

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE
ENGINEERING AND TECHNOLOGY

**LOW IMPACT DEVELOPMENT (LID) PRACTICES
IN FLOOD CONTROL OF URBAN AREAS
USING SWMM (STORM WATER MANAGEMENT MODEL)**



M.Sc. THESIS

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Department of Civil Engineering

Hydraulics and Water Resources Engineering Programme

SEPTEMBER 2019

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

**KENTSEL ALANLARDA TAŞKIN KONTROLÜNDEKİ
DÜŞÜK ETKİLİ UYGULAMALAR
(SWMM KULLANARAK)**

YÜKSEK LİSANS TEZİ

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To my family,



FOREWORD

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ABBREVIATIONS

BMP	: Best Management Practices
BOD	: Biological Oxygen Demand
DEM	: Digital Elevation Model
EPA	: Environmental Protection Agency
FFE	: First Flush Effect
GA	: Genetic Algorithm
GEV	: Generalized Extreme Value
GI	: Green Infrastructure
HEC-HMS	: Hydraulic Engineering Center - Hydrologic Modeling System
IMP	: Integrated Management Practices
LID	: Low Impact Development
MCDA	: Multi-Criteria Decision Aid
NRCS	: National Resources Conservation Service
OCM	: Optimal Control Model
OPS	: Open Street Map
RR	: Runoff Reduction
SCS	: Soil Conservation Service
SS	: Suspended Solids
SWAT	: Soil and Water Assessment Tool
SWMM	: Stormwater Management Model
TMDL	: Total Maximum Daily Load
TN	: Total Nitrogen
TP	: Total Phosphorus
TSS	: Total Suspended Solids
USDS	: Urban Storm Water Drainage System
USEPA	: The U.S. Environmental Protection Agency
WMS	: Watershed Modeling System



SYMBOLS

CN : Curve Number





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LOW IMPACT DEVELOPMENT (LID) PRACTICES IN FLOOD CONTROL OF URBAN AREAS USING SWMM (STORM WATER MANAGEMENT MODEL)

SUMMARY

At the present time, due to climate change, unsustainable water resources management and thoughtless urbanization, storm events occur more frequent and severe in urban areas resulting in human and economic loss. Mitigating these negative consequence has turned into a real challenge for water resources decision-makers making they seek innovative, effective and affordable solutions to reduce the increasing concern.

Nearly after a decade of harsh droughts drying out the lakes, wetlands and rivers, Iran was struck by three devastating and sequential floods in May 2019 spanning two weeks and almost all the country. Now after a brief recovery of the fatal catastrophe, addressing storm water management deficiencies has become of interest for all water resources involved people and this research is an attempt to examine a relatively novel and applicable solution.

In this research, Bastam city as an urbanized region in Semnan Province, Iran was modeled in SWMM software to study impacts of defined ten LID scenarios in addition to a non-LID one, on reducing the peak flow of a storm with ten year return period. LID Controls are low impact development practices designed to capture surface runoff and add some combination of infiltration, detention, and evapotranspiration to it. LID included scenarios consist of Infiltration Trenches, Bio-Retention Cells, Permeable Pavements, Rain Gardens and Rain Barrels practices.

In this research, optimal choices among different LID-included scenarios are found due to peak discharge and discharge volume reduction aspect of the designed drainage system.

The conclusion was that, Infiltration Trenches-10% and Rain Barrels-2% are respectively the most effective LID practices in this case study considering peak flow and flow volume reduction criteria. It is also inferred that, in this case study, after a certain percent of LID occupancy of the subcatchments, increasing the LID practice coverage does not have a considerable positive effect on reduction of peak flow and flow volume rates in Rain Barrel LID practice since resulted hydrographs is almost (not exactly) identical for 1% and 2% LID implementation coverage.



KENTSEL ALANLARDA TAŞKIN KONTROLÜNDEKİ DÜŞÜK ETKİLİ GELİŞME UYGULAMALARI (SWMM KULLANARAK)

ÖZET

Yeniçağın kentsel gelişmesi zemin geçirimli tabakalarının yayılımını azaltarak, yağmur suyu yüzey akışının artmasına ve yeraltı suyu beslenmesinin azalmasına sebep olmuştur ki bu da taşkın yönetimi karar mercilerine büyük sıkıntı yaratmaktadır. Günümüzde kentsel bölgelerde taşkınlar daha sık ve daha büyük ölçekte oluşmaktadır. Sözü geçen taşkınların hasarı ve su kalitesine kötü etkisi ve bu zararları hafifletebilmenin ağır maliyeti endişe yaratmaktadır. En İyi İşletme Uygulamaları (BMP) geniş bir dizi teknolojiler veya uygulamalar olarak su havzaları gelişmesinin istenmeyen etkilerini azaltarak, aslında akım rejimini kabaca olsa da havzanın gelişmesinden önceki haline benzetmesini ve bunu nehir yatak ve kıyısının yapısını en az derece de değiştirerek yapmasını hedefliyor.

Su kalitesi ve doğal su döngüsünü koruma ve restore etme amaçlı “Green Infrastructure” (GI) veya Çevreci Altyapı uygulamalarının bir kaçı, ABD’nin çevre koruma ajansı (EPA) tarafından tasarlanan SWMM bilgisayar programına, “performanslarının değerlendirme becerisi” belirgin bir şekilde ilave edilmiş ve onları LID (Düşük Etkili Gelişme Uygulamaları) olarak tanımlamıştır. Düşük Etkili Gelişme Uygulamalar aslında yağmur suyu yönetiminde su kalitesinin ve sel akıntısının istenmeyen etkilerini denetlemekte oldukça yenilikçi ve artan bir şekilde tercih edilen kavramdır.

Geçirimli döşemeler, su tutma hücreleri, yeşil çatılar, yeşil çukurlar ve benzeri küçük ölçekli yerinde uygulamalar olarak, akışı membada yani yağmur damlaları zemine düştüğünde kontrol altına almayı amaçlıyor ve LID önlemlerin bileşenlerini oluşturuyor. Son on yıl boyunca Amerika Birleşik Devletleri’nde Düşük Etkili Gelişme önlemleri kullanan mühendisler, belediyeler, federal ajanslar vb. sayısı fazlasıyla çoğalmaktadır.

Bilindiği gibi, iklim değişikliği ve hızlı kentsel gelişme olağan dışı taşkın hadiselerinin asıl sebeplerindendir. Bu olayların şiddeti ve debisi dünya çapında artmakta olup; azımsanmayacak ekonomik kayıpların yanı sıra, büyük sosyal ve çevre sorunları teşkil etmektedir.

İran’da taşkın olayları, yıllar süren su kaynakları yönetiminin çevre açısından sürdürülemez devam ettiği için daha da kötüleşiyor. Coğrafyasının çoğunluğu kuru ve yarı-kuru olan İran’da nüfus artışı, yetersiz su kaynakları yönetimi ve uzun süren kuraklıklardan dolayı son on yılda su kıtlığı ülkenin büyük bölümünde hüküm sürmekte olup ve ülke çapındaki tüm göller ve nehirler kurumuş veya tarihsel su miktarının sadece küçük bir yüzdesini taşımaktadır. Nehir yatakları ve kıyılarının uzun zaman kuru kalması, civardaki sakinlere yanlış alarm göndererek onları görünüşte düz

ve sakin ama aslında taşkına karşı savunmasız alanlarda önemli miktarda inşaat yapmaya ve kentsel gelişmeyi genişletmeye teşvik etmiştir.

Oldukça uzun süren kuraklıklardan sonra 19 Mart 2019 dan başlayarak, İran iki hafta süren üç adet şiddetli ve yinelenen sel baskınına maruz kaldı. Çok ağır feyezan başta Lorestan, Khuzestan, Fars ve Golestan eyaletlerini kapsayarak ülkenin 31 eyaletinden 26sında meydana gelirken korunmasız ve nehir yatağında inşa edilen bölgelerde 70 kişinin ölümüne ve milyonlarca dolar hasara yol açtı.

Kentsel bölgelerde yukarıda bahsedilen felaketleri önlemek ve su akışını büyük taşkınlara dönüşmeden yerinde yönetmek ve aynı zamanda su kirlenmesini azaltmak, yeraltı suyu tabakalarını beslemek, yağmur suyunu gelecek tüketimi amacıyla depolamak, göze hitap eden yeşil manzaralar oluşturmak ve çok daha fazlasını yapmayı planlıyorsak Düşük Etkili Gelişme önlemleri su kaynakları uzmanları tarafından şiddetle tavsiye edilmiştir. Bu araştırma da sadece su akışının miktarını (pik akım ve toplam akım hacmi olarak) denetmek istediğimiz için SWMM bilgisayar programının ve ona eklenen Düşük Etkili Gelişme uygulamalarının su kalitesine ile alakalı olan yönleriyle ilgilenmeyeceğiz.

Bu çalışmada İran'ın Semnan bölgesinde yer alan Bastam Şehrinde bir vaka incelenmesi yapılmış ve yukarıda değinilen olaylardan, Düşük Etkili Gelişme uygulamalar vasıtasıyla önleme yolları irdelenmiştir. İlk önce adı geçen kentsel bölgenin dış havzaları WMS ver.11 bilgisayar programıyla tanımlanmış, DEM dosyaları elde edilmiş ve SCS metodu ile şehre akan su debisi hesaplanmıştır. Daha sonra, kentsel bölge "Open Street Map" web sitesinden SWMM bilgisayar programına aktarılarak, 101 alt havzaya bölünmüş, kanallar ise kazı işlerini ve maliyeti minimuma indirmek amacı ile, caddelerin iki kenarında ve onlara paralel olarak yer almıştır.

Yukarıda adı geçen alt havzalar için her biri beş adetten (1'nci takım: ikinci ila altıncı senaryo; iki 'nci takım: yedinci ila on birinci senaryo.) oluşan iki takım Düşük Etkili Gelişme senaryosu tanımlanmıştır. Birinci senaryo da hiç bir Düşük Etkili Gelişme önlemi alınmadan, hidrolojik hesaplamalar yapılmış ve yüzeysel su şebekesinin özellikleri elde edilmiştir. İkinci ile beşinci senaryolarda sırayla sızdırma çukuru, su tutma hücresi, geçirimli döşeme ve yağmur bahçesi Düşük Etkili Gelişme önlemleri, alt havzaların yüzeyinin %5'ini kapsama şartı ile tayin edilmiştir. Altıncı senaryoda ise, alt havzaların %1 yayılma alanıyla yağmur varilleri yer almıştır.

Yedinci ila onuncu senaryolarda sırayla sızdırma çukuru, su tutma hücresi, geçirimli döşeme ve yağmur bahçesi Düşük Etkili Gelişme önlemleri, alt havzaların yüzeyinin %10'unu kapsama şartı ile tayin edilmiştir. On birinci senaryoda ise, alt havzaların %2 yayılma alanıyla yağmur varilleri yer alıyor. Yukarıda bahsedilmiş olan her bir senaryo için ayrı ayrı yüzeysel su şebekesinin özellikleri hesaplanmıştır. Buradaki amaç sözü geçen Düşük Etkili Gelişme uygulamalı on senaryonun elde edilen bilgilerini birbiriyle ve hem de Düşük Etkili Gelişme önlemi alınmayan senaryo ile mukayese ederek en iyi senaryoyu seçmek ve ayrıca Düşük Etkili Gelişme önlemlerinin kapsadığı alan yüzdesinin etkisini taşkın akımı üzerinde incelemektir.

Alınan sonuçlara göre, burada incelenen vaka çalışmasında taşkının pik akım ve toplam akım hacmini düşürme açısından sızdırma çukurları-10% ve yağmur varilleri-2% senaryoları, tanımlanan 11 senaryo içerisinde birinci ve ikinci sırayı almaktadırlar. Ayrıca, elde edilen hidrograflara göre, yağmur varilleri Düşük Etkili Gelişme önleminin alt havzalarda yayılma oranı belli bir yüzdeyi aştıktan sonra pik akım ve toplam akım hacminin düşürmesine önemli bir etkisinin olmadığını tespit edilmiştir.

Bu sonucu %1 ve %2 yağmur varili senaryolarının hidrografları hemen hemen aynı olması doğrulamaktadır.

Bundan başka incelediğimiz Bastam şehri vaka çalışmasında 3 zirvedeki senaryonun pik akım ve toplam akım hacminin düşürme oranı birbirine çok yakın olduğu görülmektedir.





1. INTRODUCTION

Urban development of modern times has reduced spanning of permeable soil layers, resulting in increased storm water runoff and decreased groundwater recharge, turning flood management to a real challenge for water resources decision-makers. Nowadays, floods appear more often and also in bigger volumes in urbanized basins, rising concerns about alleviating water quality and flood damage consequences. BMPs or best management practices refer to a broad range of proper implementations and technologies with the purpose of reducing the watershed development impacts on flow patterns to the lowest level, without changing riparian morphology (Perez-Pedini, 2005).

Over the previous decades conventional engineering solutions to storm water management concentrated on detention/retention pond BMPs (mostly placed at a downstream location), in a way that these structural facilities became the prevalent procedures to mitigate the impacts of flooding in urban watersheds (Yeh and Labadie 1997). Design, operation and optimization of single and network of detention ponds are now vastly found in respective literature (Behera et al. 1999). Although these ponds are greatly functional when it comes to reducing peak flow rates, their construction and maintenance can be rather costly and they can have unwanted impacts on a catchment while there is no organized procedure to implement them catchment-wide (Ferguson 1991).

In order to recharge groundwater and escaping from construction of expensive storage-based BMPs, infiltration weighted flood management methods ranging from permeable pavements, rain gardens, infiltration trenches to the use of kerb ramps and swales have become more and more popular recently (Potter 2004). It should be noted that infiltration-based BMPs are not mere substitutes to the storage-based BMPs, and both measures can be taken simultaneously (Brander et al. 2004).

To protect, restore, or imitate the natural water cycle through an approach called Green Infrastructure (GI) practices, EPA's SWMM software has incorporated the ability of evaluating the performance of several GI practices in an explicit manner and uses the

term low impact development (LID) controls to describe them (EPA/600/R-17/414 | October 2017). LID or Low impact development is a comparatively novel and an increasingly favored concept in storm water management for controlling unfavorable water quality and flood flow impacts of urban development (Elliott and Trowsdale, 2007). Small-scale, onsite IMPs (integrated management practices) such as permeable pavements, bio-retention cells, green roofs, grass swales, etc. constitutes the components of the LID measures with the intent of treating and infiltrating runoff at starting points when raindrops start to hit the ground. The entire goal of LID applications is to roughly reproduce a hydrologically operational landscape which mimics the predevelopment watershed circumstances or as it is called sustainable development (Dietz, 2007). Number of design engineers, states, municipalities, and federal agencies in U.S. who started to use LID applications has increased during the last decade (Pennsylvania Department of Environmental Protection, 2006).

1.1 Motivation of Study

Climate change and hasty urban development is the major cause of abnormal flood events which are enhancing in frequency and intensity throughout the globe resulting in substantial social and environmental troubles in addition to economic wastes (Zhou 2014). These rainstorm problems when it comes to Iran, exacerbates due to unsustainable water management going on for decades in the country. Water scarcity as a result of population growth combined with inefficient water resources management and droughts were prevailing over a decade in largely arid and semi-arid Iran. Most of the rivers and lakes dried out throughout the country or their water volume became only a mere percent of their historical magnitudes and consequently it led to significant municipal constructions in ephemeral river banks and flood vulnerable zones urbanization shouldn't go that far.

After a relatively long period of droughts, Iran suddenly was hit by three heavy and recurring rainstorm incidents starting march 19, 2019 continuing for two weeks. Severe flooding occurred in 26 of 31 provinces of the country most harshly in Lorestan, Khuzestan, Fars and Golestan resulting in more than 70 reported deaths nationwide by officials. Figures 1.1 and 1.2 compares before and after flood conditions in a famous gate constructed in bare river bank in Shiraz, Fars.



Figure 1.1 : Quran Gate before the flood (Shiraz, Fars).



Figure 1.2 : Road leading to Quran Gate, Shiraz few hours after severe rainfall.

Figure 1.3 shows the flooding in Aqqala town, Golestan province, while Figure 1.4 shows the same area after two weeks of the heavy rainfall, still covered with fatal flood.



Figure 1.3 : Aqqala flooding, Golestan province.



Figure 1.4 : 6 April 2019, about two weeks after the flood (Aqqala, Golestan).

If we intend to prevent disasters depicted above in urban areas and sustainably manage storm water at source before it produces large amounts of runoff, and also reduce water pollution, recharge groundwater tables, store rainfall for future use, develop beautiful

landscapes and a lot more at the same time, Low impact development (LID) measures are one of the highly recommended innovative approaches by environmental and water resources engineers and managers. Since we are interested in storm water quantity management here, we will not be concerned with water pollution aspects of SWMM and introduced LIDs in this study.

1.2 Literature Review

In this section LID-BMP related studies conducted by several researchers from different aspects of view are briefly outlined:

Yeh and Labadie (1997) argue that there is a tendency to change traditional storm water management policies and flood detention/retention facilities have become preferred engineering solutions to alleviate storm water runoff impacts in recent years. They also point out that detailed literature on design, operation and optimization of detention ponds systems is now available.

Lai et al. (2007) use SUSTAIN software to develop a decision making tool to evaluate, select and place BMPs in urban basins based on cost and effectiveness factors. This tool has the potential to help government and engineers to enhance water quality and meet other existing needs by employing cost optimization and storm water management assessment.

Identification of best LID practices' design in small urban catchments is the goal of Zhang et al. (2013) research, by applying together a multi-objective optimization with an urban storm water model. A genetic algorithm is used for optimization purposes whereas SWMM software carries out the runoff simulation. Green roofs, porous pavements and bio-retention basins are the three studied LIDs in this work.

Bio-swale implementations are highly effective in total suspended solids (TSS) reduction and this rate is 48% to 98% (Schueler, 1994; Barrett et al, 1998; Yu et al, 2001; Backstrom, 2003; Barret, 2005). Also according to the fact that nitride and phosphorus compounds accelerate eutrophication (the enrichment of water through nutrients, such as nitrogen and phosphorus and organic matter such as plants), elimination rates of these components by bio-swales are studied in several researches which present different results.

Perez-Pedini et al. (2005) coupled a distributed rainfall-runoff model and a genetic algorithm at a catchment exit to optimally locate the BMPs in order to decline peak flood flow. They claim that according to their observation the more is the number of added BMPs to the watershed the less is the watershed peak flow.

Deletic and Fletcher (2006) studied grass swales and filter strips in two different locations to find out if there is a meaningful relation in removal of sediment from urban runoff where these LIDs are implemented. They discovered that there is a peculiar exponential decline of total suspended solids (TSS) along the bio-swale. This rate is also affected by flow velocity, grass density, along with particle size and density since it is basically a physical process.

Kaini et al. (2008) set constraints on daily peak flow values and annual sediment load as treatment goals in their research OCM (optimal control model). This model is evolved by linking a semi-distributed hydrological model, Soil and Water Assessment Tool (SWAT), with a genetic algorithm (GA) to determine the least cost design (sizes, types, and locations) of structural best management practices (BMPs) whilst satisfying treatment expectations at a watershed-scale. The OCM found optimum solutions for structural BMPs they used in Silver Creek watershed, a sub-watershed of the Lower Kaskaskia basin in Illinois including detention ponds, infiltration ponds, parallel terraces, filter strips, grade stabilization structures, and grassed waterways.

The basis of methodology for selecting BMPs which Abi-Aad et al. (2010) used was over several criteria such as economic, social, water quality and water quantity under different stakeholder views and priorities by employing multi-criteria decision aid (MCDA) approaches. The study was carried out on a case study of a residential storm water network in the Greater Montreal Area. Green roofs, rain gardens, rain barrels and pervious pavement were the BMPs studied in order to attain solutions compatible with a sustainable development pattern.

Iqbal et al. (2011) studied a catchment in eastern Australia by developing a quality model to continuously simulate storm water pollutants throughout the catchment. Their model is able to take into account of simulating the accumulation and transportation of suspended solids (SS), total nitrogen (TN) and total phosphorus (TP) from the catchment as storm water pollutants when its parameters are properly estimated.

Jia et al. (2012) examined the change of use of Beijing Olympic Village (BOV) to a residential complex after the 2008 Olympics which some of inherited LID-BMPs had to be altered to address the needs of new use of the BOV including landscaping purposes and improvement of runoff control capabilities. They argue that porous pavements, green roofs and rainwater cisterns were the existing implemented LIDs in BOV's urban storm water management system and they applied a combination of two models to enhance and optimize the placement and design of LID-BMPs.

No BMP among others stood up as the best practice, considering all water quality criteria as Fassman (2012) used the probability plot compared to standard percent removal type evaluation to assess "total suspended solids" and "total and dissolved zinc and copper" removal for different BMPs (i.e. dry detention basins, retention basins, wetland basins, media filters, grassed swales, bio-retention, and permeable pavement). Detention basins are the worst in providing the quality protection amongst all mentioned implementations and do not meet the usual objective of 75% TSS elimination. Pervious pavements are capable of preventing up to 67% of the pollution collection in typical municipal districts. Contrary to copper, in most BMPs zinc removal rates satisfy the US EPA quality criteria (Fassman 2012).

Oraei et al. (2012) analyzed a multi-criteria optimization function on both quality/quantity aspects of BMPs in their case study. Measures of urban runoff quality were BOD5 (biological oxygen demand) and TSS (total suspended solid) whereas total surface runoff volume produced by sub-basins were set as runoff quantity. They established a quality and quantity model with SWMM and also roughly calculated the cost of the BMPs construction and maintenance.

Jia et al. (2015) worked on a case study in Guangdong Province, China (a college campus in Foshan). First they outlined the basics of storm water management in urban areas considering LID-BMP practices, then they used a screening approach developed on a multi-criteria selection strategy to optimally locate the viable BMPs. They utilized SUSTAIN software as a decision support system to analyze four suggested planning scenarios to choose and recommend the best two solutions to local decision-makers.

In an attempt to reduce water pollutants rather than decreasing the flood flow, Cho et al. (2015) coupled hydrologic solutions with water quality controls of 6 different LIDs ranged from 1.2 mm to 3.0 mm in terms of flood depths in a commercial site in South

Korea. The main goal of their study was to alleviate First Flush Effect or FFE (it indicates that mass emission of contaminants mostly take place at the start of the storm) by running comprehensive storm water surveillance and numerical modeling.

Karami et al. (2016) applied both innovative and traditional approaches in SWMM to evaluate urban storm water risks regarding decreasing pollutants and flood emission into receiving water bodies. Innovative procedures include LID practices such as bio-retention systems, porous pavements, infiltration trenches, and detention ponds in urban drainage networks whereas traditional techniques include enlarging canal cross sectional area and lowering their roughness. They concluded that optimal approaches can highly reduce the pollutants and flood peak in the study area.

