC-RAS model using actual cases.

Determination of Manning coefficient: One of the important relations used to determine the depth of current and profile of water level in the rivers is Manning equation which is also employed by HEC-RAS software in calculating river hydraulics.

The importance of this equation come to the fore in the calculation of a coefficient known as Manning's Roughness Coefficient which covers all influential factors in the resistance of river bed against water flow. Thus, it ought to be estimated as one of the significant and primary information in design and with regard to the condition of the river under investigation.The values of Manning coefficient varies in the study range from 0.04 to 0.083 depending on the grading, unevenness and change in area and kind of vegetation, and curvature of the route.

Structures available in the project boundary: On the whole, apart from natural factors generative of dependent morphological factors such as slope, breadth and depth, artificial factors like bridges, also, bring changes to these parameters the result of which would be morphological and morphodynamic changes in the river. In sum, six bridges such as Haaj Mohammad Rahim bridge, Vahdatieh, NazarAgha, Doroodgah, and also SarGhanaat diversion dam along the Dalaki River have been constructed (Jahfari, 2012).

Specifications of dam failure procedures: This project models Dalaki's dam failure in two conditions of piping and overtopping (Fread, 1984). The current project introduced the phenomenon of dam break that starts at 279 m above sea level, equal with Farazband's peak level, and mounts with an upward slope of 1.4 until it reaches to the height of 320 m above sea level for the break time of 48 min. Also, the phenomenon of dam failure for the break time of 48 min resulting from overtopping which starts from 320 m above sea level with a downward trend of 1 until it gets to the height of 279 m was introduced.

*Determination of longitudinal profiles for water level in the state of piping***:** Water level along the river track in the state of piping is illustrated in the figure. Water depth at the upstream is greater than downstream. It results from valley-like nature, and low breadth of river upstream.

Determination of generated hydrographs in consequence of dam failure in piping state: One of the important outputs of dam failure's simulated model and flow in the Dalaki River is the determination of flood hydrograph as a result of break phenomenon in various sections of the river.After the execution of simulated model of dam break and flow in Dalaki River, the desired hydrographs were extracted to be introduced in the figures bellow. These figures demonstrate respectively generated hydrograph on the dam section and at the boundary limit of study period related to Dalaki River. As is shown, the maximum values for floods and the time of their occurrences demonstrate an evident difference which is the result of routing and consequence of spread of flood in the under-study area.

The flood-affected area on Dalaki River on the event of dam failure in piping state: The following figures provide the area that would be affected in case of Dalaki dam break.

Determination of longitudinal profiles water level at overtopping state: Longitudinal profile of water level is among the valuable outputs of Hec-RAS. For this reason, after the execution of flow simulating model, the longitudinal profiles related to change in water level for flood for different time spans are extracted. The following figures show the model results for the flood in consequence of dam failure in overtopping state during time span of investigation on Dalaki River. As these figures show, the water depth at the upstream is greater than at downstream. The result of this is the shallowness and valley-like quality of upstream.
Determination of generated hydrographs as a result of dam failure in overtopping state: One of the important outputs of dam failure's simulating model and flow in Dalaki River is the determination of flood hydrographs as a result of the phenomenon of break in various sections of the river.
After the utilizing of dam break simulating model and Dalaki River's flow, the desired hydrographs is extracted and shown in the following figures. These figures are respectively demonstrative of generated hydrographs in the section of dam and at the end of study time span related to Dalaki River. As depicted, the maximum level of floods and time of their occurrences varies considerably. It is the result of rooting phenomenon and consequence of flood spread over investigation area.

RESULTS AND DISCUSSION
A. Hec-Ras4.1.0 model is capable of modeling nonresident flow for the given river with special subtleties. Such modeling is performed both for river in nonresident state when the flow is 500 cubic meter per second in the availability of various structures on the river and even when the flow of flood is around 78000 cubic meter per second.

