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The Impact of the Construction of a Dam on Flood Management

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Abstract

A possible strategy to mitigate the effects of flooding from an area identified as having high runoff potential will reduce the volumes of water that overflow the drainage area and build a system of a storage location in the coastal city of Tangier. The study is based on two main axes: (i) the extreme flow frequency analysis, using eight probability laws adjusted by the Maximum Likelihood method, and (ii) the estimation of the flood outflows at the dam outlet using the routing method in order to assess the effect of detention dams on water flood. Annual (Maximum) series based flood sampling procedure is adopted for constructing the Flood Frequency analysis. A numerical comparison of AIC criteria and BIC has allowed a proceeding to the selection of the most fitted law distributions. The result shows that the Gumbel law is best adapted to the predetermination of the extreme flow estimation in the Mghogha watershed for different return periods. The reservoir routing method along with rainfall-runoff processes were applied by the mean of the HEC-HMS model. The model was run under two different scenarios. Scenario 1 simulates the Mghogha basin with the absence of the reservoir. Meanwhile, scenario 2 simulates the same basin by taking into account the existence of the Ain Mechlawa reservoir within different return periods of from 2 to 200 years. Peak discharges downstream have been dramatically attenuated and water volumes have been decreased with the prolongation of the return period. For the 100 and 200 return periods, the peak discharge of flood reduction for scenario 1 and scenario 2 were 52.06 and 52.17 %, respectively, and for the flood volume was 22.46 and 22.82% respectively. Finally, the results of investigations showed a good performance of the model in the estimation of outflow peak discharge of the Ain Mechlawa Dam.

Keywords: Flash Flood; Reservoir Management; Routing Method; Mechlawa Reservoir; Tangier-Morocco.

1. Introduction

Floods occurring in hilly urban areas caused by heavy storm events are known for their violence and brutality and can be significant. This type of flood requires a response at both national and regional scales. Dam operation effects on a large part of the planning and management of water resources in a basin. But it remains a complex problem that involves multiple decision parameters as well as uncertainty [1, 2]. However, assessment and quantification of flooding impact on the hydraulic structures such as dams is required from an urban management point of view. For instance, 24 hours rain may lead to flash floods in an urban basin such as Mghogha basin. If such extreme events

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occur, the control of such floods will be difficult to manage even with the existing hydraulic structures (Bridges, concrete canals, culverts, etc.) [3]. Construction of reservoirs is one the most effective anti-flood methods. The purpose of constructing reservoirs is to control flood effects quickly and reduce the peak discharge of flood. Thus, it becomes vital to assess the role of the reservoir during such storm events in a hydrologic and hydraulic study. To improve regional flood-risk forecasting, a variety of attenuation processes can be applied to reduce the flooding risk impact. Such mitigation measures include flood forecasting and warning, adopting proper rainfall-runoff and hydraulic modelling, and flood warning management [4]. One of the most widely used Rainfall-Runoff models of the flood prediction is the Hydrologic Engineering Center's Hydrological Modelling System (HEC-HMS) [5].

Sarvarian et al. (2018) [6] investigated the impact of detention reservoirs in Abkharvar basin using HEC-HMS model. The results of the model implementation for Taleghan basin indicated that the model has great accuracy and saves time of run. The final design cost is 74.4% less than the "all of dams" scenario. In addition, the final scenario has reduced the discharge peak by 64.9% compared to the "without any dam" option.

Oleyiblo and Li (2010) [7] used Hec-hms to predicted peak discharge based on the available historical flood data. Both the flood volume and timing were fairly accurate. The initial and constant method was employed to model infiltration loss. The Soil Conservation Service unit hydrograph method was used to model the transformation of precipitation excess into direct surface runoff. The exponential recession model was employed to model baseflow. The Muskingum routing model was used to model the reaches.

Bhadoriya et al. (2020) [8] carried out climate change effect analysis on subtropical reservoir 53 catchment in India with the objectives to simulate streamflows, analyse monthly and annual change. HEC-HMS model was used to generate future inflow to a reservoir 382 in the subtropical region of India. In the case of Goodell (2005) [9], this author used HEC RAS in conjunction with the HEC-HMS hydrologic simulation software to simulate cascade failure in a stream with a high background slope. As for Yochum et al. (2008) [10], these researchers used HEC RAS to simulate the Big Bay dam rupture in 2004. The results obtained under HEC RAS were compared to those calculated using theoretical equations developed by and NCRS (1986) and Froehlich (1995) [11, 12]. However, even if the HEC-RAS model had underestimated the observed runoff gap over the study area, the values obtained were more accurate than those calculated using the theoretical equations.

A small reservoir system, such as the Ain Mechlawa, is intended to be integrated in rainfall-runoff modelling for multiple objectives such as, sediment-retaining and detention reservoir [13]. It was built in the upstream of Mghogha basin to prevent flooding that occurs around the industrial zone near by the basin downstream. This allows offering supplementary storage capacity and prolonging the retention time in case of the arrival of a flood by the mean of a big amount of water volume. To perform a runoff reservoir process in a basin, the interactions between discharge releases and storages process must be taken into account [14, 15]. On the other hand, flood routing technique is a mathematical method for predicting the changing magnitude and reducing the attenuation of the flood propagation of a dam reservoir [16]. Meanwhile, flood routing estimates the outflow hydrograph at a downstream as flood propagation flows in the upstream reservoir. This is done by determining the timing and wave propagation's shape [17, 19]. To route the flood forecasting propagation in dams, two essential methods are applied, one consists of hydrologic routing analysis and the other on hydraulic routing analysis. The hydrologic model is based on the storage continuity equation, while the hydraulic model is based on the Saint-Venant equations, which consist of the mass conservation equation and momentum equations [20].

In order to operate flood control systems, the ability of forecast flooding is essential. Flood forecasting in its current application is used to estimate phases in future flooding. Using both observed and simulated inflow hydrographs, flood forecasting can be referred to the discharge values and water surface levels at different marks within a river system [21]. Under great urbanization pressure and where recurrent floods have led to property damages, there is then a necessity to perform a hydrologic study in order to assess the impact of the Mechlawa reservoir on volumes and runoff data under two scenarios. The first scenario is to consider Mghogha basin as one catchment. The second scenario is to consider it as several sub-catchments. the location of the urban areas relative to the drainage network have important impacts on runoff response. The proximity of the dam to the Mghogha canal, to which urban storm runoff is piped, results in relatively high peak discharge. Scenario 1 is represented by an empty basin (no hydraulic structures) and scenario 2 reflects the present situation where the basin is simulated along with the existing Ain Mechlawa dam. The study focuses more particularly on the impact of the Ain Mechlaoua dam, located near the upstream watershed, on the runoff and retention of water volumes, on the Mghogha basin water management.

