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AN INVESTIGATION OF THE INFLUENCE OF A RETENTION DAM ON FLOOD CONTROL IN A SMALL CATCHMENT AREA IN AUSTRIA

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ABSTRACT: The aim of this research is to evaluate the influence of an existing retention dam on flood control in a small catchment area (the Schoeckelbach basin), which is situated at the northern Graz in Austria. In order to determine the inundation areas in the basin, first, a rainfall-runoff modeling should be carried out. In this research, rainfall-runoff modeling is done using Hec-HMS and inundation areas are investigated using Hec-RAS. This research will show that the high flood risk regions are situated at the southern basin. Then, the influence of an existing retention dam (Weinitzen dam) will be investigated on flood control in these regions. In order to model the outflow hydrograph of the dam, the modified Puls method is used. Also, the Muskingum-Cunge method is used for river routing in all reaches located at downstream of the dam. This research will show that this retention dam can reduce the inundation areas in about half of the regions and for the rest; an additional retention dam is needed.

Keywords: Flood control, Retention dam, Rainfall-runoff modeling, Routing methods, Weinitzen dam.

1. INTRODUCTION

Floods are occurred in rivers when the flow rate exceeds the capacity of the river channel. Floods are often considered as catastrophic events because they usually make major infrastructure failures. Because of climate changing over many years, big floods happen irregularly and it is often impossible to predict the time of big floods exactly. Due to these reasons and in order to assess the consequences of floods, a flood modeling should be carried out to find the high flood risk regions in a basin. Prior to do this step, a rainfall-runoff modeling should be done in order to determine flood hydrographs in all reaches and tributaries in a basin.

In this paper to do flood modeling in the basin Hec-RAS is used. This is because of this fact that the rainfall-runoff modeling has been done using Hec-HMS and all necessary data for flood modeling can be imported directly from Hec-HMS to Hec-RAS as an input file. Also, all channel characteristics can be derived using Hec-GeoRAS which is an extension for ArcGIS and these information can be provided as input file for Hec-RAS. In this paper, inundation areas are modeled for 100-year 1-day rainfall.

The procedure for preventing the harmful effects of floods is called flood control. There are a number of methods to control the consequences of floods. These methods are the construction of levees, lakes, dams, reservoirsor retention ponds to hold extra water during times of flooding.

In this paper, the influence of an existing retention dam on flood control in a small catchment area in Austria is investigated. In order to evaluate hydraulic operation of the retention dam, the modified Puls method is used. Then, the outflow hydrograph of the dam is used as inflow hydrograph for river routing at all downstream reaches. For river routing, the Muskingum-Cunge method is used. After that, inundation areas are modeled using Hec-RAS.

2. STUDY AREA

The Schoeckelbach basin is located at northern Graz (the second largest city in Austria). The basin has a drainage area of 33.79 km2. Figure 1 illustrates the Schoeckelbach basin location in Graz-Austria.

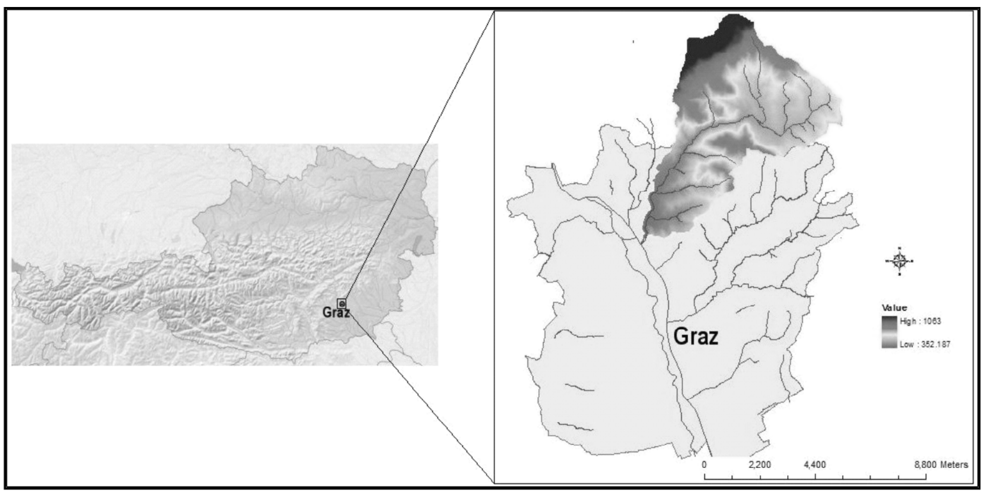


Figure 1: The Schoeckelbach basin is located at northern Graz in Austria

3. INUNDATION AREAS

In order to determine inundation areas in the basin, a rainfall-runoff modeling should be carried out. In fact, rainfall-runoff modeling gives runoff hydrographs for all junctions and reaches.These data are necessary for flood modeling. For this reason, a rainfall-runoff modeling has been already done for the Schoeckelbach basin using Hec-HMS. This process is completely expressed by Galoie *et al.* 2013 but it is briefly explained here.

3.1. Rainfall-runoff Modeling Using HEC-HMS

This model is based on the law of conservation of matter, which explains that during a given period, the total inflow into a given area must equal the total outflow from the area plus the change in storage. In fact, for a rainfall-runoff modeling (outflow), the amount of inflow (precipitation) and change in storage (loss) should be modeled. Due to this reasons, the rainfall-runoff modeling includes four different models as follows: (a) Rainfall analysis, (b) Terrain analysis, (c) Loss analysis and (d) Runoff modeling.

3.2. Rainfall Analysis

One of the most important parts of a rainfall analysis is Intensity-Duration-Frequency (IDF) analysis, which is used to capture the essential characteristics of point rainfall for shorter durations. In order to evaluate an approximately precise IDF relation, the recorded rainfall data series should be studied for identifying data gaps and also outlier data. After that, annual extremes are extracted from the recorded time series data for each duration and then, the annual extreme data is fitted to a proper probability distribution model in order to estimate rainfall quantities. In order to obtain the best-fit probability distribution model, the parameters for a few commonly used rainfall analysis distributions such as (a) Gumbel, (b) Generalized Extreme Value (GEV), (c) Log-Pearson type III (LP III) and (d) 3-parameter log-normal (LN III) distributions were estimated using L-moments method. This analysis was shown that the best-fit probability distribution for the Schoeckelbach basin is the Gumbel distribution.

