European Journal of Science and Theology, April 2013, Vol.9, No.2, 233-242

THE ASSESSMENT OF THE CULTURAL HERITAGE'S VULNERABILITY TO FLASH FLOODS IN BAHLUI RIVER BASIN, IASI COUNTY

Irina Dana Tutunaru*, Tudor Viorel Blidaru and Ionuț Claudiu Pricop

Prut Bârlad Water Basin Administration, 10 Th. Văscăuțeanu Str., 700462, Iasi, Romania

(Received 25 June 2012, revised 10 February 2013)

Abstract

Floods are natural phenomena with significant impact on population, material goods and landscape. Flash floods are characterized by a high degree of risk, primarily due to reduced possibilities to make effective forecasts, but also because of weather and climatic characteristics that changed in the last decades, thus limiting the possibilities of application of appropriate defense and adaptation measures.
In this context, the paper aims to make a preliminary assessment of vulnerability to flash floods, using hydrological simulation models based on GIS techniques applied in sub-basins, allowing a ranking of risks within relevant locations, especially concerning the cultural heritage in the county of Iasi. The development of methods for addressing such conditions creates the scientific basis for planning the required resource allocation for the protection of the cultural heritage hence for the implementation of water resources management plans and territorial development plans.

Keywords: flash floods, cultural heritage, GIS, hydrological simulation

1. Introduction

It is a well-known fact that each nation is defined, amongst other, by its history, its religious beliefs and its culture. Iasi city and Iasi County contain a large number of monuments and historical sites classified as cultural heritage, which cover a long historical period, from the famous Cucuteni culture to the medieval churches, from the Iron Age until the 20th century. Subject to degradation due to the passage of time and many other inherent factors in human settlements development, the historical artefacts that define the personality of the area are also under threat from natural hazards of different types.

The importance of the cultural and historical heritage in relation with the socio-economic development of a community led to its protection and inclusion as part of strategies for sustainable socio-economic development at national and

* E-mail: irina.tutunaru@dap.rowater.ro

local level, as specified in Law 422/2001 on the protection of historical monuments (amended and supplemented).

Actions to restore and/or conserve the heritage require the analysis of the damaging factors for each objective separately. Using scientific methods to conduct such analysis is likely to provide good reasons for decisions based on technical and economic evaluation of programs and measures needed in this field.

One of the main environmental damaging factors is represented by flood, especially the flash floods that are more difficult to forecast and manage. Floods are natural phenomena with significant impact on population, material goods and landscape.

Flash floods are characterized by a high degree of risk, primarily due to the reduced possibilities to make effective forecasts, but also because of the weather and climatic characteristics that changed in the last decades, thus limiting the possibilities of application of appropriate defence and adaptation measures.

Directive 2007/60/EC on the assessment and management of flood risks, transposed in Romanian Legislation by Water Law 107/1996 (modified and supplemented by G.O. 3/2010, Governmental Decisions 447/2003 and 846/2010) aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity.

The Bahlui River is the main water course located entirely within Iasi County. The risk of flooding is accordingly associated both with the main course of the river and with the water courses representing its tributaries. In the following paragraphs a series of features of Bahlui river basin and the risk of flooding in this basin will be defined.

2. Study area

With its basin surface of about 2,023 km², Bahlui river is the largest tributary of Jijia river. From the administrative-territorial perspective, the whole surface of the basin belongs to Iasi County, except for its north-western extremity [1]. The most northern point of the Bahlui river basin is Perisorului Hill (376.0 m altitude), marked by the 47°32’56” parallel; the 47°00’01” parallel indicates the most southern point of the basin, situated in the area of the Floroaia forest (369.2 m altitude). The western extremity is delimited by the 26°41’49” meridian, on the Tudora Hill (586.0 m altitude), and the eastern extremity is given by the 27°44’17” meridian, in the confluence point of Bahlui and Jijia Rivers, at an absolute altitude of 35 m. The length of the hydrographical network exceeds 3,100 km, out of which 119 km are included in the main river.

From a geo-morphological point of view, the Bahlui river basin belongs to the Moldavian Plain, part of the Moldavian Table. The plain of the Bahlui river and the lower part of the Jijia river catchments area jointly form the southern part of Moldavian Plain. It mainly consists of clayey-marly and sandy deposits, covered by alluvial fans. Intense corrosion and landslides are common.