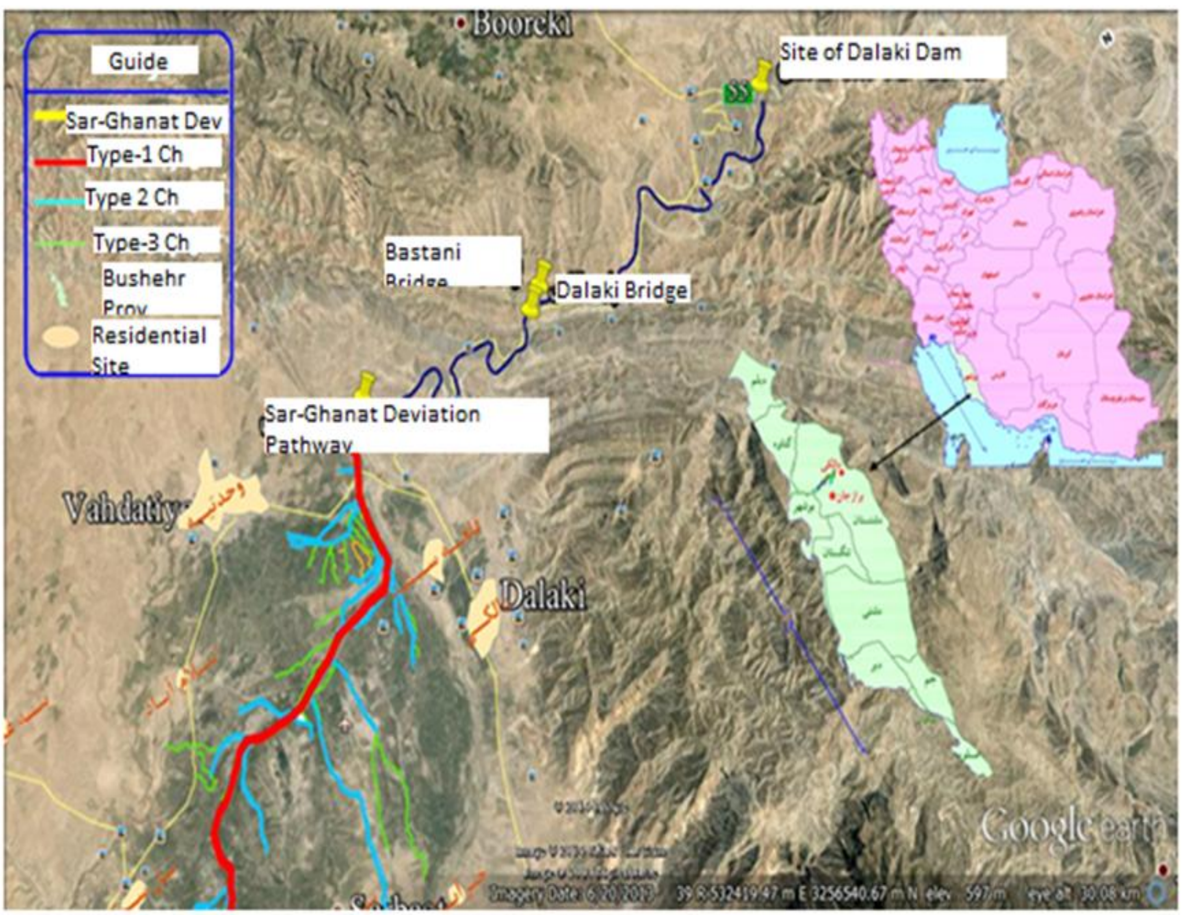

Figure 1: Map of boundary under investigation

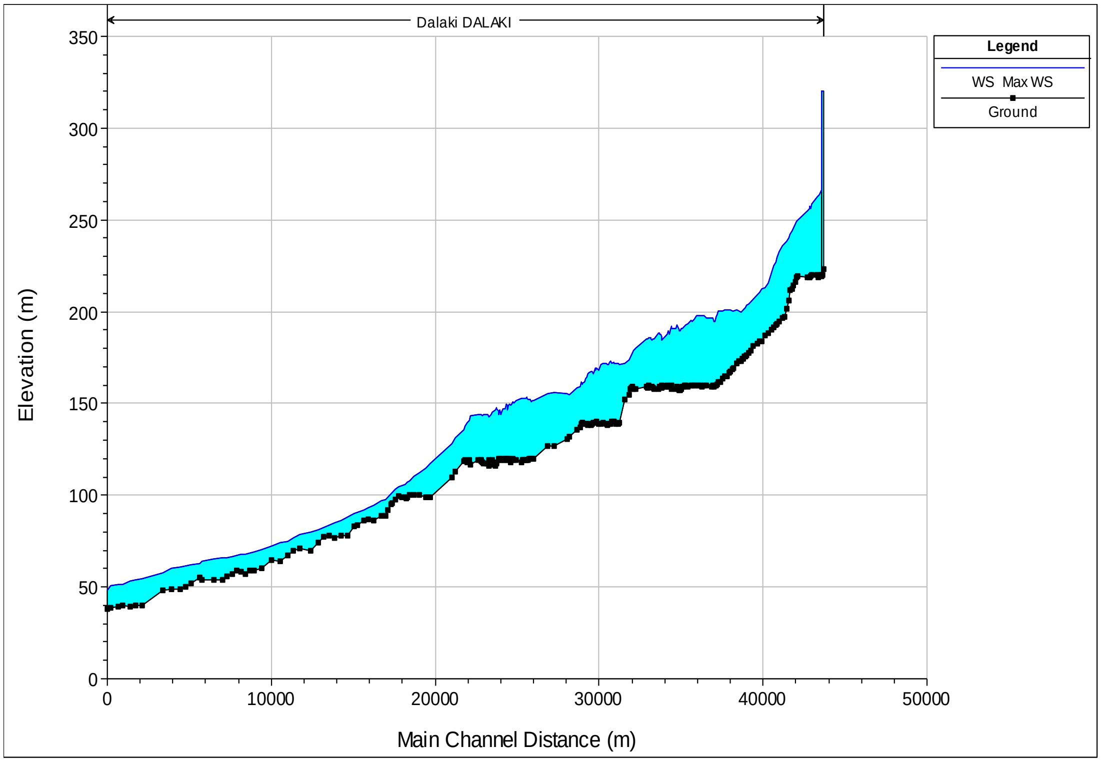

Figure 2: Water level profile in maximum flow in consequence of dam failure in piping state