Then, the Gumbel distribution was used to estimate the IDF parameters (Sherman Eq.) and using a simple graphical method (Raghunath, 2006) the final results were obtained as follows:

$$i = \frac{1100Tr^{0.22}}{(t+10)^{0.879}} \qquad Tr \leq 25 \tag{1}$$

$$i = \frac{1000Tr^{0.187}}{(t+10)^{0.88}} \qquad Tr > 25 \tag{2}$$

These two equations were used in rainfall-runoff modeling of the Schoeckelbach basin.

3.3. Terrain Analysis

The aim of terrain analysis is to perform an initial analysis of the terrain and to prepare the dataset for further processing (Tarboton, 2003). A Digital Elevation Model (DEM) of the study area and its river network are required as input for terrain analysis. In this paper, a very high resolution DEM (micro-scale: 1mÍ1m) was used as input for Hec-GeoHMS. Terrain analysis contains several steps which should be done step by step as follows: DEM reconditioning, fill sinks, flow direction, flow accumulation, stream network, stream segmentation, catchment grid delineation, catchment polygon processing, drainage line processing, drainage point processing, watershed aggregation, longest flow path for catchments and slope. More information can be found in Hec-GeoHMS user’s manual (Hec-GeoHMS user’s manual, 2009).

3.4. Loss Analysis

In this paper, SCS-CN method is used for estimation of rainfall losses. The curve number procedure is a widely used method for estimating direct runoff from rainfall on small to medium-sized basins. The major factors that determine CN are the hydrologic soil group

(HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC) (Mockus, 1964).

3.5. Rainfall-runoff Modeling

Rainfall – runoff modeling for the Schoeckelbach basin was done for 100-year 1-day rainfall. In this section, a frequency storm was used in the meteorological model. The intensities were computed using IDF relation. In Schoeckelbach basin because of its conditions (some small rivers with [0.29×lag time < 5 min]), a computational time step of one minute is possible. For calibrating the model, Peak-weighted root mean square (PWRMSE) method was used (Hec-HMS user's manual, 2010).

Rainfall-runoff modeling was shown that the high flood risk regions in the Schoeckelbach basin are located at southern basin. This modeling for 100-year 1-day rainfall was shown that inundation areas were happened for all reaches located at downstream of junction J168. The total length of these reaches is about 7 km. Figure 2 illustrates the amount of runoff for all junctions in the Schoeckelbach basin for 100-year 1-day rainfall and Figure 3 illustrates junctions' name.

In order to reduce and control the inundation areas, a retention dam (Weinitzen Dam) was constructed at upstream of Junction J162. The operation of this retention dam is investigated in the next section.

4. FLOOD CONTROL USING A RETENTION DAM

A retention dam is constructed in order to reduce storm water runoff and to prevent flooding.As it was shown in the previous section, the most of regions with high flood risk are situated at the southern Schoeckelbach basin. This part of the basin is very important for flood risk management because urban area is also placed here. Due to this reason, a retention dam (Weinitzen Dam) was constructed in the basin in 2012. Table 1 summarizes the information of Weinitzen dam.

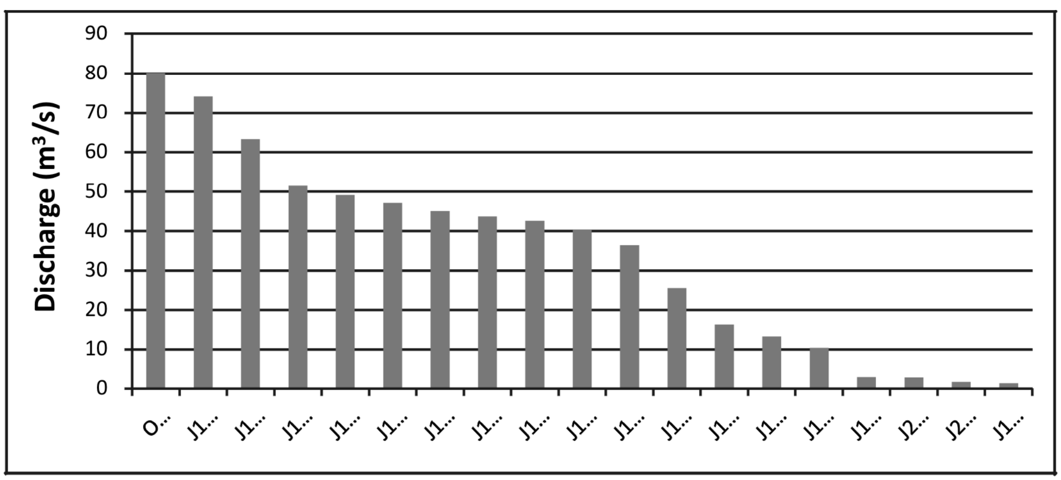


Figure 2: The discharges for 100-year 1-day rainfall modeling at the river tributaries

