# GIS possibilities and topographical measurements on torrential hydrographyc network used to elaborate risk maps of flooding

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***Abstract:*** *The paper is a study of torrential watershed with small area from Brasov county where topographical measurements were made on the torrential hydrographyc network. The main morphometrycal elements of the torrential watershed and hydrographyc network were computed also. Using facilities of AutoCAD the maximum flow capacity of high-water was calculated by two acknowledged methods (rational method and method of hourly rain). Finally, for elaboration of risk maps of flooding the necessary elements resulted base on specified data and measurements but using HEC-RAS software too.*

***Keywords:*** *torrential watershed, topographical measurement, flood natural risk map, AutoCAD, HEC-RAS*

## 1. Introduction

The risk maps of flooding are data used by governmentally or locally administrative organization that have to provide the administration of crisis conditions in case of effective or potential flooding (Ionescu, 2006; ***, 2003; ***, 2005).

According to possibilities of estimation and quantification, the damages can be classified in four categories:

a. direct damages of materials – representing the cost to give back the initial shape of affected areas or the cost to replace the destroyed or deteriorated objectives. In this case the wastes refer to a mean value occurred in mean year, materialized by the extent of management works on the surface;
b. direct damages – consisting in waste of human lives. To estimate this damage, the elaboration of risk maps of flooding considers in case of our country the registering of peoples'number directly affected, without a forecast of number of dead peoples and without an equalization of lives cost;
c. indirect damages – resulting by perturbation of economic and social life. These damages can be measured in money as well as the wastes from first category;
d. damages representing by irreversible destruction or deterioration of cultural and ecological values. These wastes are difficult or impossible to estimate, they analyzing differently, without their registering in risk maps of flooding (Ionescu, 2006).

We analyzed in this paper a torrential watershed with small area (65 hectares) and covered with forest vegetation (fig. 1). The torrential watershed is placed on Porții Valley (Bran locality, Braşov County), being a subordinate unit of this. The Bucegi Mountain in the east and south and Piatra Craiului Mountain in the west surround the studied area (***, 1960; ***, 1983).

Geologically, the land was formed in inferior to middle Cretacic and it is made up from conglomerates and limestones with a crystalline and bladed support and from the depression pathway with crystalline nuclei, limestone bocks that are bladed and included in conglomerates, sandstones and marls also, these constituting in geological substratum on which the soils created.

With a medium and even low resistance at erosion, these rocks encourage the starting of pluvial erosion and amplify the torrential transport.

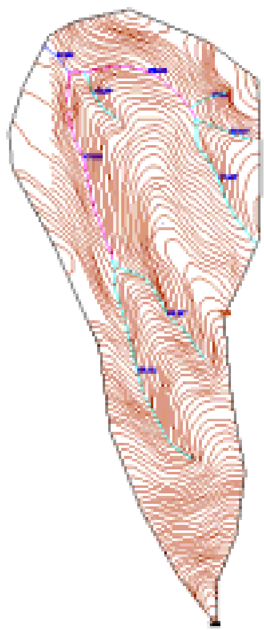

Fig 1. The studied torrential watershed

## 2. Calculation of the morphometrycal elements of watershed

The taking over of elements regarding the hydrographyc network and the level curves too was achieved by using the L-35-87-D-b-1-I and L-35-87-D-b-1-II base plans and 530-442 ortophotoplan. Besides, different measurement on the field were made with a total station. These refer to hydrographyc network for which three cross sections were taken on every its segment.

Using the AutoCAD, the most important morphometrycal parameters of the watershed were computed, as follows:

a. ***The surface*** was calculated by utilization of function *Terrain – Terrain Model Explorer – Create Surface*, that creates automatically the *NamelayerSRF-BDR* layer and it specifies the value of surface in area *Extended Surface Statistics*. The founded value is F=649857.13 $m^2 \approx 65$ hectares. The result is a small watershed, that is a watershed with an increased predisposition at torrentiality, knowing that the chance of uniform cover by a torrential rain exists;
b. ***The perimeter*** results automatically in AutoCAD, the numbers of the both characteristics appearing together. In this case, $P_b=3619.75 \approx 3.6$ km;
c. ***The mean length of watershed*** was computed with the known formula:

$$\overline{L}_b = \frac{P_b}{4} + \sqrt{\frac{P_b^2}{4} - F} = 1316.939 \approx 1.3km. \quad (1)$$

d. ***The shape of watershed*** was studied using the next coefficients:

- Gravelius coefficient: $Gr \cong 0{,}282 \cdot \frac{P_b}{\sqrt{F}} = 1.26$; (2)
- Ratio of circularity: $RC = 12{,}566 \cdot \frac{F}{P_b^2} = 0.63$; (3)
- Ratio of elongation: $Ra = \frac{4{,}51\sqrt{F}}{P_b + \sqrt{P_b^2 - 16F}} = 0.59$. (4)

These results indicate that the studied watershed is temperately elongated.

e. ***The minimum, maximum and mean altitude.*** Minimum ($H_{min}$) and maximum ($H_{max}$) altitude haven't important signification regarding hydrology. Their identification is very easy, either consulting of database for the elaborated project or using *Inquiry – Surface Elevation* fuction. In case of mean altitude for watershed with small area and homegenous relief a simple expression can be used, that is based on half-sum of extreme altitudes and for the other cases the known formula is used. The last considers the specific weight of each altitudinal zone included beetwen two level curves. On the situation of studied watershed, the next values were computed:

$$H_{\min} = 990m;\ H_{\max} = 1400m;\ H_{med} = \frac{H_{\min} + H_{\max}}{2} = 1195m; \quad (5)$$

$$H_{med} = \frac{\sum_{n}^{n+1} F_{i,i+1} \times \frac{H_i + H_{i+1}}{2}}{F} = 1119.53m \quad (6)$$

The last formula (6) gives the best solution obviously. Using AutoCAD the mean altitude is found automatically with *Create Surface – Terrain – Terrain Model Explorer* function (fig. 2).

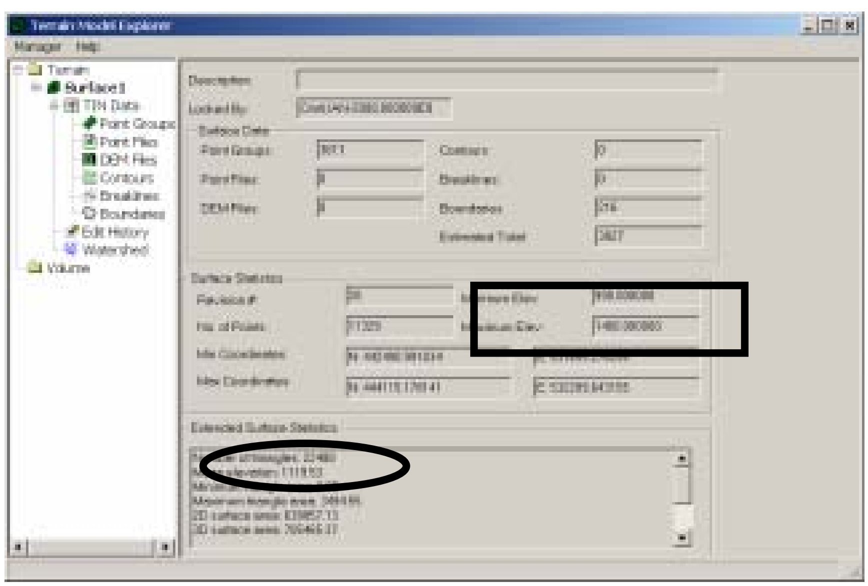


Fig. 2. Data regarding minimum, maximum and mean altitude

f. ***The height of watershed***. In accordance to each situation, either maximum height or mean height of the watershed can be computed (Clinciu and Lazăr, 1999). The values of studied watershed are as follows:

$R_{max} = H_{max} - H_{min} = 410m$; (7)

$R_{med} = H_{med} - H_{min} = 205m$; (8)

$R_{med} = H_{med} - H_{min} = 129.53m$; (9)

g. ***The slope of watershed*** can result using AutoCAD in two ways:

- by achievement of network with vertical and horizontal lines using *Array* function, overlapping with digital model of land. In the knots of network, the values of slopes result resorting to *Label Slope (Terrain – Surface Utilities)* function. With this values, the mean slope of the watershed can be calculated ($I_{med} = 45.8\%$);
- by recourse to *Create Surface (Terrain – Terrain Model Explorer)* function, in the area *Extended Surface Statistics* the mean value of slope results too ($I_{med} = 46.6\%$).

h. ***The length of mountainsides from watershed.*** Usually, the length of a mountainside can be computed with AutoCAD in a few ways:

- in the case of 2D system, the length of a mountainside results using a polyline (with actively perpendicular mode in *OSNAP*), to draw the line of the highest slope beetwen one point from thalweg to the chosen point from topographical line of the analyzed mountainside;
- in the case of TIN model, *Slope Arrows... (Terrain – Surface Display►)* function is used to indicate the general orientation of trickling from watershed. By their analyze, the line of the length for each mountainside can be discovered.