The described area is characterized by a temperate-continental climate. Temperatures in the Bahlui catchment area range between extremes of -30^{0}C to 40^{0}C with monthly averages ranging from -2 to -3^{0}C in the winter to 18-20^{0}C in the summer. The yearly average precipitation varies from 400 to 500 mm. In the spring and summer precipitation is highest due to frontal and thermal activity. Intensive convective rain showers are common during the warm summer months.

The months with the richest precipitations are May and June, sometimes July when the recorded precipitation is 75 mm monthly. 25-35 mm per month fell from December to March. Characteristic for Iasi's climate are the summer torrential rains. The lack of rainfall for more than 10-14 days may lead to drought. Podu Iloaiei–Vladeni and Harlau-Probota areas are prone to repeated or prolonged droughts.

The most important tributaries of Bahlui river are the following: Buhalnita Magura, Bahluiet, Voinesti on the right; Gurguiata, Totoesti, Bogonos, Cacaina, Ciric, Chirița, on the left side of the river.

3. Research method

Factors generating flash floods and/or worsening flooding conditions:

- physiographic factors (influencing the production function and the transfer function);
- anthropic interventions (lack of anti-erosion measures, deforestation and abandoned wood offal on the slopes, inadequate agricultural practices, extensive use of flood prone areas including buildings and deposits close to the river bed).

The preliminary screening of Small Basins Generating Flash Floods based on the Physiographic method [2] uses extensively GIS maps [ESRI USA, ArcGIS 9, *Getting Started With ArcGIS*] for Bahlui river basin, including:

- Sub-basins (till the 6th order, with surfaces of 200 km^2 maximum),
- Land use,
- Soil map.

The workflow mainly achieves the information overlaying these three layers and obtaining the digital map of Curve Number (CN from SCS model). CN values, characterizing the hydrologic soil groups, as presented in Table 1 [3].

For a given river basin, CN global index is rated as the weighted average of partial surfaces F_i, characterized by CN_i index. Based on this map, the concentration time is computed as shown in Figure 1.

$$T_{LAG} = (3{,}28084 * L)^{0{,}8} * \frac{(S+1)^{0{,}7}}{1900\sqrt{I_B}} \quad (1)$$

$$S = \frac{1000}{CN} - 10 \quad (2)$$

Table 1. Curve Number (CN) values.

Description of land use	Hydrologic soil group			
	A	**B**	**C**	**D**
Paved parking lots, roofs, driveways	98	98	98	98
Streets and roads				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Cultivated (agricultural crop) land				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contours)	62	71	78	81
Pasture or range land				
Poor (<50% ground cover or heavily grazed)	68	79	86	89
Good (50-75% ground cover; not heavily grazed)	39	61	74	80
Meadow (grass, no grazing, mowed for hay)	30	58	71	78
Brush (good, >75% ground cover)	30	48	65	73
Woods and forests				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83
Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77
Open spaces (lawns, parks, golf courses, cemeteries, etc.)				
Fair (grass covers 50-75% of area)	49	69	79	84
Good (grass covers >75% of area)	39	61	74	80
Commercial and business districts (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential areas				
1/8 Acre lots, about 65% impervious	77	85	90	92
1/4 Acre lots, about 38% impervious	61	75	83	87
1/2 Acre lots, about 25% impervious	54	70	80	85
1 Acre lots, about 20% impervious	51	68	79	84

Parameters that appear in Figure 1 are listed below:
T_C – concentration time (hours) - period of time required for storm runoff to flow to the outlet from the point of a drainage basin having the longest travel time;
T_{LAG} – lag time (hours) is the period of time between the peak of a storm event and the flood peak;
L – length of main river bed (m);
I_B – average slope of the basin %;

S - maximum storage capacity [*Iowa Stormwater Management Manual*, 2C-3 *Time of Concentration*. Version 2; December 5, 2008].

Both L and I_B are obtained based on processing GIS maps using an appropriate scale. As a result of this procedure, the identification of basins having Tc < 6 hours is obtained. As recommended in literature, a time of concentration smaller than 6 hours represents a significant hydrologic risk to flash floods [2, p. 2]. By overlying the GIS map of historical monuments, those vulnerable at flash floods will be indentified.