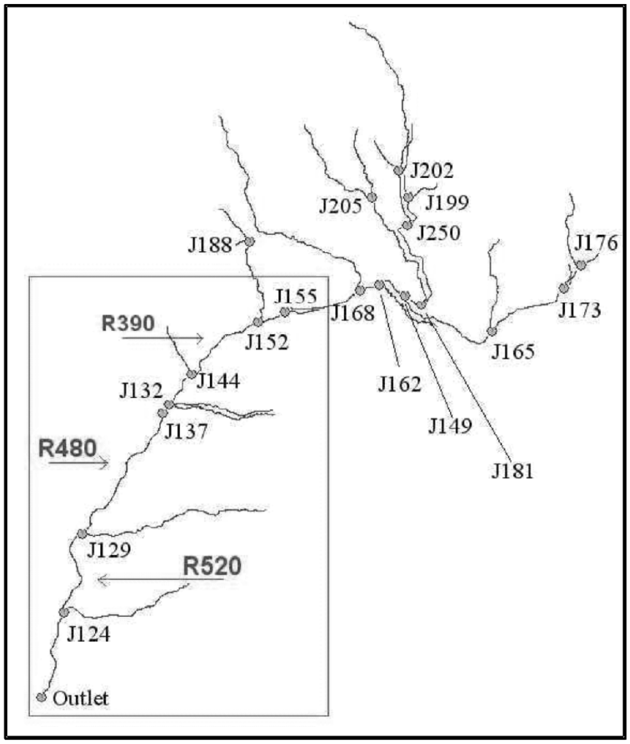


Figure 3: The name of river tributaries in the Schoeckelbach basin (red border: inundation areas)

Table 1
The Retention Dam Information1

Dam name	*Weinitzen*
Dam type	Retention dam
Dam height	8.5 m
Dam length	222 m
Maximum volume of storage	215,000 m^3
Maximum water surface area	78,900 m^2
Maximum water elevation	439.5 m.a.s.l
Dam operation	Reduction of the incoming flood peak runoff by nearly 50%

Figure 4 shows the Elevation-Volume curve for the reservoir of Weinitzen dam. Also, Figure 5 illustrates dam position in the Schoeckelbach basin in 2D and 3D views.

Hydraulic operation of this retention dam is investigated for two different sizes of outlet pipe (R = 0.9 m and R = 0.4 m) using river and reservoir routing methods. For this reason, the modified Puls method for reservoir routing and Muskingum-Cunge method for river routing are used.

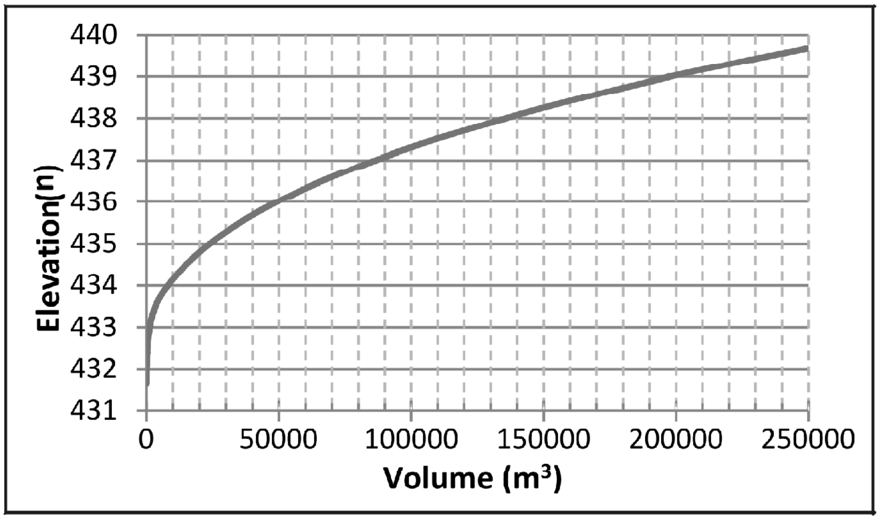


Figure 4: Elevation-Volume (storage) curve for Weinitzen reservoir

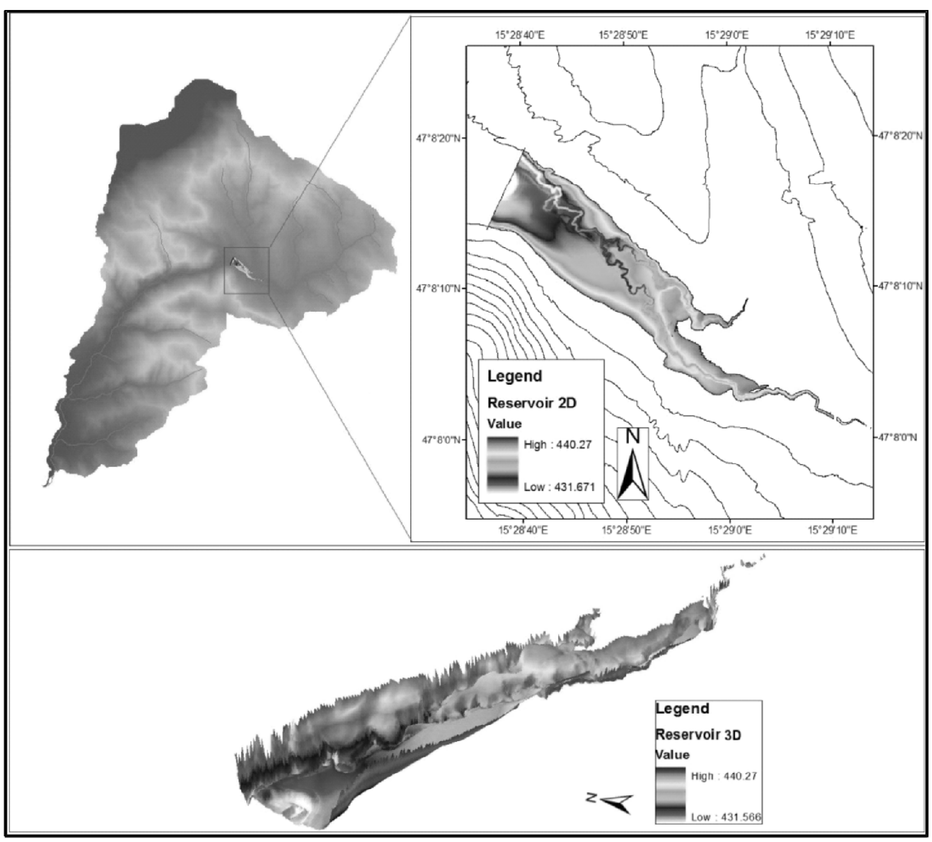


Figure 5: The position of Weinitzen dam in the Schoeckelbach basin (2D and 3D views)