Jennifer et al. (2006) studied the quantity and quality of storm water runoff from 3 types of different media including crushed-stone, porous-pavement and asphalt driveways in a case study located in Connecticut, USA. They concluded that asphalt pavements are the worst regarding both high discharge and high pollutant amounts. Permeable pavement turned out to have least contaminants of all, whereas its infiltration was greater than asphalt and less than crushed-stone driveways. They observed that infiltration rates reduced to some extent during the process of the study at both permeable pavement and crushed-stone driveways as a result of fine particles blocking the pores in these media and yet their use is more advantageous than conventional asphalt paver in managing the nonpoint pollution.

The impacts of detention ponds on urban sewer systems were studied by Lim et al. (2014). Minimizing discharge and the installation cost were the two goals they sought throughout their research by deciding optimal volume and placement of these facilities using a multi-objective genetic algorithm. Rainfall-runoff simulation was carried out by EPA's SWMM and sequential optimization was done via Visual C++ programming tool on a case study located in S city, South Korea. They recommended studying all LID practices so that decision makers can have further options to select from.

Duan et al. (2016) studied an urban drainage network consisting of 127 sub-basins, 95 main pipes, 2 pump stations, 2 outlets to the adjacent river and 2 exiting detention tanks located in SA, China. Their research was based on optimum design and use of LID practices in order to effectively manage urban storm water drainage system (USDS) and flood control. They came to the conclusion that LID implementations

when linked with detention reservoirs in an optimal way, both flooding risk and installation expenses decline to a great extent. Furthermore, they found out that LID measures can decrease the flooding risk in a wide range while the positive impact of detention tanks is locally restricted.





2. THEORITICAL FRAMEWORK

2.1 Low Impact Development

The U.S. Environmental Protection Agency (USEPA) defines low impact development (LID) as “an approach to land development (or re-development) that works with nature to manage storm water as close to its source as possible” (US EPA, 2010). LID is “a storm water management and land development strategy that emphasizes conservation and the use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely reflect pre-development hydrologic functions” (San Diego RWQCB 2013). This approach focuses on maintaining or restoring the natural hydrological processes of a site, providing opportunities for natural processes to take place. Key principles in LID include:

- preserving natural site features;
- small scale, integrated storm water management controls dispersed throughout the site;
- minimizing and disconnecting impervious areas;
- controlling storm water as close to its source as possible;
- prolonging storm water runoff flow paths and times; and
- creating multi-functional landscapes.

LID best management practices (BMPs) are techniques that rely on natural processes to manage water quantity and quality, including:

- absorption;
- infiltration;
- evaporation;
- evapotranspiration;
- filtration through standing plant material and soil layers;
- potential pollutant uptake by select vegetation; and

- biodegradation of pollutants by soil microbial communities.

LID-BMPs (ecosystem-based approaches to managing and treating storm water runoff) promote maintenance of the hydrologic cycle, shown for a natural environment in Figure 1.1, where rainwater is able to provide soil moisture for plants, infiltrate to recharge groundwater aquifers and allow for evaporation and transpiration of water back into the atmosphere. The properties of natural materials such as soil, gravel, vegetation and mulch reduce the volume and peak flow rates of runoff reaching receiving streams and enhance the quality of storm water entering our receiving water bodies. As a landscape becomes more developed, many of the functions of the hydrologic cycle shown in Figure 2.1 are impaired. LID-BMPs seek to restore these natural processes to the urbanized landscape.

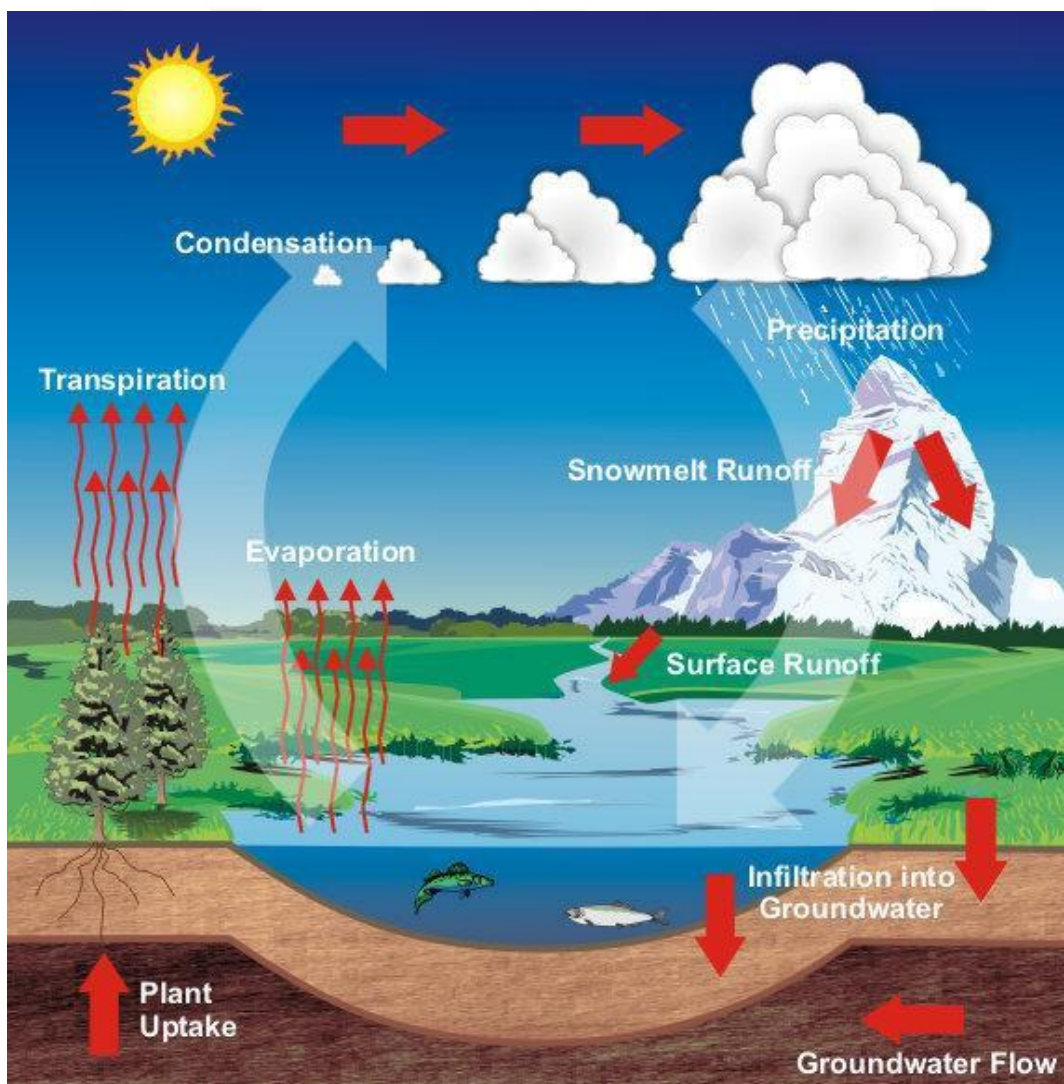


Figure 2.1 : The Natural Hydrologic Cycle.

2.2 Goals of LID-BMP Based Development

There are three primary storm water management objectives that typically drive LID-BMP applications. These are:

- storm water volume control;
- storm water peak flow control; and
- storm water quality enhancement

LID-BMP facilities often address all three of these storm water management objectives at some level. Facilities may also be designed to work in series within a development to meet the regulatory requirements driving these objectives.

Applications of LID-BMPs provide many benefits to storm water management, the environment and communities. Some of these benefits can be assigned monetary value while others are more intangible environmental or social benefits that are difficult to assign a quantitative value.

2.3 Benefits of LID Implementations

- Protects surface and groundwater resources
- Reduces nonpoint source pollution
- Applicable to green fields, brown fields, and urban developments
- Groundwater recharge
- Meets total maximum daily load (TMDL) and other storm water requirements
- Ancillary benefits, including aesthetics, quality-of-life, air quality, water conservation, and property values

2.4 Challenges and Limitations of LID Practices

Not all sites can effectively use all LID techniques. Soil permeability, existing soil contamination, slope, and water table characteristics might limit the potential for local infiltration. Urban areas planned for multi-family and mixed-use development or high-rise construction and locations with existing high contaminant levels in the soil might be severely limited or precluded from using LID infiltration techniques on-site. A more community-level approach to LID, rather than a site-by-site approach, might be

warranted. Other non-infiltration LID techniques such as street trees, permeable pavements with an underdrain, raised sidewalks, rainwater harvesting with appropriately designed barrels or cisterns, and vegetated roofs/modules/walls are still an option for projects in the urban setting; however, these techniques must be carefully integrated into projects with thorough consideration of engineering and geotechnical limitations.

2.5 LID and Storm Water Management Planning

Consideration of the strategies outlined in Figure 2-2 during the planning phase of a storm water management scheme helps guide the decision-making process when selecting and designing BMPs to manage storm water. The construction activities involved in translating a design concept for a storm water management scheme into on-the-ground solutions will vary depending on what BMPs are included.

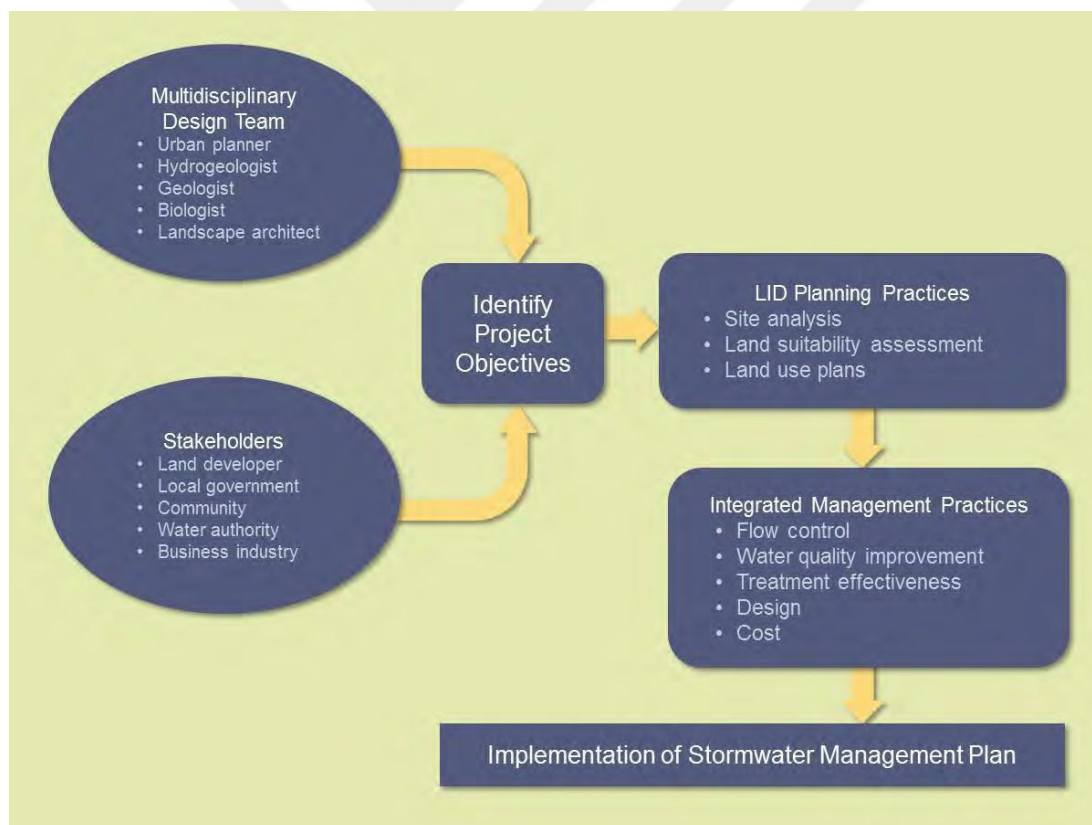


Figure 2.2 : LID planning and implementation.

Strategies fall under the two broad categories of: Planning Practices; and IMPs (Integrated Management Practices). Common LID planning practices include site

design planning based on natural land contours and decreasing the impervious surface. These methods include the following:

- Reducing impervious surfaces
- Disconnecting impervious areas
- Conserving natural resources
- Using cluster/consolidated development
- Using xeriscaping and water conservation practices

2.6 Overview of LID-BMPs

As stated earlier, LID Best Management Practices are intended for managing storm water near or at its source in addition to efficiently conveying and discharging excess storm water into a receiving water body. Although there are various types of LID-BMPs, they all follow the same principle of “slowing it down, spreading it out, and soaking it in” (EPA, 2011), aimed at replicating the natural hydrological processes of absorption, infiltration, evaporation and evapotranspiration.

Through a literature review, Seven LID features are selected to be presented here:

(1) bio-retention; (2) bio-swales; (3) permeable pavements; (4) box planters; (5) green roofs; (6) volume-storage and reuse IMPs and (7) naturalized drainage ways.

2.6.1 Bio-retention / Rain gardens

Bio-retention systems are essentially surface and sub-surface water filtration systems. They function like sand filters; however, whereas sand filters provide water quality treatment via passage of storm water through a sand medium, bio-retention systems use both plants and underlying filter soils to remove contaminants and reduce storm water runoff volumes. Due to the variety of treatment mechanisms at work within the system, bio-retention areas consistently provide relatively high load reductions for most pollutants.

Bio-retention areas are typically planted with grasses, shrubs, and trees that can withstand short periods of saturation (i.e., 12–96 hours) followed by longer periods of drought (Figure 2-3). In addition to transpiring significant storm water volumes, vegetation can enhance pollutant removal, reduce soil compaction, and provide ecological and aesthetic value (Barrett et al. 2013; Hatt et al. 2009; Li et al. 2009).

Vegetation adapted to the San Diego region is preferable for use in bio-retention areas because native ecotypes can typically tolerate periods of extreme drought and can promote infiltration and evapotranspiration with their root systems.



Figure 2.3 : Bio-retention area (San Diego, California).

The fundamental differences between a bio-retention area and a conventional planting bed are that bio-retention areas utilize engineered soils and vegetation to capture and treat rainwater and are located at the low point of a landscape. Rainwater then flows either naturally or through an inlet into the bio-retention area's concave surface. Depending on the ability of the sub-soils to infiltrate water (hydraulic conductivity), a bio-retention area may have four layers, including (Figure 2.4):

1. plantings and aged mulch;
2. topsoil, natural or amended;
3. gravel drainage layer; and
4. under drain with cleanouts.

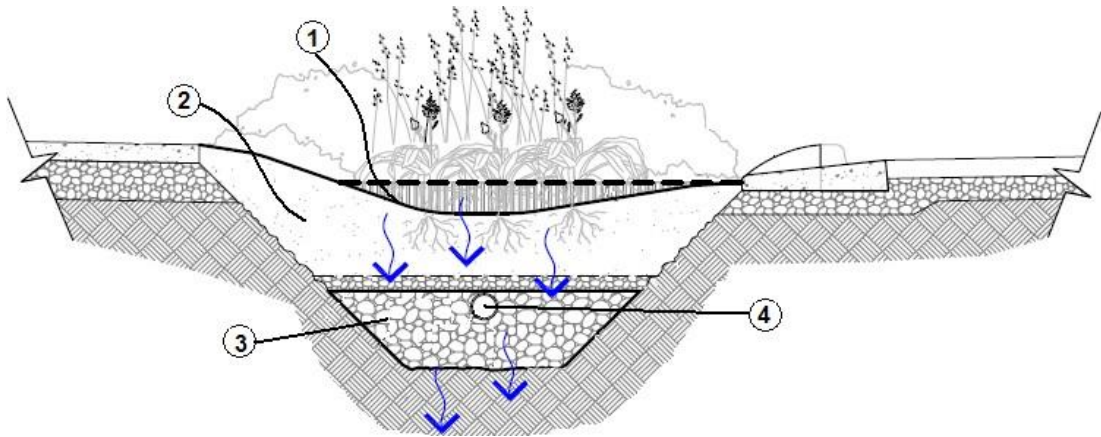


Figure 2.4 : Bio-retention Area Components.

Bio-retention can be adapted and incorporated into almost any landscape. Common applications of bio-retention include parking lot islands, areas along the perimeter of pavement, throughout landscaped areas, near roof downspouts, and along roadways. Examples of bio-retention are provided in Figure 2-5 and Figure 2-6. (San Diego)



Figure 2.5 : Parallel bio-retention areas treat parking structure runoff conveyed by a concrete flume (North Carolina State University campus).

2.6.2 Bio-swales / Bio-retention swales / Vegetated swales

Bio-swales, also referred to as linear bio-retention are channels with grass and other vegetation, enhanced topsoil, and an underlying infiltration layer (Claytor, 1996; RCA,

2009; MDEP, 1997). They are designed to slow runoff velocities by increasing surface roughness.



Figure 2.6 : Bio-retention parking lot island (San Diego).

Increased surface roughness results in increased surface contact time, allowing more infiltration, evaporation, transpiration and water quality enhancement prior to the runoff entering another storm water management facility. Examples of bio-swale applications are depicted in Figure 2.7.



Figure 2.7 : Bio-retention swale in median (rendering).

Bio-swales differ from common grass swales. Grass swales have limited infiltration potential since they usually do not have an enhanced top soil or infiltration under layer. The layers of a bio-swale are similar to those of bio-retention areas, as shown in Figure 2.4.

Bio-retention swales can be applied in situations similar to bio-retention, including parking lot islands, along the perimeter of paved areas, throughout landscaped areas, near roof downspouts, and along roadways. Bio-retention swales are well-suited to green street retrofit projects because of their narrow, in linear design. Examples of bio-retention swales are provided in Figure 2-8 and Figure 2-9.



Figure 2.8 : Parking lot bio-retention swales (Oceanside, California).



Figure 2.9 : Ellerslie Fire Station #27 in Edmonton.

2.6.3 Permeable pavement

Permeable pavements can infiltrate storm water while simultaneously providing a stable load-bearing surface (Figure 2-10).



Figure 2.10 : Example of pervious concrete.

While forming a surface suitable for walking and driving, permeable pavements also contain sufficient void space to infiltrate runoff into the underlying reservoir base course and soil. Permeable pavement can dramatically reduce impervious surface coverage without sacrificing intensity of use.

The four main categories of permeable pavements include poured-in-place pervious concrete, permeable asphalt concrete, permeable pavers, and granular materials. All of these permeable pavements (except some low-traffic unit pavers) have the same type of reservoir base course (a layer of material directly under the surface layer).

This base course provides a stable load-bearing surface as well as an underground reservoir for water storage, which eliminates the possibilities of mud, mosquitoes, and safety hazards that are sometimes perceived to be associated with ephemeral surface drainage. The base course can store large volumes of runoff, and can be linked to roof runoff collection systems when aboveground cisterns are not feasible. In Europe and Australia, subsurface reservoir layers have been used to store and reuse storm water to offset non-portable water demand and for geothermal heating and cooling. As with cisterns, proper precautions must be taken to prevent accidental ingestion of reused storm water from a reservoir layer.

In general, the structure of permeable pavement consists of four layers (Figure 2.11):

1. permeable pavement or pavers;
2. 'choker course' or bedding layer of washed stone;
3. reservoir layer consisting of clean washed uniformly graded aggregate or a tank consisting of a matrix of open weave boxes; and
4. perforated underdrain incorporated into the reservoir layer as required.

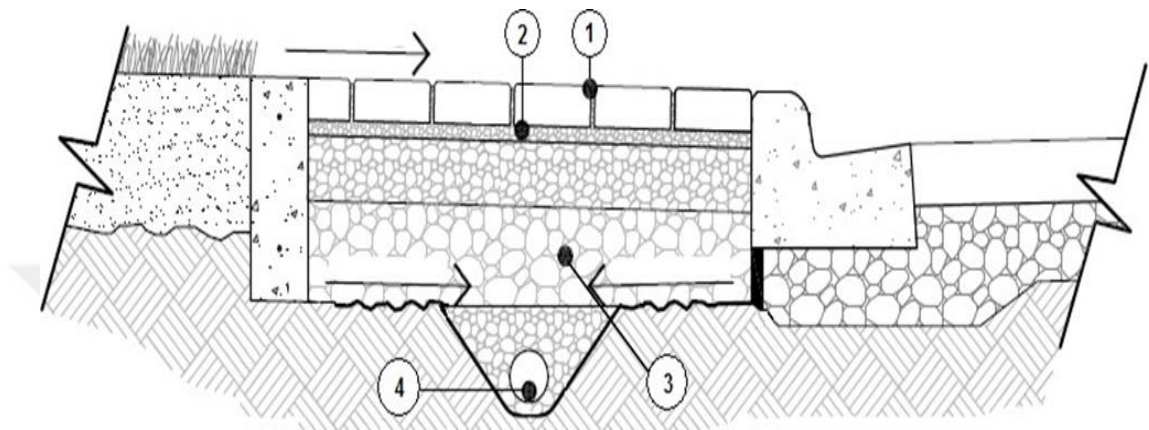


Figure 2.11 : Components of Permeable Pavement Facilities.

Permeable pavements can be used in a wide array of applications, including parking lots, parking lanes on light duty roads, pedestrian plazas, and alleys. Examples of permeable pavement are provided in Figure 2-12, Figure 2-13, and Figure 2-14.



Figure 2.12 : Permeable interlocking concrete pavers.



Figure 2.13 : Permeable asphalt concrete (El Cajon, California).



Figure 2.14 : Pervious concrete (San Diego, California).

2.6.4 Box planters

Infiltrating box planters are similar to bio-retention systems as they use vegetation and amended soils to filter and retain storm water (Figure 2.15). There are three types of box planters that may be implemented based on site characteristics and requirements:

- contained planters with outlet only through overflow;
- flow-through planters with an underdrain outlet; and
- infiltration planters that drain through deep infiltration and groundwater recharge.

A planter typically consists of a concrete box, which may or may not have a lined or concrete bottom (depending on whether infiltration is desirable), filled with a soil medium, and planted with trees, shrubs or flowering species. An alternative to the concrete box is a matrix of buried plastic cells (Figure 2.16) that can be assembled to any required shape and size. The matrix provides structural support for sidewalks and roadways while allowing for deep root penetration and storm water management through infiltration, filtration and interception.



Figure 2.15 : Box planter installation including trees in Kitchener, ON.