The mean length of mountinsides from watershed was calculated with the next expression:

$$\overline{L}_v = 5.5\frac{F}{L_r} = 132.26m. \quad (10)$$

The example emphasizes that the mountainsides with mean length there are. In this situation the length of hydrographyc network ($L_r$) was computed using *Inquiry – Continuous Distance* function.

## 3. Calculation of morphometrycal elements of the hydrographyc network

a. ***The hydrographyc rank***. In concordance with Strahler system, the torrential watershed contains sectors with I, II and III ranks.

b. ***The length of riverbed.*** This parameter can result in AutoCAD using *Inquiry – Continuous Distance* function. The function achieves a labeler of the measured element with corresponding distance also, for case.

$$L_{ar} = \frac{L_a}{\cos\alpha} = 1224.69m = 1.22km \quad (11)$$

c. ***The mean slope of the main riverbed***. In the classical mode this parameter results such as a fraction between the level difference of extreme points and horizontal length of the riverbed: $I_a = \frac{H_{am} - H_{av}}{L_a} = 0.18 \rightarrow I_a = 18\% \rightarrow I_a = 10^0 8'$. The values $H_{am}$=1204.9m and $H_{av}$=985.4m were computed using *Inquiry – Surface Elevation* function.

## 4. Estimation of the maximum flow capacity of high-water

In situations of torrential watersheds from Romania, the forecast of the maximum flow capacity of high-water is accomplished by indirect methods. That are methods based on the rain which is the source of high-water and the elements of watershed that can influence the formation and propagation process of high-water (Clinciu and Lazăr, 1999).

Even there are many methods to compute the maximum flow capacity of high-water, in this paper we used only two of them:

a. ***The rational method***, that utilizes the follow expression (Munteanu et al, 1979):

$$Q_{\max 1\%} = 0{,}167 \cdot c \cdot i_{1\%} \cdot F \qquad (12)$$

where:

c is the mean coefficient of trickling in the watershed;

$i_{1\%}(mm/\min)$ - the mean intensity of rain used in estimation with 1% probability, having an equal duration with the concentration time of trickling in the watershed;

F(hectare) – the area of watershed.

First, the concentration time of trickling was calculated. The *Hidrology (Hidrology - Runoff► - Time of Concentration (Tc)...)* module was utilized for this, finding in this way $T_c = 11.65\min \cong 12\min$ (fig. 3). The mean intensity of rain required in estimation was computed further on, using the concentration time of trickling ($I = 2.7mm/\min$). Therefore, considering the precipitation generated by rain used in estimation and the hydrological category of land, the retention coefficient resulted ($c_z$). After that, the infiltration coefficient ($c_I$) was found depending on mean intensity of rain used in estimation and the soil texture. Using the $c_z$ and $c_I$ values, the trickling coefficient for the watershed resulted (c=0.31). In this way $Q_{\max 1\%} = 9.09m^3/s$ was computed.

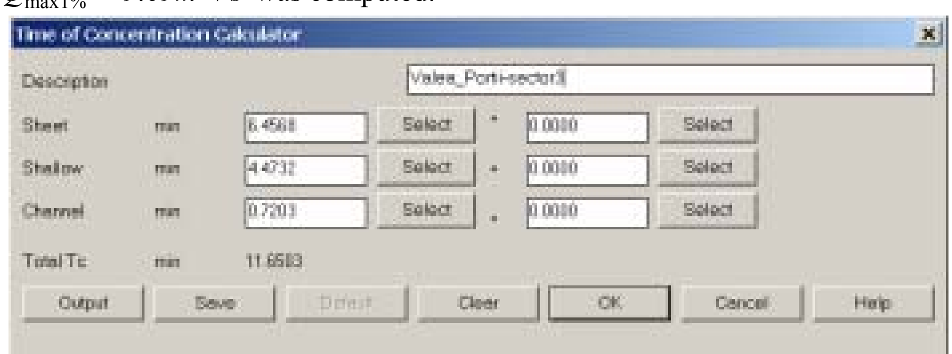


Fig. 5. Estimation of concentration time of trickling using AutoCAD

b. **The method of hourly rain** is base on the follow formula:

$$Q_{\max 1\%} = \frac{0.28 \cdot F \cdot c \cdot H_{60}}{(F+1)^n}, \qquad (13)$$

where:

F($km^2$) is the area of torrential watershed;

c – mean coefficient of trickling, that is established for geographical regions from Romania (c=0.70);

$H_{60}$(mm) – maximum hourly precipitation, in cases of climatic zones from Romania, at 1% probability ($H_{60}$=115mm);
n – exponent smaller than one, having districts in Romania (n=0.48).