4.1. The Modified Puls Reservoir Routing Method

This method is based on the continuity equation and an empirical or analytical relationship between discharge and storage within the reach. The simplest form of the continuity equation can be written as follow:

$$I - O = \frac{\Delta S}{\Delta t} \tag{3}$$

Where I is the average inflow to the reservoirduring Δt, O is the average outflow from the reservoir during Δt and S is storage within the reservoir. In reservoir routing, the inflow hydrograph is known, and the outflow hydrograph from the reservoir is unknown. Equation (3) can be rewritten as follow:

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

In which subscripts 1 and 2 denote time steps K and $K + 1$. In this equation, all parameters on the left side are known and two parameters (S_2, O_2) on the right side are unknown. To find these unknown parameters, a relationship between storage and discharge is needed as follow:

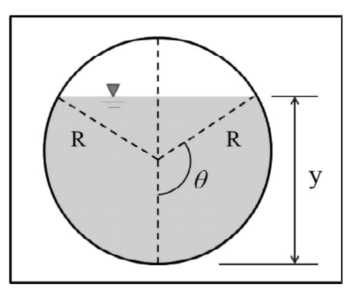
$$S = f(Q) \tag{5}$$

This depends on the geometry of the reservoir and its outlet. For this reason, discharges for various water elevations in the reservoir should be calculated. Then Storage-Outflow Function (SOF) "[(2S/Δt) + Q_O] vs Q_O" should be plotted. Now, it is possible to route the inflow hydrograph using equation (4) and SOF curve.

Hydraulic parameters for circular pipes are summarized in Table 2 and outflow discharges calculated for some selected water level in the reservoir are presented in table 3.

Table 2
Hydraulic Parameters for Circular Pipes

Area	$A = R^2\left(\theta - \frac{\sin 2\theta}{2}\right)$
Wetted perimeter	$P = 2R\theta$
Hydraulic radius	$R_h = \frac{R}{2}\left(1 - \frac{\sin 2\theta}{2\theta}\right)$
Manning's formula	$Q = \frac{1}{n} A R_h^{\frac{2}{3}} S_o^{0.5}$
Orifice flow	$Q = 0.6A\sqrt{2gh}$
Ogee spillway discharge	$Q = cLH^{3/2}$



A partly full, circular pipe with uniform flow

L: Length of spilway crest (8m)
H: Headover spilway crest (H=2/3(h-7.5))
c: Coefficient of discharge (Ogee: 3.5-4.0)

Table 3
Outflow Discharges (R = 0.4 m) for Selected Water Levels in the Reservoir (n = 0.035, So = 1.2% and c = 3.8)

h (m)	*θ(rad)*	*A (m^2)*	*P (m)*	*R_h (m)*	*Q - Pipe (m^3/sec)*	*Q - Ogee (m^3/sec)*	*Q_{out} (m^3/sec)*
0	0	0	0	0	0	-	0
0.5	3.6454	0.33	1.458	0.226	0.384	-	0.384
1	6.2831	0.50	2.513	0.2	1.035	-	1.035
2	6.2831	0.50	2.513	0.2	1.690	-	1.690
4	6.2831	0.50	2.513	0.2	2.535	-	2.535
6	6.2831	0.50	2.513	0.2	3.162	-	3.162
8	6.2831	0.50	2.513	0.2	3.683	5.85	9.533
8.5	6.2831	0.50	2.513	0.2	3.802	16.55	20.352

Table 4 summarized calculation of Storage-Outflow Function (SOF) for some selected water levels in the reservoir and outlet pipe size of R=0.4 m.

Table 4
Calculation of Storage-Outflow Function [(2S/Δt) + Q_{out}] for selected water levels in the reservoir (Δt = 60 sec) (R = 0.4 m)

h (m)	*Q_{out} (m^3/sec)*	*S = Storage (Fig. 4) (m^3)*	*SOF (m^3/sec)*
0	0	0	0
0.5	0.384	67.18	2.66
1	1.035	566.94	19.96
2	1.690	4784.37	161.19
4	2.535	40265.22	1344.72
6	3.162	119241	3977.87
8	9.533	188063.6	8344.95
8.5	20.352	215000	9136.95

Figure 6 illustrates SOF for two outlet pipes of the Weinitzen retention dam.

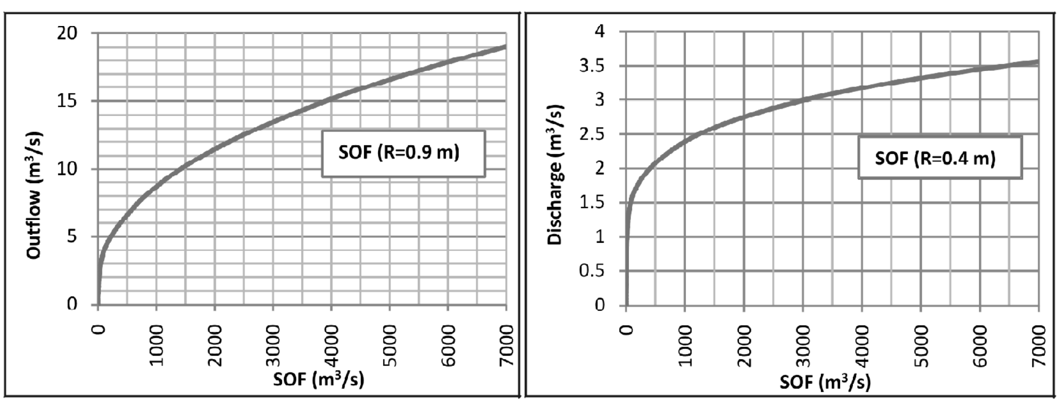


Figure 6: Storage-Outflow Function for Weinitzen dam; (left) R=0.9 m and, (right) R=0.4 m

For reservoir routing using modified Puls method, equation (4), inflow hydrograph to the reservoir and SOF are needed. A Flowchart for calculating outflow discharge using Modified-Puls method is shown in Figure 7.