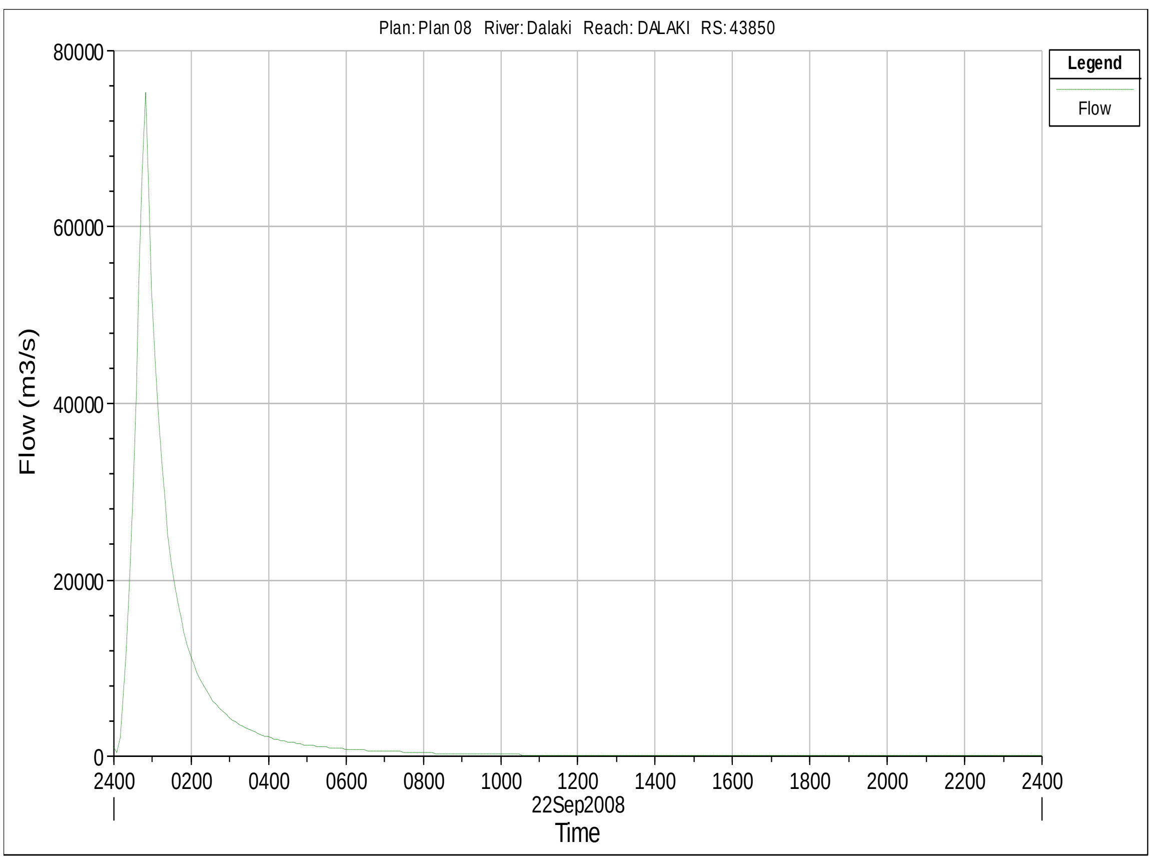

Figure 3: Generated hydrograph resulting from dam failure in dam section in piping state