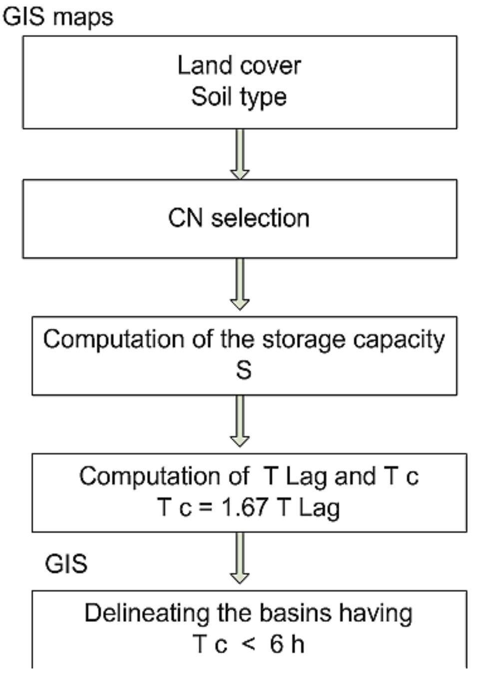

Figure 1. Physiographic method steps.

4. Case study

As mentioned in the chapter above, it is necessary to overlay the following data, in GIS format:

- Sub-basins - the layer used is in vector format, polygon data. In the Romanian Waters Cadastre, published in 1992, there are 49 sub-basins in Bahlui river catchment's area, 48 of tributaries till 6^{th} order plus the Bahlui own river basin; their minimum surface is about 8 km^2 and the maximum is of 120 km^2, with an average of 33 km^2. Attributes associated to this vector layer are lengths of rivers, areas, the average slope and average altitude of river basins, etc.
- Land cover – it was used the Corine land cover 2005 shape file, polygon data, as can be seen in Figure 2 using Engels notation for land cover types.

- Soil structure - a layer containing the soil structure; the main soil groups, as they are sandy, various texture, sandy-clay, silty clay, etc., were regrouped by their consistence in light, medium and heavy texture, as shown in Figure 3.

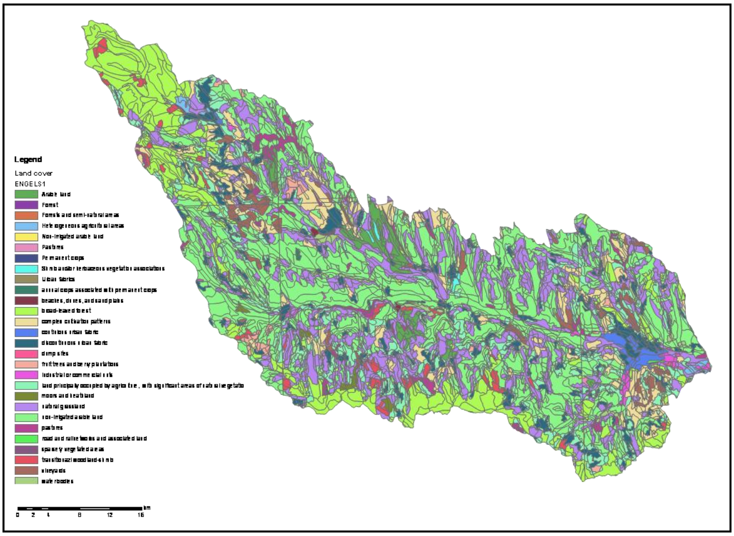

Figure 2. Bahlui river basin – land cover.