Hence, the aim of this research is to simulate the present and likely future water resource systems of the ungauged Mghogha basin and Mechlawa dam by providing operating reservoir data such as storage-discharge data. This data enables and informs decision makers on the operation and management of the reservoir over a period of time and was developed during the construction of the reservoir. To do so, and with a view to issuing flow forecasts to inform decision-makers to better manage potential floods, this research focused on flood forecasting using a rainfall-runoff model "HEC-HMS hydrological model. This model is commonly used and has been employed for carrying out various types of researches including building flood forecasting models and assessing the impacts of small dam removals in order of developing a flood early warning system [22]. In order to assess the role of the Mechlawa reservoir in the floods management, this study investigates the flood frequency of Mechlawa reservoir, as well as simulates the routing floods process by the HEC-HMS model.

In this study, flood frequency analysis (FFA) is applied for estimating the return period of the outflow hydrographs. Which constitutes the selection of a frequency distribution fitted to the data set. It constitutes the basis of flood mitigation measures, including the design of flood control structures. In literature, the most used criteria for selecting a distribution are Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC). We first compared the efficiency of Gumbel distribution, log-normal distribution, generalized extreme value (GEV) distribution, Pearson and Log-Pearson type 3 distributions, Weibull distribution, gamma distribution and exponential distribution for fitting the marginal distributions of long series of the maximal annual rainfall data; (P). Since the Gumbel was selected as the most appropriate distribution, the 10-year, 20-year, 50-year, 100-year, and 200-year design floods were calculated. Considering the existence of the dam, the corresponding values were 11022, 12631, 17189, 19607 and 26575 m^3/s, respectively

Hydrographs obtained by this model are provided for flood management purposes such as, flow forecasting, reservoir spillway design and flood damage reduction [23, 24]. In order to set up reservoir routing methods using HEC-HMS, storage capacity curve and elevation - discharge were defined [25]. The hydrograph was routed through the dam before the water propagation reaches the basin downstream. The Outflow Curve routing method which processes the Control Specifications model at the same time step as the simulation had been selected [23]. To satisfy the selected storage-discharge curve method, the storage indication method was applied for routing the total inflow entering to the studied reservoir.

The boundary conditions to the channel reaches (routing method) are the upstream (inflow) flow hydrographs. These boundary conditions are the same for all return periods, although using different hydrographs. Inputs of the model include CN, as well as SCS lag and routing lag, estimated by basin's DEM (Digital Elevation Model) using GIS. The meteorological model in the HEC-HMS for Mghogha basin is set up by entering 5-min rainfall data for all the assigned return periods. The precipitation model is simulated using the Soil Conservation Service (SCS) curve number (CN) method. The model output consists of discharge hydrographs defined as dam's outflows for different return periods.

2. Materials and Methods

2.1. Study Area

The Ain Mechlawa dam is a small hydraulic structure built in Mghogha basin to reduce water volume and to manage floods. It is located near the upstream Mghogha basin with Storage capacity of 0.66 Mm^3 per year via spilling and with 26 m height as shown in Figure 1. Meanwhile, the altitude of the water body at time t_0 is 62 m. The Mghogha Basin is one of the sub-basins of the Tangerois watershed. It's located to the south of the bay of Tangier (NW of Morocco) and limited with the coordinates of 35°45 and 35°50' north and meridians 5°45' and 5°.

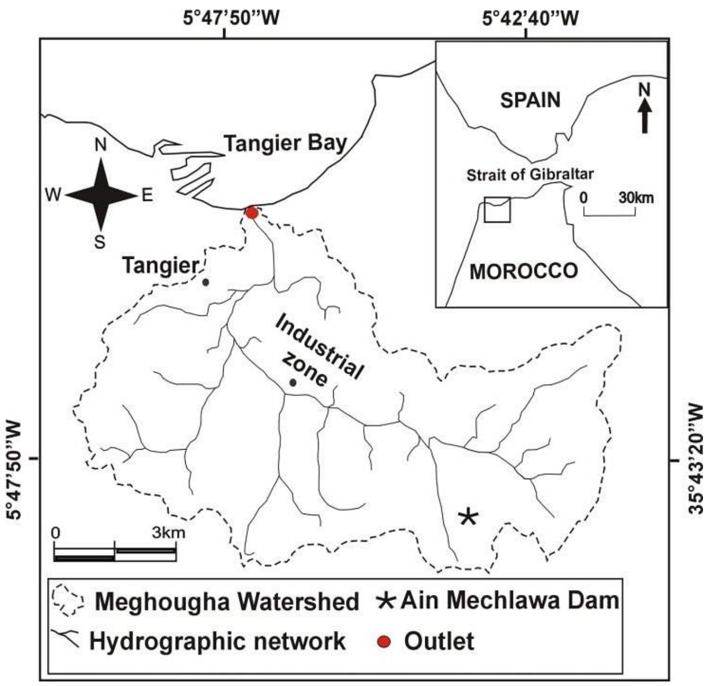

Figure 1. Geographic location of the study area

The basin has a total length of 18.066 Km and a geographical area of 75.464 km^2. The minimum and maximum altitudes of the region are 5 and 455 m above the sea level, respectively; the average altitude of the basin is 230 m and the average slope is 13.7% as illustrated in Figure 2.

