ESTIMATING PEAK FLOOD IN KRUPPÁ WATERSHED WITHIN THE MORAVA RIVER BASIN, CZECH REPUBLIC

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ABSTRACT

An analysis of the trends in flood-related damage, number of people stricken and number of casualties provides an idea of how serious the situation is. Damage is expected to rise inexorably in the years to come, partly due to greater risk posed by large urbanised areas, destruction of forest systems in the river basin and due to climate changes taking place. Hence, the need for an improved peak flood computation and forecasting system is urgent and beyond the scope of any doubt and debate. An attempt was therefore made to determine peak flood flow in Kruppa watershed based on the combination of the contributing factors of flood formation. The main objective of the study was to compute peak flood discharge at the point of interest (Staré Město). Based on the existing hydraulic structures and planned ones within the watershed, the values for $\boldsymbol{Q_{100}}$, $\boldsymbol{Q_{20}}$ **and** $\boldsymbol{Q_2}$ were estimated and compared with the ones available with the river board corporation, Povodi Moravy responsible for management of flood in the watershed. The model estimated values calls for reformulation of flood management strategies within the watershed.

Keywords: flood, runoff formation, peak discharge, compute, damage, watershed

1. Introduction

Of all the tricks in Mother Nature's weather bag, one of the deadliest today is flooding. The problem of flooding is as old as time and is a global problem that has been increasing at a worrisome pace in recent years. Natural flooding of large areas did not create dangerous situations in a pre-historic world. The expansion of human activity and the aggregation of people in large and more urbanised areas have increased damages caused by floods. Hence, control and management of floodwater have become a problem of vital necessity. Since the end of the 18th century onwards, with the advent of the industrial age, there have been two causes of action viz. hydraulic works on the territory, such as land reclamation works, which in many cases upset a land's equilibrium based on overflow and the channelling of watercourses, especially in mountain and foothill areas, with the result that the problem of flooding is brought downstream, even to areas that were not originally flood-prone. In addition, recent years have seen booming population, indiscriminate industrialisation and urbanisation creating extremely dangerous situations. In floodplain areas that are inhabited or with houses built at the foot of dikes, the safety tends to vanish during prolonged periods of flooding.

An analysis of the trends in flood-related damage, number of people stricken and number of casualties provides an idea of how serious the situation is. Damage is expected to rise inexorably in the years to come, partly due to greater risk posed by large urbanised areas, destruction of forest systems in the river basin and due to climate changes taking place. Losses cannot be avoided when major floods occur but flood preparedness can considerably help reduce flood damage and the cost in terms of lives lost. Hence, the need for an improved flood computation and forecasting system is urgent and beyond the scope of any doubt and debate. It is therefore necessary to develop a method by which the peak flood formation at the point of discharge due to rainstorms affecting different zones of the basin can be determined. The proposed approach to determine flood flow is therefore a combination of the contributing factors of flood formation. The main objective of the study was to compute peak flood discharge at the point of interest (Staré Město) in Kruppá watershed within the Morava river basin, Czech Republic.

2. Specific Objectives

Specific objective of the study was to compute peak flood discharge for the Kruppá watershed within the Morava river basin in Czech Republic.

3. Data Used

Various data used for the purpose of the study were sourced from Povodi Moravy, a river board corporation responsible for management of the Morava river basin with head office being located in Brno, Czech Republic. This apart, values of various other input parameters were either derived or deduced. Data were collected, organised, analysed and interpreted to incorporate into the model. The data supplied to this author are regularly collected by the various government owned organisations of the Czech Republic and are assumed to be sufficiently accurate. This author is by no way responsible for the quality of the data due to the fact that the author had no influence in the process of data collection.

4. Methodology

Runoff is a very complicated process due to the fact that it depends on a plethora of factors, both direct and indirect. However, for the sake of simplicity, the whole process of runoff can be assumed to depend on a number of quantifiable factors viz. morphometric elements, soil and vegetative condition, climatic condition and also cultural and geographical condition. The model used for the purpose of the study encompasses most of the quantifiable parameters and can be represented as given in Section 4.3. The steps involved in derivation of the model are not presented in this paper due to limitation of space.