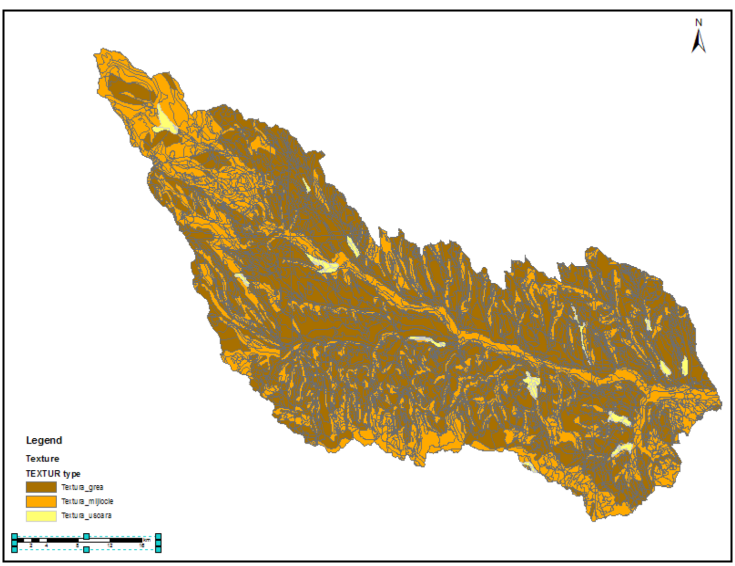

Figure 3. Bahlui river basin – soil structure.

By spatial analysis over those information layers, the CN values were computed for each subdivision of sub-basin surface (CN_i); corresponding to those parameters the Tc_i was obtained and finally the Tc for each sub-basin, as seen in Figure 4. All basins having a value of the concentration time under 6 (hours) are considered to be vulnerable at flash floods (colored in light blue in Figure 4).

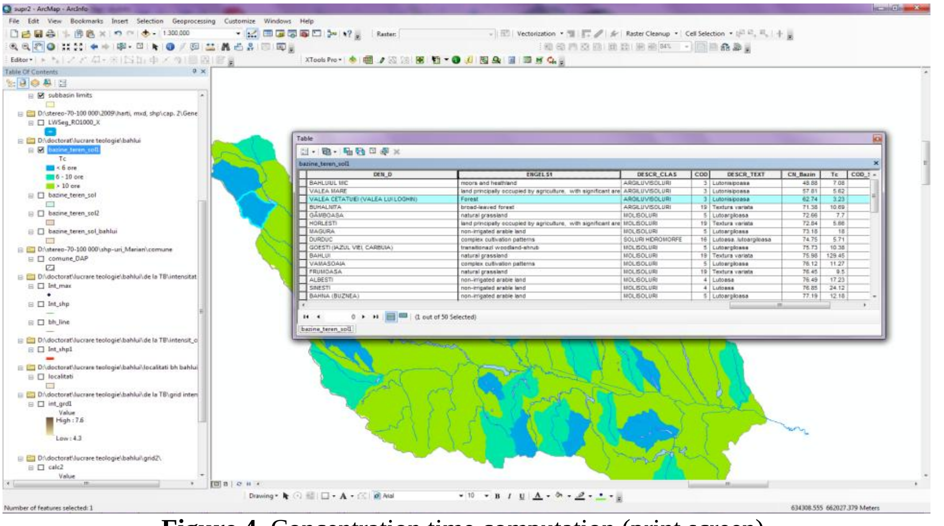

Figure 4. Concentration time computation (print screen).