Box planters can also aid in reducing runoff volume and peak flows. The primary mechanisms of storm water management for infiltrating box planters (Figure 2.17) include:

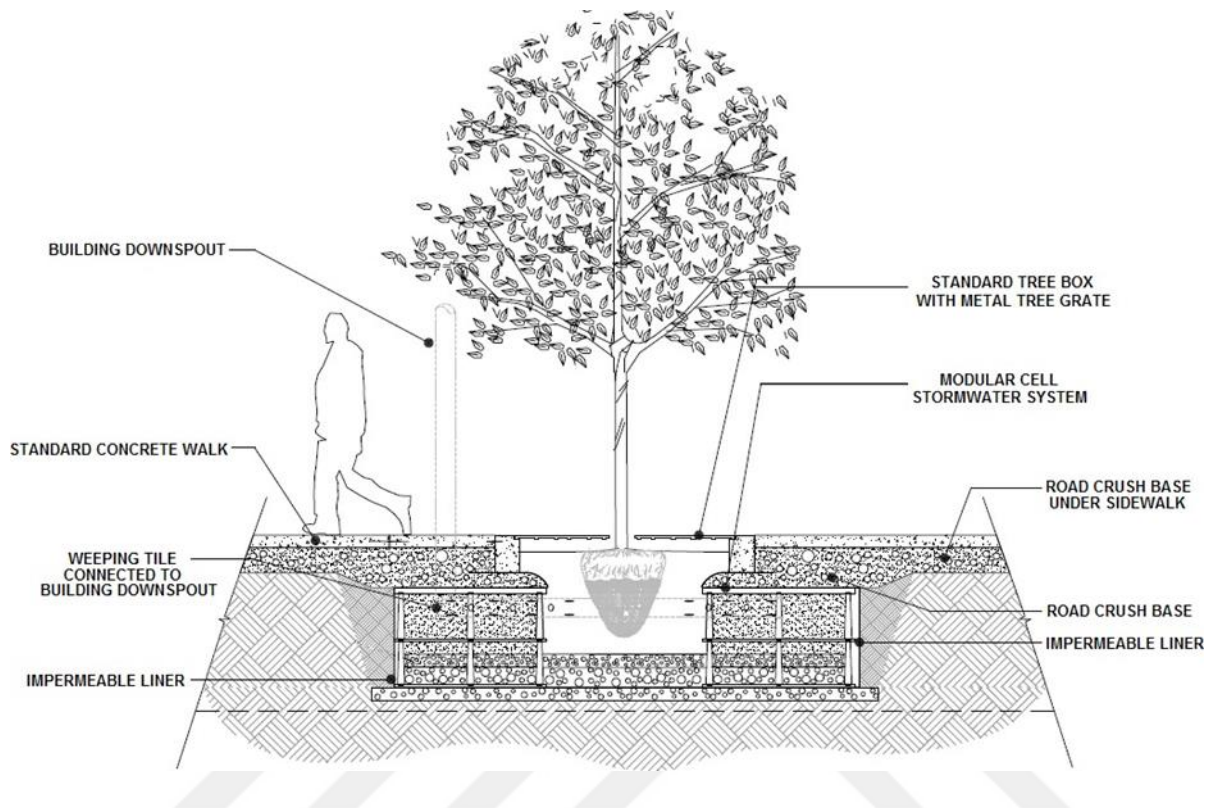


Figure 2.16 : Tree trench box planter with soil cells.

1. surface infiltration;
2. transpiration;
3. deep infiltration (optional); and
4. delayed release to the minor system.

Typically, storm water enters the infiltrating box planter through a curb cut and infiltrates through a layer of mulch and soil. Some of the water is retained by the soil and subsequently used by the vegetation and released through evapotranspiration. Depending on the native soils' characteristics, infiltrated water will percolate (deep infiltration) to the groundwater table. If infiltration is not an option a perforated underdrain placed near the bottom of the box planter will convey excess water to the storm drainage system or a reservoir for re-use purposes (such as irrigation).

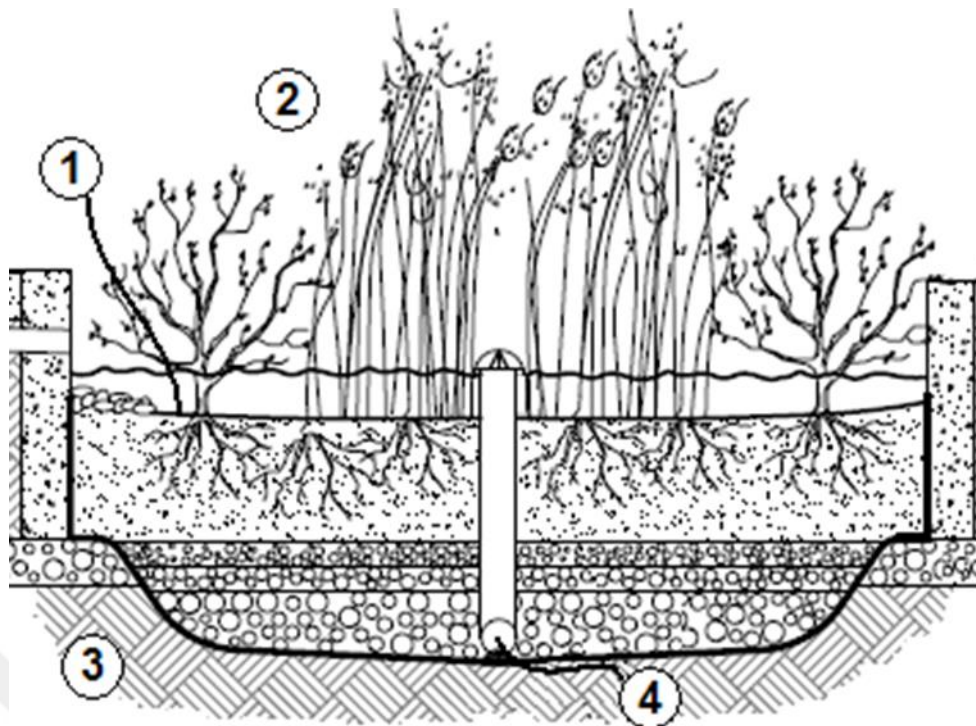


Figure 2.17 : Storm water management mechanisms in a box planter.

2.6.5 Green roofs / Vegetated roofs

Green roofs consist of live vegetation established on top of buildings. There are two types of green roofs: extensive and intensive (Figures 2.18 and 2.19). An extensive green roof consists of a relatively thin layer of growing medium (approximately 50 to 150 mm) and a ground cover type of plant that is hardy to the harsh conditions of a rooftop. An intensive green roof consists of soil depths of at least 300 mm and may include woody plants such as shrubs and trees. Intensive green roofs are often used as public green spaces. Both types of green roof consist of a series of layers as illustrated in Figure 2.20.

In addition to storm water volume reduction, vegetated roofs offer an array of benefits, including extended roof lifespan, improved building insulation and energy use, reduction of urban heat island effects, opportunities for recreation and rooftop gardening, noise attenuation, air quality improvement, wildlife habitat, and aesthetics.

Although commonly called green roofs, vegetated roofs need not be green year-round and are often planted with drought-tolerant desert plants.



Figure 2.18 : Extensive vegetated roof.



Figure 2.19 : Intensive plantings on the top level of a parking structure.

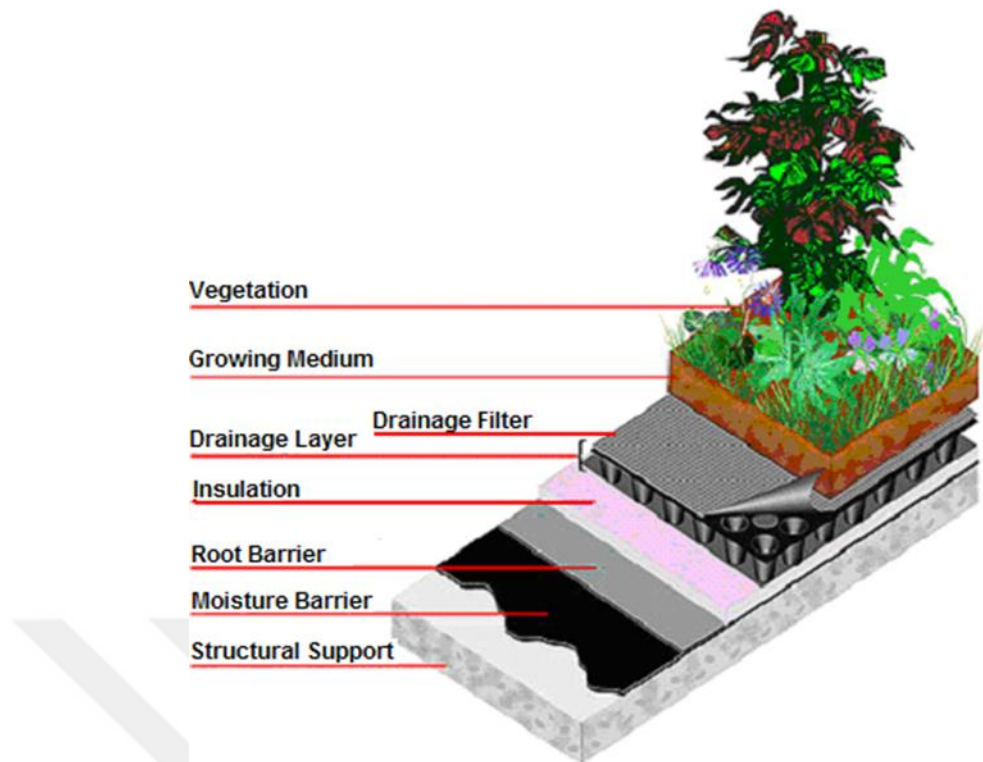


Figure 2.20 : Layers of a Green Roof.

2.6.6 Volume-storage and reuse IMPs

Techniques used to capture and store runoff from rooftops and other surfaces can be used at many scales to meet hydro-modification and water quality goals. On a smaller scale, properly sized rain barrels can be used to mitigate rooftop runoff from small residential dwellings and outbuildings. Cisterns (either surface or subsurface containers) and subsurface reservoir beds can be used for capturing and storing larger volumes of runoff from both rooftop and overland flow. Rainwater harvesting is most effective for hydrologic and water quality control if adequate capacity is available to capture the desired water quality volume—this is accomplished by slowly dewatering the temporary storage reservoir (preferably to irrigate a vegetated area or to offset other potable water uses) between storm events.

A cistern is an above-ground storage vessel with either a manually operated valve or a permanently open outlet (Figure 2.21). If the cistern has an operable valve, the valve can be closed to store storm water for irrigation or infiltration between storms. This system requires continual monitoring by the resident or grounds crews, but provides greater flexibility in water storage and metering. If a cistern is provided with an operable valve and water is stored inside for long periods, the cistern must be covered to prevent mosquitoes from breeding. A cistern system with a permanently open outlet

can also provide for metering storm water runoff. If the cistern outlet is significantly smaller than the size of the downspout inlet (e.g., ¼- to ½-inch diameter), runoff will build up inside the cistern during storms, and will empty out slowly after peak intensities subside. The cistern must be designed and maintained to minimize clogging by leaves and other debris. In the drier regions of the County, cisterns and rain barrels might only fill up a couple times a year and might be more practical when the system is supplemented with graywater from a County- permitted graywater system.



Figure 2.21 : Rain barrels.

A cistern typically holds several hundred to several thousand gallons of rainwater and come in a variety of sizes and configurations. Figure 2.22 shows a typical aboveground plastic cistern and Figure 2.23 shows the same cistern with a wooden wrap. Cisterns can be placed below ground as shown in Figure 2.24.

Smaller cisterns (fewer than 100 gallons), or rain barrels, can be used on a residential scale (Figure 2.25). Collected water can be used to supplement municipal water for non-portable uses, primarily irrigation.

Although useful for raising public awareness and for meeting basic irrigation needs, rain barrels do not typically provide substantial hydrologic benefits because they tend to be undersized relative to their contributing drainage area.



Figure 2.22 : Typical plastic cistern.



Figure 2.23 : Wood wrapped cistern.



Figure 2.24 : Below-ground cistern.



Figure 2.25 : Residential rain barrel.

2.6.7 Naturalized drainage ways

Naturalized drainage ways are surface storm water conveyance features that use wetland zones, drop structures and natural materials and vegetation to replace storm sewer mains or prevent erosion of existing drainage ways (Figures 2.26 and 2.27). They generally have frequent or continuous runoff (base flow), even during periods of little or no precipitation. Base flow in these facilities results from residential irrigation and outdoor water use.

Naturalized drainage ways are often used as replacements for storm sewer trunks. As more development occurs in upstream catchments, increased base flows are observed in the drainage ways. These facilities are generally viewed as great amenities to surrounding communities and provide a refuge for birds and wildlife in the area.

Naturalized drainage ways are typically larger than grass swales, more engineered than natural wetlands and in some cases may appear similar to a small creek. Velocities of urban runoff and storm water are slowed using natural vegetation, increased resistance along the flow path and drop structures (MDEP, 1997). Additionally, prolonged storm water contact with natural materials promotes the hydrologic cycle through evaporation and transpiration.



Figure 2.26 : The Preserve in Denver, CO.



Figure 2.27 : Naturalized drainage way and wetland.

Naturalized drainage ways usually follow property lines and utility rights-of-way. Infiltration from naturalized drainage ways is typically not a significant contributor to the hydrologic cycle due to saturated soils and / or direct connection with the groundwater table.

Where longitudinal slopes exceed 1%, drop structures are used to reduce flow velocities and maintain flat grades. The primary mechanisms of storm water management in a naturalized drainage way are shown in Figure 2.28 and include:

1. slowed velocities through channel roughness and drop structures; and
2. evaporation and transpiration from surface flows and plant uptake.

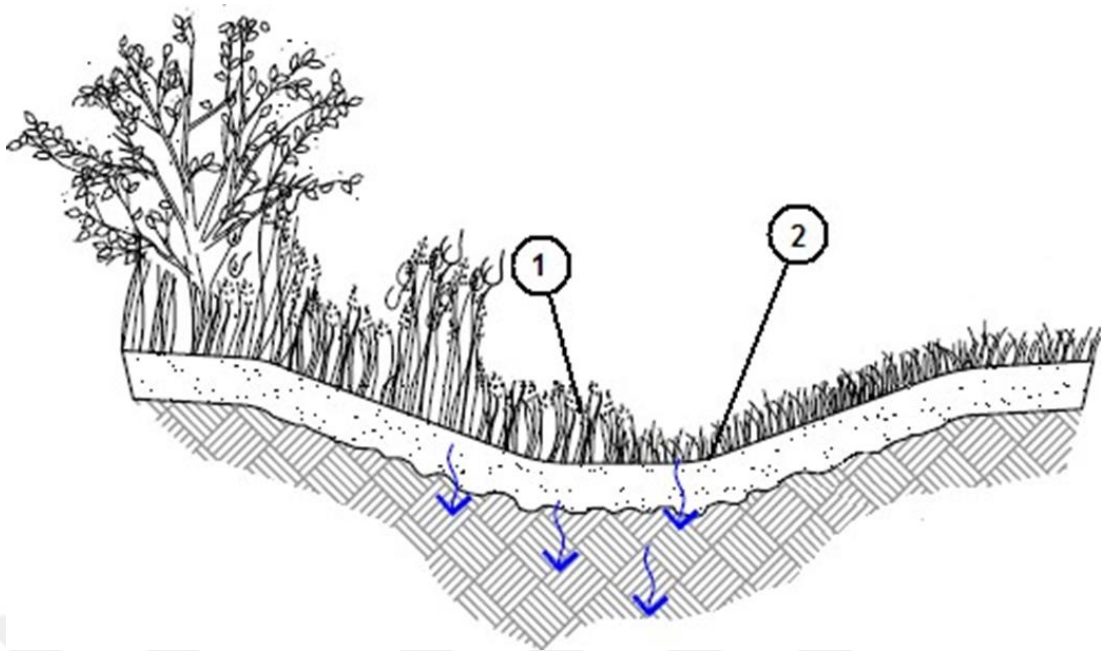


Figure 2.28 : Storm Water Management Mechanisms in a Naturalized Drainage Way.

2.7 Performance of LID-BMPs

LID-BMPs replicate natural hydrological processes to manage surface runoff due to urbanization. They reduce both runoff volumes and rates and improve storm water quality.

In general, treatment of storm water begins with filtration of particulates as runoff flows over the surface and through vegetation, and again when it infiltrates through mulch and soil layers. Water is retained in the growing medium and contributed back to the hydrologic cycle through evapotranspiration. Soil microbes within the soils provide decomposition for pollutants such as hydrocarbons and nutrients. Soils also allow metals and chemicals to sorb to soil particles and compounds within the soil, preventing their release to receiving streams.

For permeable pavements, water quality benefits begin with filtration of storm water through the porous asphalt / concrete or bedding course layer. Contaminants such as fine particulates, oil and grease and heavy metals will be trapped within the pore structure of the porous asphalt / concrete or bedding course layer.

Due to the site specific characteristics of LID features, performance varies from site to site. Performance also depends heavily on design objectives and quality of

construction. Table 2.1 summarizes overall performance of LID-BMPs for reduction of annual runoff and some key pollutants.

Table 2.1 : Observed Removal Efficiencies (%) in LID-BMP Facilities in the USA and Canada.

Pollutant	Bio-retention / Rain Garden	Vegetated Swale ¹	Box Planter / Green Roof ²	Permeable Pavement ³	Naturalized Drainage Way ⁴
Annual Runoff Reduction (RR)	50~90	40~80	45~60	45~75	
Total Suspended Solids	59-90	65-81	86	85-89	80
Hydrocarbons		65			
Metals	80-90	20-50		35-90	40-70
Total Phosphorus	5-65	25	59	55-85	20
Total Nitrogen	46-50	15-56	32	35-42	40
Bacteria		negative	37	40-80	

¹ based on monitoring results for grass swales

² filtering practices

³ infiltration practices

⁴ based on monitoring results for wet swales

(CWP, 2007a; Claytor et al, 1996)

3. SWMM AND LID CONTROLS

Effective storm water management requires a thorough understanding of the characteristics of rainfall-runoff generated during storm events. The U.S. Environmental Protection Agency's (EPAs) Storm Water Management Model (SWMM) is a popular urban/suburban rainfall-runoff model used by water resource professionals and researchers. SWMM can be used for single event or long-term (continuous) simulation of runoff quantity and quality. The runoff component operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators (Figure 3.1). Since SWMM Version 5.0.019 the capability of explicitly evaluating the performance of several green infrastructure (GI) practices has been included. SWMM was first developed in 1971¹ and has undergone several major upgrades since then². It continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well. The current edition, Version 5, is a complete re-write of the previous release.

SWMM uses the term low impact development (LID) controls for GI that are designed to capture surface runoff and provide some combination of detention, infiltration, and evapotranspiration. The GI/LID controls modeled in SWMM include bio-retention cells, rain gardens, green roofs, infiltration trenches, permeable pavements, rain barrels, rooftop disconnections, and vegetative swales.

Running under Windows, SWMM 5 provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses.

This latest re-write of SWMM was produced by the Water Supply and Water Resources Division of the U.S. Environmental Protection Agency's National Risk

Management Research Laboratory with assistance from the consulting firm of CDM-Smith.



Figure 3.1 : Rainfall-runoff management system.

3.1 Hydrological Features of SWMM Modeling

SWMM accounts for various hydrologic processes that produce runoff from urban areas. These include:

- time-varying rainfall
- evaporation of standing surface water
- snow accumulation and melting
- rainfall interception from depression storage
- infiltration of rainfall into unsaturated soil layers
- percolation of infiltrated water into groundwater layers
- interflow between groundwater and the drainage system
- nonlinear reservoir routing of overland flow
- capture and retention of rainfall/runoff with various types of low impact development (LID) practices.

Spatial variability in all of these processes is achieved by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between subcatchments, or between entry points of a drainage system.

3.2 Hydraulic Features of SWMM Modeling

SWMM also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through a drainage system network of pipes, channels, storage/treatment units and diversion structures. These include the ability to:

- handle networks of unlimited size
- use a wide variety of standard closed and open conduit shapes as well as natural channels
- model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- utilize either kinematic wave or full dynamic wave flow routing methods
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels.

3.3 Water Quality Control Features of SWMM Modeling

In addition to modeling the generation and transport of runoff flows, SWMM can also estimate the production of pollutant loads associated with this runoff. The following processes can be modeled for any number of user-defined water quality constituents:

- dry-weather pollutant buildup over different land uses
- pollutant washoff from specific land uses during storm events

- direct contribution of rainfall deposition
- reduction in dry-weather buildup due to street cleaning
- reduction in washoff load due to BMPs
- entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system
- routing of water quality constituents through the drainage system
- reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels.

3.4 Typical Applications of SWMM

Since its inception, SWMM has been used in thousands of sewer and storm water studies throughout the world. Typical applications include:

- design and sizing of drainage system components for flood control
- sizing of detention facilities and their appurtenances for flood control and water quality protection
- flood plain mapping of natural channel systems
- designing control strategies for minimizing combined sewer overflows
- evaluating the impact of inflow and infiltration on sanitary sewer overflows
- generating non-point source pollutant loadings for waste load allocation studies
- evaluating the effectiveness of BMPs for reducing wet weather pollutant loadings.

3.5 LID Controls in SWMM

LID Controls are low impact development practices designed to capture surface runoff and provide some combination of detention, infiltration, and evapotranspiration to it. They are considered as properties of a given subcatchment, similar to how Aquifers and Snow Packs are treated. SWMM can explicitly model eight different generic types of LID controls (Table 3.1):

Table 3.1 : LID controls in SWMM.

LID Type	Description
	Bio-retention Cells are depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas.
	Rain Gardens are a type of bio-retention cell consisting of just the engineered soil layer with no gravel bed below it.
	Green Roofs are another variation of a bio-retention cell that have a soil layer laying atop a special drainage mat material that conveys excess percolated rainfall off of the roof.
	Infiltration Trenches are narrow ditches filled with gravel that intercept runoff from upslope impervious areas. They provide storage volume and additional time for captured runoff to infiltrate the native soil below.
	Continuous Permeable Pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix. Normally all rainfall will immediately pass through the pavement into the gravel storage layer below it where it can infiltrate at natural rates into the site's native soil. Block Paver systems consist of impervious paver blocks placed on a sand or pea gravel bed with a gravel storage layer below. Rainfall is captured in the open spaces between the blocks and conveyed to the storage zone and native soil below.
	Rain Barrels (or Cisterns) are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.

Table 3.1 (continued) : LID controls in SWMM.

LID Type	Description
	Rooftop Disconnection has downspouts discharge to pervious landscaped areas and lawns instead of directly into storm drains. It can also model roofs with directly connected drains that overflow onto pervious areas.
	Vegetative Swales are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it.

Bio-retention cells, infiltration trenches, and permeable pavement systems can contain optional drain systems in their gravel storage beds to convey excess captured runoff off of the site and prevent the unit from flooding. They can also have an impermeable floor or liner that prevents any infiltration into the native soil from occurring. Infiltration trenches and permeable pavement systems can also be subjected to a decrease in hydraulic conductivity over time due to clogging.

Although some LID practices can also provide significant pollutant reduction benefits, at this time SWMM only models the reduction in runoff mass load resulting from the reduction in runoff flow volume.