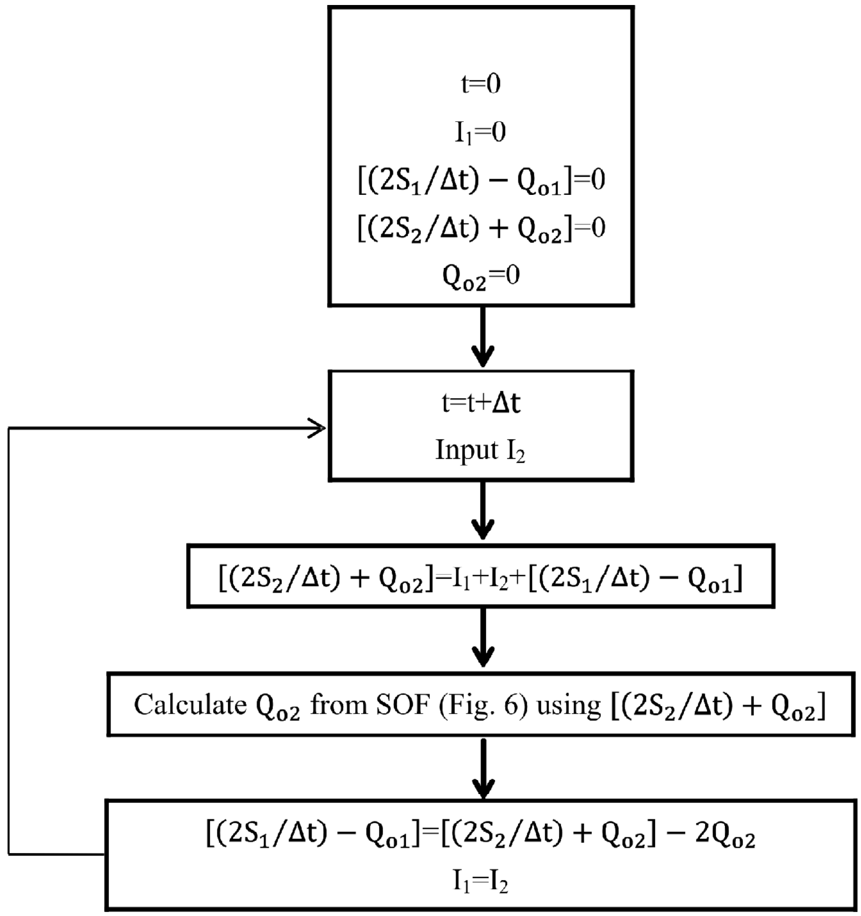


Figure 7: Flowchart for calculating outflow discharge using Modified-Puls method

4.2. The Muskingum-cunge River Routing Method

The Muskingum channel routing method is based on two equations. The first is the continuity equation (4). The second equation is a relationship of storage, inflow, and outflow of the reach:

$$S = K[xI + (1 - x)O] \qquad (6)$$

K is storage constant which has the dimension of time and *x* is a dimensionless constant. An approximation for *K* is the travel time along the reach (Raghonath, 2006). The value of *x* is between 0.0 (maximum attenuation) and 0.5 (minimum attenuation).

Cunge (1969) modified the Muskingum method by computing the routing coefficients in a particular way. Cunge conducted that the Muskingum method is essentially a linear kinematic wave solution and that the flood wave attenuation shown by the calculation is due to the numerical diffusion of the scheme itself. The equation which is applicable to each sub-reach for each time step is:

$$O_{i+1}^{j+1} = C_1 O_i^{j+1} + C_2 O_i^j + C_3 O_{i+1}^j + C_4 \quad (7)$$

The routing coefficients are expressed as follows (User's Manual of Hydrology, 1997):

$$C_1 = \frac{-1 + Cr + G}{1 + Cr + G} \quad (8)$$

$$C_2 = \frac{1 + Cr - G}{1 + Cr + G} \quad (9)$$

$$C_3 = \frac{1 - Cr + G}{1 + Cr + G} \quad (10)$$

C_4 accounts for the effect of lateral inflow $\left(\overline{q}_i\right)$ along the Δx sub-reach:

$$C_4 = \frac{\overline{q}_i \, \Delta x \, Cr}{1 + Cr + 2G} \quad (11)$$

In which Cr is the Courant number:

$$Cr = \frac{c\Delta t}{\Delta x} \quad (12)$$

and G is the Cell Reynolds number (the ratio of hydraulic diffusivity to grid diffusivity) which is defined as follow:

$$G = \frac{q_0}{cS_0 \Delta x} \quad (13)$$

Now, routing coefficients in Eq. 6 can be expressed as follows:

$$K = \frac{\Delta x}{c} \quad (14)$$

$$x = \frac{1}{2}(1 - G) \quad (15)$$

In Equations (11) to (15), c is kinematic wave celerity, Δx is reach length, $q_0 = \left(= \frac{Q}{T}\right)$ is reference discharge (Q) per unit width (T), S_0 is bed slope and is routing period.

As it can be seen in Eq. (13), G may be greater than one for very small values of Δx. This can lead Eq. (15) to negative values for x which allows the use of shorter reaches than would otherwise be possible if x were restricted to positive values and this is one ofthe advantages of Cunge method in comparison to Muskingum method because in Muskingum method x is restricted between 0 and 0.5.

In order to estimate routing coefficients, first G and Cr should be estimated. It requires an estimate for wave celerity (c) in addition to grid size (Δx, Δt).

The celerity wave (c) can be obtained from:

$$c = \frac{1}{T}\frac{dQ}{dy} \tag{16}$$

Where T is the top width. This equation can be used when cross section geometry and stage-discharge rating are available.