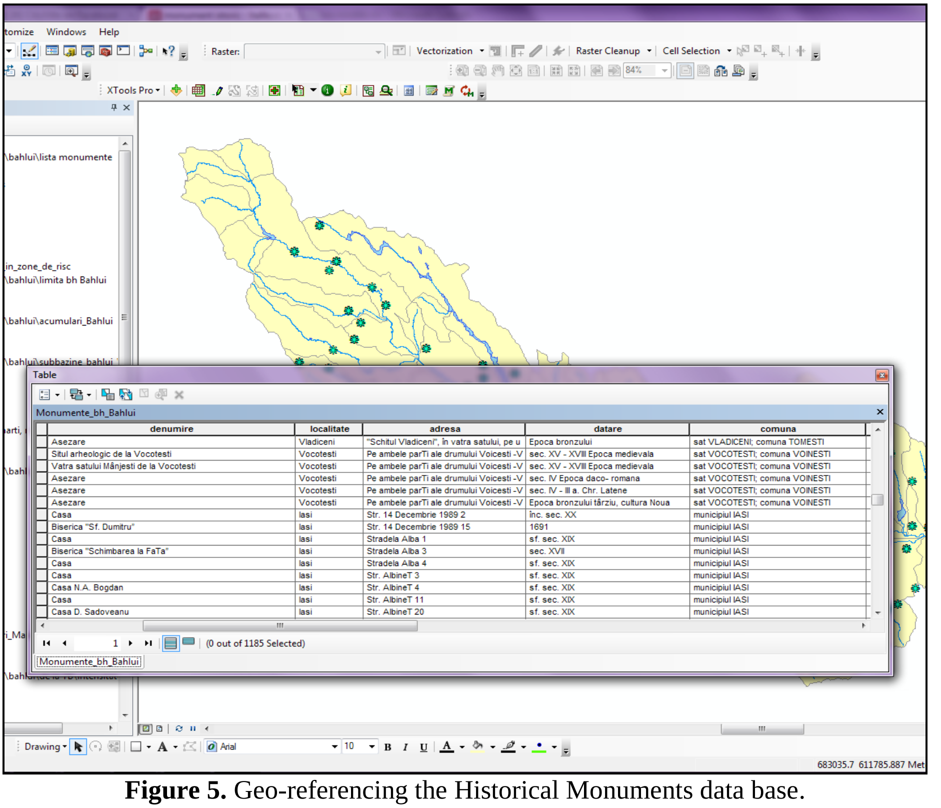

Figure 5. Geo-referencing the Historical Monuments data base.

4.1. Historical monuments

The National Register of Historic Monuments in Romania includes sites, buildings, structures, and objects considered worthy of preservation due to their importance for Romanian cultural heritage. The list of monuments was published in the Annex of Ministerial Order no. 2.361/2010 to amend the Annex 1 to the Order of the Minister of Culture no. 2314/2004, approving the list of historical monuments. According to this list, in Iasi County, there are 1630 historical monuments, from each 1187 monuments in Bahlui river basin area. For being used as GIS layer it was necessary to geo-reference the data base containing the list, using the objective locality coordinates, as seen in Figure 5. Each object has an LMI code (List of the Historical Monuments code) that uniquely identifies historical monument or archaeological site, and includes, in this order:

- Romanian county code/acronym, using ISO 3166-2:RO;
- letters indicating the importance of the monument (e.g. ImA); group A contains historical monuments of universal and national value, group B contains historical monuments representative for local cultural heritage;
- a serial number (e.g. 00001.01).

As a first result it can be mentioned the creation of a georeferenced map of the historical monuments disposal in Bahlui river basin (Figure 6). By overlapping the layer containing the historical monuments with the layer containing the spatial distribution of the concentration times values, in which those sub-basins having T_C lower than 6 hours were selected, a new layer containing only those historical monuments located in flash flood vulnerable areas is created.

5. Results and discussion

The historical monuments included in the vulnerable to flash floods areas from the Bahlui river basin are presented in Figure 7. They are 8 localities in which are placed 21 objectives. All these monuments are included in B group.

Hydrological analysis' results, correlated with the cultural heritage locations show that, unlike the locations for medieval churches and defence construction sites, which generally have a protected placement site - on hills or dominating heights, the ancient settlements, medieval hearths, etc., directly related to water supply needs of the populations of that time, are generally located – similar to contemporary settlements - near watercourses. It can be seen that there are relatively many locations in this situation. Field studies are likely to bring additional information in this regard.

It is also important to notice that on several locations in Bahlui river, catchment hydraulic structures for flood defence, managed by Prut – Barlad Water Basin Administration, are in place and operational.