3.6 LID Representation

LID controls are represented by a combination of vertical layers whose properties are defined on a per-unit-area basis. This allows LIDs of the same design but differing area coverage to easily be placed within different subcatchments of a study area. During a simulation SWMM performs a moisture balance that keeps track of how much water moves between and is stored within each LID layer. As an example, the layers used to model a bio-retention cell and the flow pathways between them are shown in Figure 3.2. The various possible layers consist of the following:

- The Surface Layer corresponds to the ground (or pavement) surface that receives direct rainfall and runoff from upstream land areas, stores excess inflow in depression storage, and generates surface outflow that either enters the drainage system or flows onto downstream land areas.

- The Pavement Layer is the layer of porous concrete or asphalt used in continuous permeable pavement systems, or is the paver blocks and filler material used in modular systems.
- The Soil Layer is the engineered soil mixture used in bio-retention cells to support vegetative growth. It can also be a sand layer placed beneath a pavement layer to provide bedding and filtration.
- The Storage Layer is a bed of crushed rock or gravel that provides storage in bio-retention cells, porous pavement, and infiltration trench systems. For a rain barrel it is simply the barrel itself.
- The Drain System conveys water out of the gravel storage layer of bio-retention cells, permeable pavement systems, and infiltration trenches (typically with slotted pipes) into a common outlet pipe or chamber. For rain barrels it is simply the drain valve at the bottom of the barrel while for rooftop disconnection it is the roof gutter and downspout system.
- The Drainage Mat Layer is a mat or plate placed between the soil media and the roof in a green roof whose purpose is to convey any water that drains through the soil layer off of the roof.

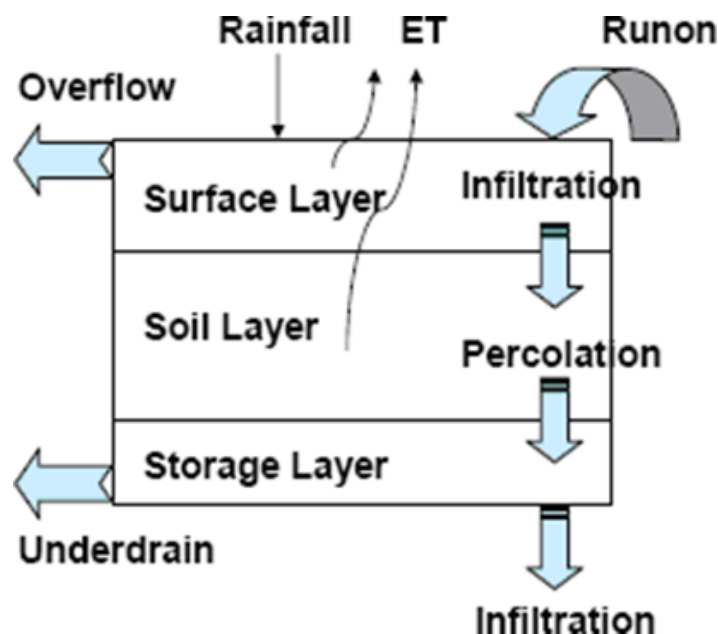


Figure 3.2 : Conceptual diagram of a bio-retention cell LID.

Table 3.2 indicates which combination of layers applies to each type of LID (x means required, o means optional).

Table 3.2 : Layers used to model different types of LID units.

LID Type	Surface	Pavement	Soil	Storage	Drain	Drainage Mat
Bio-Retention Cell	x		x	o	o	
Rain Garden	x		x			
Green Roof	x		x			X
Permeable Pavement	x	x	o	x	o	
Infiltration Trench	x			x	o	
Rain Barrel				x	x	
Roof Disconnection	x				x	
Vegetative Swale	x					

3.7 How to Place and Use LIDs Within Subcatchments

There are two different approaches for placing LID controls within a subcatchment:

- place one or more controls in an existing subcatchment that will displace an equal amount of non-LID area from the subcatchment
- create a new subcatchment devoted entirely to just a single LID practice.

The first approach allows a mix of LIDs to be placed into a subcatchment, each treating a different portion of the runoff generated from the non-LID fraction of the subcatchment. It should be noted that under this option the subcatchment's LIDs act in parallel - it is not possible to make them act in series (i.e., have the outflow from one LID control become the inflow to another LID). Also, after LID placement the subcatchment's Percent Impervious and Width properties may require adjustment to compensate for the amount of original subcatchment area that has now been replaced by LIDs (Figure 3.2). For example, suppose that a subcatchment which is 40% impervious has 75% of that area converted to a permeable pavement LID. After the LID is added the subcatchment's percent imperviousness should be changed to the percent of impervious area remaining divided by the percent of non-LID area remaining. This works out to $(1 - 0.75) * 40 / (100 - 0.75 * 40)$ or 14.3 %.

Under this first approach the runoff available for capture by the subcatchment's LIDs is the runoff generated from its impervious area. If the option to re-route some fraction of this runoff to the pervious area is exercised, then only the remaining impervious

runoff (if any) will be available for LID treatment. Also note that green roofs and roof disconnection only treat the precipitation that falls directly on them and do not capture runoff from other impervious areas in their subcatchment.

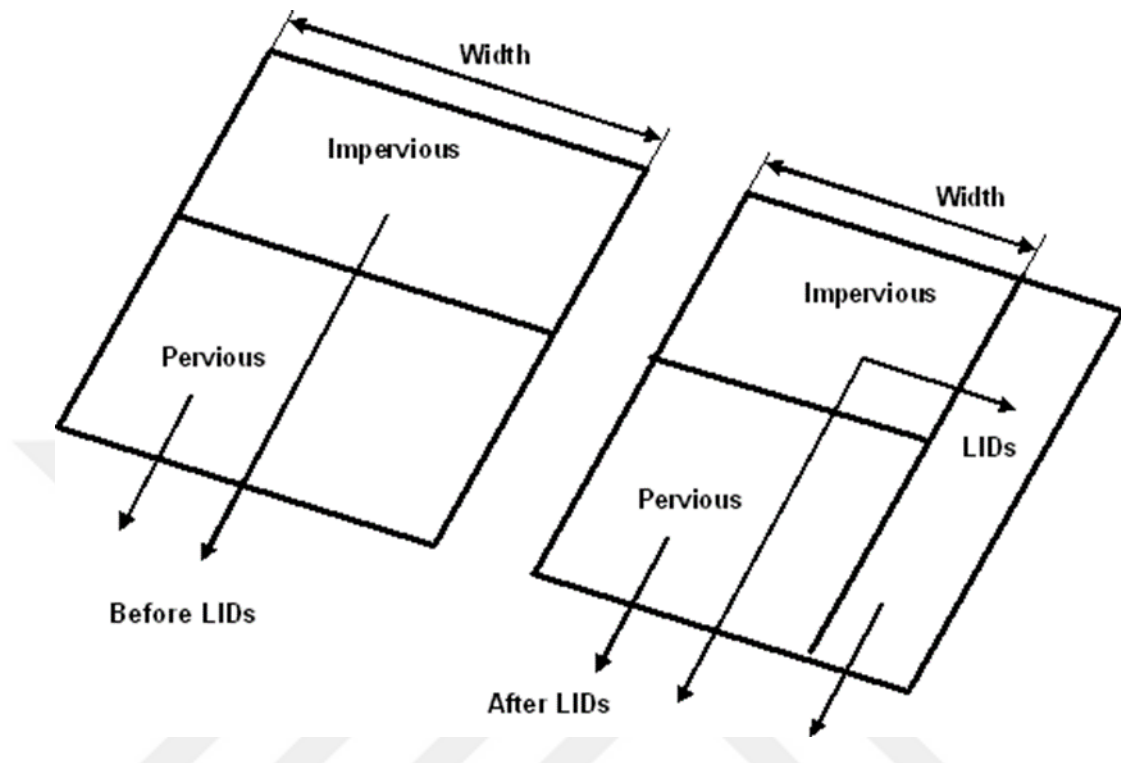


Figure 3.3 : Adjustment of subcatchment parameters after LID placement.

The second approach allows LID controls to be strung along in series and also allows runoff from several different upstream subcatchments to be routed onto the LID subcatchment. If these single-LID subcatchments are carved out of existing subcatchments, then once again some adjustment of the Percent Impervious, Width and also the Area properties of the latter may be necessary. In addition, whenever an LID occupies the entire subcatchment the values assigned to the subcatchment's standard surface properties (such as imperviousness, slope, roughness, etc.) are overridden by those that pertain to the LID unit.

Normally both surface and drain outflows from LID units are routed to the same outlet location assigned to the parent subcatchment. However, one can choose to return all LID outflow to the pervious area of the parent subcatchment and/or route the drain outflow to a separate designated outlet (When both of these options are chosen, only the surface outflow is returned to the pervious sub-area).



4. CASE STUDY INTRODUCTION AND DEVELOPED SWMM MODEL

In this section, the case study characteristics are introduced and afterwards developed SWMM model including LID controls is depicted.

4.1 Case Study Introduction

This study is carried out on Bastam city, the capital of Bastam district located in Shahrud county, Semnan province, Iran. Bastam was founded in the 6th century in the Greater Khorasan. It is 6 kilometers north of Shahrud. Historically, the city is known for its Islamic monuments from the Ilkhanid period and its association with the mystic Bayazid Bastami. The Alborz mountains are to the north of the city. At the 2006 census, Bastam population was 7'382, in 1997 families. Shahrud county is subdivided into three districts: The Beyarjomand District, Bastam District, and the Central District. There are 6 cities in the county: Shahrud, Beyarjomand, Kalateh Khij, Mojen Rudian and Bastam. The county's population was 238'830, in 70'598 families at the census conducted in 2010. Semnan Province is one of the 31 provinces of Iran. It is in the north of the country, and its capital is Semnan. The province of Semnan covers an area of 96'816 km² (5.9% of country area) and stretches along Alborz mountain range in the north and spans to desert of Dasht-e Kavir in the south. Its population estimated to be 589'742 according to 2005 census. Figure 4-1 shows Semnan Province in country subdivisions and Figure 4-2 depicts Shahrud County and Bastam District in Seman Province.

Figure 4-3 shows annual precipitation sum in 30 major watersheds of the country during a 49-year period starting from 1969 and Figure 4-4 shows annual precipitation distribution in Semnan Province. According to these maps, annual accumulative precipitation average of Iran is 250 mm. Likewise, annual accumulative precipitation average of Iran's central dessert watershed which Bastam city and under study basins are located in is 148 mm. More than 75 percent of annual average precipitation occurs in winter and spring seasons.



Figure 4.1 : Semnan Province in country subdivisions



Figure 4.2 : Shahrud County and Bastam District in Seman Province.

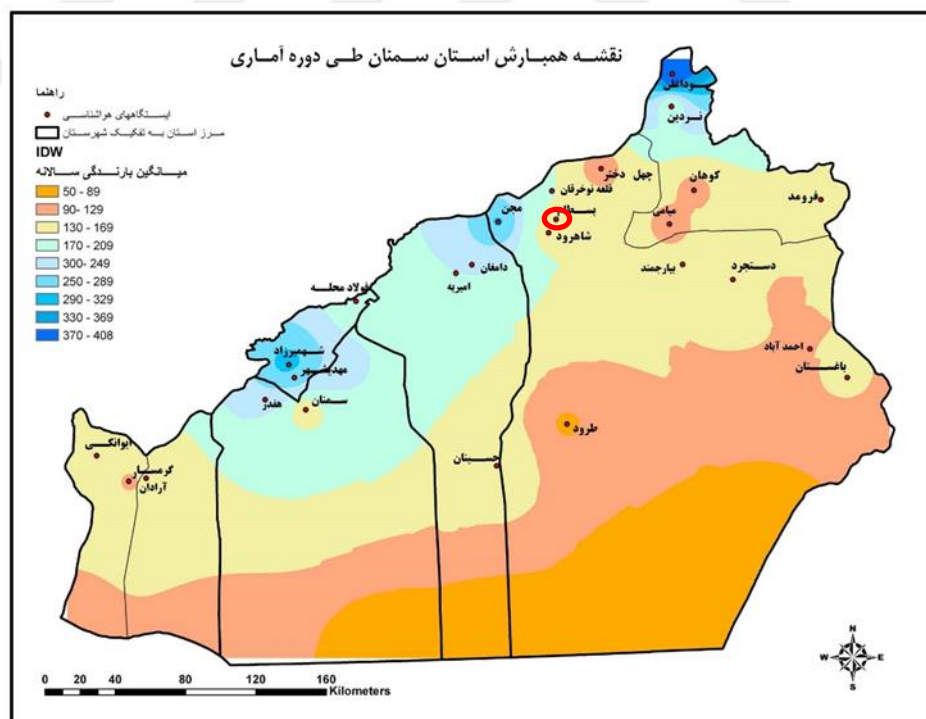
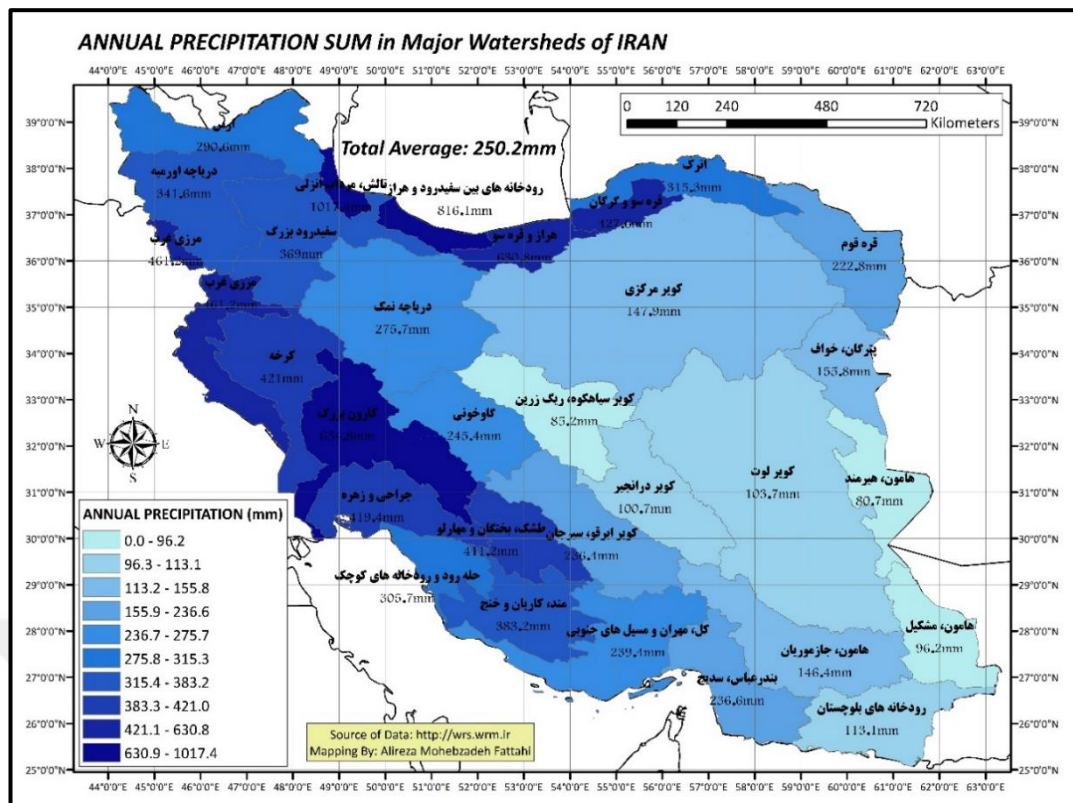


Figure 4.4 : Annual precipitation distribution in Semnan Province.

Shahrud County is located in arid climate of Seman Province and Bastam District which is located to the north of this county is in the vicinity of semi-arid climate.

Climatic zoning of Semnan Province is shown in Figure 4-5 whereas climatic zoning of Shahrud County and Bastam District is shown in Figure 4-6.

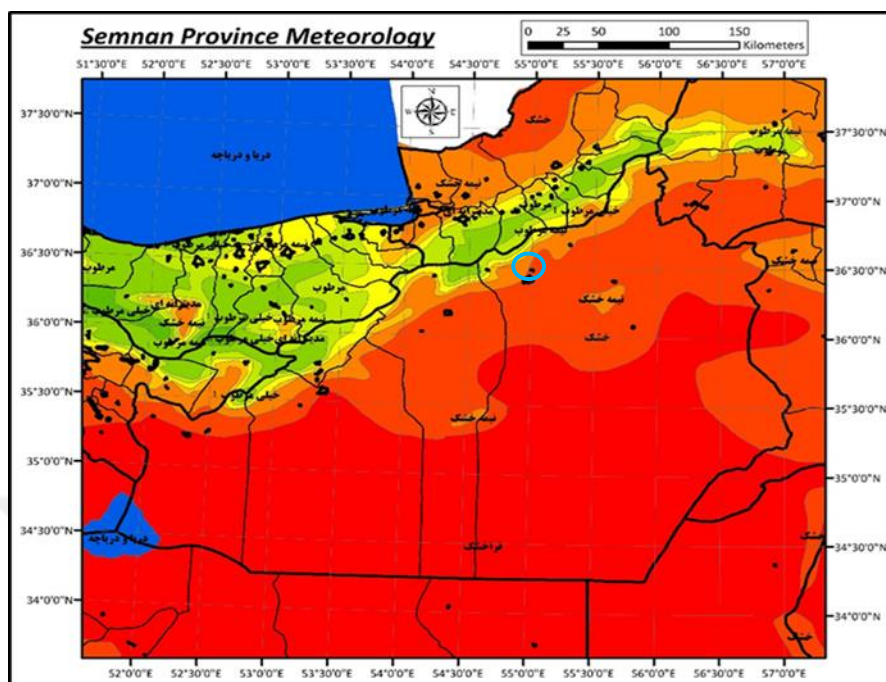


Figure 4.5 : Climatic zoning of Semnan Province (arid and semi-arid).

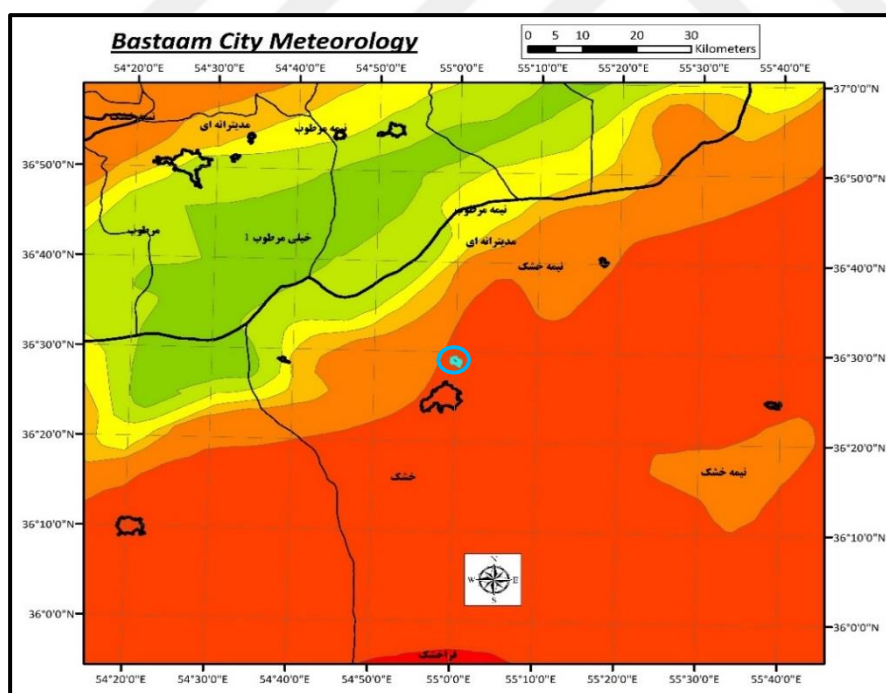


Figure 4.6 : Climatic zoning of Shahrud County and Bastam District.

In Figures 4-7 through 4-12 several satellite images (plan views and 3D) from study area and related watersheds are shown.