As result, $Q_{\max 1\%} = 11.52 m^3 / s$ .

## 5. Topographical measurements on the torrential hydrographyc network and GIS using for elaboration of risk maps of flooding

To estimate the level water in any point from torrential hydrographyc network, topographical measurements regarding cross sections in three points situated in each sector of the riverbed, were made. The minimum number of the points (3) depending on GIS software (HEC-RAS) that provides a general representation of the network based on development of hydrographyc nerwork in space and of cross sections that are configured. These points were in advance established on 530-442 ortophotoplan. For each section two or three points from riverbed and three points from each bank were taken (fig. 4). Therefore, a few stages were followed:

a. digitization of hydrographyc network. This operation can be done directly in HEC-RAS, by anticipated bringing of base plans or/and corresponding ortophotoplan, either in AutoCAD or another software and its processing in HEC-RAS ;
b. introduction of specific data for each cross section from land, information that were taken with total station. The introduction can be achieved directly in *Cross Section Coordinates* database, specifically in HEC-RAS software, or by their bringing from a GIS database;

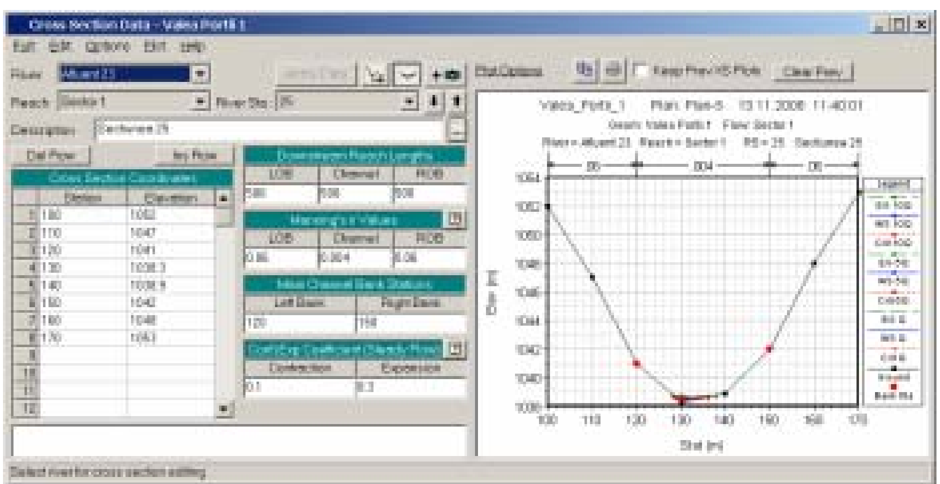

Fig. 4. Cross section from first sector of the tributary no. 23

c. introduction of the values computed for the flow-capacity of each riverbed sector. It was considered that each sector takes the upstream flow-capacity too (fig. 5). Besides, potential values of the flow-capaciy were taken into account from each sector with 5 or 10 years of interval;