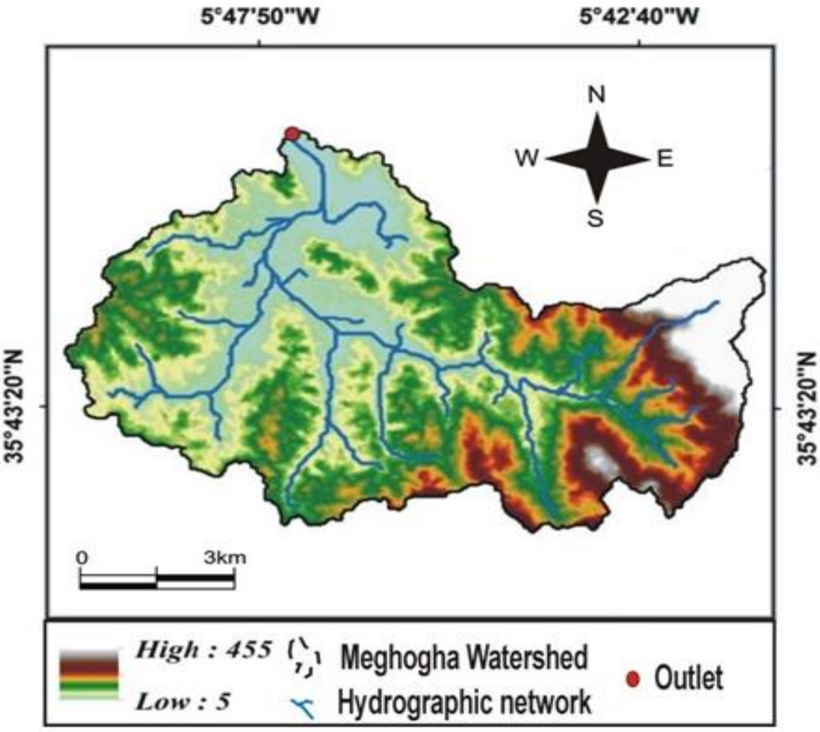

Figure 2. Digital Elevation Model of the Mghogha Watershed

The climate is typically Mediterranean influenced by the nearby Atlantic Ocean with average annual temperatures between 20 and 24 °C. The average annual precipitation of the study area for the last five years is approximately 750 mm. About 90% of this rainfall is received from October to April. The land use is approximately covered by 38.58 % of urban area, 21.66% of bare soil, 13.94% of agricultural, and 25.82% of forest, while the dominant soil type is Sand Clay Loam accounting for almost 43.6% of the total soil types. Due to high slope of the basin and high amount of impermeable soil, the Mghogha basin quickly reacts to high amounts of rainfall which leads to heavy water volume propagation. Therefore, the construction of detention dams for controlling the flood within the basin has a great importance.

2.2. Context Description

The main goal of this research is to integrate reservoir operation data with the HEC-HMS model for the ongoing water resource project of flood risk prevention plan, which is part of the urban development program for Tangier city. The following steps illustrate the procedures of the Ain Mechlawa flood routing model and it is as the following:

- Develop HEC-HMS model for the Ain Mechlawa subbasin using DEM, rainfall, runoff and reservoir data;
- Assess the extreme flow frequency analysis, using the rainfall annual maximum series data and the maximum likelihood method;
- Estimate the peak inflows for the 2, 10, 20, 50, 100- and 200-years projects using HEC-HMS;
- Evaluate the impact of Ain Mechlawa reservoir on Mghogha basin.

In order to evaluate the role of dams in the flood control management operations, this research investigates on integrating the characteristics of the Mechlawa reservoir with the rainfall-runoff method process using the HEC-HMS model. This model analyses the impact of detention reservoirs for different scenarios using the reservoir storage data in order of developing a flood early warning system [22]. The first step was the collection of data mainly provided by the Agence des Bassins Hydraulique de Loukkos (ABHL), the delegation of Tangier's Ministry of Equipment, the National Institute for Agricultural Research (INRA) and the company AMANDIS Company. The data collected includes the storage-discharge date, the Digital Elevation Model (DEM), meteorological data and soil data. The second important data required to conduct a reservoir routing is the inflow hydrograph representing flows coming from the contributing basin. The calculation of the volume stored by the reservoir is obtained from the volume remaining in the reservoir. Mockus (1967) [29] stated that through a reservoir-stream system, the storage-discharge relation is employed by systematically solving the storage equation (the continuity equation), each solution being a step in delineating the outflow hydrograph. In order to define the reservoir routing parameters under HEC-HMS, the curve Storage vs. discharge must be defined so that the output hydrograph would be routed through the reservoir before reaching the downstream. The storage-discharge data was then introduced on HEC-HMS to present the reservoir water retention in order to obtain the outflow hydrograph at the spillway gate.