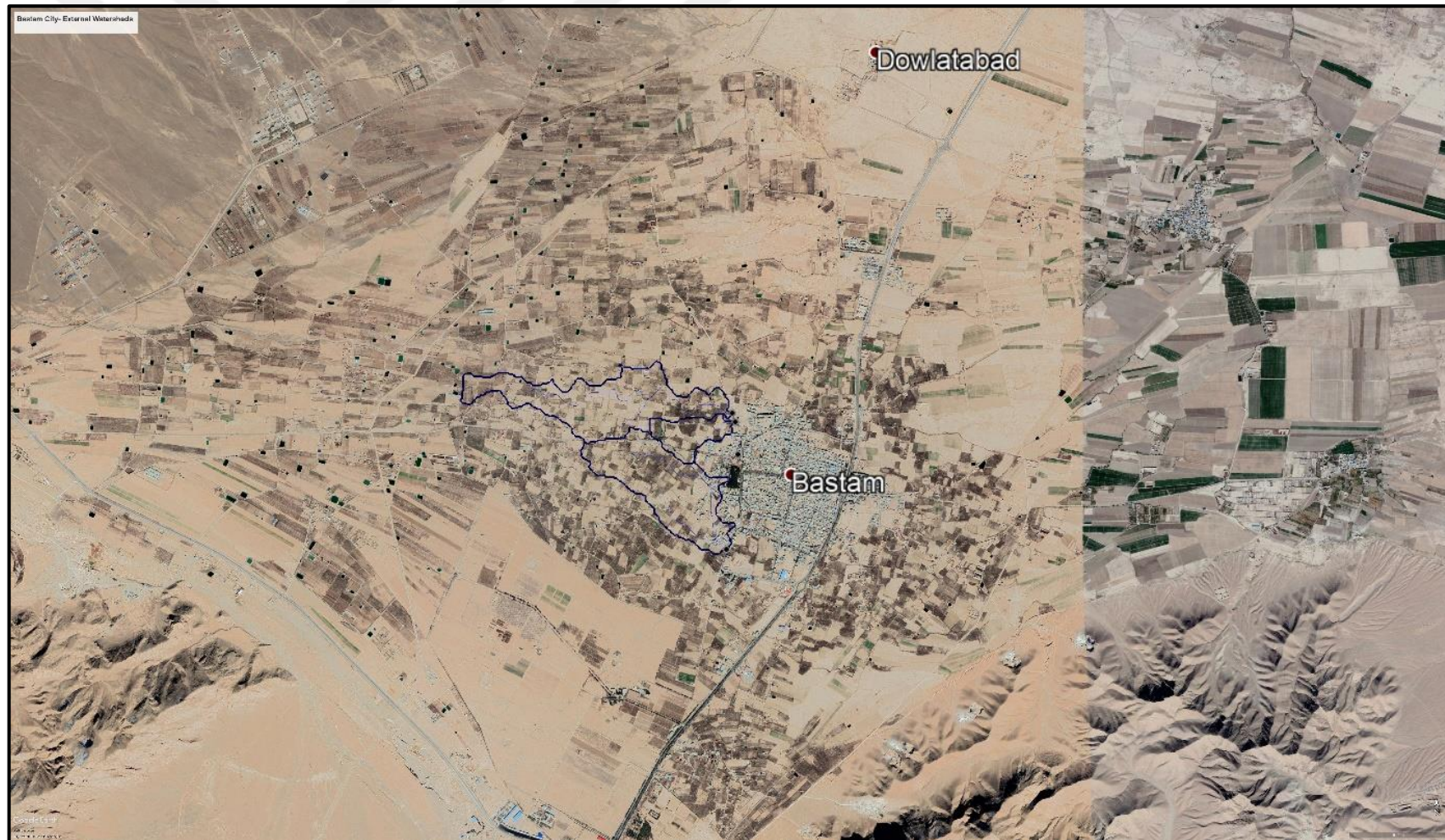


Figure 4.7 : Bastam city and external watersheds satellite image, plan view-1



Figure 4.8 : Bastam city and external watersheds satellite image, plan view-2

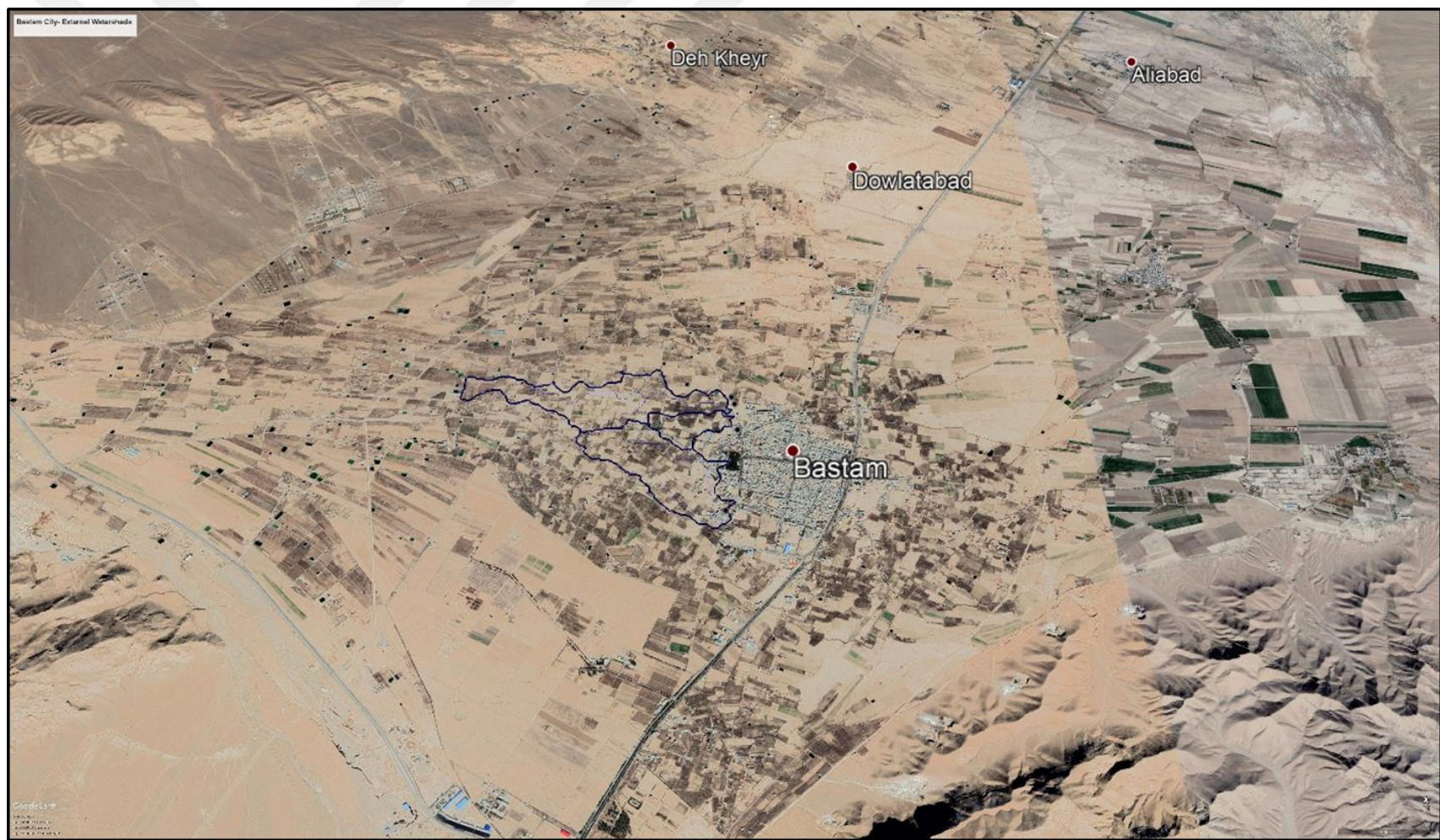


Figure 4.9 : Bastam city and external watersheds satellite image, 3D-1



Figure 4.10 : Bastam city and external watersheds satellite image, 3D-2



Figure 4.11 : Bastam city satellite image, plan view, 2004



Figure 4.12 : Bastam city satellite image, plan view, 2019.

As shown through figures 4-7 to 4-10 external watersheds of the study area are located to the west of Bastam city, extending over agricultural lots with high infiltration and low slope rates. In figures 4-11 and 4-12 we see that Bastam city has not been developed significantly in last 15 years (from 2004 to 2019) and just vegetation coverage has grown thinner in these years due to a decade of drought.

4.2 Research Methodology and Developed Model

Research methodology is fully outlined in Figures 4.13 through 4.15. Methodology includes hydrological, hydraulic and LID-practices models.

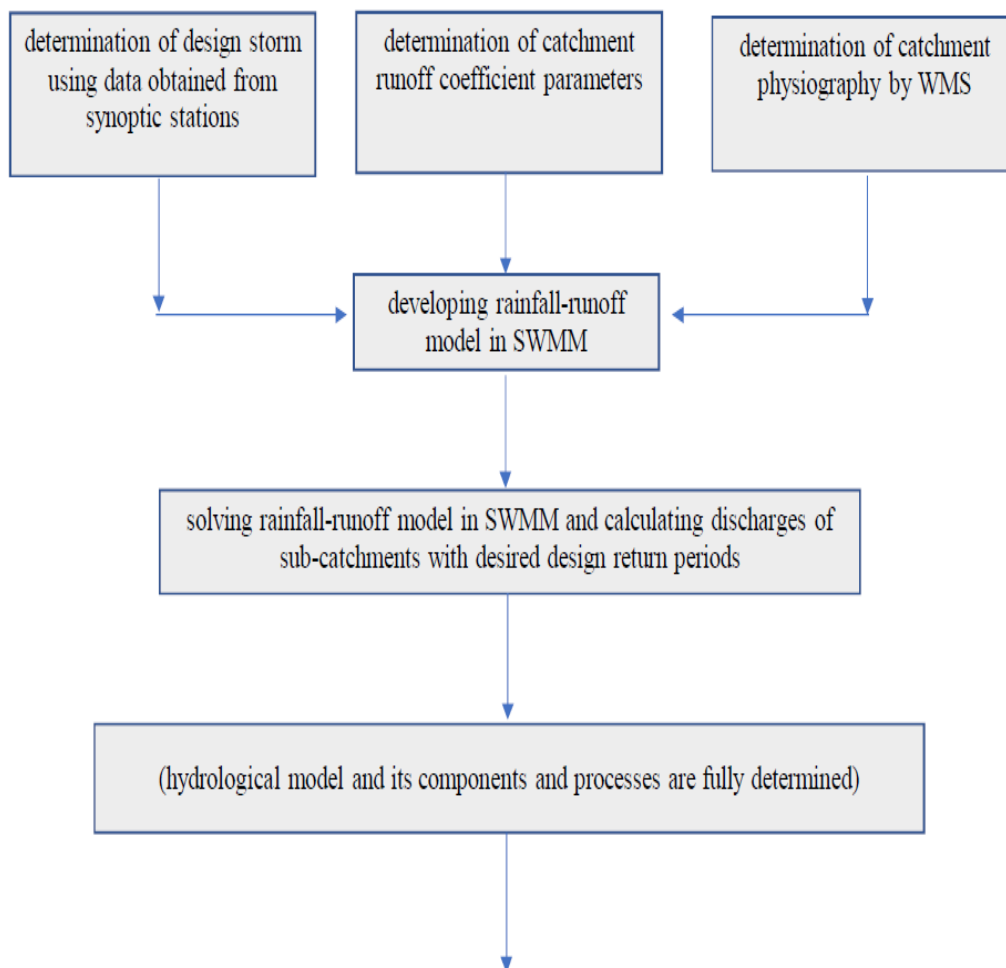


Figure 4.13 : Methodology 1- hydrologic model.

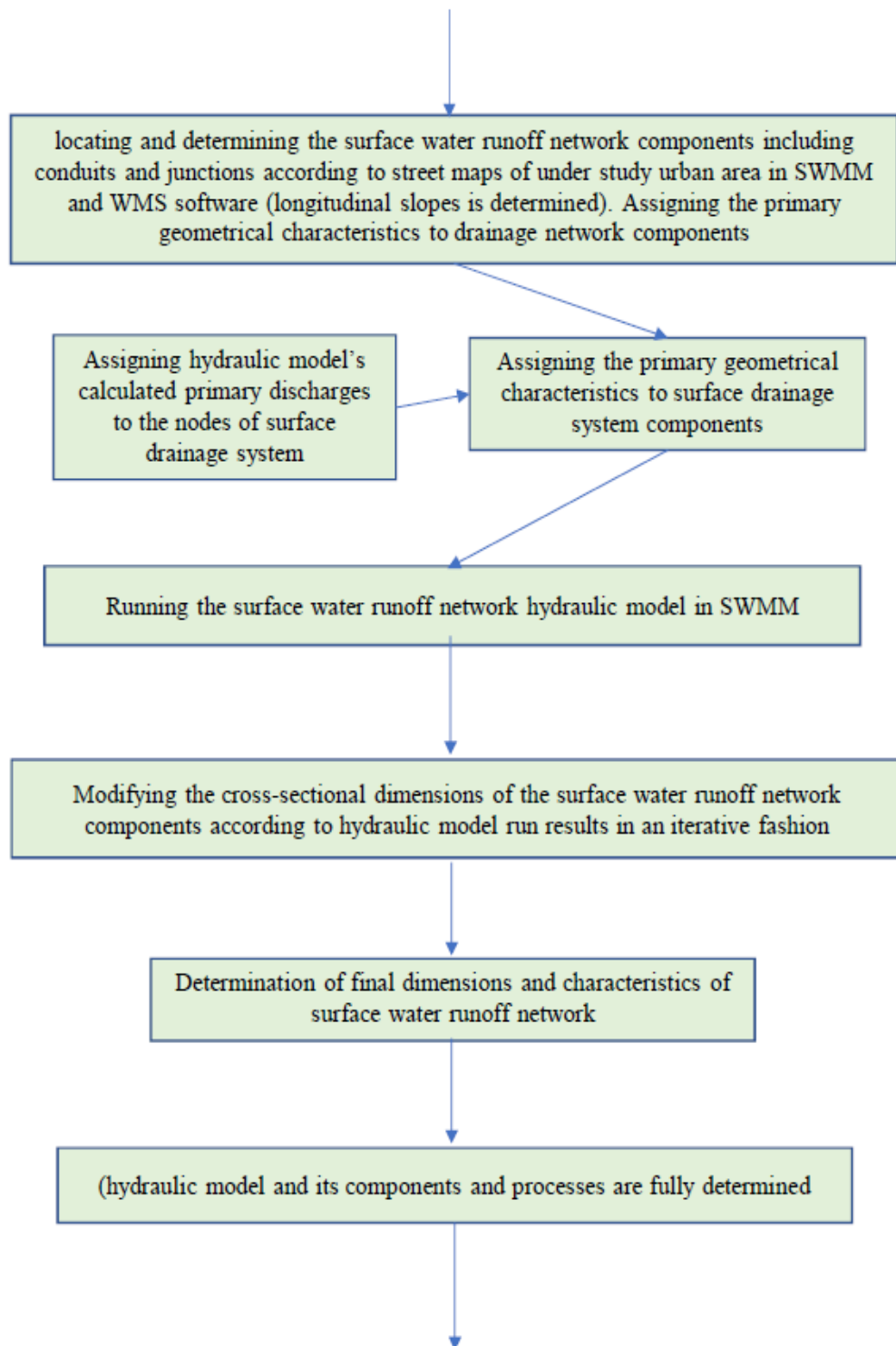


Figure 4.14 : Methodology 2- hydraulic model.

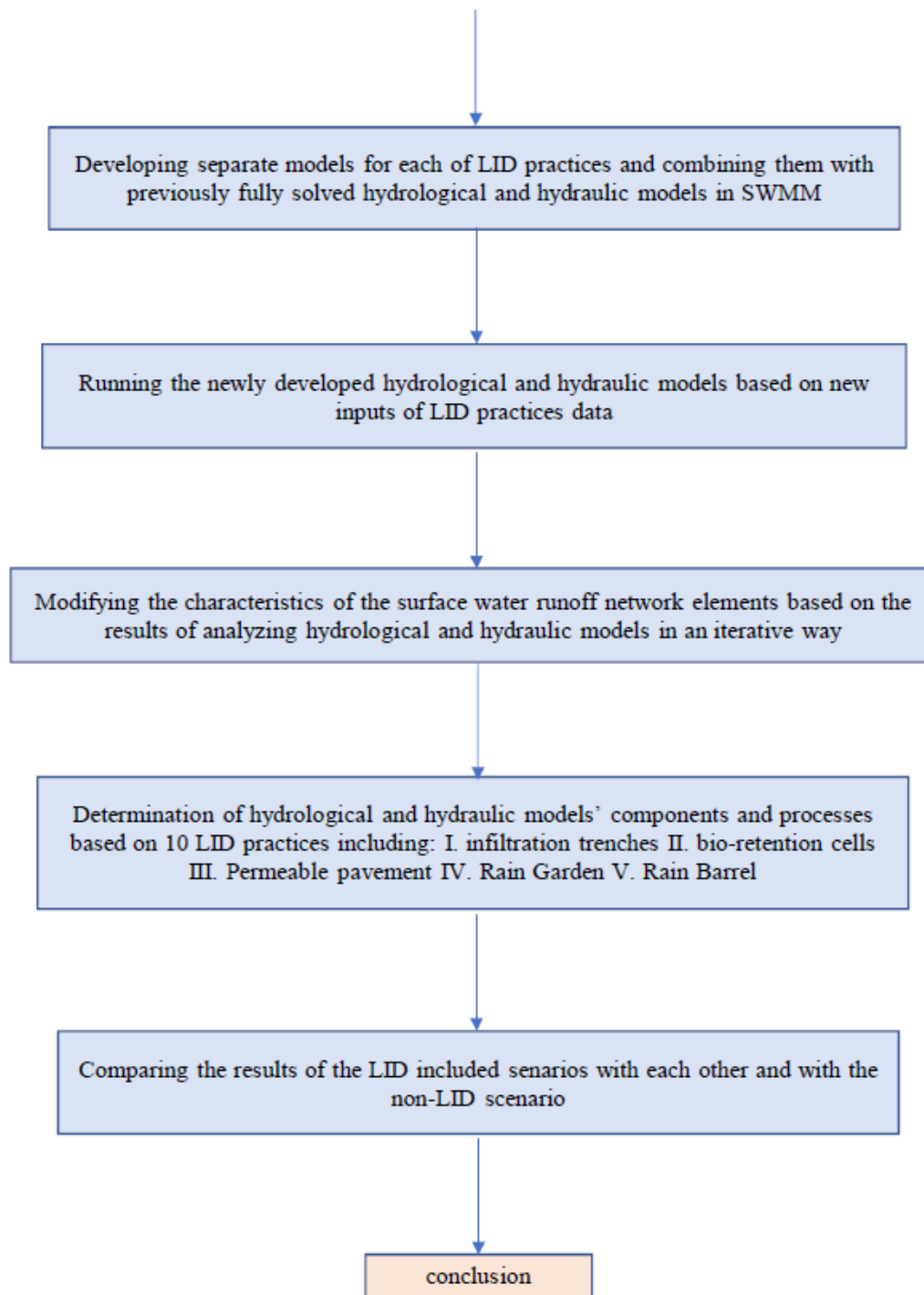


Figure 4.15 : Methodology 3- LID implementations.

4.2.1 Introducing geometrical and physiographical properties of watersheds

Figure 4.16 shows hydrographical network and rivers surrounding Bastam city. Topographic conceptual model of Bastam city's external watersheds is depicted in Figures 4.17 and 4.18, whereas their physiographical conceptual model is shown in Figures 4.19 and 4.20.

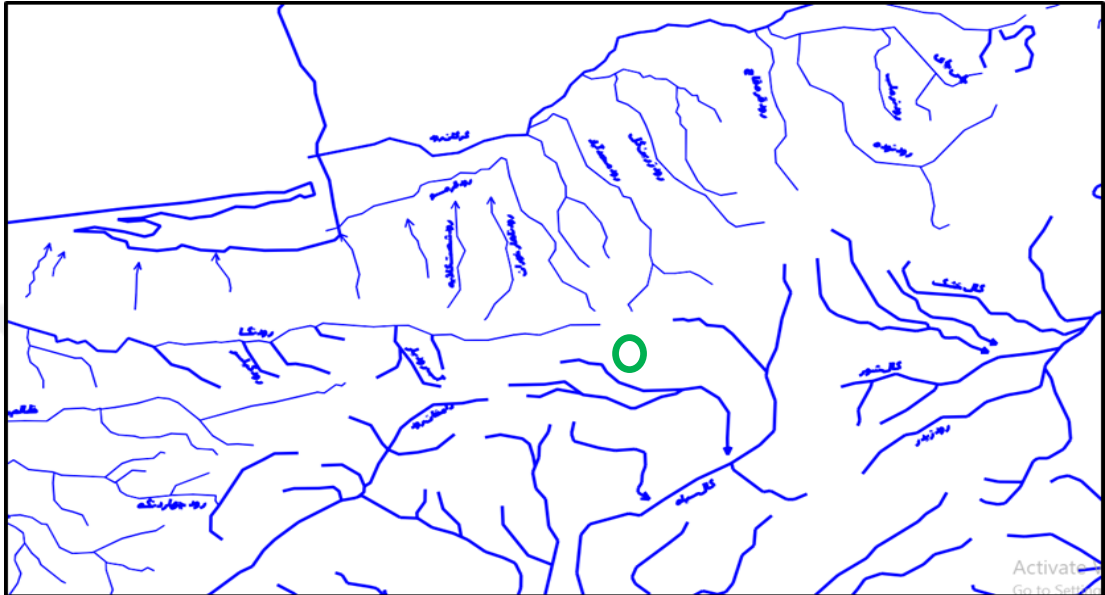


Figure 4.16 : Hydrographical network and rivers surrounding Bastam city

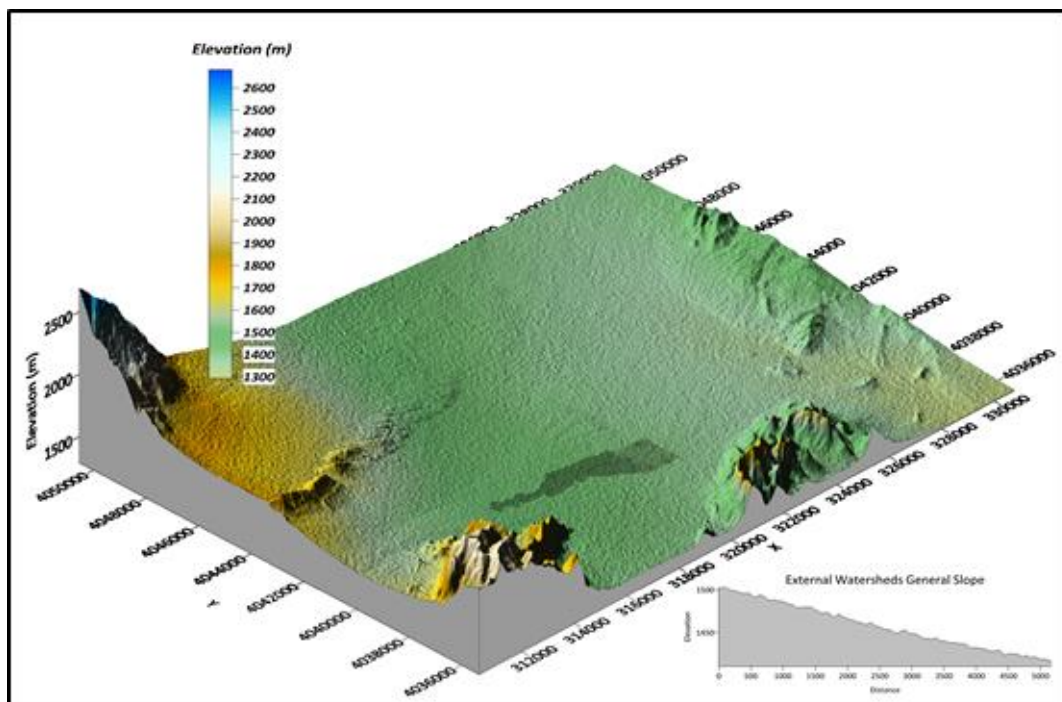


Figure 4.17 : Conceptual topographic model of Bastam city external watersheds-3D.

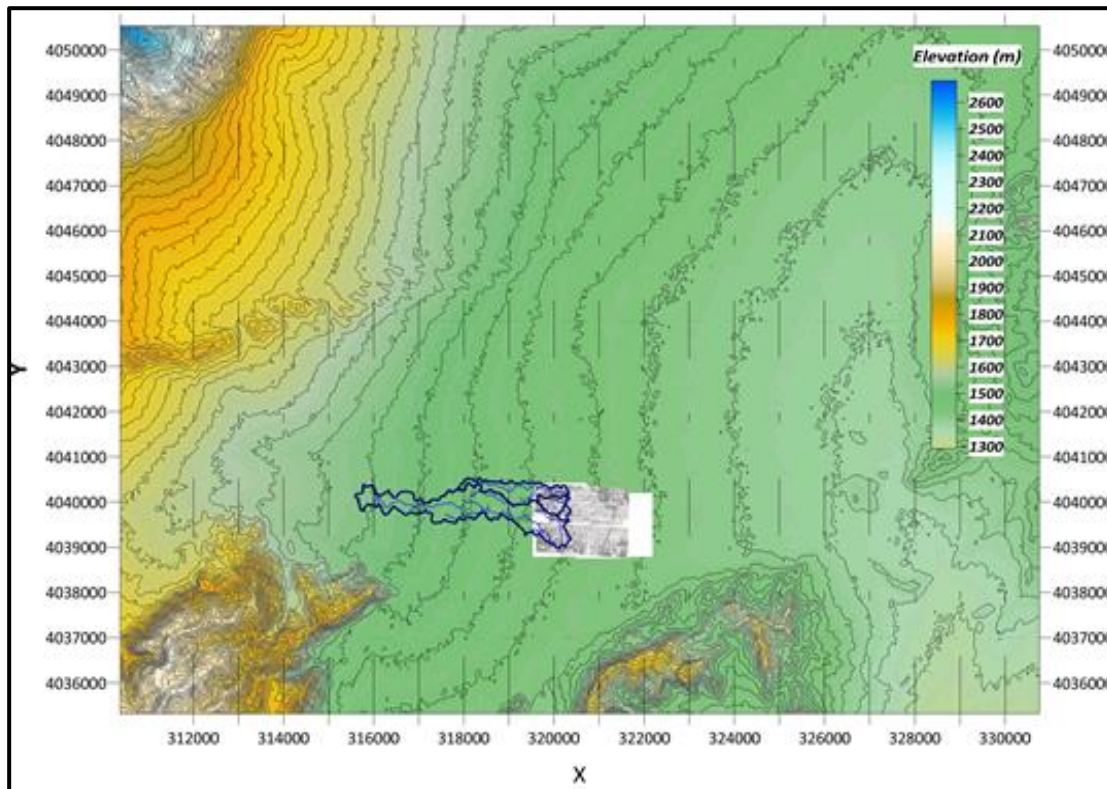


Figure 4.18 : Conceptual topography model of Bastam city's external watersheds.

