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# Urban runoff management in order to reduce flood risks (case study: phase 2 of the new city of Hashtgerd)

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**Abstract**

Flooding in urban areas due to the defect or any inefficiency in urban drainage systems causes great damage to public and private buildings and other infrastructures. Therefore, in order to management of runoff, phase 2 of the new city of Hashtgerd was selected. To simulate the rainfall-runoff process, SWMM model was used. Eight factors including percentage of impervious area, slope, width, percentage of impervious area without surface storage, n-Manning's coefficient of impervious areas, n-Manning's coefficient of pervious areas, depth of depression storage on pervious and impervious areas were investigated. Results of model sensitivity analysis showed that n-Manning's coefficient of impervious areas, width, slope and percentage of impervious areas were more effective in changing the peak flow. According to the results, the possibility of flooding is low due to the barren lands and high permeability of the study area and it is more important in areas near the basin outlet. However, with regard to the urban sprawl in recent decades, city residents and officials will suffer from flooding in future. Therefore, this model could be used for predicting the risk of flooding, drainage design and cost estimate, urban management, and identifying priority areas for flooding problem.

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## Introduction

Annually, the life and property of the people are threatened by floods around the world. Changes in land use, increasing urbanization, non-methodical constructions, old sewage system, and development of impervious lands in urban areas have significant effects on the incidence of this risk. According to figures released by the United Nations, among natural disasters, flood has inflicted the most damage to human, as one third of the economic losses of natural disasters are related to flood and two thirds of the world's population is directly or indirectly affected by its consequences (Omidvar *et al.*, 2006).

Increasing urbanization in recent decades and the rapid growth of cities towards the upstream watersheds, also climate change and its effects on spatial and temporal patterns of precipitation have strongly influenced rainfall-runoff process in urban areas. Urban development is generally associated with an increase in impermeable surfaces such as roads and rooftops, construction of hydraulic drainage systems of the runoff caused by cloudburst, soil compaction and the change in the vegetation of the region. Urban development also leads to contamination of water due to suspended sediments, heavy metals, hydrocarbons, nutrients and pathogens (Burton and Pitt, 2001). Complexity in urban areas and drainage infrastructure of urban watersheds has a potential impact on natural runoff (Chen *et al.,* 2009).

Since almost all cities of Iran have been spread on alluvial fans, small and large basins or watersheds are entered from marginal mountains. Urbanization with indirect involvement within these watersheds leads to disrupting the balance of hillsides, removal of vegetation, soil compaction, and changes in the profile of the stream, and increases the severity of sudden floods and sediment volume (Hoseinzadeh and Jahadi toroghi, 2007).

Development of towns, cities and improper construction of collection networks and surface water disposal lead to maximum flood discharge and this may increase the risks and damages to the towns located downstream of the region (Sanjari, 2010).

Urban runoff management includes control of runoff and modification of drainage systems. High-intensity rainfalls, reduced permeability due to urban development and runoff collection systems with long life are of the main reasons for occurrence of floods in urban areas (Radmehr, 2010).

To reduce the consequences and adverse impacts of the mentioned cases, correct design and providing sufficient capacity for collection networks and surface water disposal are necessary. This requires a simulation using an appropriate model. Among the various methods for estimating surface runoff, Storm Water Management Model (SWMM) is the best method used in most studies of urban runoff. Ahmadi *et al.*, (2007), investigated the quality of surface water collection network in City of Masaal in west of Guilan province through stimulation of surface water collection network by using MIKE SWMM. The results of this study indicated that the use of the mentioned software for simulation and optimization of runoff collection and disposal systems is suitable for urban flood management. To stimulate surface drainage network conducted in MIKE SWMM, Fallah Tafti *et al.,* (2008) determined the height of the runoff, outflow hydrograph of sub-catchment and another set of input parameters with linear and nonlinear reservoir equations and with the help of GIS software. Finally, flood storage area was determined by evaluation of the system performance against a rainfall. They showed that the results were effective in design of runoff disposal systems and optimization and management of urban runoff. Tajbakhsh *et al.*, (2009) reviewed the urban runoff collection system by MIKE SWMM in east Eqbal catchment (basin) of Mashhad. Analysis of precipitation network showed that six runoff transfers had deficiency and flood occurred. Sharifian *et al*., (2009) studied the simulation of one of the sub-catchments of Shiraz through SWMM for selected return periods (three years for subsidiary network and 10 years for main network). Final results of simulation showed the inefficiency of drainage system in some parts of the network and corrective strategies were also presented.