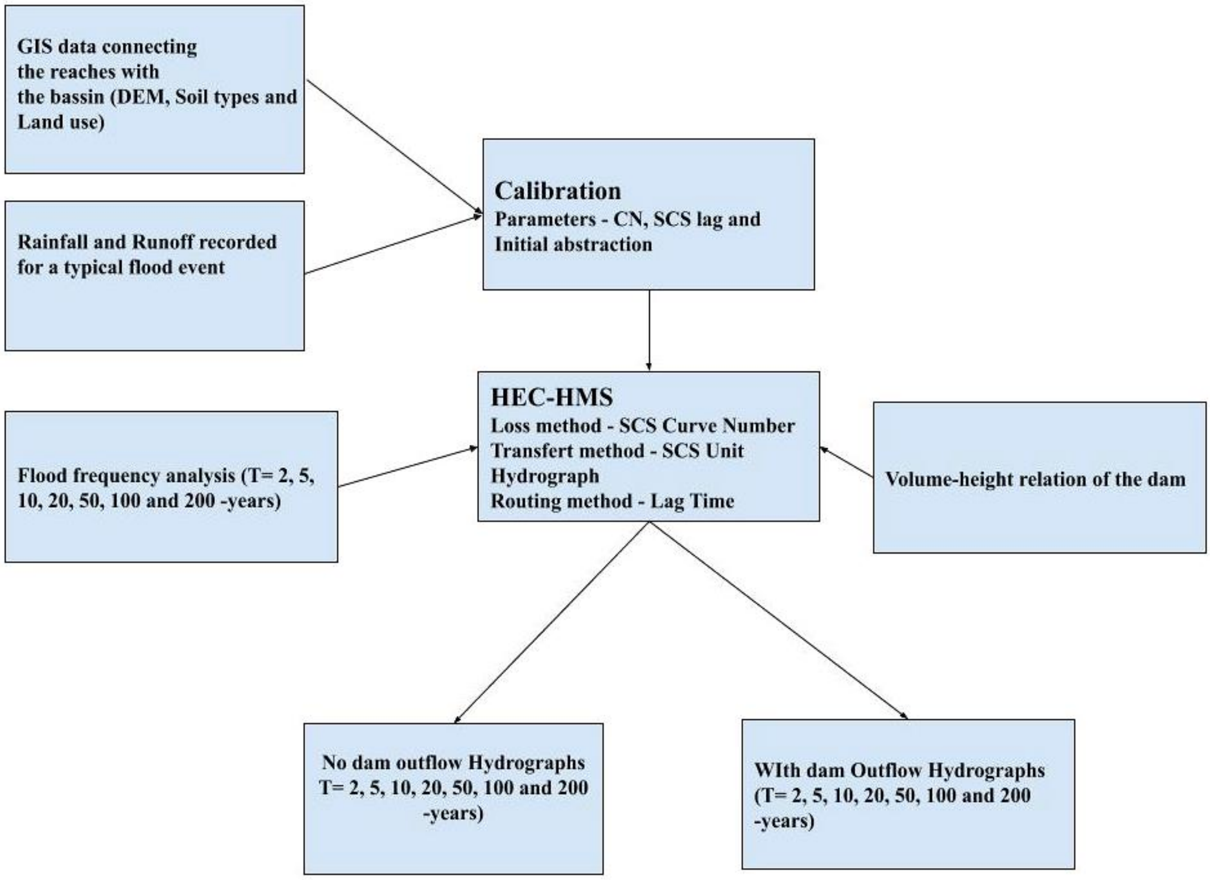

Figure 3. Flowchart of the methodology used to derive peak discharges and the dam outflows, including data inputs, main calculation methods used within the HEC-HMS and list of parameters used for model calibration and validation

2.3. Setting a reservoir Model

This section describes, in detail, the methods involved in the analysis of data input obtained from pluvial events, prior to the modeling of the inflow-outflow. To model a reservoir model on HEC-HMS, the storage-discharge relationship is required [23]. This depends on the characteristics of the reservoir, the outlet and the spillway. The Ain Mechlawa reservoir inflow and outflow data are obtained from the Water Resources Department. There are 4 data requirements that are necessary to obtain the modelled output:

- Stage-storage relationship;
- Stage-discharge relationship;
- Stage-elevation;
- Inflow hydrograph.

Occurring during the recession limb of low flow events, the discharge-rating curve was developed from the outflow hydrograph by the Water Resources Department. Note that the stage and discharge data are collected at one-minute intervals. A second order polynomial equation was fit to the data and the y-intercept of the equation was set to zero, as shown in Figure 4.

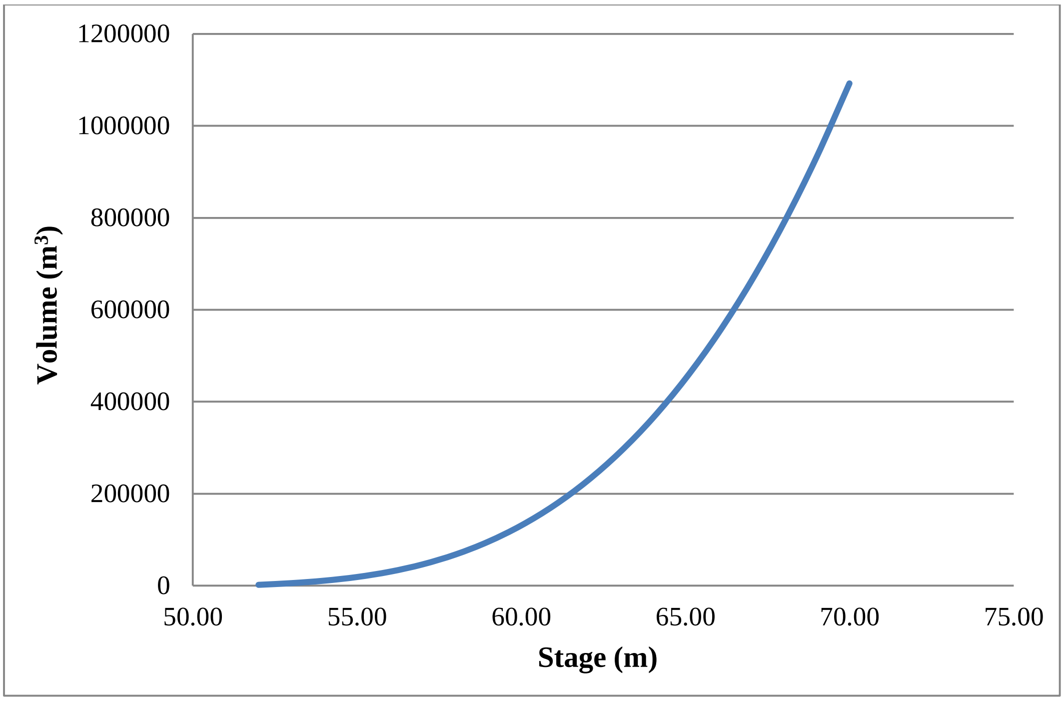

Figure 4. Elevation- discharge rating curve (Agence des Bassins Hydraulique de Loukkos)

Using Equation 1, the volume occurring at each measured depth value was determined, and the discharge-rating curve was generated:

$$V = -1166.1 + 2876.8h - 101.3h^2 + 156.8h^3 V = -1166.1 + 2876.8h - 101.3h^2 + 156.8h^3 \quad (1)$$

Using the continuity equation, a mass balance was used to assess the attenuation that the volume underwent as it entered the reservoir and an inflow hydrograph was then produced. The continuity equation states that the change in volume of storage for a given time interval is equal to the volume of inflow minus the volume outflow, as given by Feldman (2000) [26] in Equation 2 shown below:

$$I - O = \frac{\Delta S}{\Delta t} I - O = \frac{\Delta S}{\Delta t} \quad (2)$$

Where; Δt: The time interval; I: Inflow rate during the time interval; O: Outflow rate during the time interval; ΔS: The change in volume of storage during the time interval.

Numerous models perform reservoir routing using the Modified Puls or storage indication method which assumes unregulated free flow at the outlet of each reservoir by rearranging the continuity equation [27]. This method assumes that the Outflow starts at the same time inflow starts, Therefore, the volume inflow at the head of the dam propagates instantaneously through the studied reservoir without taking account of its length [24]. After the necessary relationships between storage within the reservoir and outflow volume, as shown in Figure 5, storm events could be verified. Based on the continuity equation, the hydrologic-routing could be demonstrated as shown in the following Equations 3 and 4:

$$\frac{I_1 - I_2}{2}\Delta t - \frac{O_1 - O_2}{2}\Delta t = S_1 - S_2 \frac{I_1 - I_2}{2}\Delta t - \frac{O_1 - O_2}{2}\Delta t = S_1 - S_2 \quad (3)$$

$$(I_1 - I_2) + \left(\frac{2S_1}{\Delta t} - O_1\right) = \left(\frac{2S_2}{\Delta t} - O_2\right)(I_1 - I_2) + \left(\frac{2S_1}{\Delta t} - O_1\right) = \left(\frac{2S_2}{\Delta t} - O_2\right) \quad (4)$$

Where I_1, O_1 and S_1 represent the value at the beginning time step; I_2, O_2 and S_2 are the value at the end of the time step while Δt is the change over both time steps.

