Frequency Analysis of Hydraulic Modeling As A Way to Forecast Flooding on the Allala River

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Abstract. The article presents research on modeling the recurrence of emergency situations caused by flooding on the Allala river. It is proposed to predict the frequency of floods using the Saint-Venant equation for hydrodynamic modeling. The HEC RAS model was used to compare flood intensity with different water level positions in the river. The parameters of the water source were measured on a section of 8 km long. As a result of research, it was found that the existing coastal protection structures on the banks of the Allala river are insufficient to prevent an emergency flood situation at peak river flows.

Keywords: flood, river, simulation, dam, water level.

1. Introduction
The Allala river is a tributary of Algeria's longest river, the Sheliffa, and is located in the Northwest of the country. During the year, the Allala river experiences small water flows that occur only when precipitation occurs, as with most rivers in Algeria. However, in excessively wet years, the amount of precipitation falling on the research territory exceeds the average annual norm for the region and is of a stormwater nature. As a result of this situation, the largest flood in the last twenty years occurred in 2017. As a result of the disaster, coastal territories were affected. Therefore, the aim of the research is to develop a method for predicting flood risks on the Allala river using hydraulic modeling.

Using the Baratin method to quantify confidence intervals, a set of curves was constructed, from which the corresponding curve was selected, which characterized the reconstruction of the annual peak discharge based on the hydrograph of the stage from 1973 to 2017. Based on the results of this stage and the FFA, the peak flood hazard is calculated for the deferred return period. The HEC RAS model simulates the water level for different locations of the Allala river. The simulation results confirmed that the existing embankment system is not sufficient to withstand the risk of flooding. Therefore, it is necessary to build flood models that will help predict flooding both in real time and in floodplain mapping (Prabeer Kumar Parhi) using the results of HEC RAS.
2. Methods
The Sidi Akkacha hydrometric station was established in 1972 and is geographically located at the outlet of the Oued-Allala watershed, which has an area of 296.34 km$^2$, a perimeter of 94.59 km, an average slope of 2.25 %, and an internal water channel of 31.57 km. The highest flood level recorded at the station was achieved with a discharge of 538 m$^3$/s, which corresponds to a water level of 6.1 m (March 1979).

2.1 Frequency analysis of data
Frequency analysis is used to determine the number of occurrence of random events and assess the accuracy of flood prediction. In this study, the null statistical hypotheses used for data analysis are the exponential distributions of Weibull and Gumbel. The result shows that the distribution of data from the Sidi-Akkacha measuring station follows an exponential distribution with a mathematical expectation of 129; an asymmetry coefficient (CS) = 1.71; an average square deviation (Sd) = 121; an kurtosis coefficient (Ck) = 4.72 and a coefficient of variation (Cv) = 0.936.the adequacy of the models was checked using the Chi–square criterion.

The estimated flood flow for different periods is shown in Figure 1.

![Figure 1. Forecast of peak flood discharges](image)

2.2 The model HEC-RAS
The River Analysis System (HEC-RAS) hydrological engineering centers, developed by the US army corps of Engineers, allow one-dimensional stationary and 1D-and 2D-non-stationary calculations of river hydraulics. It is an integrated software system designed for interactive use of a multi-tasking, multi-user network environment (Brunner, 2016),( Ramakrishnan,2020)

HEC-RAS depends on the finite-difference solutions of the Saint-Venant equations (equations (1) - (2))

\[
\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 \quad \ldots \ldots \quad (1)
\]

\[
\frac{\partial Q}{\partial t} + \frac{\partial (Q/A)}{\partial x} + gA \frac{\partial H}{\partial x} + gA(S - S_f) = 0 \ldots \ldots \quad (2)
\]

where $A$ is the cross-sectional area perpendicular to the flow; m$^2$

$Q$-flow rate, m$^3$/s;

$g$-acceleration of free fall;

$H$– water height, m;

$S$-bed tilt;
$S_f$—energy slope;
t— the temporal coordinate;
x—control points.

Equations (1) and (2) are solved using the well-known four-point implicit box finite-difference scheme (Prem Lal et al, 2011).

2.3 Performance criterion
The performance of the model is evaluated by the following indicators:

Mean square deviation (RMSE)

Field studies were performed along the length of the river section (8) km. A longitudinal profile of the riverbed is constructed (Figure 2).

![Figure 2. Longitudinal profile of the riverbed](image)

Hydrological surveys on the studied section of the river were determined in 62 channels at a distance of 120 m from each other. Typical research areas are shown in the figure (Figure 3).
3. Result and discussion
The peak flood value will be used as input data for the HEC-RAS hydrodynamic model. Theoretical peak flood discharges will be modeled in 50 and 100 years. The scaling model is a necessary step in applying the model for parameter estimation and refinement (Legates et al). In our simulation, the HEC RAS model is scaled by splitting the manning roughness coefficient (n), the latter is split for the main channel and then for the channel super banks using the observed marks during the last flood, which was in January 2017 (Figure 4).

Figure 3. Cross-sections of the Allalariverbed used to develop the HEC-RAS model

Figure 4. Mapping the HEC-RAS model using the observed water surface (January 2017 flood)

Figure 5 shows studies on modeling the water surface in a river during peak discharges over 50 and 100 years.

Figure 5. water surface Profile using HEC-RAS for peak runoff of 50 and 100 years
Tables 1 and 2 show the results of studies on the height and location of dams for the flood plan, the level of water rise, and the maximum flow of water during flood periods.

**Table 1. Height and location of the embankment for the flood plan return period of 100 years**

| Station | Left Embankment | Right Embankment |
|---------|-----------------|------------------|
| 37      | 0.55            | -                |
| 35      | 0.1             | -                |
| 21      | 0.96            | -                |
| 9       | 1.25            | -                |

**Table 2. Rise level and water flow during flood periods**

| year     | Flood duration          | Maximum Water surface(m) | Maximum Discharge (m³/s) |
|----------|-------------------------|--------------------------|--------------------------|
| 2006     | Jan-31, 7:00 to Feb-1, 8:00 | 4.74                     | 325.25                   |
| 2012     | Feb-6, 23:00 to Feb-7, 00:00 | 2.45                     | 78.22                    |
| 2013     | Apr-24,22:00 to Apr-25,7:00 | 2.3                      | 71.2                     |
| 2017     | Jan-3:00,7:00 to Jan25,00:00 | 4.88                     | 385.5                    |

The above results (Figure 6 and 7) show that the existing embankment system on the left Bank of the Allala river is not sufficient to withstand the floods of the 50-year and 100-year return periods. Thus, the HEC-RAS model for estimating the magnitude of the flood and the corresponding water level profile shows that a maximum of 1.25 m on the left Bank (1.2 km downstream) is necessary to protect low-lying areas of the old Tenes from flooding.
4. Discussion and conclusion
The simulation performed with the development of the HEC RAS program can be used to forecast the frequency and intensity of flooding on the Allala river. The resulting HEC RAS model allowed us to establish that in the event of flooding on the river, additional strengthening of the banks is necessary at the following sites: station 35-37 on the left embankment of the river, station 22-21 on the left embankment of the river, station 10-8 on the left embankment of the river. The height of the dams should vary from 0.55 to 1.25 m.

If the construction of dams is used for flood control, then the location and height of the embankments should be arranged taking into account the output data of HEC-RAS 5.0.3.

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