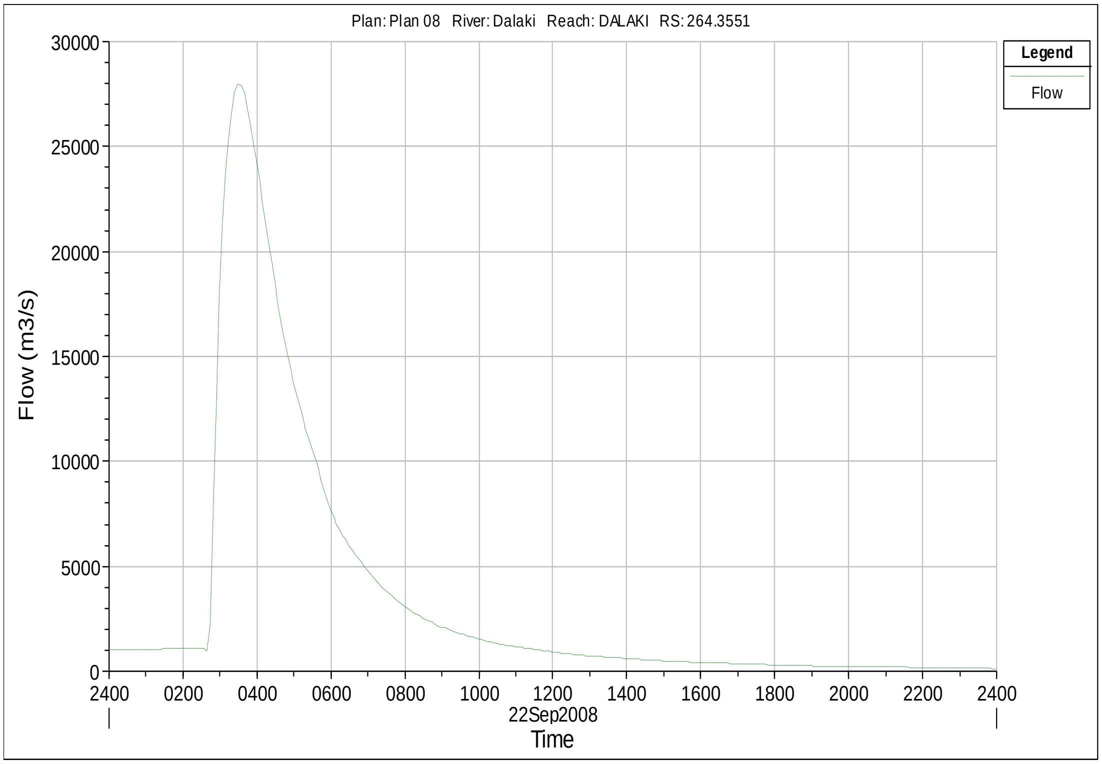

Figure 4: Generated hydrograph resulting from dam failure in final section in piping state

Figure 5: Flood-affected area of Dalaki River resulting from dam failure

Research Article

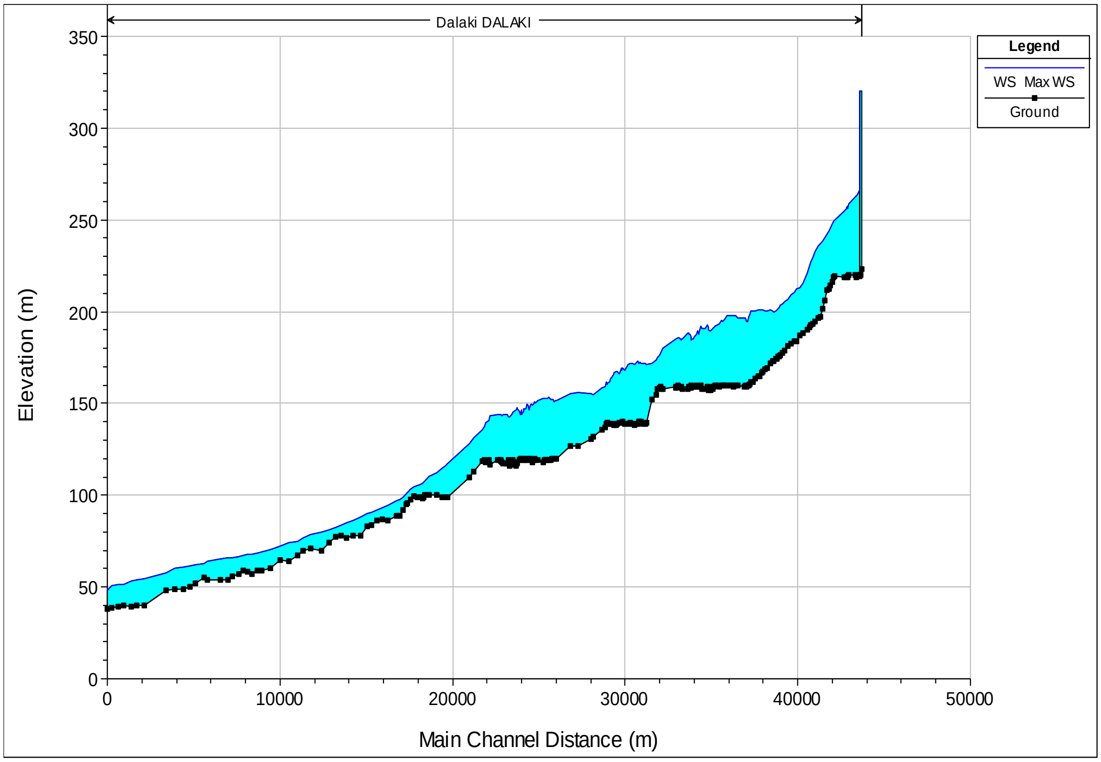

Figure 6: Water level profile in maximum level resulting from dam failure in overtopping state