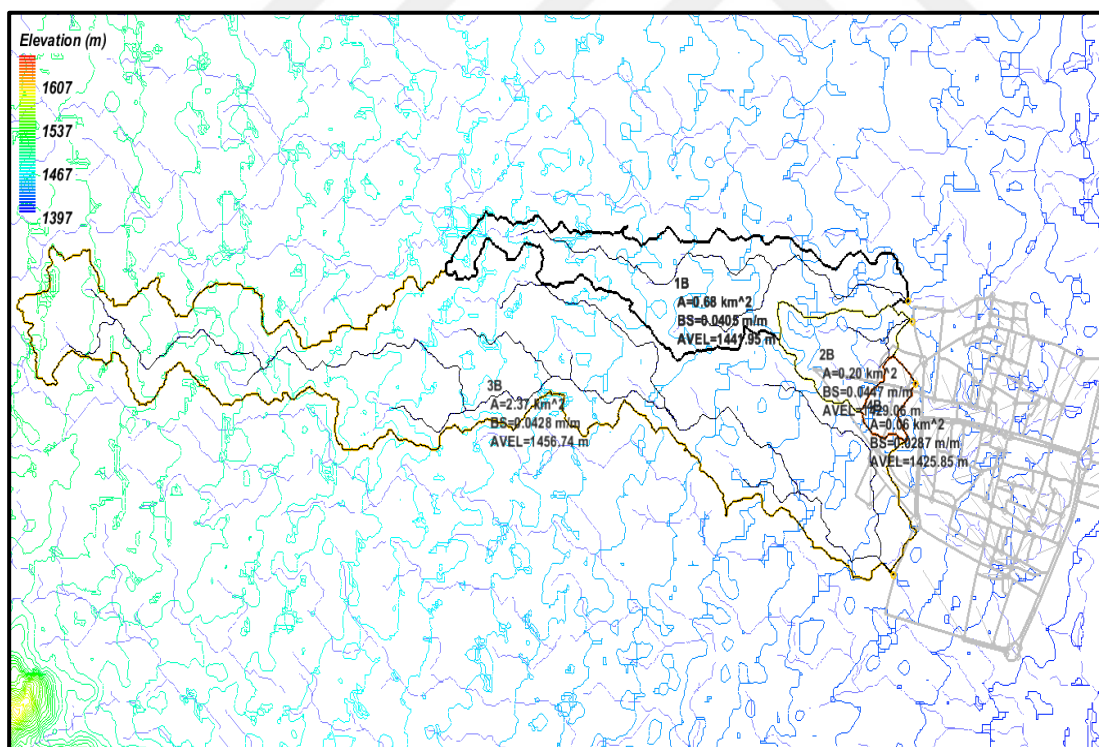


Figure 4.19 : Conceptual physiography model of Bastam city external watersheds.

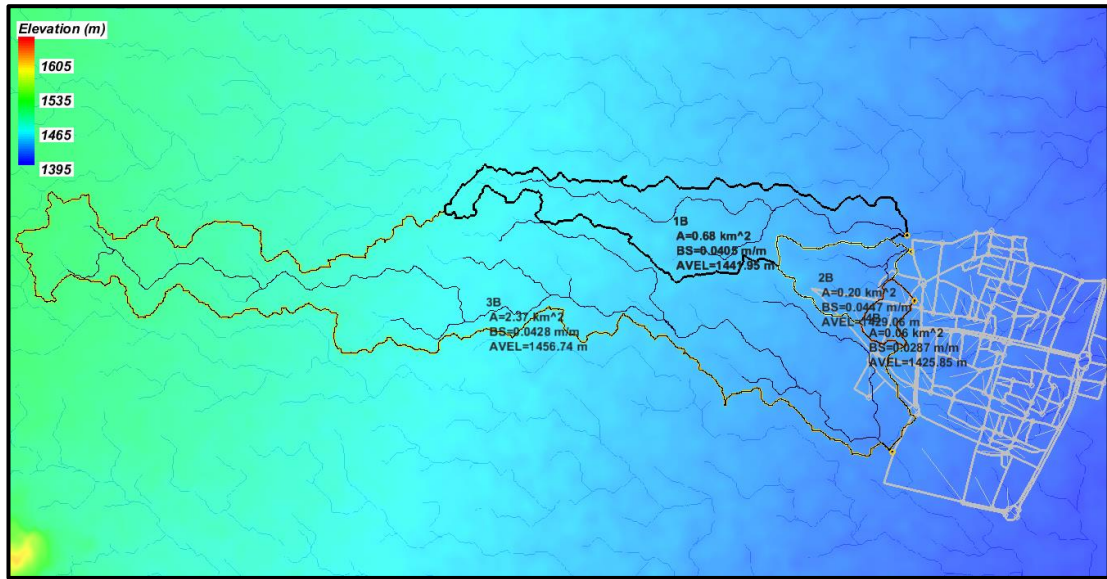


Figure 4.20 : Conceptual physiography model of Bastam city external watersheds.

4.2.2 Developing hydrological model for external watersheds

As shown in Figure 4.20, the area under study is Bastam city in Semnan Province, Iran, with a span of 142.6 hectares, including 101 subcatchments and 4 exterior watersheds with a total area of 3.31 km².

Hydrologic calculations of the exterior watersheds peak discharge for 25-year flood return period has been carried out through SCS rainfall-runoff method (unit hydrograph), whose rainfall data is obtained by performing 24-hours rainfall statistical analysis on Bastam rain gauge station. Considering its location and altitude this station properly represents under study watersheds rainfall (Table 4.1). The software that is used for this purpose is HEC-HMS (Hydraulic Engineering Center - Hydrologic Modeling System) which is based on high accurate numerical modeling and is mounted on WMS (Watershed Modeling system) computer program. WMS is also used to determine geometrical and physiographical properties of the watersheds and subcatchments. On the other hand, hydrological calculations of Bastam city subcatchments peak discharge for 10-year flood period has been carried out through SWMM software, with the above-mentioned rainfall data.

Table 4.1 : Used rain gauge station characteristics.

Station Name	River Name	Longitude	Latitude	Elevation (m)	from Year
Bastam	MOJEN	54-58-57	36-28-12	1500	1970

Figure 4.21 shows observed annual maximum 24-hour rainfall depths in Bastam rain gauge (rainfall data has been gathered for 45 years in this station since 1970) and their non-exceedance probability. Tables 4.2 and 4.3 lists observed and predicted annual maximum 24-hour rainfall depths predicted by GEV statistic distribution using HyfranPlus software while figure 4.22 depicts this set of data graphically.

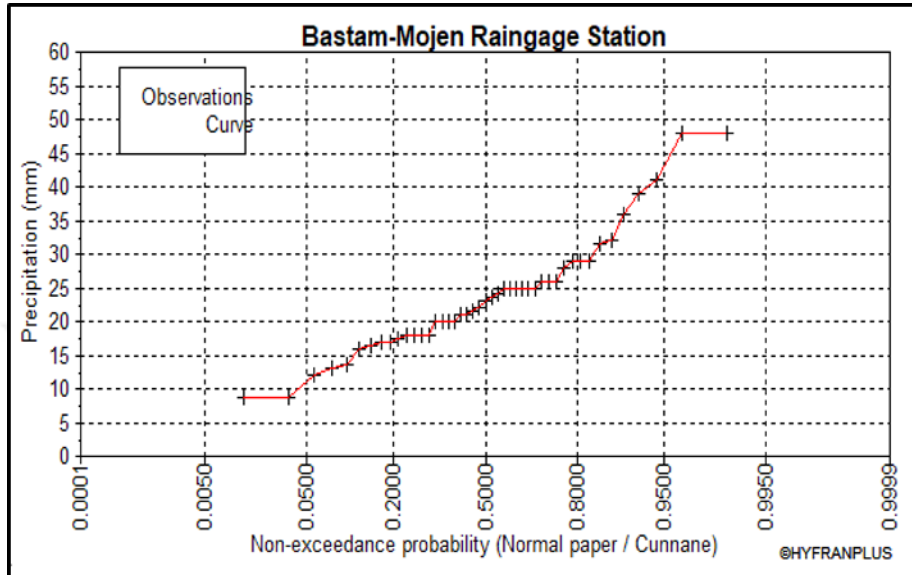


Figure 4.21 : Observed annual max. 24-hour rainfall depths in Bastam rain gauge.

Table 4.2 : Observed and predicted annual max 24-hour rainfall depths- GEV statistic distribution.

Data No.	Plot Position	Actual Data	Predicted Data
1	0.022	8.7	11.15
2	0.044	12	12.43
3	0.065	13	13.32
4	0.087	13	14.03
5	0.109	13.5	14.65
6	0.13	16	15.2
7	0.152	16.5	15.71
8	0.174	17	16.19
9	0.196	17	16.64
10	0.217	17.5	17.07
11	0.239	18	17.49
12	0.261	18	17.9
13	0.283	18	18.3
14	0.304	18	18.7
15	0.326	20	19.09
16	0.348	20	19.48

Table 4.2 (Continued): Observed and predicted annual max 24-hour rainfall depths-GEV statistic distribution.

Data No.	Plot Position	Actual Data	Predicted Data
17	0.37	20	19.87
18	0.391	20	20.26
19	0.413	21	20.65
20	0.435	21	21.04
21	0.457	21.5	21.44
22	0.478	22	21.84
23	0.5	23	22.26
24	0.522	23.5	22.68
25	0.544	24	23.11
26	0.565	24.8	23.55
27	0.587	25	24
28	0.609	25	24.48
29	0.63	25	24.97
30	0.652	25	25.48
31	0.674	25	26.01
32	0.696	26	26.58
33	0.717	26	27.18
34	0.739	26	27.81
35	0.761	28	28.49
36	0.783	29	29.23
37	0.804	29	30.04
38	0.826	29	30.93
39	0.848	31.5	31.93
40	0.87	32	33.08
41	0.891	36	34.42
42	0.913	39	36.05
43	0.935	41	38.14
44	0.957	48	41.08
45	0.978	48	46.11

Table 4.3 : Rainfall depth prediction for different return periods.

Return Period	Probability	Prediction
500	0.998	63.88
200	0.995	56.95
100	0.99	51.8
50	0.98	46.72
25	0.96	41.68
10	0.9	35.03
5	0.8	29.87
2	0.5	22.26

Summary of rainfall statistical analysis is presented in Table 4.4. according to this analysis 10-year – 24-hour design storm depth is 35 mm and 25-year – 24-hour design storm depth is 41.7 millimeters.

Table 4.4 : Summary of performed statistical analysis on Bastam rain gauge station.

Station Name	Elevation (m)	from Year	P _{mean} MaxDaily (mm)	P _{max} Daily (mm)	P _{10 Year} Daily (mm)	P _{25 Year} Daily (mm)
Bastam	1500	1970	37.8	68	35	41.7

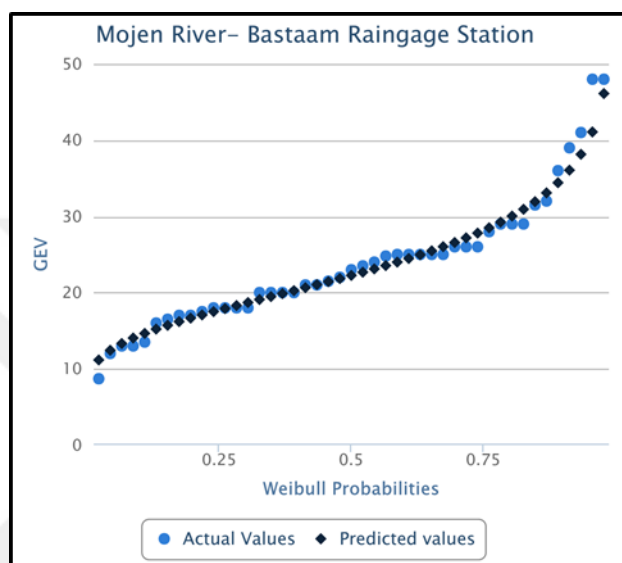


Figure 4.22 : Observed and predicted annual maximum 24-hour rainfall depths predicted by GEV statistic distribution.

Since precipitation intensity is not uniformly distributed during rainfall event and this has a direct effect on hydrograph shape and peak, Ghahreman method is employed here to account for this uncertainty in predicting rainfall temporal distribution. This way, 10-year storm design hyetograph is calculated to be like Table 4.5. Figure 4.23 shows these data graphically.

Table 4.5 : Summary of performed statistical analysis on Bastam rain gauge station.

Return Period (Yr)	15 min	1 hr	2 hr	3 hr	6 hr	12 hr
10	7.21	14.32	19.61	23.5	30.1	35.1

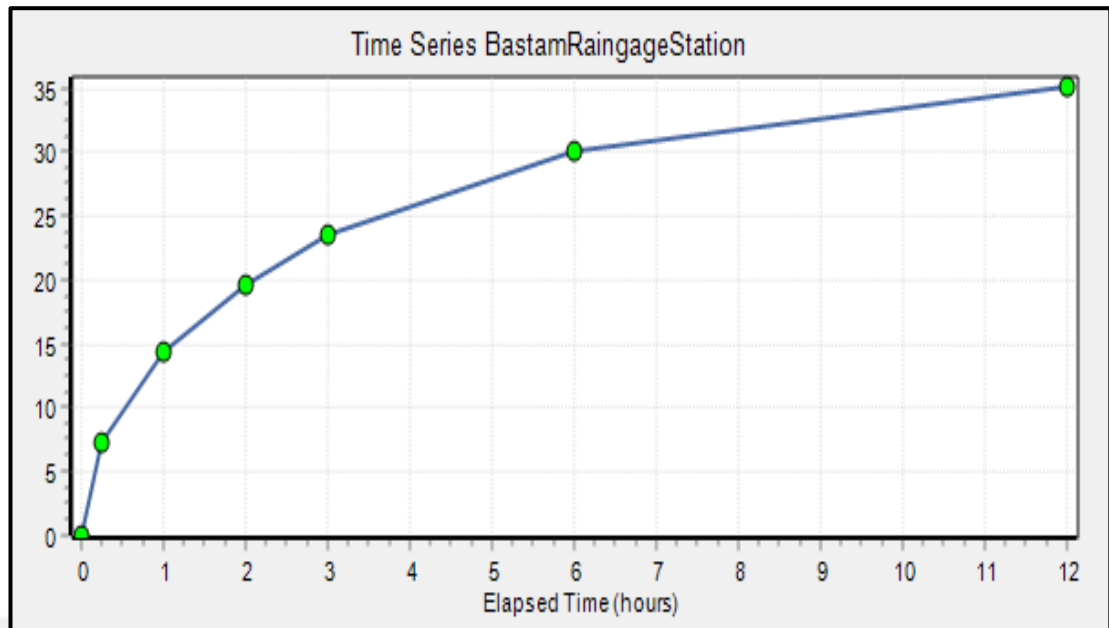


Figure 4.23 : 10-year storm design hyetograph (mm).

As it is shown in land use and soil type map (Figure 4.25 and Figure 4.26) of the watersheds, Bastam city is located in alluvial lands with agricultural use which naturally possesses a fair degree of infiltration. As stated earlier, HEC-HMS software mounted in WMS is used to calculate the discharge of 4 external watersheds (Figure 4.25). Geometrical and physiographical characteristics of exterior watersheds are listed in Table 4.6 and summary of modeling output is shown in table 4.7. 25-year storm event hyetograph and resulted hydrograph of the largest watershed is shown in Figure 4.27.

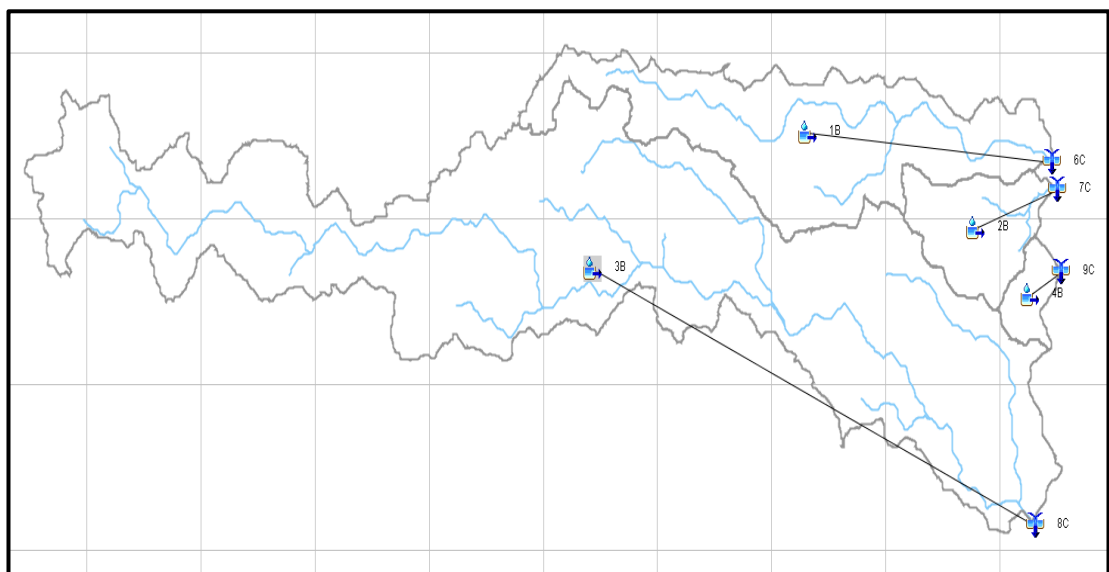


Figure 4.24 : Conceptual model of Bastam city external watersheds in HEC-HMS.

Table 4.6 : Geometrical and physiographical characteristics of exterior watersheds.

Basin Name	Area (km ²)	CN	Basin Slope	Max Flow Distance (m)	Max Flow Slope	Basin Length (m)	Basin Shape Factor	Basin Average Elevation (m)
1B	0.68	77.5	0.041	3173.6	0.014	2464.1	8.98	1.06
2B	0.2	78	0.045	928.2	0.019	717.6	2.64	0.6
3B	2.37	76.5	0.043	6581.5	0.013	4795	9.71	1.28
4B	0.06	79	0.029	430.1	0.014	316.3	1.75	0.02

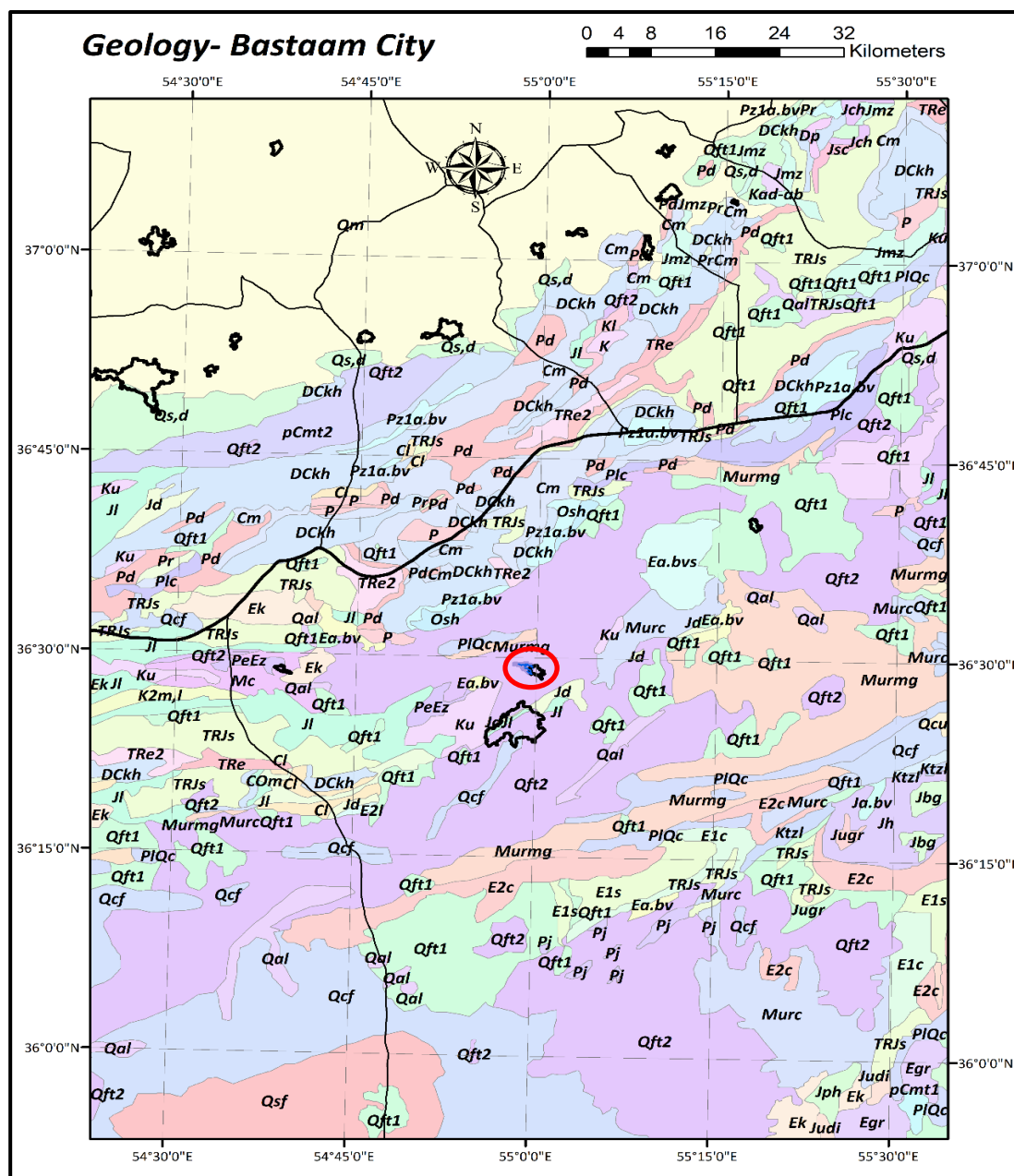


Figure 4.25 : Bastam Geology: Qft2: Low level pediment fan and valley terrace deposits.