Peterson and Wicks (2006) used SWMM to estimate physical parameters like size of aqueduct (waterways) in Karstic system at central Missouri, and the accuracy of the results was confirmed. Dongquan *et al.,* (2009) applied SWMM and GIS to simulate rainfall and runoff of Macau's urban area. The results showed that the use of GIS was very useful to acquire some important parameters of SWMM, and SWMM has a considerable flexibility when adequate parameters are available. Gironas *et al.,* (2010) studied new applications of SWMM and showed that this model was widely used for quantitative and qualitative urban runoff simulation.

The purpose of this research was to study the drainage system of phase 2 of the new city of Hashtgerd and its suitability with urban flooding resulted from rainfall using SWMM software and also investigation on adequate ability of drainage systems for runoff disposal.

## Materials and methods

*Study area*

Phase 2 of the new city of Hashtgerd with an area of 372 hectares is the best new city in terms of settlement principles, comfort and health issues (according to the Department of Housing and Urban Development, 2005). The study area is located in Savojbolagh and Tehran province, surrounded to the southern slopes of the Alborz Mountains, Hashtgerd city, Qazvin province, and cities of Kordan and Karaj, from the north, south, west and east, respectively. It is located between latitudes 35° 59′ and longitudes 50° 44′. It should be noted that water does not enter the basin form the upstream part of the study area (Fig.1.).

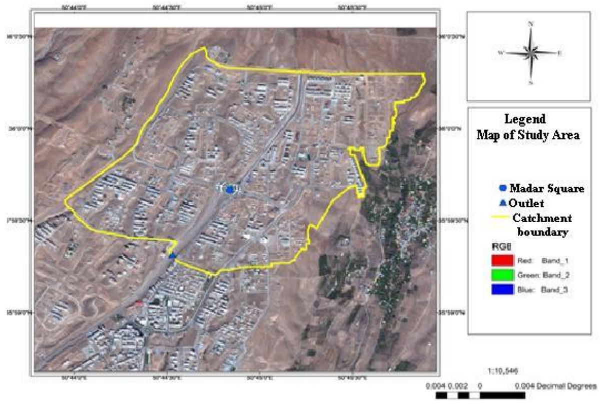


**Fig. 1.** Image of the study area (Phase 2 of the new city of Hashtgerd).

Due to the consideration of all Hydrological parameters affecting urban runoff, SWMM was used In order to simulate urban runoff.

*In this study, the process was summarized as follows:*

1- Determination of catchment and sub-catchment boundaries

2- Calculation of parameters needed for SWMM including width, n-Manning's coefficient of impervious and pervious areas and channels, depth of depression storage on pervious and impervious areas, infiltration rate, the data needed for connections, data of runoff drainage system, meteorological data and hydrological data.

3- SWMM sensitivity analysis

*To calculate runoff with different return periods as input of the hydraulic model, it is needed to calculate rainfall intensity summarized as follows:*

Calculation of watershed time of concentration

2- Calculation of design rainfall

- Intensity - Duration – Frequency (IDF) curves

- Intensity – Duration equations

-Temporal distribution pattern of rain storm and hyetograph of the catchment.

After calculating the design rainfall with return periods of 2, 5, 10, 25 and 50 years, corresponding runoff was calculated using the SWMM model.

Entering the characteristics of subbasins in SWMM
Characteristics of subbasins are presented in table 1.

**Table 1.** Characteristics of subbasins in SWMM.

| | |
|---|---|
| Output point of subbasin | Longitude coordinates |
| Percentage of impervious area | Latitude coordinates |
| n-Manning's coefficient of pervious area | Area (ha) |
| n-Manning's coefficient of impervious area | Width (m) |
| Depression storage of pervious area (mm) | Slope (%) |
| Depression storage of impervious area (mm) | Permeability model |

According to the characteristics and drainage network map, characteristics of nodes (The intersection points) entered to SWMM are presented in table 2.