To determine the S2 and O2 values in Equation 4, a second relation between storage volume and outflow volume is needed [20]. Using the calculated value of $(\frac{2S_2}{\Delta t} + O_2)$ along with the storage indication curve, the outflow value for the next time interval was determined.

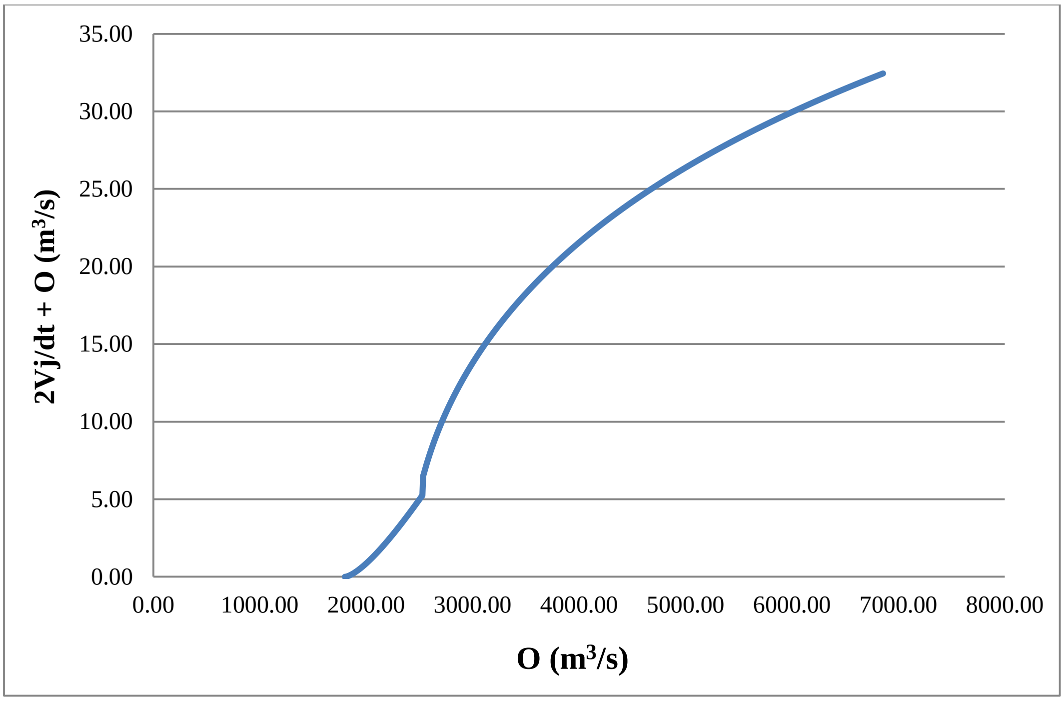

Figure 5. Storage Indication Curve of Ain Mechlawa (Agence des Bassins Hydraulique de Loukkos)

3. Results and Discussions

3.1. Simulation of Mghogha Basin without Hydraulic Structures

In an ungauged catchment such as Mghogha basin, SCS Unit Hydrograph (SCS UH) method was applied for the rainfall-runoff transformation computation, while SCS Curve Number method was used to define the loss infiltration method. Whereas reservoir routing parameters were derived and obtained from literature and MINISTRE OF EQUIPMENT. This section discusses verification analysis of the developed model. Model verification involved simulating the reservoir data scenario 1 and 2 through HEC-HMS. In case no dam and canal exist, the loss and transformation models were calibrated using the observed instantaneous rainfall-runoff series of an adjacent small basin having the same physical and morphological properties as Mghogha basin. Meanwhile, the calibrated hydrologic parameters are obtained from a previous study on the Mghogha basin. Basin parameters such as initial abstraction, the lag time and CN were generated by the mean of ArcMap and were introduced as the main input parameters of the HEC-HMS model. The calibration was carried out for the period from 23 to 24 of October 2008 between 00:00 and 01:00 with an interval time of 10 min. On the other hand, to define the meteorological model for ungauged basins, The SCS-24 hours storm model type I distribution (short duration, high intensity rainfall) was selected in order to create hydrographs. Since it corresponds almost perfectly with the observed hyetograph of the 23th October 2008 (156.4 mm), and storm runoff can be predicted accordingly.

To estimate the Mechlawa reservoir's future runoff contributions to Mghogha basin, firstly, the basin was divided into three sub-basins (W 670, W 870 and W 1110) (Figure 6) in order to distinguish between peak flow at the following spots: the urbanized part of the basin which includes the industrial zone and which is located nearby the downstream of the basin (W670). The semi-urbanized part is situated in the middle of the basin (W870) and the lower sub basin (W1110) where the dam of Mechlawa is located. Each sub-basin is connected through a reach system which is routed using "Lag Time" method and transports the outflow from the reservoir to W 870 and W 670.