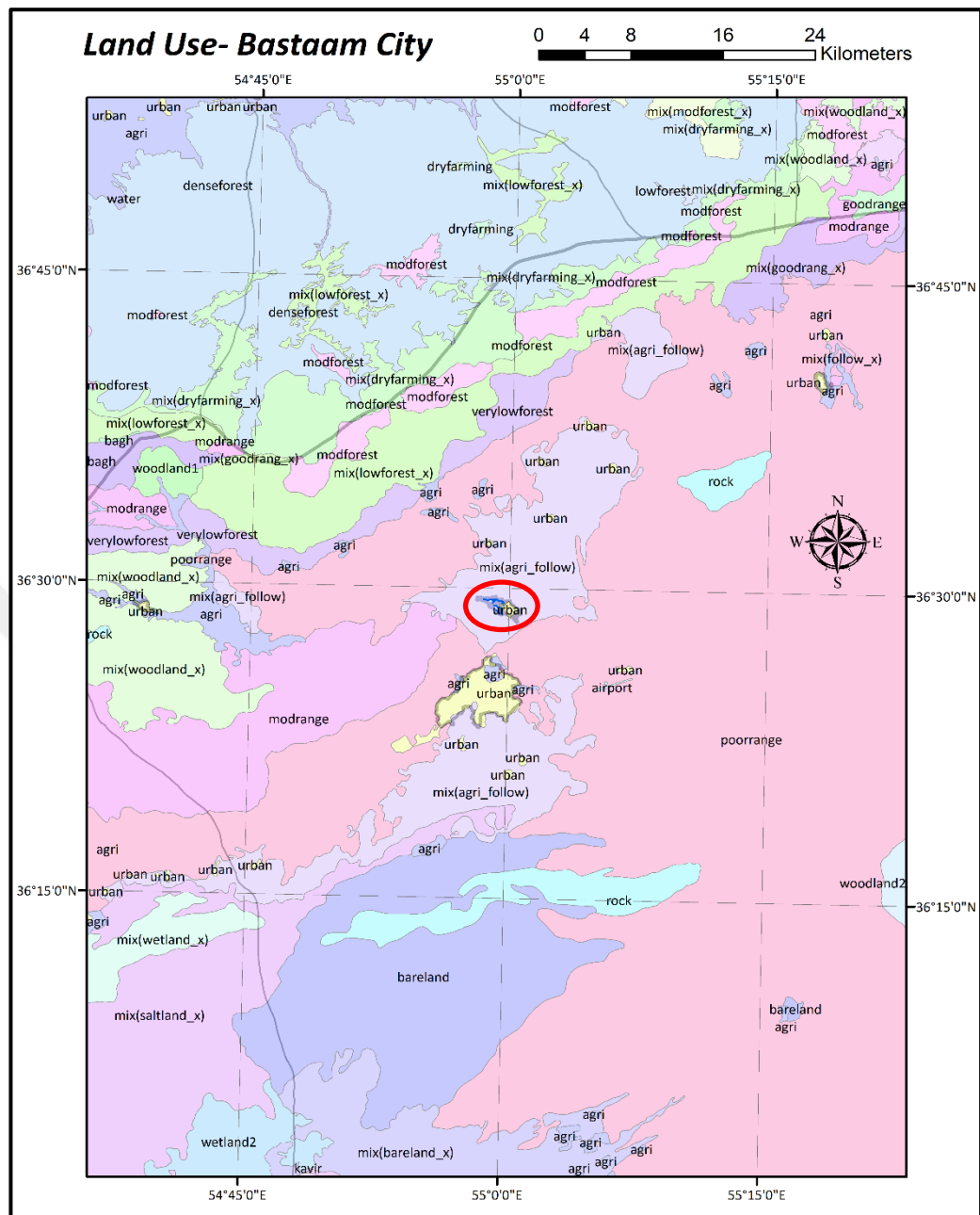


Figure 4.26 : Bastam city land use map.

Table 4.7 : Summary of model output of exterior watersheds.

Basin Name	Area (km2)	CN	Basin Slope	Max Flow Distance (m)	Max Flow Slope	Basin Average Elevation (m)	Peak Discharge (m3/s)	Volume (1000 m3)
1B	0.68	77.5	0.041	3173.6	0.014	1441.9	0.39	4.8
2B	0.2	78	0.045	928.2	0.019	1429.1	0.18	1.5
3B	2.37	76.5	0.043	6581.5	0.013	1456.7	0.91	15.3
4B	0.06	79	0.029	430.1	0.014	1425.8	0.07	0.5

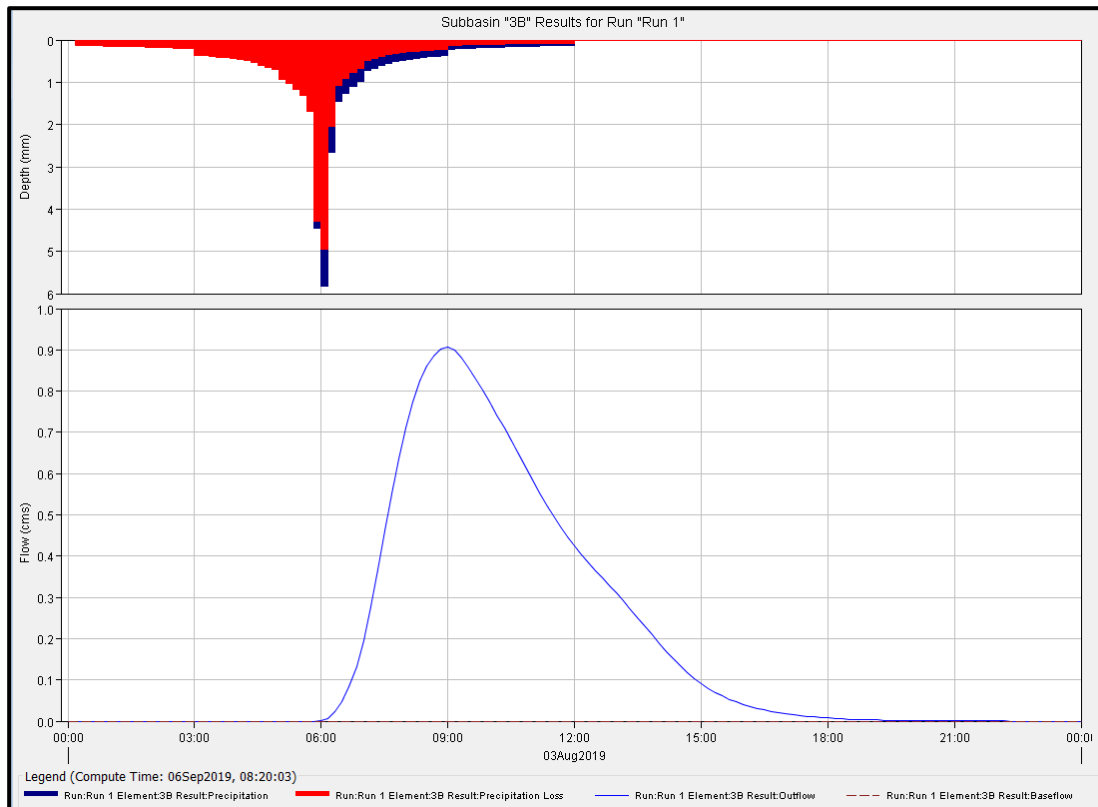


Figure 4.27 : 25-year storm event hyetograph and resulted hydrograph of the largest external watershed.

4.2.3 Developing hydraulic model for urban subcatchments (1st Scenario)

Drainage system model of Bastam city is developed in SWMM software. It consists of 101 subcatchments, 298 conduits with length of 36 km and 229 nodes connecting these links (Figures 4.28 and 4.29). Placement of conduits is carried out due to city urbanization i.e. along and at the level of streets to avoid extra earthwork. Street locations and directions are obtained from Open Street Map website. Topography (DEM) file yields junction elevations and therefore conduit slopes are calculated automatically by SWMM. 25 percent of catchment area is assumed to be impervious. Hydrologic routing is done by solving dynamic wave equations.

A rectangular section with the dimensions of 40x30 (width x depth) is considered to be the surface-water network cross section (Figure 4.30) since performance of LID practices will be examined and compared later on. Summary of drainage network of Bastam city characteristics is shown in Figure 4.31 and Geometrical/physiographical properties of Bastam city subcatchments and corresponding peak flows are presented in Table 4.8. Instantaneous discharge time series table of the drainage system and corresponding hydrograph is displayed in Table 4.9 and Figure 4.32.



Figure 4.28 : Bastam city as backdrop to developed drainage network in SWMM.

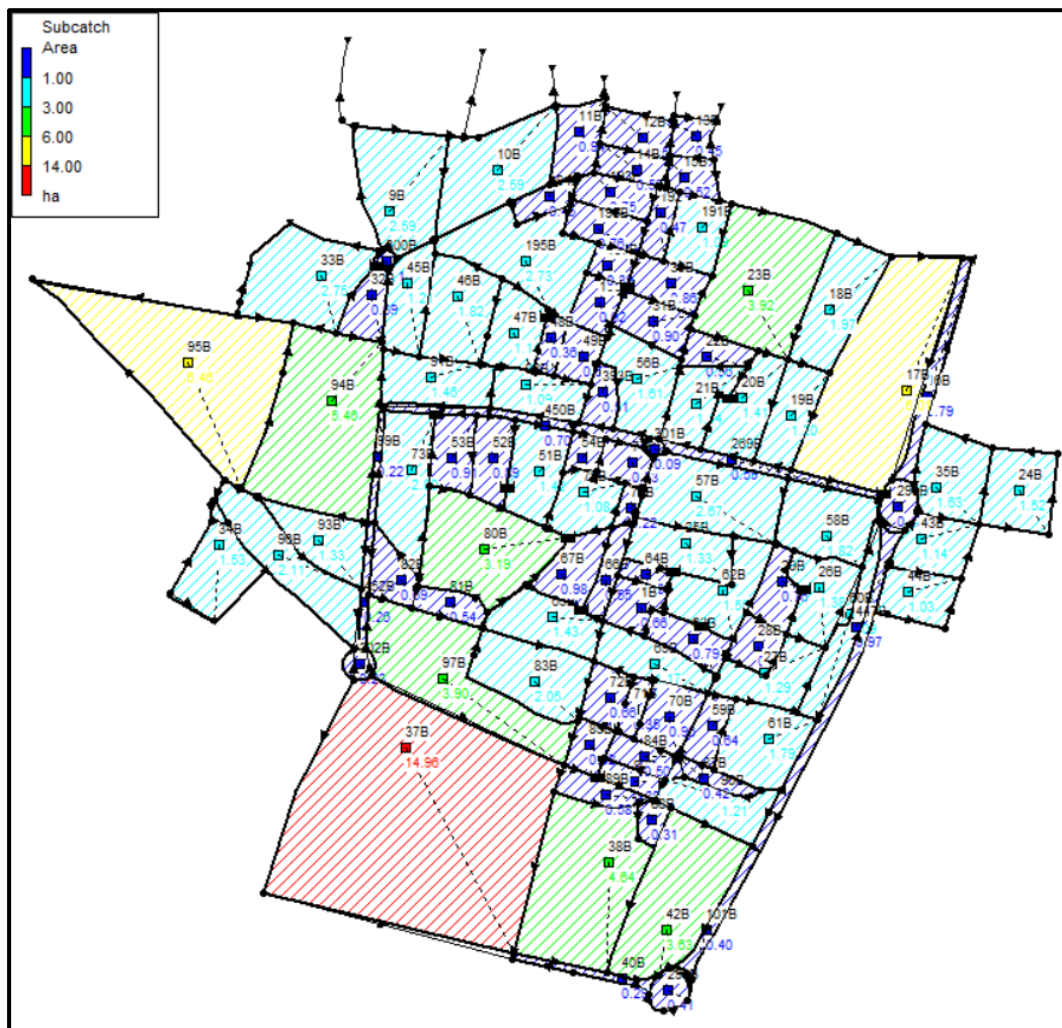


Figure 4.29 : Drainage system model of Bastam city- developed in SWMM.

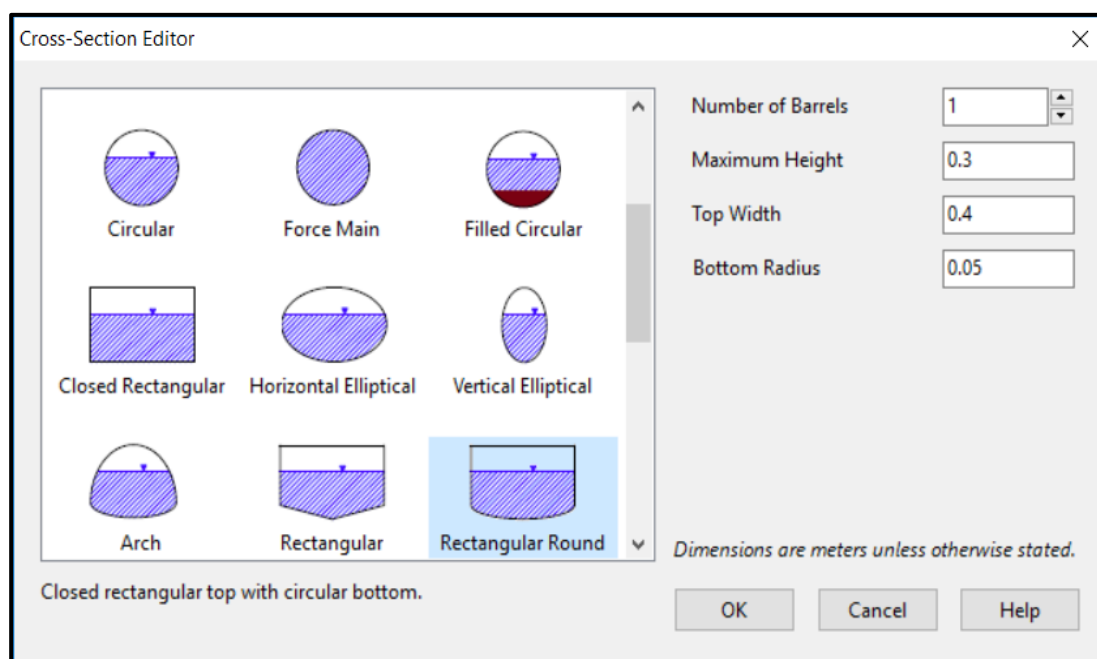


Figure 4.30 : Geometrical shape of the used cross section for conduits.

Project Summary		×
Raingages	1	▲
Subcatchments	101	
Aquifers	0	
Snowpacks	0	
RDII Hydrographs	0	
Infiltration Model	CURVE_NUMBER	
Junction Nodes	229	
Outfall Nodes	11	
Divider Nodes	0	
Storage Nodes	13	
Conduit Links	298	
Pump Links	0	
Orifice Links	0	▼

Figure 4.31 : Summary of drainage network properties of Bastam city in SWMM.

Table 4.8 : Hydrologic calculation results of the study area- Non-LID

No.	Subcatchment	Area ha	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	0.26	35.1	11.86	16.61	0.04	0	0.473
2	299B	0.41	35.1	18.84	13.92	0.06	0	0.397
3	29B	0.76	35.1	24.7	9.56	0.07	0.01	0.272
4	28B	0.63	35.1	23.13	11.33	0.07	0.01	0.323
5	25B	1.33	35.1	31.23	3.57	0.05	0.01	0.102
6	16B	0.79	35.1	11.86	9.49	0.07	0	0.27
7	17B	6.01	35.1	25.92	4.19	0.25	0.02	0.119
8	300B	0.1	35.1	19.51	10.68	0.01	0	0.304
9	33B	2.75	35.1	25.09	6.88	0.19	0.02	0.196
10	93B	1.33	35.1	24.85	7.74	0.1	0.01	0.22
11	96B	2.11	35.1	25.09	6.76	0.14	0.02	0.193
12	12B	0.75	35.1	24.7	9.6	0.07	0.01	0.274
13	52B	0.89	35.1	28.11	6	0.05	0.01	0.171
14	53B	0.91	35.1	28.11	5.98	0.05	0.01	0.17
15	51B	1.42	35.1	25.33	6.53	0.09	0.01	0.186
16	58B	1.8	35.1	31.23	3.5	0.06	0.01	0.1
17	302B	0.23	35.1	19.61	9.74	0.02	0	0.278
18	34B	1.53	35.1	25.09	7.15	0.11	0.01	0.204

Table 4.8 (Continued): Hydrologic calculation results of the study area- Non-LID

No.	Subcatchment	Area ha	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
19	10B	2.59	35.1	25.57	5.63	0.15	0.02	0.16
20	18B	1.97	35.1	25.81	4.73	0.09	0.01	0.135
21	19B	1.2	35.1	24.61	8.16	0.1	0.01	0.232
22	85B	0.52	35.1	22.27	12.19	0.06	0.01	0.347
23	71B	0.35	35.1	27.12	6.98	0.02	0	0.199
24	72B	0.66	35.1	24.7	9.56	0.06	0.01	0.272
25	73B	2	35.1	25.81	4.56	0.09	0.01	0.13
26	195B	2.73	35.1	25.33	6.38	0.17	0.02	0.182
27	46B	1.82	35.1	25.57	5.82	0.11	0.01	0.166
28	91B	1.46	35.1	31.23	3.57	0.05	0.01	0.102
29	60B	1.09	35.1	31.23	3.48	0.04	0	0.099
30	61B	1.79	35.1	25.33	6.44	0.12	0.01	0.183
31	269B	0.59	35.1	11.86	16.53	0.1	0	0.471
32	298B	0.47	35.1	18.17	15.66	0.07	0.01	0.446
33	95B	6.46	35.1	25.66	5.48	0.35	0.04	0.156
34	37B	14.96	35.1	25.81	5.06	0.76	0.08	0.144
35	194B	0.45	35.1	22.84	11.6	0.05	0.01	0.33
36	193B	0.75	35.1	27.69	6.46	0.05	0	0.184
37	191B	1.09	35.1	25.57	5.3	0.06	0.01	0.151
38	32B	0.69	35.1	24.41	9.85	0.07	0.01	0.281
39	94B	5.46	35.1	25.92	4.36	0.24	0.02	0.124
40	49B	0.59	35.1	23.27	11.12	0.07	0.01	0.317
41	92B	1.09	35.1	31.23	3.57	0.04	0.01	0.102
42	393B	0.51	35.1	31.23	3.59	0.02	0	0.102
43	196B	0.62	35.1	27.26	6.82	0.04	0	0.194
44	197B	0.39	35.1	22.42	12.09	0.05	0.01	0.344
45	198B	0.76	35.1	24.7	9.56	0.07	0.01	0.272
46	30B	0.86	35.1	23.98	10.34	0.09	0.01	0.295
47	31B	0.9	35.1	24.13	10.2	0.09	0.01	0.291
48	56B	1.61	35.1	24.85	7.79	0.13	0.02	0.222
49	24B	1.52	35.1	25.81	5.02	0.08	0.01	0.143
50	35B	1.63	35.1	24.61	8.27	0.13	0.02	0.236
51	43B	1.14	35.1	31.23	3.59	0.04	0.01	0.102
52	9B	2.59	35.1	25.33	6.28	0.16	0.02	0.179
53	81B	0.54	35.1	23.98	10.38	0.06	0.01	0.296
54	82B	0.69	35.1	23.98	10.4	0.07	0.01	0.296
55	80B	3.19	35.1	25.42	5.99	0.19	0.02	0.171

Table 4.8 (Continued): Hydrologic calculation results of the study area- Non-LID

No.	Subcatchment	Area ha	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
56	90B	1.21	35.1	25.81	4.86	0.06	0.01	0.139
57	86B	0.39	35.1	27.26	6.84	0.03	0	0.195
58	87B	0.42	35.1	27.83	6.33	0.03	0	0.18
59	70B	0.96	35.1	26.26	7.95	0.08	0.01	0.226
60	84B	0.5	35.1	23.7	10.66	0.05	0.01	0.304
61	69B	1.17	35.1	24.61	8.08	0.09	0.01	0.23
62	63B	0.79	35.1	24.13	10.18	0.08	0.01	0.29
63	62B	1.55	35.1	25.57	5.79	0.09	0.01	0.165
64	57B	2.67	35.1	31.23	3.56	0.09	0.02	0.101
65	192B	0.47	35.1	27.54	6.63	0.03	0	0.189
66	48B	0.36	35.1	23.13	11.31	0.04	0.01	0.322
67	47B	1.14	35.1	24.85	7.84	0.09	0.01	0.223
68	45B	1.21	35.1	25.81	4.83	0.06	0.01	0.138
69	22B	0.56	35.1	31.23	3.59	0.02	0.01	0.102
70	21B	1.14	35.1	24.85	7.62	0.09	0.01	0.217
71	20B	1.41	35.1	24.85	7.6	0.11	0.01	0.216
72	23B	3.92	35.1	25.92	4.49	0.18	0.02	0.128
73	65B	2.09	35.1	25.33	6.19	0.09	0.01	0.176
74	59B	0.64	35.1	30.11	3.88	0.02	0	0.111
75	83B	2.05	35.1	25.09	7.26	0.15	0.02	0.207
76	97B	3.9	35.1	31.23	3.53	0.14	0.03	0.101
77	78B	0.22	35.1	22.56	11.91	0.03	0	0.339
78	74B	0.53	35.1	27.12	6.98	0.04	0	0.199
79	450B	0.7	35.1	11.86	16	0.11	0.01	0.456
80	54B	0.33	35.1	22.99	11.48	0.04	0	0.327
81	40B	0.28	35.1	11.86	17.79	0.05	0	0.507
82	42B	3.63	35.1	25.57	5.34	0.19	0.02	0.152
83	38B	4.64	35.1	25.33	6.17	0.29	0.03	0.176
84	13B	0.45	35.1	24.84	9.4	0.04	0	0.268
85	15B	0.52	35.1	26.55	7.67	0.04	0	0.218
86	11B	0.94	35.1	24.55	9.73	0.09	0.01	0.277
87	14B	0.59	35.1	27.54	6.63	0.04	0	0.189
88	79B	1.08	35.1	25.09	7.03	0.08	0.01	0.2
89	67B	0.98	35.1	24.84	9.39	0.09	0.01	0.267
90	66B	0.55	35.1	25.98	8.24	0.05	0	0.235
91	301B	0.09	35.1	17.48	16.72	0.02	0	0.476
92	99B	0.22	35.1	11.86	15.36	0.03	0	0.438