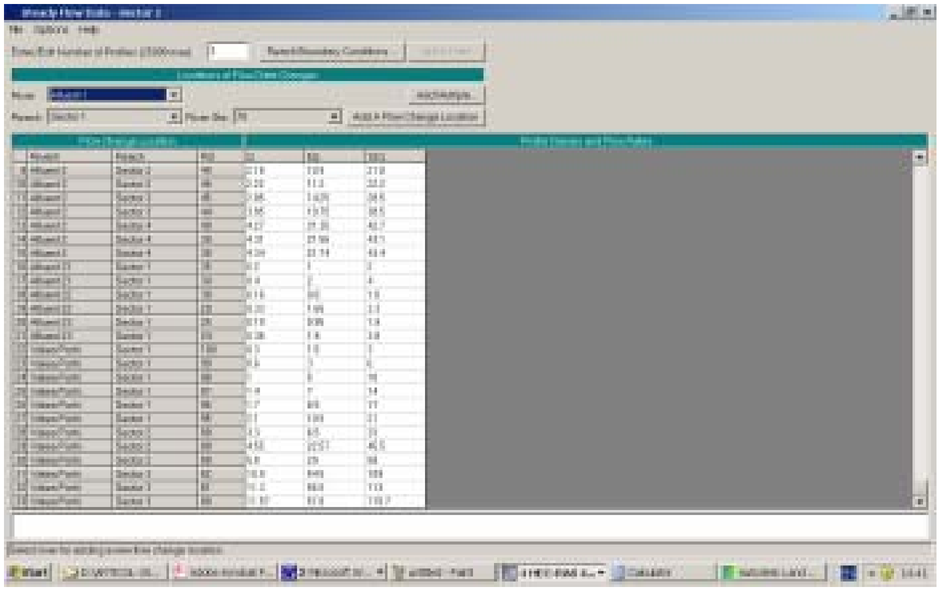

Fig. 5. Specification of the values of flow-capacity in three variants (Q, 5Q, 10Q)

d. definition of the corresponding junctions (points from confluence) and length of arcs that intersect in respective points;
e. specification of condition regarding the normal depth in estimable section (fig. 6);
f. starting of the simulation regarding plotting of water level from entire hydrographyc network. Observing the studied sections (fig. 7), a conforming system of management works can be chosen (finding number and height of works), and on the other hand the risk map of flooding can be elaborated in case of research area. In this example the volume of sediments wasn't computed and because of this the simulation began with the assumption of a sub-critically trickling regime (without the weight of sediments);
g. analysis of each sector from riverbed, by observing the longitudinal development (fig. 8), by computing of slope for each homogenous part, by studying of cross section in each existing point, by analyzing of water level and its variation mode too, in concordance with cross development of the riverbed, by quickly computing of level differences between successive sections etc.