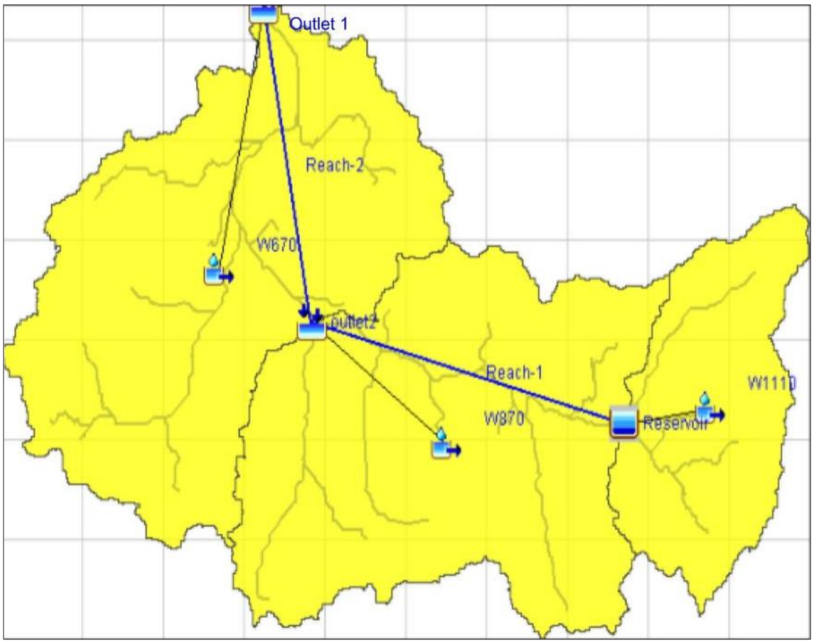

Figure 6. Ain Mechlawa run model under HEC-HMS

Furthermore, the global model with its initial settings was adjusted during the optimization approach in order to make the simulated future inflow hydrographs. In scenario 1, the parameters were optimized, in particular, the curve number and initial abstraction, and then applied across the Mghogha basin for scenario 2. For the calibration of the loss and the transform methods at an ungauged basin like Mghogha, we have recourse to the method of transposition, which allows the use of the recorded rainfall and flow of an adjacent gauged watershed, in the occurrence Kalaya for this study case. Adopting the calibrated hydrologic parameters, the model can, accordingly, be simulated to predict the future inflow-outflow for different return periods. The reservoir inflow hydrograph is used to verify how good the developed model is in simulating the future inflow values. The calibrated physical input of the sub-basins is shown in Table 1:

Table 1. Example Hydrological characteristics of the three sub-basins extracted via GIS

Sub-basins	Physical components		Loss method		Transform method	
	Surface (Km^2)	Slope (%)	Perimeter (km)	Initial Abstraction	CN	Lag Time (hours)
W 670	32.4095	11.31	32.4	9.59	84.101	1.56
W 870	30.6236	14.78	30.624	10.92	82.3	1.24
W 1110	12.42068	17.98	12.421	9.97	83.58	0.63

Outflow data is simulated by using the observed inflow as input to HEC-HMS. Under HEC-HMS, the Storage vs. discharge data which is an initial condition, has been defined and was then introduced into HEC-HMS to obtain the outflow hydrograph for the defined return periods. Three different routing methods are available under HEC-HMS. The first (Outflow Curve) is designed using a storage / output function. The second method (Specified Releases) uses user-specified outputs. The last method (Outflow Structures) is designed to take into account the regulation of the reservoir through facilities such as valves and evacuators. In this study, the Outflow Curve method was adapted considering the storage-discharge data input. The concrete channel of Mghogha was taken into account in order to assign the Lag Time routing system between the outlet of the reservoir passing through the entrance of the industrial zone and finally to the basin outlet.

To attribute the Reservoir Element to HEC-HMS, the Paired Data table, which describes the inflow hydrograph for the Reservoir, had been introduced into the model. The total discharge represents the flow out of the main spillway at elevation 62 m above the reservoir datum. During a storm, the outflow is dragged from the emergency spillway at 67 m above the reservoir datum. Once the dam Storage curve data is inputted, the model can be run to assess how the reservoir performs under the selected storm as shown below in Figure 6. Table 2 shows storage volumes for a correspondent total discharge.

Table 2. Spillway Releases for various storage-discharge values (Agence des Bassins Hydraulique de Loukkos)

Storage volume (10^3 m^3)	Total discharge (m^3/s)
0	0
226922	1800
227830	1808
228741	1815
229654	1822
230569	1829
231487	1837
232408	1844
233331	1851
234256	1859
235185	1866
236115	1874
237049	1881
237985	1889
238923	1896
239864	1904
240808	1911

A reservoir tends to attenuate the impact of excess water by storing the water volumes and then releasing it gradually through either the outlet pipe or over the emergency spillway [24]. The amount of inflow entering the drainage area (sub-basin 1) was converted into volume based on the regression equation obtained from the storage-rating curve. The relation between the reservoir volumes against, the dam elevation upstream, the inlet hydrograph to the reservoir is given in Figure 7.