**Table 2.** Characteristics of nodes in SWMM.

| | |
|---|---|
| Height of node | The maximum The maximum depth of the current node (m) |
| Unit of flow measurement | ponding level of the current node |
| Routing method | aqueduct length (m) |
| Roughness of aqueduct | Geometric diagram of aqueduct |

*Determination of watershed and subbasins boundaries*
After field visits and matching AutoCAD Map of the area (at a scale of 1:1000) and topographic maps and satellite images with study area Due to the location of streets, houses and Shielding of the city, watershed boundary was determined. To simulate rainfall – runoff, GIS system was used. After field studies and using the map, it was found that phase 2 of the new city of Hashtgerd is surrounded by barren lands from the north and east and is surrounded by other phases from the west and south. As a result, common border of the blocks with barren lands and other phases was selected as the basin boundary. The study area was divided into 95 subbasins.

*Calculation of parameters needed for SWMM*
*Determination of roughness coefficient and depth of depression storage on pervious and impervious areas and channels*
The use of supplementary tables is the most practical method for estimating the value of n.
An example of this table with the necessary explanations is available in the model guide. In current study, these tables were used to estimate roughness coefficient as well as depth of depression storage on pervious and impervious areas and channels.

*Physical characteristics of subbasins*
The area, width and slope of subbasins were calculated using ArcGIS software. The percentage of impervious areas was calculated using land use map and satellite images.

*Time of concentration*
Watershed time of concentration is one of the most important parameters effective in rainfall–runoff simulation and the Hyetograph of design rainfall is obtained based upon this parameter. Rainfall duration time was assumed equal to Watershed time of concentration.

In this study due to the small size of the study area (watershed), California equation was applied to estimate the time of concentration. It was calculated as 36 minutes.

*SWMM sensitivity analysis*
In current research, sensitivity of rainfall - runoff model was investigated by absolute-sensitivity analysis. For this purpose, eight factors including percentage of impervious area, slope, width,

percentage of impervious area without surface storage, n-Manning's coefficient of impervious areas, n-Manning's coefficient of pervious areas, depth of depression storage on pervious and impervious areas were selected. Peak flood discharge was selected as dependent variable as the most effective parameter to estimate flood. A 40-minute design rainfall with a return period of 25 years was used for sensitivity analysis. By changing the parameters the model was implemented and the results were recorded and their effects on the basin outlet peak flood discharge were measured.

*Calculation of design rainfall*

*Intensity - Duration - Frequency (IDF) curves*

According to Bell (1) precipitation was estimated as follows:

Bell Equation-

(A)

$$p^{t}_{T} = \left(0.52 + 0.21\ Ln\ (T)\right) \times \left(0.54 t^{0.25} - 0.5\right) \times P^{60}_{10}$$

(B)

$$p^{60}_{10} = 2.2598\ X_1^{1.1374} \times X_2^{-0.3072}$$

Equation (A) is used to estimate rainfall for 5 to 120 minutes with return periods of 2 to 100 years with regard to one hour rainfall with a return period of 10 years.

In which $p^{t}_{T}$ is amount of rainfall (mm) in a duration time of t minute and a return period of T year.

Finally, after entering all data in sub-basins (sub-catchments), connection points, channels, outlets, and also entering rainfall data to the model, SWMM was run.

**Results**

TIN map was prepared using ArcMap software, and area, slope and height classes were calculated (Fig.2.).

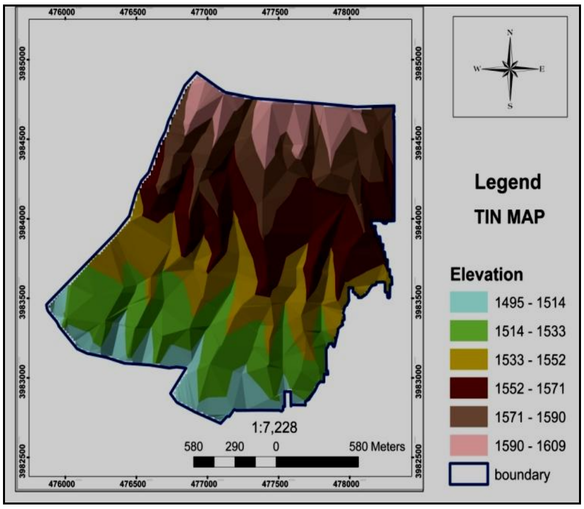


**Fig. 2.** TIN map of the study area(Phase 2 of the new city of Hashtgerd).

*Channels data*

Channels data included channel No, upstream and downstream node No, channel length, channel depth, channel width, shape and n-Manning's coefficient. Crossing of waterways in upstream and downstream was considered as nodes. Parameters of length and n-Manning's coefficient were obtained by GIS and SWMM, and depth, width and shape of the channel (waterway) were obtained through field studies.