4.1 The Kruppá Watershed

This watershed lies in the uppermost region of the Morava river basin near the Czech-Poland border. The drainage pattern within the watershed is shown below. The watershed is located on the left bank of river Morava covering an area of about 40.66 km^2 and falls in the 100 or >100-year floodplain. The discharge measuring station for this watershed is located at a place called Staré Město, which is about 550 m above the mean sea level. Details about the watershed and the computed values of different parameters are provided below.

Fig. 1: Location of Czech Republic in Europe

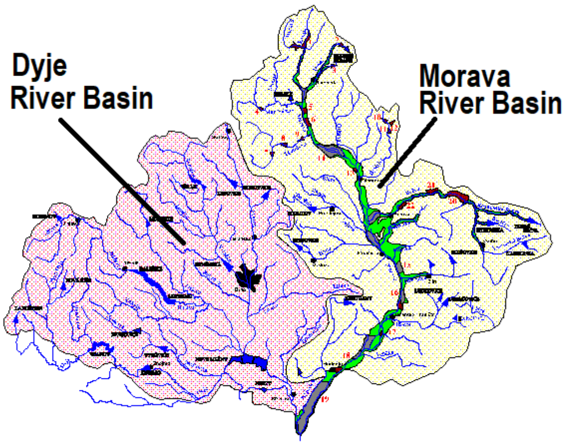

Fig. 2: Morava and Dyje river basins, Czech Republic

Fig. 3: Kruppa watershed within the Morava river basin

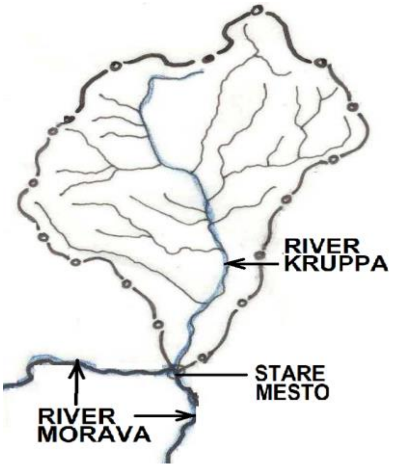

Fig. 4: Drainage pattern of Kruppa watershed

4.2 The Model Set-up

The following basic steps were carried out to set-up the model.

- Delineation of the watershed with the help of topographic map. However, supplementary information such as municipal drainage maps was also consulted to obtain an accurate depiction of the basin's extent and boundary.

- Determination of the number and type of stream network to be used in the model keeping in mind the factors viz. the purpose of the study and the hydro-meteorological variability throughout the watershed. The watershed is intended to represent an area, which has the same hydrologic/hydraulic properties. The assumption of uniform precipitation and infiltration over a watershed becomes less accurate as the sub-basin area increases.

- The watershed and its components are linked together to represent the connectivity of the river basin. This completes the watershed schematic

4.3 The Model

The model may functionally be represented as follows.

Maximum Discharge ($Q_{\max}$)= f (*Coefficient of runoff, Co-efficient of non-uniformity of rain storm, Co-efficient of shape, Land cover of the catchment, Duration and amount of precipitation)*

Maximum Discharge, $Q_{\max} = 16.67\, C_{ru} \cdot \beta \cdot C_s \cdot A\left(\frac{H}{T}\right)$

where,

C_{ru}	Coefficient of runoff that is determined from nomogram or from the formula $=(\xi \times C_f) \times (i+0.1)^{0.345} \cdot T^{0.15}$
i	Intensity of rainstorm, mm/min
ξ	Soil co-efficient
β	Coefficient of non-uniformity of the rainstorm
A	Area of the basin, km^2
C_s	Coefficient of shape of watershed
H	Total amount of precipitation, mm
T	Total duration of rainstorm, min

4.4 Results and Discussion

4.4.1 Input parameters to the model and estimated values

The following table provides list of input parameters to the model, their values and model estimated maximum discharge values with reference to the gauging station at Staré Město. This is followed by a comparison of model estimated discharge values with those obtained from Povodí Moravy for floods of different frequencies Q_{100}, Q_{20}, Q_2.