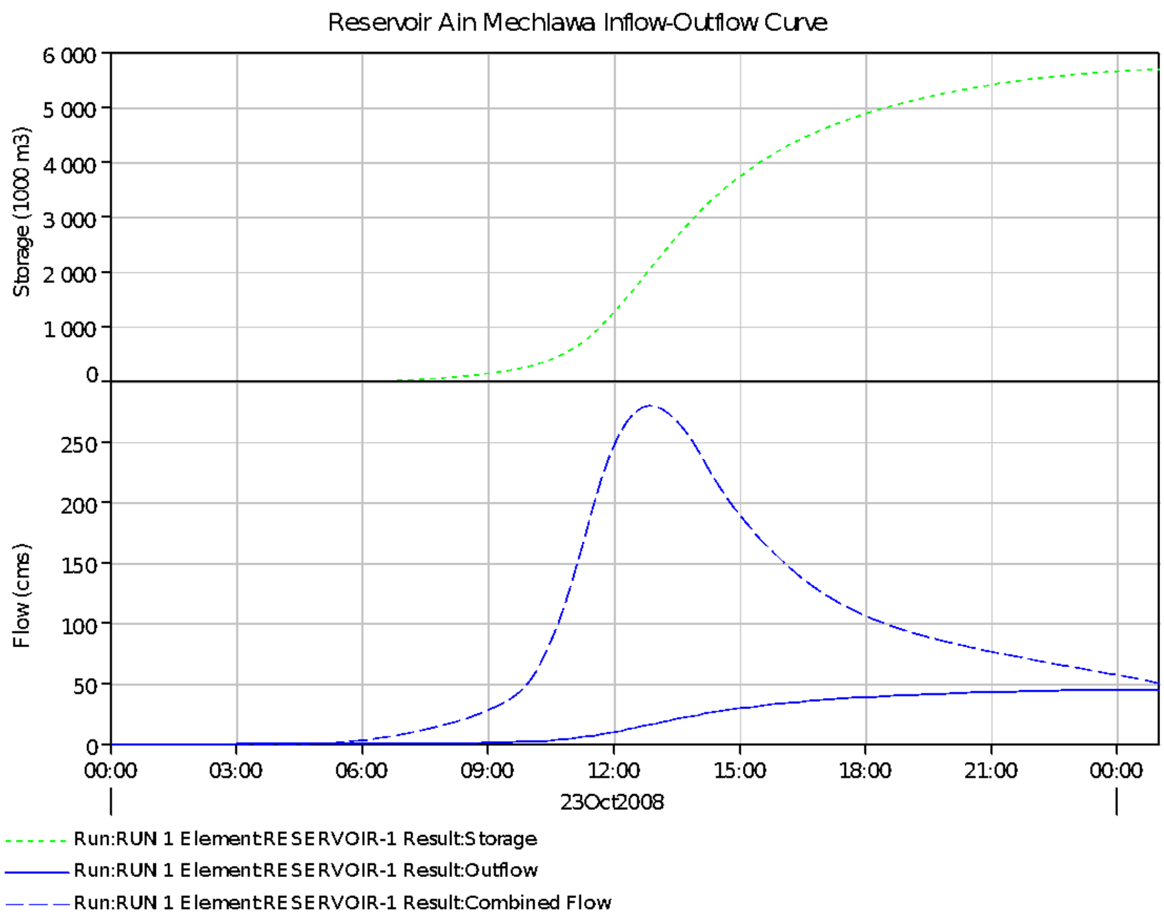

Figure 7. Impact of detention on 200-years inflow-outflow return period

The storage is provided to mitigate the peak inflow as shown in Figure 7. The inflow and outflow hydrographs were approximately having the same peak value until the capacity of the culvert is exceeded. Then water is stored and the outflow depends on the downstream and upstream water-surface elevations and the time distribution runoff. On the other hand, the construction of Mechlawa dam resulted in delay of the peak discharge at the dam output. The flood at the reservoir output propagating to (sink 1) industrial zone is delayed from 42 to 71 min. That indicates the efficiency of the dam in flood control. Furthermore, by comparing the output hydrographs for the two scenarios, it can be seen that the distribution and elongation of the output hydrograph is significant and the flood control has been able to control the severity of flood very well.

3.2. Simulation of the Mechlawa Dam Future Outflows to the Mghogha Basin

This study proposed the Maximum Likelihood method for model selection. After estimating parameters of eight law distributions, the Shannon entropy value of each distribution was calculated. Then, the distribution with the highest entropy value was selected as the best fitted one. The statistical frequency analysis of rainfall had been carried out to estimate the outflow frequency values. Therefore, the annual maximum precipitation series for a long series of observations (1920-2009), obtained from the Tangier meteorological station was used to obtain the correspondent inflow values. The frequency study consists of performing an adjustment for the daily maximum precipitation data series by a statistical law to determine the rainfall intensity for different return periods. Objective techniques for selecting the most appropriate probabilistic model are needed to improve the estimate of project flood [28]. However, selecting the best distribution is an important step in frequency analysis. The general outcome of model selection was studied by Mockus (1967) [29], who introduced the principle of likelihood as a theoretical basis for the selection of the most faithful law in relation to the sample, and by Viessman and Lewis (2003) [30] who, by developing a similar idea in a Bayesian context, proposed the Bayesian Information Criterion for the selection of the best fit. Gumindoga et al. (2017) [28] evaluated whether the model of selection criteria can help identify the best probabilistic model. The study demonstrated that model selection criteria are a valuable tool for reducing the uncertainty of the flood estimate. The distribution laws were evaluated using two criteria called Bayesian information criterion (BIC) and Akaike information criterion (AIC). These criteria made it possible to compare the degree of adjustment of the various distributions, taking into account the number of their parameters, since the best adjustments had to correspond to the minimum values of these criteria. Extensions of these methods include corrections used with small samples [31] and other generalizations [32-34] applied the Akaike information criterion to simple case studies.

The extreme events are identified considering various thresholds. Gumbel distribution is found to best fit the data and selected for the computation of the thresholds. The estimation of inflow for different frequencies was based on the Gumbel maximum likelihood distribution assumption. Peak discharge values are derived based on The annual (maximum) series (AM), also called the block (annual) maxima [35], considering the rainfall data for recurrence intervals of 10–, 20–, 50– and 100–years in the meteorological model in HEC-HMS and assuming that the entire catchment received the same amount of rainfall. The peak discharge values estimated through the synthetic hydrograph method are presented in Table 4. The values for the 2, 5, 10, 50, 100- and 200-years rainfall are show in Table 3:

Table 3. Precipitation amount (mm) for different return periods

	Rainfall (mm)						
Periods (years)	2	5	10	20	50	100	200
24 hours	63	82.9	95.9	108	125	137	149

Hurvich and Tsai (1989) [36] applied three model discrimination procedures to identify the best appropriate probability distribution. Nevertheless, the study considers only two-parameter distributions. Therefore, the capacity of model selection techniques must take into account the principle of parsimony of the distributions of theoretical frequencies [37].

- Akaike Information Criteria (AIC)

Akaike's information criterion measures the quality of fitting a statistical model. In the general case, the AIC can be written in the form:

$$AIC = -2\log(L) + 2kAIC = -2\log(L) + 2k \quad (5)$$

Where k is the number of parameters in the statistical model and L is the maximized value of the likelihood function for the estimated model. In practice, after the calculation of the AIC, the model is selected with the minimum AIC value.

- le critère Bayésien (BIC)

The Bayesian information criterion (BIC) is a criterion for selecting the best model (among a set of models) for fitting data series. It is based on the likelihood function, and is closely related to the Akaike criterion (AIC).

$$BIC = -2\log(L) + 2\log(n)\; BIC = -2\log(L) + 2\log(n) \tag{6}$$

Where k is the number of parameters in the statistical model, L is the optimized value of the likelihood function for the estimated model and n is the sample size. In the practical application, after the calculation of the BIC, the model is chosen with the minimum value BIC.

The following table provides the statistical data used to verify the validity of the Gumbel distribution relating to the sample. Indeed, it can be noticed from Table 14 that the sample and the population have relatively the same mean and more or less the same standard deviation with a slight variation which shows the homogeneity of the data analyzed. The calculation of the theoretical values and of the asymptotic confidence interval is carried out at a percentage of 95%. For of significance of 5%, the sample of the maximum annual daily rainfall observed fits perfectly to the Gumbel distribution. The distribution with the lowest value of BIC and BIC was selected as the best-fitted distribution. According to Table 4, the value of Gumbel distribution was the lowest, thus it was chosen as the optimal distribution of study case.