*Nodes data*

Nodes data included node No, maximum depth and node level. Maximum node level (1597 m) and maximum depth (0.45 m) were recorded for node No. 4 and minimum node balance (1509 m) and minimum depth (0.1 m) was obtained for node No. 142. The name of node in SWMM and node level was obtained by GIS, and the maximum depth of node was recorded through field studies and SWMM.

*Results of sensitivity analysis*

For model sensitivity analysis, the initial values of the eight parameters were reduced 10% and 20% and then model was run. This was done in a return period of 25 years for the entire basin (watershed) and the model was run 40 times in total. For example, if the roughness coefficient of impervious areas increases up to 20% and other parameters remain constant, peak flow (flood) will decrease -1.1%. Results of model sensitivity analysis are presented in fig.(3.-5.)

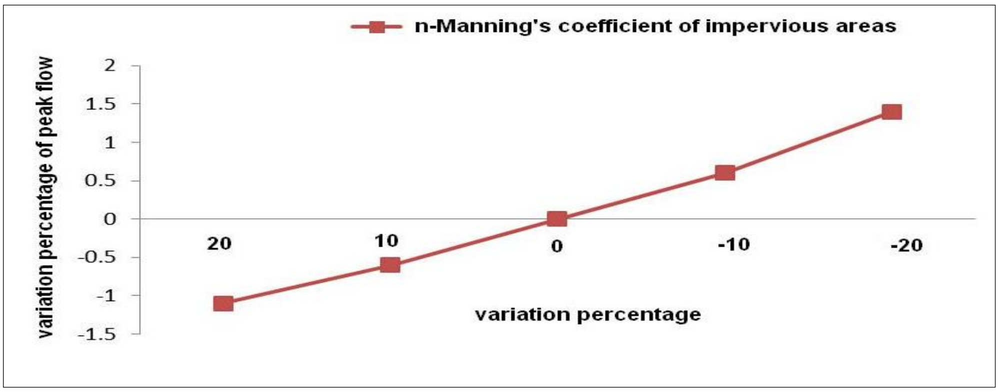


**Fig. 3.** variation percentage of n-Manning's coefficient of roughness in impervious areas and its effect on peak flow.