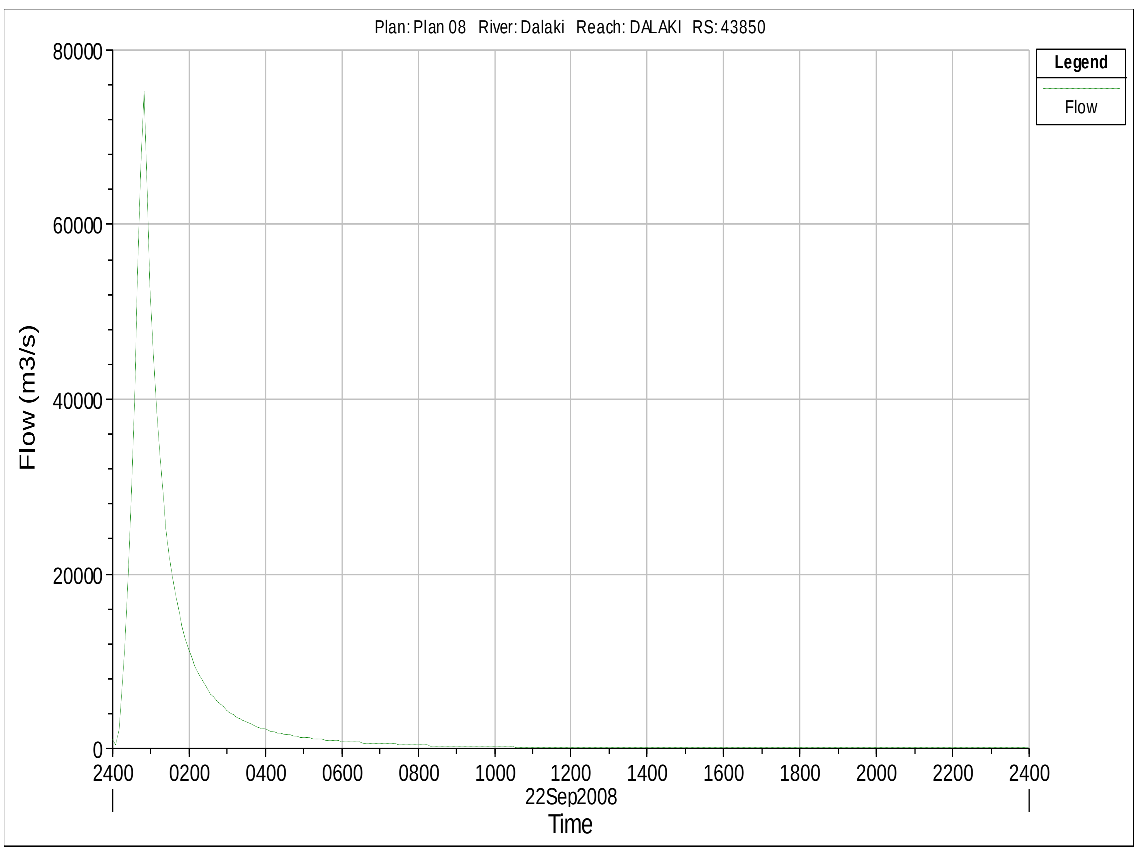

Figure 7: Generated hydrograph resulting from dam failure in dam section in overtopping state