Δx and Δt should be taken as sufficiently small values in order to approximate closely the actual shape of the hydrograph. For smoothly rising hydrographs, a minimum of $\frac{t_p}{\Delta t} = 5$ is recommended (Ponce and Theurer, 1982).

Since the Courant and Cell Reynolds numbers are inversely related to Δx, therefore to keep Δx sufficiently small, Courant and Cell Reynolds numbers should be kept sufficiently large.

The Muskingum-Cunge method works best when the numerical dispersion is minimized (this means that Cr should be kept close to one). Also, routing coefficient C_1 should not be less than or equal to zero (Eq. 7) therefore:

$$Cr + G \geq 1 \tag{17}$$

For calculating routing coefficient G, first Δx is chosen as entire reach length. If the practical criterion (Eq. 17) is not established, then the reach is divided into sub-reaches as the value of Cr should be close to one.

5. RESULTS AND DISCUSSIONS

The reservoir routing for the Weinitzen dam is done using the modified Puls method and Figure 8 illustrates the final results. As it can be seen in this Figure, the pipe size not only effects on the peak outflow but also on the time of emptying and maximum volume of storage in the reservoir.

In order to understand better the effect of this retention dam (with these two different outlet pipes) on flood control in the Schoeckelbach basin, the inundation areas with these new hydrographs are investigated. For this reason, the Muskingum-Cunge method is used for river routing and inundation areas for all reaches are determined using Hec-RAS (Hec-RAS user's manual (2010)).

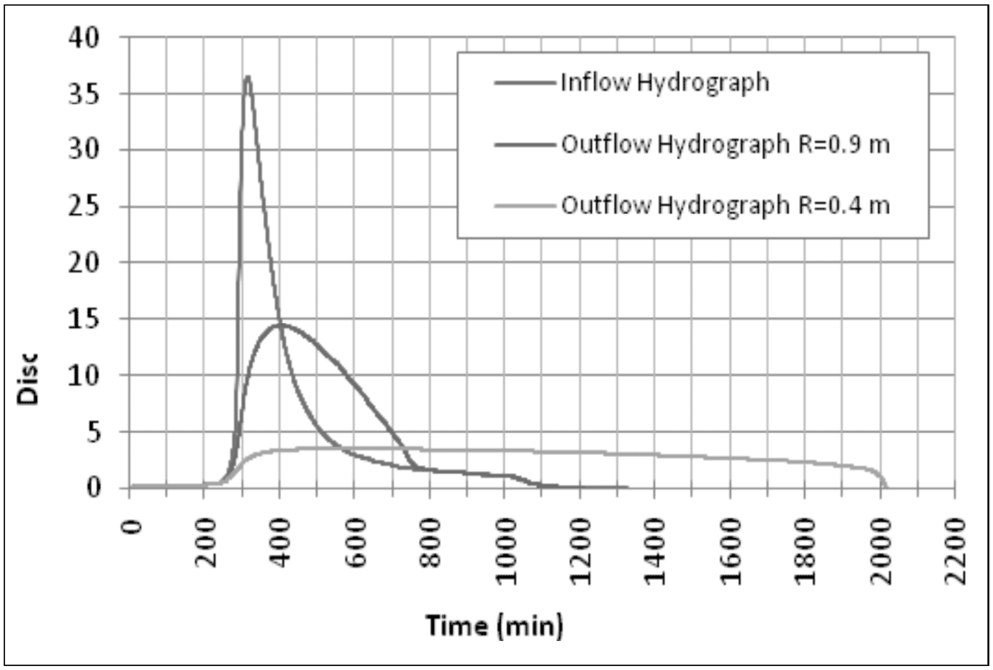


Figure 8: Retention dam, inflow and outflow for two pipes, R=0.9 m with maximum volume of storage in the reservoir=104,400 m3; and R=0.4 m with maximum volume of storage in the reservoir=207,000 m3

For flood modeling, at first, river characteristics are extracted using Hec-GeoRAS which is an extension for ArcGIS. After importing river data into Hec-RAS, runoff hydrograph for each river is calculated using Muskingum-Cunge routing method and then these hydrographs are defined for the rivers in Hec-RAS.

Figures 9, 10 and 11 illustrate the influence of the retention dam on inundation areas in three reaches R390, R480 and R520 respectively (see Figure 3 for their positions). R390 is located between 1 and 2 km downstream of the retention dam and R480 is located between 3 and 5 km downstream of the retention dam.As it can be seen in Figures 9 and 10, the inundation areas can be controlled by the retention dam. This is because of this fact that these reaches are located almost close to the retention dam. But this is not applied for reach R520.Reach R520 is located between 5 and 6 km downstream of the retention dam. Because of this long distance, the inundation areas are not reduced too much (and for all reaches located at downstream of junction J129 until the basin outlet). Figure 12 illustrates runoff hydrographs in junction J129. As it can be seen in this Figure, the influence of the size of outlet pipe on the peak discharge is not significant in this junction. Wenitzen dam only can control 100-year flood in the Schoeckelbach basin until about 3-4 km downstream of the dam as it can be seen in Figures9 and 10. For this reason, an additional retention dam between the outlet of the Schoeckelbach basin and current retention dam is needed. The best place for the additional retention dam is at upstream of junction J129.

It should be noted that for flood control it is possible to construct levee too but in the Schoeckelbach basin the length of river with high flood risk is about 7 km. Construction of levee on this river is costly so, retention dam is better than levee for this basin.