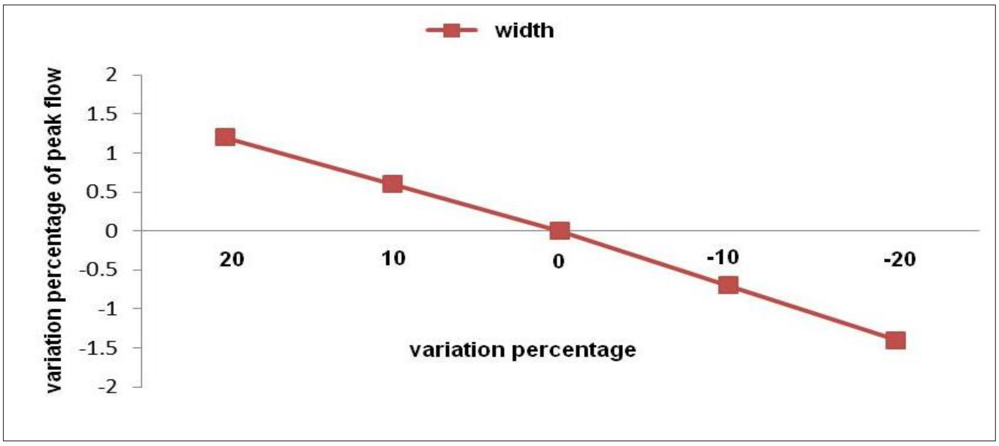


**Fig. 4.** Variation percentage of width and its effect on peak flow.

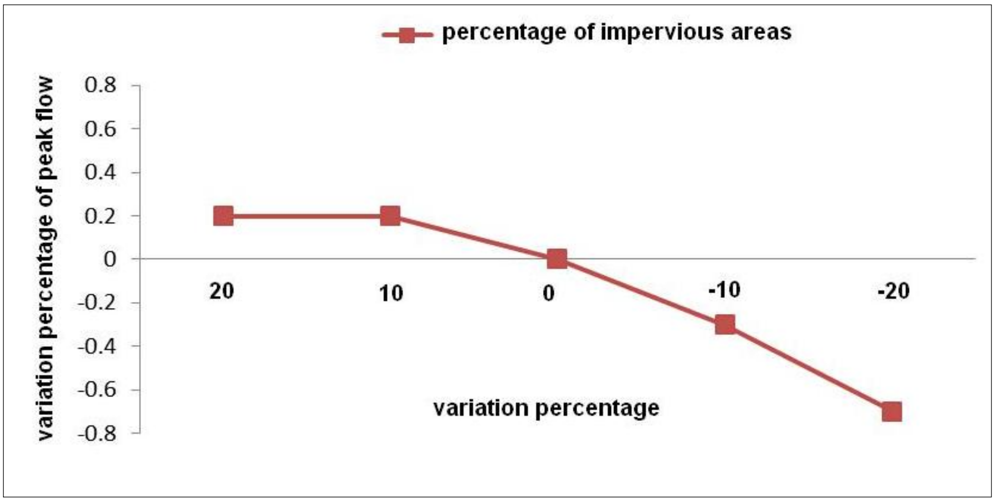


**Fig. 5.** Variation percentage of impervious areas and its effect on peak flow.

According to the results, n-Manning's coefficient of impervious areas, width, slope and percentage of impervious areas had the greatest effect on peak flow, respectively (Fig 3.-5.).

**Discussion**

Our studies showed that Phase 2 of Hashtgerd City was located in a steep region with an average slope of 12%. Sixty percent of the study area was under the cover of pathways and buildings. The mean annual precipitation was 265 mm and maximum rainfall intensity in 2, 5, 10 and 25-year return periods were 175.06, 268.67, 329.63, and 406.38, respectively. Given the facts above and atmospheric characteristics, urban runoff management is of utmost importance in order to prevent damages caused by flood.

According to field studies, a part of the City is not fully developed and also developed regions are located beside the barren lands. Meanwhile, many residential complexes have absorbed wells which runoff from the roof of these complexes is directed to the wells. Consequently, runoff production and areas that will be flooded is low. Also, in some parts of the city houses are in the shape of villa and runoff enters into the city's drainage system. As a result, these regions will be flooded in return periods more than 10 years.

Urban development is more in downstream of the City (southern side of the basin) and the possibility of flooding is higher due to impervious areas (commercial, residential, streets, petrol stations and so forth). To solve this problem, runoff can be calculated according to different return periods and also pervious areas could be increased by increasing the number of urban green spaces. This result is in agreement with results of Lager and Smith (1974).

In general, to determine the relationship among model variables and also priorities of the parameters on model output, sensitivity analysis was used.

Certainly, knowledge on the internal relations of any model parameters helps to understand the relationships of parameters and determine the sensitivity of model in different points and thus a better application of the model is provided in order to further its efficiency (Kousari *et al.,* 2010).

Among eight factors studied in this research, n-Manning's coefficient of impervious areas, width, slope, and the percentage of impervious areas had the most impact on the variations of peak flood, respectively. The reason can be attributed to the physical nature of the basin and it is consistent with results of (Dalir, 2009 and Falahtafti, 2005).

According to the fact that SWMM considers hydraulic and hydrological characteristics of waterways and nodes and physical characteristics of hydrological subunits, the calculations made by this model are more precise than those of experimental models and methods such as curve number (CN) because CN method is able to identify critical points and waterways.

These results are in agreement with results of other researchers (Ahmadi *et al.,* (2006) Falahtafti *et al.,* (2007) ‹Peterson and Wicks (2006) ‹Dongquan *et al.,* (2009) ‹Gironas *et al.,* (2010).

One of the main causes of flooding in urban passages is dumping garbage in the ditches by the citizens and blocking streams by construction debris that lead to flooding and health problems. This is gaining more importance when drainage system is not efficient enough for runoff discharge.

As stated above, n-Manning's coefficient of impervious areas, width, slope, and the percentage of impervious areas were identified as influencing factors on increased surface runoff. Among these factors under current conditions, it seems that no serious changes could be done in relation with slope of the region, impervious areas affected by the asphalt of the streets and width considering the formation of constructed buildings and existing

land uses. But bed roughness coefficient is of the the factors that could be increased somewhat through the management of inhibitory effects. Municipal wastes especially bulky wastes such as bottles of soft drinks and mineral water that easily move with water flow and are accumulated, are inhibitory factors which leads to prevent water movement.
It seems that the ease of municipal waste discharge should be considered in addition to the calculation of the dimensions of water transfer channels based upon flow rate.