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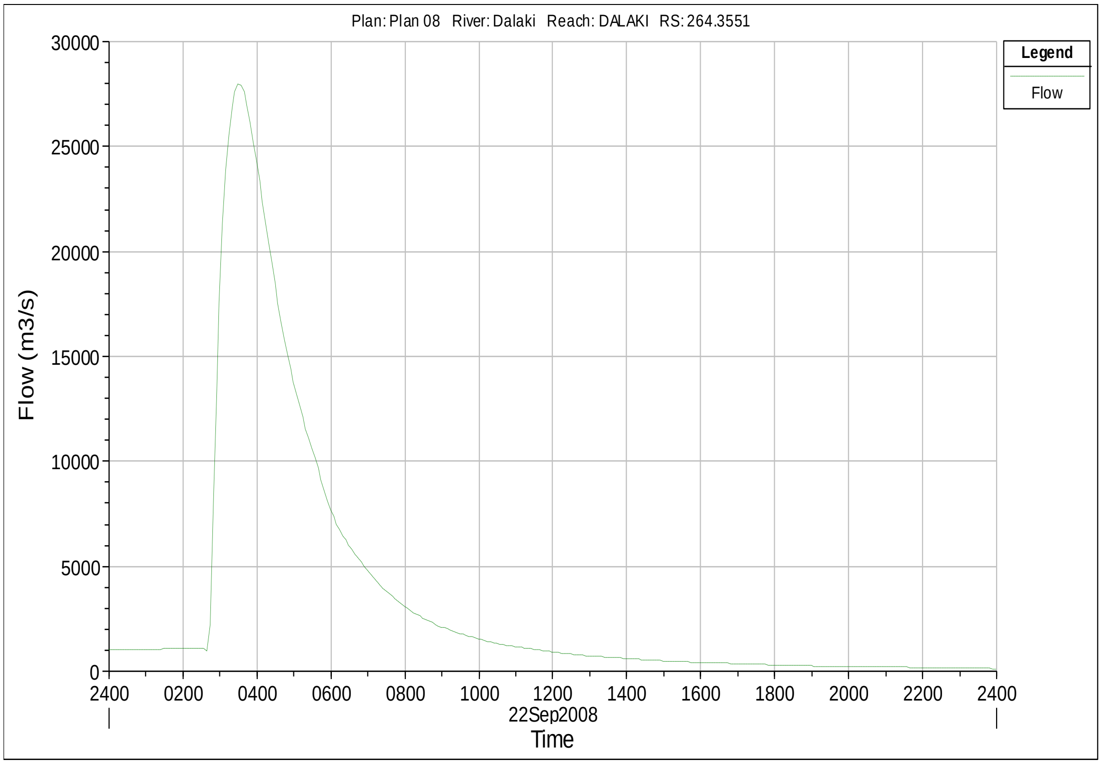

Figure 8: Generated hydrograph resulting from dam failure in final section in overtopping state

B.Hec-Ras4.1.0 model is sensitive in response to parameters such as geometry of the river (very high), Manning coefficient, abrupt increase in the slope along the river, input hydrograph (values and shape), preliminary conditions ,location and time distance (the final parameters is in fact related to all available methods). Whatever the Manning coefficient is lower, the stability occurs sooner. The occurrence of each of these conditions results in difficult achievement of stability. In places where there are abrupt slopes, the stability cannot be achieved during the defined time span for other sections. For the sake of stability in these sections, the meshing must be done with smaller grids on that particular spot. In various sections distance interval is 1.5 meter whereas in the neighborhood of slope breakers this values decreases to 0.1 meter and with a gradual change equals the meshing of other spots.

C. Data input in Hec-Ras4.1.0 model is very easy. In Hec-Ras model change in time span for the sake of achievement of stability is very simple. On the other hand, this software enjoys the capability of intersection interpolation.

D. A review program is a useful tool in creating flood zoning maps which is in turn helpful for management decision making at the time of crisis.

Conclusion

A. On the event of Dalaki's dam break at upstream, there occurs such a rise in water level as a result of mountainous area that connecting road from Bushehr province to Fars province would be cut off.

B. After the passage of flood resulted from Dalaki dam break from Band-e SarGhanat, it reaches to the plain and would strike on its way, such villages as Sar-e Ghanat, BenehJaMishi and parts of Sarbast village.

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