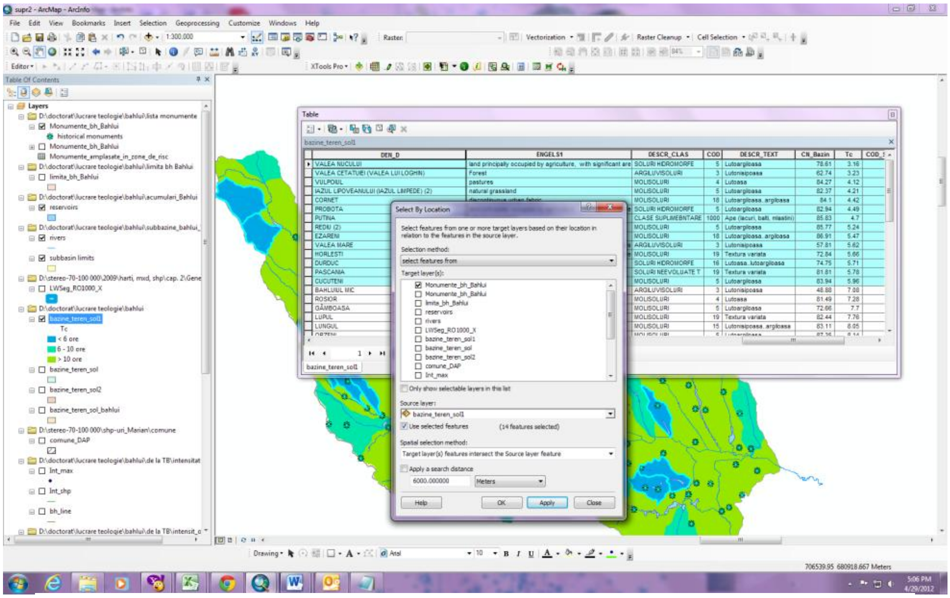

Figure 6. Selecting the historical monuments within vulnerable to flash flood sub-basins.

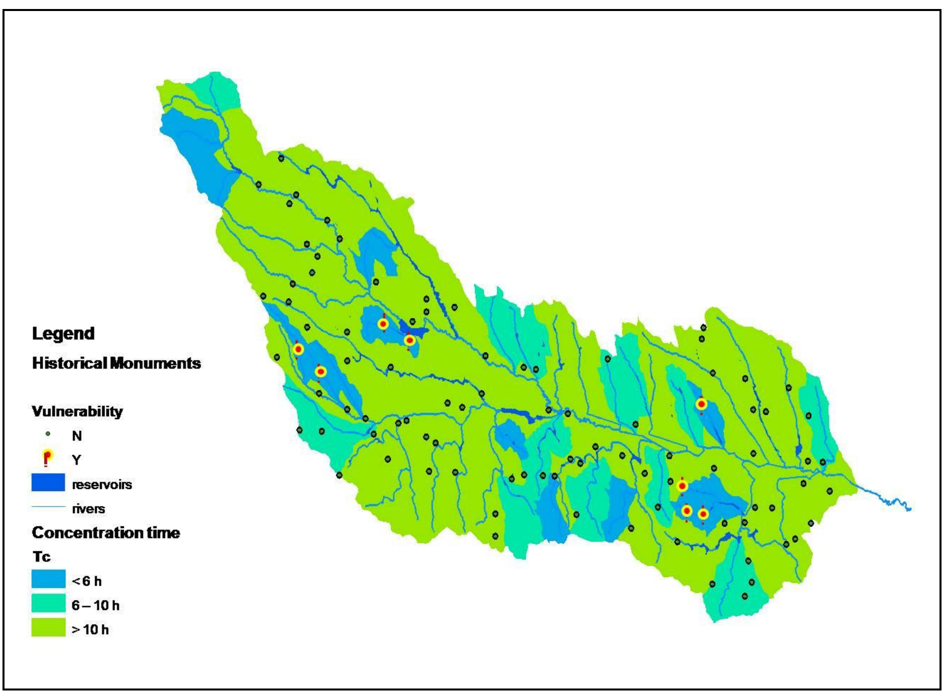

Figure 7. Historical monuments situated in vulnerable at flash floods basins.

5. Conclusions

Analysis could be further developed from a theoretical point of view, both by using different/complementary hydrological parameter estimation methods of flood characteristic for the study area, and dedicated software simulations. Despite difficulties in determining accurately the specific hydrological parameters for the studied sub-basins and proper assessment of weather-related parameters, the complete hydrological study is likely to provide a clear quantitative evaluation, which, among other means, may represent an effective support for decisions concerning the cultural heritage.

This research can be completed and correlated with other methods such as GIS mapping of historical sites, risk analysis relative to other natural and/or anthropogenic factors, procedures based on multi-criteria analysis.

References

[1] A. Mihu-Pintilie and G. Romanescu, Present environment and sustainable development, **5(2)** (2011) 15.
[2] ***, Monitorul Oficial, **647(1)** (2008) 23.
[3] V.T. Chow, D.R. Maidment and L.W. Mays, *Applied Hydrology – Civil Engineering*, Mcgraw-Hill, New York, 1988, 175.