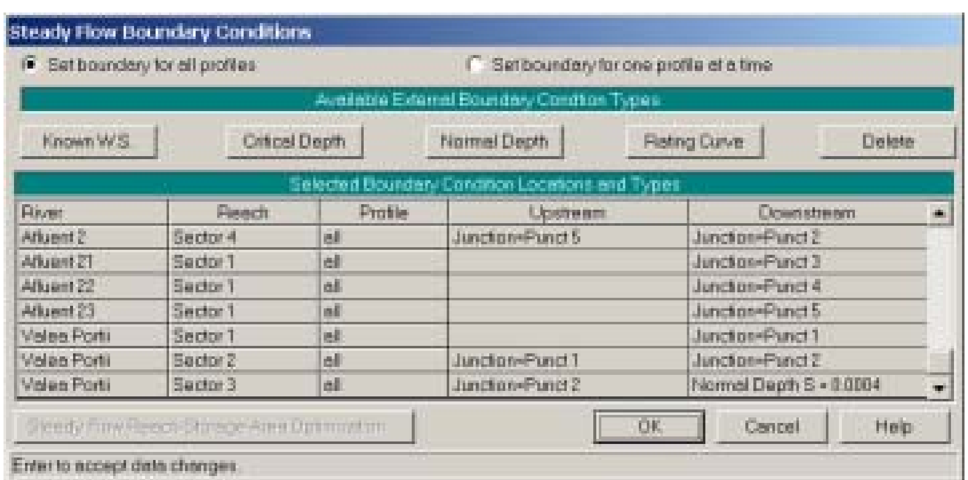

Fig. 6. Imposingness of conditions in calculable section

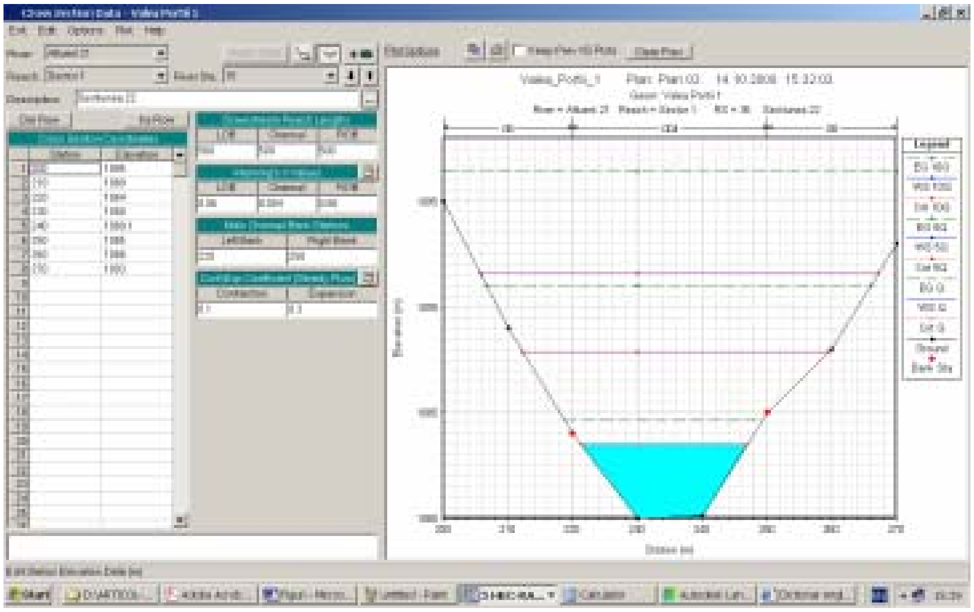

Fig. 7. Level of water in a cross section

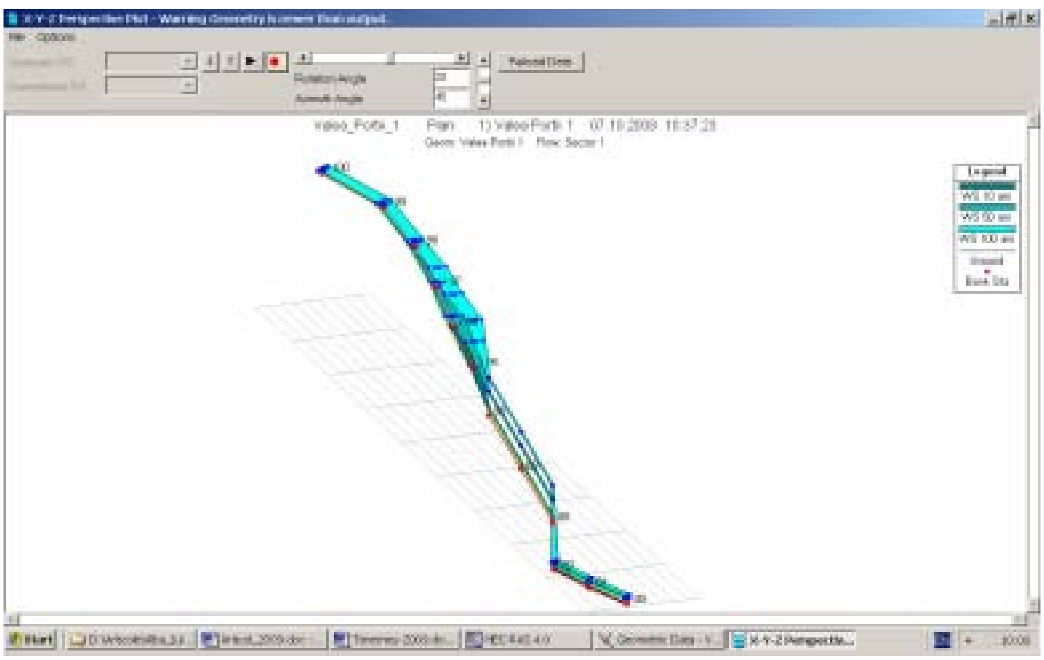

Fig. 8. Development of riverbed in space

## 6. Conclusion

The decisions of this scientific work go in two directions, at least:

a. Utilization of AutoCAD software to calculate the main morphometrycal parameters and to forecast the maximum flow capacity of high-water, offers many advantages as follow:

- possibilities for a easy elaboration of digital model of the land (Tereşneu, 2005, Tereşneu and Brad, 2006), this being the start for the next calculations;
- utilization of Watershed function gives also the possibility for a correct delimitation of the torrential watershed that is base on general directions of trickling the function considers only the units with depression type (which demonstrate by due directions of trickling that bring a contribution in the current watershed). In the cases of nearby watersheds, a special importance has to give areas with flat type that will be distributed in one or another watershed depending on their affiliation weight;
- automatic estimation of a morphometrycal parameters that are very important (surface, mean altitude, mean slope etc.) with the elaboration of digital model of land.

In conclusion, the computing of morphometrycal parameters of a torrential watershed and the forecast of its maximum flow capacity of high-water are achieved in AutoCAD with less effort than classical method and with a high accuracy and quality of results.

b. Knowing the value of maximum flow capacity of high-water and with metric measurements specifically on torrential watershed (minimum three cross sections), using HEC-RAS software, the level of water can be obtained in each point of the riverbed and in this way the risk map of flooding can be elaborated for studied area, the last being data used by governmentally or locally administrative organization to provide the administration of crisis conditions in case of effective or potential flooding (***, 2003).

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