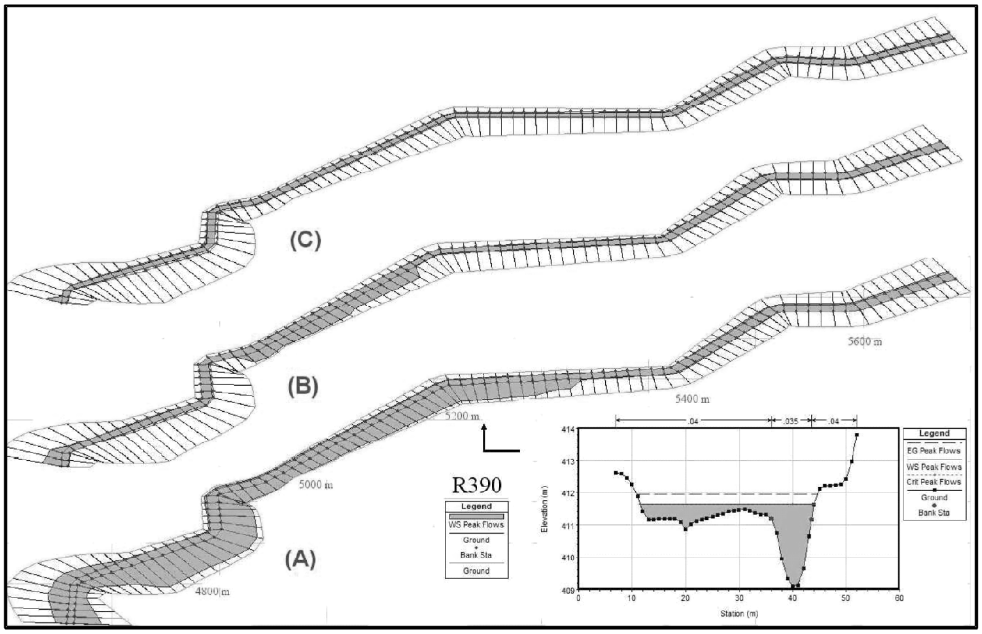


Figure 9: The influence of the retention dam on inundation area in river R390, (A) without retention dam, (B) with retention dam, outlet pipe R=0.9 m and (C) with retention dam, outlet pipe R=0.4 m (see Figure 3 for the river position)

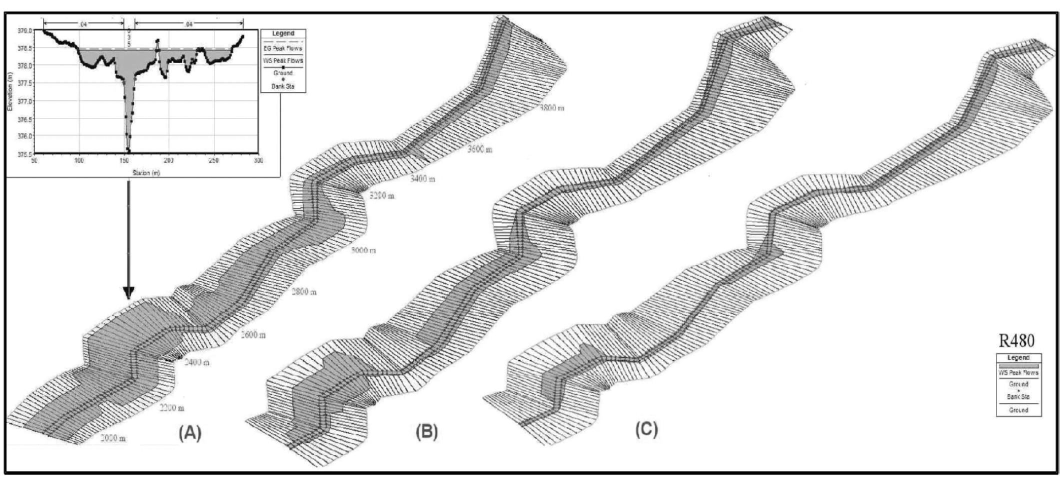


Figure 10: The influence of the retention dam on inundation area in river R480, (A) without retention dam, (B) with retention dam, outlet pipe R=0.9 m and (C) with retention dam, outlet pipe R=0.4 m (see Figure 3 for the river position)

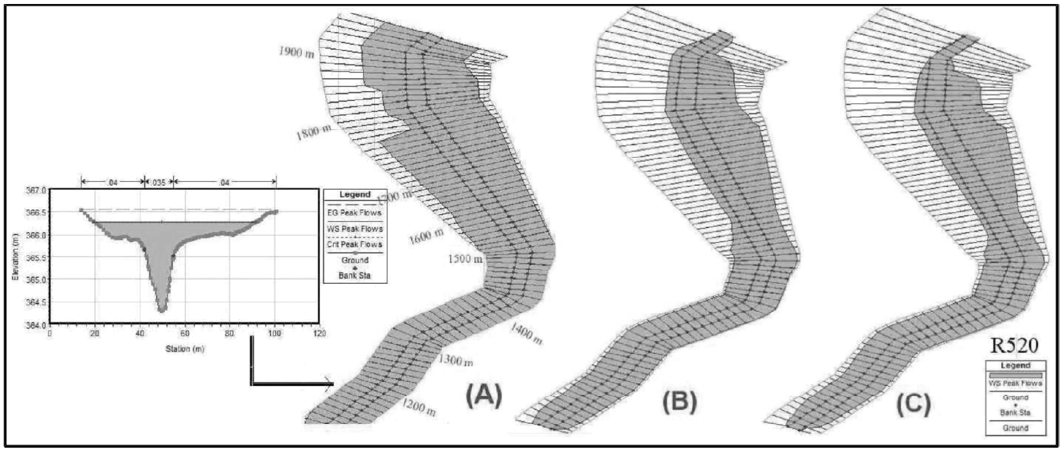


Figure 11: The influence of the retention dam on inundation area in river R520, (A) without retention dam, (B) with retention dam, outlet pipe R=0.9 m and (C) with retention dam, outlet pipe R=0.4 m (see Figure 3 for the river position)