Table 1: Input parameters to the model and their values

Sl. No.	Input Parameters	Values of Input Parameters		
		for Q_{100}	**for Q_{20}**	**for Q_2**
1	Area of the watershed, A (km^2)	40.66	40.66	40.66
2	Length of the main riverbed, L (km)	9.50	9.50	9.50
3	Slope of the river (by air), J_r (%)	5.00	5.00	5.00
4	Slope by computation (balanced), $J_b = (0.75\times J_r)$(%)	3.75	3.75	3.75
5	Average valley slope, J_v (%)	7.84	7.84	7.84
6	Forest cover on the watershed, A_f (km^2)	24.40	24.40	24.40
7	Total length of streams, $\sum l$ (km)	45.00	45.00	45.00
8	The climatic coefficient, K	4.50	4.50	4.50
9	Soil coefficient, ξ	0.24	0.24	0.24
10	Highest elevation in the watershed, $H_{\max}$ (m)	1050.00	1050.00	1050.00
11	Highest elevation along the river course, $R_{\max}$ (m)	1025.00	1025.00	1025.00
12	Lowest elevation in the watershed, $H_{\min}$ (m)	550.00	550.00	550.00
13	Surface parameter, m	0.60	0.60	0.60
14	Coefficient of runoff, C_{ru}	0.37	0.33	0.30
15	Computed length of valley slope, l_0 (m)	373.03	373.03	373.03
16	Computed duration of rainstorm, T (min)	297.46	337.76	422.71
17	Calculated quantity of rainfall, H (mm)	91.25	61.43	35.36
18	Rainfall intensity, i (mm/min)	0.310	0.180	0.084
19	Forest cover coefficient, C_f	0.89	0.89	0.89
20	Coefficient of form of the watershed, C_s	1.12	1.12	1.12
21	Maximum width of the watershed, W_m (km)	11.60	11.60	11.60
22	Average width of the watershed, W (km)	7.76	7.76	7.76
23	Rainfall non-uniformity coefficient, β	0.80	0.84	0.88
24	Maximum discharge of rainstorm, $Q_{\max}$, (m^3/sec)	**69.66**	**37.88**	**16.83**

Table 2: Comparison of model estimated discharge values with those obtained from Povodí Moravy for floods of different frequencies (Q_{100}, Q_{20}, Q_2)

Location of Gauging Station and Watershed Area (km^2)	**100-Year Discharge, Q_{100} (m^3/sec)**		**20-Year Discharge, Q_{20} (m^3/sec)**		**2-Year Discharge, Q_2 (m^3/sec)**	
	Model Estimated Value	In Record of Povodí Moravy	Model Estimated Value	In Record of Povodí Moravy	Model Estimated Value	In Record of Povodí Moravy
Staré Město (40.66 km^2)	69.66	64.60	37.88	39.20	16.83	12.80

In the above table, the model estimated values pertaining to $\boldsymbol{Q}_{100}$, $\boldsymbol{Q}_{20}$ **and** Q_2 have been compared with those available with the Povodí Moravy a. s., Brno. It has been envisaged that this would assist the concerned authorities to reconsider their formulations for designing flood control and mitigation structures within the Kruppá watershed in specific.

4.4.2 Watershed prioritisation based on flood proneness and expected damage

In addition to the above an attempt was also made to assign priority to the Kruppá watershed in terms of its flood proneness and expected damage. This is presented in Table 3 and Table 4. This has been done based on the estimated values of peak discharge at the outlet of the watershed, number of inhabitants that may be affected and the concentration of both movable and immovable property that is under the risk of a major flood of the magnitude of the July 1997 flood. It is however suggested that a detailed survey in the form of inventory of resources may be carried out before deciding to implement measures and plan regarding the mobilisation of resources in the watershed.