Table 4. The results of the selection model for the eight law distributions. The BIC and AIC values are listed in order from least to greater value

Model	Degree of freedom	P-value	$\chi 2$	BIC	AIC
Gumbel	6	0.38	6.4	411.218	406.604
Lognormal	-	0.94	-	411.414	406.801
Log-Pearson type 3	5	0.27	6.4	412.115	407.695
GEV	5	0.44	4.8	412.137	407.717
Gamma	6	0.42	6	415.065	411.452
Weibull	6	0.18	8.8	424.605	420.992
Normal	-	0.94	-	427.230	423.617
Pearson type 3	5	0.034	12	430.995	425.575

Based on the comparison of the graphic adjustment quality and the statistical adjustment criteria shown in Table 4, it is assumed that the Gumbel distribution presents the best compromise for the adjustment of the maximum daily rain variable. It best adjusts to the data of the meteorological station of Tangier city. As well as its BIC and AIC criteria generated by the method of maximum likelihood are lower compared to other statistical laws. In order to evaluate the potential of the flood control strategies, simulated input peak flow corresponding to a given return period is converted into an inflow at the studied dam to simulate the flood outflow for each of the return periods investigated. Abdessamed and Abderrazak (2019) [38] reported a good accuracy of HEC-HMS model in simulating peak discharges in an urban Mediterranean catchment during flood events. In an urban catchment in Central Texas, USA, Knebl et al. (2005) [39] reported a good accuracy of the HEC-HMS model in simulating the rainfall-runoff response of 12 sub-basins. Ferreira et al. (2020) [40] uses HEC-HMS model to assess Mitigating Flood Hazard in a Mediterranean Peri-Urban Catchment under distinct return periods (10, 20, 50 and 100 years) ,with resolution of 5-minute intervals. The model was simulated using SCS Unit Hydrograph (SCS UH) method for the rainfall-runoff transformation computation, and SCS Curve Number method for the loss infiltration computation. The peak discharges at the outlet for the 10–, 20–, 50– and 100–year storms of 6.1, 7.6, 9.9 and 11.8 m^3/s, respectively. A summary of the contribution of the dam was made by comparing between the peak flows from the frequency study and the storage volumes before and after the construction of the dam. Below, Table 5 illustrates the values of input and output flood of the reservoir:

Table 5. The summary of output floods of the basin for different scenarios

Return period (years)	Scenario 1	Scenario 2	Flood attenuation (%)
	Peak storage 10^3 m^3		
2	1971.4	1605	18.59
5	3096.2	2449	20.90
10	3900.4	3055.8	21.65
20	4672.6	367 8.9	21.27
50	5786.5	4511.7	22.03
100	6588.4	5108.7	22.46
200	7400.5	5711.5	22.82
	Peak discharge m^3/s		Flood attenuation (%)

2	80.4	40	49.75
5	132.7	67.5	50.87
10	170.3	87.4	51.32
20	206.4	106.6	51.65
50	258.5	134.2	51.91
100	295.8	154	52.06
200	333.5	174	52.17

In order to assess the peak outlet discharge values in the selected model, a comparison was made between peak discharges and the volumes of with dam and with no dam's hydrographs. As can be seen, the results show that as the return periods increase, and by increasing the outlet discharge, the flood reduction has been decreased. The effect of detention reservoirs on the storage volume and the peak discharge at the output of the Mechlawa dam from 2 to 200-year return period for both scenarios is described in Table 5. The analysis results show that the implementation of the reservoir influences the peak discharge and the flood volume at the reservoir output. The 100 and 200 return periods were selected since the Ain Mechlawa construction main goal is generally managing floods within those return periods. Additionally, it is important to mention that the analysis results show that the implementation of Mechlawa reservoir influences the peak inflow discharge and the water volume at the dam output when the peak inflow succeeds 40 m^3/s. Furthermore, for a no dam case, the peak outflow decreases from 170.3 m^3/s for a 10-years return period to 333.5 m^3/s for 200-years return period. Meanwhile, the peak outflow for scenario 2 for 200-years return period decreases from 333.5 to 174 m^3/s. This shows that the flood event, which was the most remarkable of Tangier city basin (400 m^3/s), is rather a 10-year flood. In addition, the peak discharge of flood attenuation for scenario 1 and scenario 2 were 52.06 and 52.17%, respectively, and for the flood volume was 22.46 and 22.82% respectively. As seen in the above figure, the dam is located at upstream areas of the basin and has been implemented on the main river of Mghogha basin. In other words, therefore, no further dam construction is expected at the downstream of the basin.

4. Conclusion

In this study, a forecast model was developed to evaluate the impact of the construction of the Mechlawa dam on the flood water of the Mghogha basin. This paper used eight generalized distributions to carry out the FFA and for parameter estimation. A model selection criterion based on Akaike and Bayesian information criteria was developed to choose the best-fitted distribution. The Gumbel distribution is found to be the most appropriate distribution for the design flood estimates for the Mghogha basin. On the other hand, the assessment indicated that the construction of detention reservoir leads to the decrease of a very high peak discharge and the volume of a reference flood that occurred on the 23th of October, 2008 and prevents a possible flooding in the industrial zone near by the downstream of the Mghogha River. The construction of the reservoir has significantly changed the flow regime of the upper Mghogha canal. The developed approach is established using daily inflow to the Mechlawa dam. The observed inflow values are determined from the storage-discharge data while simulated outflow values were determined from the calibrated HEC-HMS model using observed rainfall and runoff data for the heavy storm event of 23/10/2008. The basin model was set using the Soil Conservation Service (SCS) curve number method by the mean of HEC-HMS. With the intervention of the storage reservoir, there is an appreciable reduction in the flood water in terms of peak inflow discharge and water volume. For example, as the return period rises from 2 or 10 to 100 years, the peak inflow discharge reduces from 80.4 to 40 m^3/s for 2 years return period and from 333.5 to 174 m^3/s for 200 years return period, indicating about 49.8 and 52.2% reduction. In terms of flood volume attenuation, 39.45 and 40.38% respectively for 2 and 200 years return periods. The calibration of the model showed that a reduction of the amount of water volumes would prevent from accurately reproducing the flood magnitude that occurred during the 2008 storm event. The study results are expected to be helpful for reservoir planning and management measures against flood. However, the studied model has some limitations. For example, the model does not take into account the sewer drainage system of the urban areas, which can play a relevant role on inflow-outflow hydrograph shape, and thus may affect flood predictions.

5. Declarations

5.1. Author Contributions

I.K. modeled the numerical simulations and methodology; M.A. review and editing; A.B resources and validation; A.H.A. supervision and project administration. All the authors contributed to the discussion of the results; I.K. wrote the paper that was then revised by all the authors. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in article.

5.3. Funding

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5.5. Conflicts of Interest

The authors declare no conflict of interest.

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