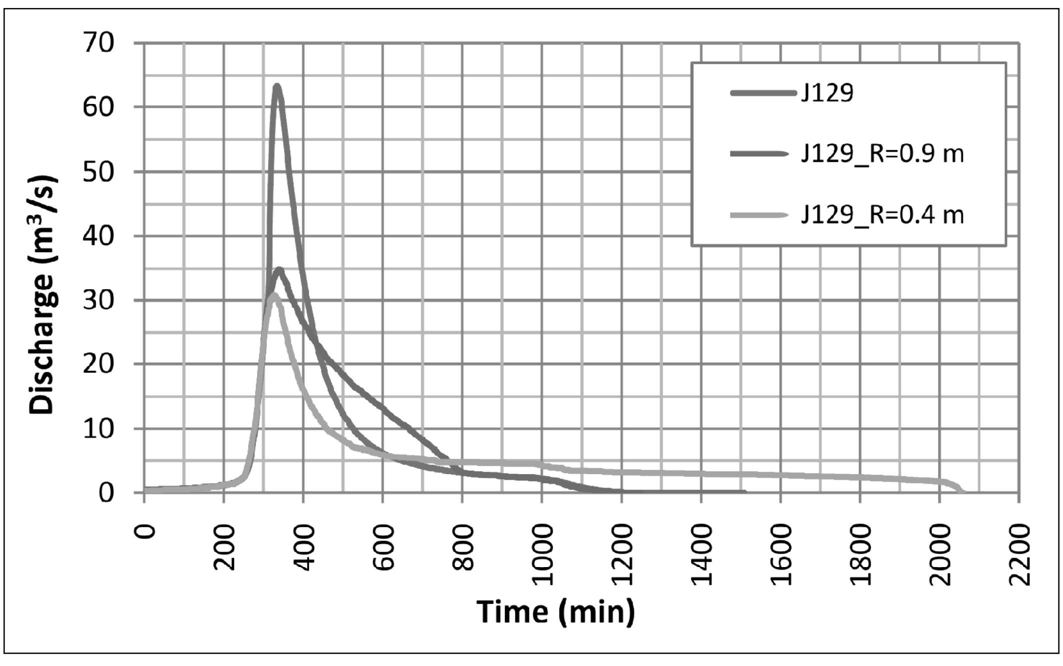


Figure 12: Runoff hydrographs for junction J129; (Blue curve): without retention dam, (Red curve): with retention dam, outlet pipe R=0.9 m and (Green curve): with retention dam, outlet pipe R=0.4 m (see Figure 3 for the junction position)

6. CONCLUSIONS

This paper has described the influence of an existing retention dam (which was constructed in 2012) on flood control in the Schoeckelbach basin (Austria). In order to model the inundation areas for 100-year 1-day storm, runoff hydrographs in all reaches are needed. For this reason, prior to flood modeling, a rainfall-runoff modeling should be carried out. This process has been done for the Schoeckelbach basin (see Galoie *et al.* 2013) and all runoff hydrographs are imported into Hec-RAS. Also, river characteristic which are the necessary data for flood modeling are extracted from very high resolution Digital Elevation Model (1m×1m) using Hec-GeoRAS. The process of flood modeling is shown that inundation areas (with about 7 km long) are located at southern the basin. In order to prevent and control the harmful effects of the floods in these areas, a retention dam (Weinitzen dam) was constructed. In this paper, hydraulic operation of this retention dam has been investigated. For river and reservoir routing, the Muskingum-Cunge method and Modified Puls method are used respectively. The final results have been shown that this retention dam only can control inundation areas until 3-4 km downstream of the dam and for the rest areas; an additional retention dam is needed.

Note

http://wasser.graz.at/cms/beitrag/10124679/2551353/

References

[1] Cunge, J.A. (1969), Food Propagation Computation Method (Muskingum Method).*Journal of Hydraulic Research*. **7 (2)**,205-230.

[2] Galoie M., Zenz G., and Eslamian S. (2013), Determining the High Flood Risk Regions Using a Rainfall-Runoff Modeling in a Small Catchment Area in Austria. *Journal of Flood Engineering*. **4(1-2)**, 9-27.

[3] Galoie M., and Zenz G. (2012), Rainfall-runoff modelling for the Schoeckelbach basin using ArcGIS, Hec-HMS and Hec-GeoHMS. International Conference of Numerical Modelling SimHydro, Sep., France.

[4] Guange-Te W. and Singh V. P. (1992), Muskingum method with variable parameters for flood routing in channels. *Journal of Hydrology*, **137**, 57-76.

[5] Hec-GeoHMS User's Manual. (2009), Hec-GeoHMS Geospatial Hydrologic Modeling Extension Version 4.2. US Army Corps of Engineers, Hydrologic Engineering Center, May.

[6] Hec-GeoRAS User's Manual. (2009), Hec-GeoRAS GIS Tools for Support of Hec-RAS using ArcGIS Version 4.2. US Army Corps of Engineers, Hydrologic Engineering Center, September.

[7] Hec-HMS User's Manual. (2010), Hydrologic Modeling System (Hec-HMS) Version 3.5. US Army Corps of Engineers, Hydrologic Engineering Center, August.

[8] Hec-RAS User's Manual. (2010), River Analysis System (Hec-RAS) Version 4.1. US Army Corps of Engineers, Hydrologic Engineering Center, January.

[9] Maidment D. R. (1993), Handbook of Hydrology. McGraw Hill Publication, Texas-USA.

[10] Mockus V. (1964), National Engineering Handbook, Section 4, Hydrology. NEH Notice **4-102**.

[11] Ponce, V.M., and F.D. Theurer. (1982), Accuracy Criteria in Diffusion Routing.*ASCE Journal of the Hydraulics Division***108 (HY6),** 747-757.

[12] Raghunath, H. M. (2006), Hydrology Principles – Analysis – Design (2nd Edition). New Age International Publishers, New Delhi.

[13] Tarboton D. G. (2003), Terrain Analysis Using Digital Elevation Models in Hydrology, 23rd ESRI International Users Conference, San Diego, California, July 7-11, USA.

[14] User's Manual of Hydrology (UM 2/96-97). (1997), Flood Estimation for Large Catchments Using Deterministic Approach. National Institute of Hydrology, Jal Vigyan Bhawan, Roorkee-247 667.