Table 3: Basic parameters to determine the level of priority

Sl. No.	**Level of Priority→ Parameters↓**	**Very High**	**High**	**Medium**	**Low**
1	Discharge	>100-year	50-100-year	20-50 year	2-20-year
2	Inundation (% of total basin area)	>10%	5-10%	3-5%	1-3%
3	Loss of public property	>20%	15-20%	10-15%	5-10%
4	Loss of private property	>10%	6-10%	3-5%	1-3%
5	Structures damaged	>8%	6-8%	3-5%	1-2%
6	Other losses	Very high	High	Medium	Low

Table 4: Prioritisation of based on Flood Proneness and Expected Damage

Sl. No.	**Name of Watershed**	**Located in MRB Floodplain**	**Vulnerability**	**Priority**
1	Kruppá	100-year	Very high	1

5. Conclusion and Recommendations

It may seem strange to end a study of this nature with an observation that future progress is very strongly linked to the acquisition of new data and to new experimental work, but that, in the opinion of this author, is the state of the science. The recognition that hydrological science is in greater need of more and better experimentation than of more and better models, although the latter must follow the former has been recognised for many years. To make progress with the issues of heterogeneity and scaling, hydrologists will have to come to terms with the need to pay closer attention to gathering appropriate, high-quality data. It is also clear that, solutions to the modelling problems are vexed and query about phenomena that varies with time and space scales are of legitimate scientific interest, there is room for more than just one approach. Empirical studies of potential relationships among measurable watershed characteristics and the estimated parameters of some watershed model are needed as much as are small-scale studies of physics-based models. This is not to say that most efforts should be aimed at only input-output relationships of watersheds. There is much to be learned about complex flow paths within catchments and models based on our best representation of physical processes will remain an essential part of studies designed to understand catchment processes. To be sure, there are unresolved (and perhaps some unresolvable) problems associated with the use of mathematical models of watershed responses, but these should not be misconstrued to imply that models are not useful. When unreasonable expectations are set for models, it is quite easy to be critical e.g. when regulators want to take the term validation as applied to models to mean proven to provide absolute truth; scientists must continue to rediscover that there is no single solution to all the problems. Despite this limitation of models, they are useful. Models can be used to critically analyse a problem, to organise our thinking and to formulate critical experiments to test hypotheses. This optimistic view of the utility of models notwithstanding, watershed modelling in the future must continue to make inroads in the critical areas of treatment of heterogeneity and of scaling. To fall on this line future works in the Kruppá watershed may be carried out considering the following aspects in mind.

- The methodology formulated and tested in the course of this study for the Kruppá watershed would provide considerably good results when used for smaller watersheds. The model may not be highly accurate at predicting peak flows resulting from rainfall events as the watershed area increases. When more data are available, an attempt should be made to improve the model. More testing is required to substantiate this and testing in a genuine real-time environment is suggested.

- Models using radar derived rainfall estimates should be investigated as they can provide improved performance over those using rain gauge derived rainfall estimates. However, rain gauge derived data should be used for verification.

- The area in which the biggest improvements in flood forecasting can be made is in that of real-time model adjustment.

- A possible direction for future research is that of composite systems, where the current model would be only one component. It is possible that improvements in flood forecasts could be made by modelling for example base flow or snowmelt separately. Further, the present model may be coupled with a rainfall-forecasting model to improve its accuracy.

- A significant deficiency of most rainfall-runoff models used either for discharge computation or for stream floodplain analysis is that the locations of structures impacted by floodwaters, such as bridges, roads and buildings cannot be effectively compared to the floodplain location. Studies may be undertaken to develop a procedure to take computed water surface profiles generated from a hydraulic model and draw a map of the resulting floodplain in ArcView GIS.

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