In addition, municipal waste management should also be efficient with regard to the above considerations.

**Suggestions**

With regard to the results of this study, the following suggestions are recommended.

1. Soil erosion in upstream has created numerous valleys which should be considered in design of north-south streets.

2. Due to the greater volume of runoff towards south and downstream, construction of medium to large channels and deep ditches with adequate width and slope are necessary to collect and conduct surface water.

3. Trees and green spaces along streets are good potentials to direct excess runoff. Along all streets, there are water-conducting channels that the excess water runoff can be diverted into green spaces and thus optimum utilization as well as increased penetration is provided.

**Acknowledgement**

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**References**

**Ahmadi Z, Fazl oula R, Shahnazari A, Ashrafzadeh A.** 2006. Evaluation the performance of urban flood drainage system using computer simulations (case study: Masal). Second Conference on Water Resources Management.

**Burton Jr, GA, Pitt, R.** 2001. Storm water Effects Handbook: A Tool Box for Watershed Managers. Scientists and Engineers, CRC/Lewis Publishers, Boca Raton, Florida.

**Chen J, Hill AA, Urbano LD.** 2009. A GIS-based model for urban flood inundation. Journal of Hydrology **373,** 184-192.

**Dalir E.** 2009. The simulation of the function of sewerage network during the rainfall using the integrated model MIKE SWMM and Arc view (Case Study: A part of the sewage network in Mashhad). M.Sc. Thesis of Civil Engineering, Ferdowsi University of Mashhad, 195 p.

**Dongquan Z, Jining C, Haozheng W, Qingyuan T, Shangbing C, Zheng S.** 2009. GIS-based urban rainfall-runoff modeling using an automatic catchment-discretization approach: a case study in Macau. Environ Earth Sciences **59,** 465–472.

**Falahtafti A, Sharifi MB.** 2007. The simulation of drainage network of surface runoff in Mashhad using integrated model MIKE SWMM and GIS. M.Sc. thesis of Water Engineering, Ferdowsi University of Mashhad.

**Falahtafti A.** 2005. The simulation of drainage network of surface runoff in Mashhad using integrated model MIKE SWMM and GIS. M.Sc. thesis of Water Engineering, Ferdowsi University of Mashhad.

**Hoseinzadeh R, and Jahadi toroghi M.** 2007. Effects of Mashhad urban sprawl on natural drainage pattern and intensification of urban flooding. Journal of Geographical Researches **61,** 145-159.

**Jorge gironas, Larry A.roesner, Lewis A.rossman, Jennifer d Vis.** 2010. A new applications manual for the storm water management model (SWMM). journal of Elsevier, environmental modeling and software **25,** 813-814.

**Kousari MR, Saremi Naeini MA, Tazeh M, Frozeh MR.** 2010. Sensitivity analysis of some equation for estimation of time of concentration in watersheds. Arid Biom Scientific and Research Journal **1,** 1-11.

**Omidvar B, Ghazaban F, Emami K, Khodaee H.** 2006. Flood risk management using multivariate decision method at three sub-basins of Golestan province. First International Conference on Natural Disaster.

**Peterson E, Wicks C.** 2006. Assessing the importance of conduit geometry and physical parameters in karst systems using the storm water management model (SWMM). journal of Hydrology **329,** 294-305.

**Radmehr A.** 2010. Management of urban surface runoff using spatial multi-criteria decision making method. M.Sc. thesis of Water Resources Engineering, University of Tehran.

**Sanjari M.** 2010. Urban flood management using data from the adjacent watershed and SWMM software, Case Study: A part of urban watershed at district 22 of Tehran. M.Sc. thesis, Science and Research Branch, Islamic Azad University of Tehran.

**Sharifian RA, Roshan A, Ouji MM.** 2008. Application of SWMM model in design and evaluation of collection systems and urban surface water disposal. Seventh Iranian Hydraulic Conference.

**Tajbakhsh M.** 2008. A survey on urban runoff collection system by computer simulation, Case Study: Mashhad eastern Eqbal basin. 3rd Iran Water Resources Management Conference.