Table 4.8 (Continued): Hydrologic calculation results of the study area- Non-LID

No.	Subcatchment	Area ha	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
93	26B	1.38	35.1	25.09	7.24	0.1	0.01	0.206
94	27B	1.29	35.1	31.23	3.56	0.05	0.01	0.101
95	447B	0.97	35.1	11.86	10.13	0.1	0	0.289
96	101B	0.4	35.1	11.86	15.96	0.06	0	0.455
97	64B	0.3	35.1	31.23	3.65	0.01	0	0.104
98	88B	0.31	35.1	26.26	7.88	0.02	0	0.225
99	89B	0.58	35.1	27.26	6.85	0.04	0	0.195
100	44B	1.03	35.1	24.85	7.72	0.08	0.01	0.22
101	1B	0.66	35.1	26.02	9.01	0.06	0.02	0.257

Table 4.9 : Instantaneous discharge time series of the drainage system - Non-LID

Elapsed Time	Precipitation (mm/hr)	Run off (CMS)
0:15:00	43.26	0.00
0:30:00	0.00	0.79
0:45:00	0.00	0.42
1:00:00	42.66	0.27
1:15:00	0.00	1.18
1:30:00	0.00	0.61
1:45:00	0.00	0.38
2:00:00	31.74	0.26
2:15:00	0.00	0.95
2:30:00	0.00	0.51
2:45:00	0.00	0.34
3:00:00	23.34	0.24
3:15:00	0.00	0.73
3:30:00	0.00	0.46
3:45:00	0.00	0.33
4:00:00	0.00	0.25
4:15:00	0.00	0.21
4:30:00	0.00	0.17
4:45:00	0.00	0.15
5:00:00	0.00	0.13
5:15:00	0.00	0.12
5:30:00	0.00	0.10
5:45:00	0.00	0.10
6:00:00	39.60	0.09

Table 4.9 (Continued): Instantaneous discharge time series of the drainage system - Non-LID

Elapsed Time	Precipitation (mm/hr)	Run off (CMS)
6:15:00	0.00	1.00
6:30:00	0.00	0.55
6:45:00	0.00	0.36
7:00:00	0.00	0.27
7:15:00	0.00	0.22
7:30:00	0.00	0.18
7:45:00	0.00	0.15
8:00:00	0.00	0.13
8:15:00	0.00	0.12
8:30:00	0.00	0.10
8:45:00	0.00	0.09
9:00:00	0.00	0.09
9:15:00	0.00	0.08
9:30:00	0.00	0.07
9:45:00	0.00	0.07
10:00:00	0.00	0.06
10:15:00	0.00	0.06
10:30:00	0.00	0.05
10:45:00	0.00	0.05
11:00:00	0.00	0.05
11:15:00	0.00	0.05
11:30:00	0.00	0.04
11:45:00	0.00	0.04
12:00:00	30.00	0.04
12:15:00	0.00	0.64
12:30:00	0.00	0.39
12:45:00	0.00	0.28
13:00:00	0.00	0.21
13:15:00	0.00	0.17
13:30:00	0.00	0.15
13:45:00	0.00	0.13
14:00:00	0.00	0.12
14:15:00	0.00	0.11
14:30:00	0.00	0.10
14:45:00	0.00	0.09
15:00:00	0.00	0.08
15:15:00	0.00	0.08

Table 4.9 (Continued): Instantaneous discharge time series of the drainage system - Non-LID

Elapsed Time	Precipitation (mm/hr)	Run off (CMS)
15:30:00	0.00	0.07
15:45:00	0.00	0.07
16:00:00	0.00	0.07
16:15:00	0.00	0.06
16:30:00	0.00	0.06
16:45:00	0.00	0.06
17:00:00	0.00	0.06
17:15:00	0.00	0.05
17:30:00	0.00	0.05
17:45:00	0.00	0.05
18:00:00	0.00	0.05
18:15:00	0.00	0.05
18:30:00	0.00	0.05
18:45:00	0.00	0.04
19:00:00	0.00	0.04
19:15:00	0.00	0.04
19:30:00	0.00	0.04
19:45:00	0.00	0.04
20:00:00	0.00	0.04
20:15:00	0.00	0.04
20:30:00	0.00	0.04
20:45:00	0.00	0.04
21:00:00	0.00	0.03
21:15:00	0.00	0.03
21:30:00	0.00	0.03
21:45:00	0.00	0.03
22:00:00	0.00	0.03
22:15:00	0.00	0.03
22:30:00	0.00	0.03
22:45:00	0.00	0.03
23:00:00	0.00	0.03
23:15:00	0.00	0.03
23:30:00	0.00	0.03
23:45:00	0.00	0.03
0:00:00	0.00	0.03

In this study, hydrologic calculations for LID practices are executed in 11 scenarios, each scenario is followed by determination of their drainage network runoff characteristics displayed in corresponding tables and graphs. Table 4.10 introduces mentioned scenarios in detail, all applied on 25%-fraction impervious surface of the subcatchments. LID included scenarios results will be compared to each other and to the non-LID scenario to identify the best one. Non-LID scenario's hydrological calculations are already done in previous pages.

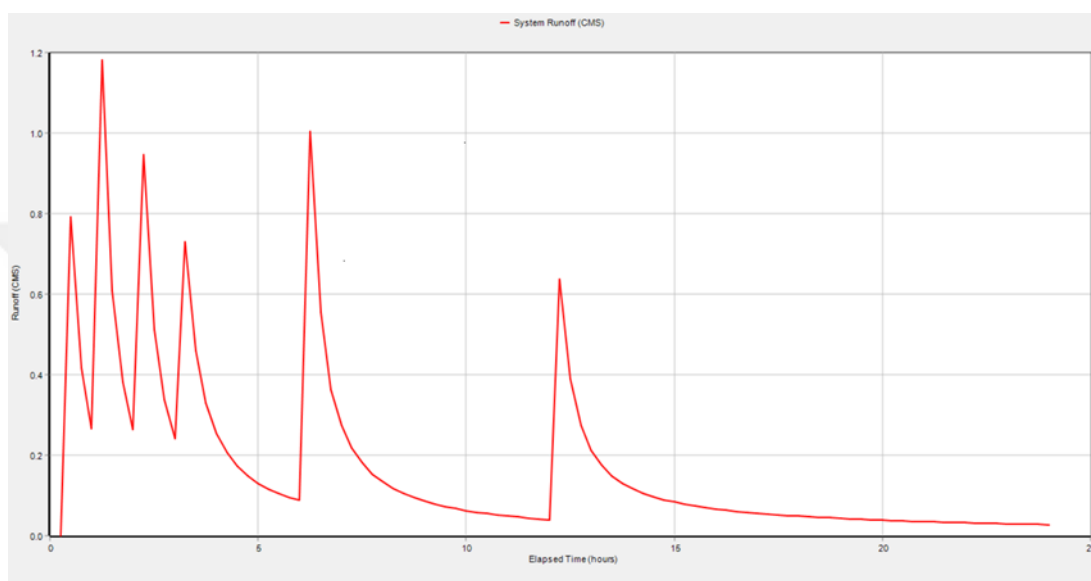


Figure 4.32 : 10 year return period hydrograph- Non-LID.

Table 4.10 : LID-Practices included Scenarios.

Scenario Description		LID practice	Area of subcatchments occupied with LID practice (%)
1st		Non-LID	0
2nd		Infiltration Trenches	5
3rd		Bio-Retention Cells	5
4th	1st set of LID-scenarios	Permeable Pavements	5
5th		Rain Gardens	5
6th		Rain Barrels	1
7th		Infiltration Trenches	10
8th		Bio-Retention Cells	10
9th	2nd set of LID-scenarios	Permeable Pavements	10
10th		Rain Gardens	10
11th		Rain Barrels	2

4.2.4 2nd scenario results - Infiltration trenches LID-5%

Figures 4.33 through 4.35 show SWMM model input data in 2nd scenario (infiltration trenches). Table 4.11 shows the hydrologic calculation results of the under study subcatchments while Table 4.12 shows implemented LID's operation summary on them. Table 4.12 shows instantaneous discharge time series of drainage system and Figure 4.36 shows 10 year return period hydrograph.

The image shows the 'LID Control Editor' dialog box for an 'Infiltration Trench'. The 'Control Name' is 'InfiltrationTrench' and the 'LID Type' is 'Infiltration Trench'. The 'Surface' tab is selected, showing parameters: Berm Height (0.0), Vegetation Volume Fraction (0.0), Surface Roughness (0.1), and Surface Slope (1.0). A diagram on the left shows a cross-section of the trench with 'Surface' and 'Storage' layers, and a 'Drain*' at the bottom. The 'Drain*' is marked as '*Optional'. Buttons for 'OK', 'Cancel', and 'Help' are at the bottom.

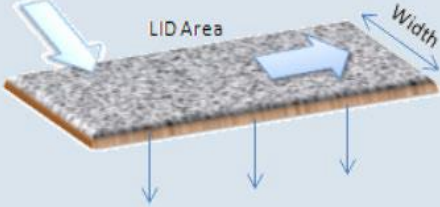
Figure 4.33 : SWMM model input data in 2nd scenario-1.

The image shows the 'LID Control Editor' dialog box for an 'Infiltration Trench', with the 'Storage' tab selected. The 'Control Name' is 'InfiltrationTrench' and the 'LID Type' is 'Infiltration Trench'. The 'Storage' tab shows parameters: Thickness (300), Void Ratio (0.75), Seepage Rate (0.5), and Clogging Factor (0). The diagram on the left is identical to Figure 4.33, showing 'Surface', 'Storage', and 'Drain*' layers. The 'Drain*' is marked as '*Optional'. Buttons for 'OK', 'Cancel', and 'Help' are at the bottom.

Figure 4.34 : SWMM model input data in 2nd scenario-2.

LID Usage Editor

LID Control Name: **InfiltrationTrench**



☐ LID Occupies Full Subcatchment

Area of Each Unit (sq ft or sq m): **25**

Number of Units: **65**

% of Subcatchment Occupied: **5.015**

Surface Width per Unit (ft or m): **5**

% Initially Saturated: **5**

% of Impervious Area Treated: **100**

Send Drain Flow To:
(Leave blank to use outlet of current subcatchment)

☐ Return all Outflow to Pervious Area

Detailed Report File (Optional):

OK Cancel Help

Figure 4.35 : SWMM model input data in 2nd scenario-3.

Table 4.11 : Hydrologic calculation results of the subcatchments- 2nd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	10	13.85	0.04	0	0.395
2	299B	35.1	15.29	11.85	0.05	0.01	0.337
3	29B	35.1	19.57	8.64	0.07	0.01	0.246
4	28B	35.1	18.22	10.29	0.06	0.02	0.293
5	25B	35.1	25.31	3.51	0.05	0.02	0.1
6	16B	35.1	9.99	8.75	0.07	0.01	0.249
7	17B	35.1	21.12	3.82	0.23	0.03	0.109
8	300B	35.1	15.94	9.83	0.01	0	0.28
9	33B	35.1	20.27	6.63	0.18	0.04	0.189
10	93B	35.1	20.08	7.27	0.1	0.02	0.207
11	96B	35.1	20.46	6.29	0.13	0.03	0.179
12	12B	35.1	19.59	8.95	0.07	0.01	0.255
13	52B	35.1	22.4	5.77	0.05	0.01	0.165
14	53B	35.1	22.38	5.58	0.05	0.01	0.159
15	51B	35.1	20.45	6.21	0.09	0.02	0.177
16	58B	35.1	25.31	3.19	0.06	0.01	0.091
17	302B	35.1	16	8.6	0.02	0	0.245
18	34B	35.1	20.27	6.79	0.1	0.03	0.193

Table 4.11 (Continued): Hydrologic calculation results of the subcatchments- 2nd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
19	10B	35.1	20.65	5.47	0.14	0.03	0.156
20	18B	35.1	21.03	4.41	0.09	0.02	0.126
21	19B	35.1	19.89	7.7	0.09	0.02	0.219
22	85B	35.1	17.77	10.64	0.06	0.01	0.303
23	71B	35.1	21.62	6.67	0.02	0	0.19
24	72B	35.1	19.56	8.59	0.06	0.01	0.245
25	73B	35.1	21.03	4.3	0.09	0.02	0.123
26	195B	35.1	20.46	6.15	0.17	0.04	0.175
27	46B	35.1	20.65	5.58	0.1	0.02	0.159
28	91B	35.1	25.3	3.45	0.05	0.02	0.098
29	60B	35.1	25.32	3.08	0.03	0.01	0.088
30	61B	35.1	20.46	6.21	0.11	0.03	0.177
31	269B	35.1	9.99	14.56	0.09	0.01	0.415
32	298B	35.1	14.76	13.29	0.06	0.01	0.379
33	95B	35.1	20.7	5.33	0.34	0.07	0.152
34	37B	35.1	20.82	4.92	0.74	0.16	0.14
35	194B	35.1	18.12	10.61	0.05	0.01	0.302
36	193B	35.1	22.07	6.2	0.05	0.01	0.177
37	191B	35.1	20.84	5.02	0.05	0.01	0.143
38	32B	35.1	19.47	9.02	0.06	0.01	0.257
39	94B	35.1	21.12	4.04	0.22	0.03	0.115
40	49B	35.1	18.45	10.14	0.06	0.01	0.289
41	92B	35.1	25.32	3.54	0.04	0.02	0.101
42	393B	35.1	25.27	3.22	0.02	0.01	0.092
43	196B	35.1	21.7	6.28	0.04	0.01	0.179
44	197B	35.1	17.89	10.73	0.04	0.01	0.306
45	198B	35.1	19.57	8.64	0.07	0.01	0.246
46	30B	35.1	19.01	9.3	0.08	0.02	0.265
47	31B	35.1	19.14	9.44	0.08	0.02	0.269
48	56B	35.1	20.07	7.26	0.12	0.03	0.207
49	24B	35.1	20.84	4.77	0.07	0.02	0.136
50	35B	35.1	19.7	7.89	0.13	0.03	0.225
51	43B	35.1	25.32	3.59	0.04	0.02	0.102
52	9B	35.1	20.46	6.08	0.16	0.04	0.173
53	81B	35.1	19.02	9.48	0.05	0.01	0.27
54	82B	35.1	19.02	9.51	0.07	0.02	0.271

Table 4.11 (Continued): Hydrologic calculation results of the subcatchments- 2nd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
55	80B	35.1	20.52	5.82	0.19	0.04	0.166
56	90B	35.1	20.83	4.53	0.05	0.01	0.129
57	86B	35.1	21.72	6.41	0.03	0	0.183
58	87B	35.1	22.14	5.7	0.02	0	0.162
59	70B	35.1	20.81	7.34	0.07	0.01	0.209
60	84B	35.1	18.8	9.81	0.05	0.01	0.28
61	69B	35.1	19.88	7.51	0.09	0.02	0.214
62	63B	35.1	19.24	9.29	0.07	0.02	0.265
63	62B	35.1	20.65	5.65	0.09	0.02	0.161
64	57B	35.1	25.31	3.49	0.09	0.04	0.1
65	192B	35.1	21.92	6.02	0.03	0.01	0.172
66	48B	35.1	18.2	9.85	0.04	0.01	0.28
67	47B	35.1	19.89	7.55	0.09	0.02	0.215
68	45B	35.1	20.83	4.49	0.05	0.01	0.128
69	22B	35.1	25.27	3.26	0.02	0.01	0.093
70	21B	35.1	20.08	7.21	0.08	0.02	0.205
71	20B	35.1	20.07	7.08	0.1	0.03	0.202
72	23B	35.1	20.92	4.26	0.17	0.03	0.121
73	65B	35.1	20.65	5.82	0.08	0.02	0.166
74	59B	35.1	24.31	3.16	0.02	0	0.09
75	83B	35.1	20.27	6.95	0.14	0.03	0.198
76	97B	35.1	25.32	3.47	0.14	0.04	0.099
77	78B	35.1	17.97	9.99	0.02	0.01	0.285
78	74B	35.1	21.6	6.48	0.03	0.01	0.185
79	450B	35.1	9.99	14.25	0.1	0.01	0.406
80	54B	35.1	18.1	10.25	0.03	0.01	0.292
81	40B	35.1	9.82	15.54	0.05	0	0.443
82	42B	35.1	20.84	5.08	0.18	0.04	0.145
83	38B	35.1	20.65	5.86	0.27	0.06	0.167
84	13B	35.1	19.81	8.74	0.04	0.01	0.249
85	15B	35.1	21.03	7.01	0.04	0.01	0.2
86	11B	35.1	19.47	9	0.08	0.02	0.256
87	14B	35.1	21.95	6.27	0.04	0.01	0.179
88	79B	35.1	20.27	6.66	0.07	0.02	0.19
89	67B	35.1	19.8	8.62	0.08	0.02	0.246
90	66B	35.1	20.6	7.81	0.04	0.01	0.223

Table 4.11 (Continued): Hydrologic calculation results of the subcatchments- 2nd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
91	301B	35.1	14.13	13.9	0.01	0	0.396
92	99B	35.1	10	13	0.03	0	0.37
93	26B	35.1	20.27	6.86	0.09	0.02	0.195
94	27B	35.1	25.32	3.52	0.05	0.02	0.1
95	447B	35.1	9.99	9.23	0.09	0.01	0.263
96	101B	35.1	9.99	14.22	0.06	0.01	0.405
97	64B	35.1	25.32	3.72	0.01	0.01	0.106
98	88B	35.1	20.88	6.78	0.02	0	0.193
99	89B	35.1	21.71	6.37	0.04	0.01	0.182
100	44B	35.1	20.07	7.23	0.07	0.02	0.206
101	1B	35.1	25.28	3.56	0.02	0.02	0.101

Table 4.12 : LID operation summary-2nd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	InfiltrationTrench	177.83	12	46.11	0	6.43	126.16
2	299B	InfiltrationTrench	186.08	12	55.73	0	6.43	124.78
3	29B	InfiltrationTrench	192.77	12	61.94	0	6.43	125.27
4	28B	InfiltrationTrench	196.32	12	66.13	0	6.43	124.63
5	25B	InfiltrationTrench	198.93	12	68.03	0	6.43	125.34
6	16B	InfiltrationTrench	196.04	12	62.07	0	6.43	128.4
7	17B	InfiltrationTrench	196.37	12	62.29	0	6.43	128.52
8	300B	InfiltrationTrench	201.25	12	69.56	0	6.43	126.12
9	33B	InfiltrationTrench	201.35	12	69.91	0	6.43	125.88
10	93B	InfiltrationTrench	198.93	12	68.05	0	6.43	125.32
11	96B	InfiltrationTrench	198.05	12	66.54	0	6.43	125.95
12	12B	InfiltrationTrench	201.54	12	70.67	0	6.43	125.31
13	52B	InfiltrationTrench	198.54	12	65.73	0	6.43	127.25
14	53B	InfiltrationTrench	193.13	12	60.34	0	6.43	127.22
15	51B	InfiltrationTrench	197.66	12	66.08	0	6.43	126.02
16	58B	InfiltrationTrench	196.25	12	62.54	0	6.43	128.14
17	302B	InfiltrationTrench	187.06	12	55.09	0	6.43	126.41
18	34B	InfiltrationTrench	199.17	12	67.97	0	6.43	125.64
19	10B	InfiltrationTrench	200.19	12	67.81	0	6.43	126.81
20	18B	InfiltrationTrench	197.11	12	63.72	0	6.43	127.83
21	19B	InfiltrationTrench	201.58	12	70.84	0	6.43	125.17

Table 4.12 (Continued): LID operation summary-2nd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
22	85B	InfiltrationTrench	192.2	12	62.24	0	6.43	124.4
23	71B	InfiltrationTrench	200.97	12	68.76	0	6.43	126.65
24	72B	InfiltrationTrench	191.52	12	60.69	0	6.43	125.27
25	73B	InfiltrationTrench	199.23	12	65.57	0	6.43	128.09
26	195B	InfiltrationTrench	199.95	12	68.21	0	6.43	126.18
27	46B	InfiltrationTrench	198.16	12	66.01	0	6.43	126.59
28	91B	InfiltrationTrench	196.86	12	65.98	0	6.43	125.31
29	60B	InfiltrationTrench	194.99	12	60.82	0	6.43	128.6
30	61B	InfiltrationTrench	200.27	12	68.59	0	6.43	126.12
31	269B	InfiltrationTrench	198.21	12	66.27	0	6.43	126.37
32	298B	InfiltrationTrench	191.29	12	61.49	0	6.43	124.24
33	95B	InfiltrationTrench	199.71	12	67.23	0	6.43	126.91
34	37B	InfiltrationTrench	199.91	12	66.98	0	6.43	127.36
35	194B	InfiltrationTrench	201.74	12	71.6	0	6.43	124.58
36	193B	InfiltrationTrench	200.73	12	68.18	0	6.43	126.98
37	191B	InfiltrationTrench	198.96	12	66.2	0	6.43	127.19
38	32B	InfiltrationTrench	199.06	12	68.29	0	6.43	125.21
39	94B	InfiltrationTrench	197.32	12	63.44	0	6.43	128.31
40	49B	InfiltrationTrench	198.77	12	68.48	0	6.43	124.73
41	92B	InfiltrationTrench	199.94	12	69.04	0	6.43	125.33
42	393B	InfiltrationTrench	188.86	12	58.31	0	6.43	124.99
43	196B	InfiltrationTrench	192.85	12	60.61	0	6.43	126.67
44	197B	InfiltrationTrench	197.38	12	67.38	0	6.43	124.44
45	198B	InfiltrationTrench	192.77	12	61.93	0	6.43	125.27
46	30B	InfiltrationTrench	193.83	12	63.28	0	6.43	124.98
47	31B	InfiltrationTrench	201.6	12	70.97	0	6.43	125.07
48	56B	InfiltrationTrench	197.29	12	66.45	0	6.43	125.28
49	24B	InfiltrationTrench	196.92	12	63.95	0	6.43	127.41
50	35B	InfiltrationTrench	199.48	12	68.84	0	6.43	125.08
51	43B	InfiltrationTrench	200.12	12	69.65	0	6.43	124.91
52	9B	InfiltrationTrench	200.5	12	68.67	0	6.43	126.27
53	81B	InfiltrationTrench	198.44	12	67.89	0	6.43	124.99
54	82B	InfiltrationTrench	199.12	12	68.58	0	6.43	124.98
55	80B	InfiltrationTrench	200.5	12	68.43	0	6.43	126.51
56	90B	InfiltrationTrench	194.46	12	61.29	0	6.43	127.6
57	86B	InfiltrationTrench	196.55	12	64.29	0	6.43	126.7
58	87B	InfiltrationTrench	189.04	12	56.51	0	6.43	126.96

Table 4.12 (Continued): LID operation summary-2nd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
59	70B	InfiltrationTrench	194.27	12	62.7	0	6.43	126.02
60	84B	InfiltrationTrench	201.65	12	71.18	0	6.43	124.9
61	69B	InfiltrationTrench	197.18	12	66.42	0	6.43	125.2
62	63B	InfiltrationTrench	199.41	12	68.77	0	6.43	125.08
63	62B	InfiltrationTrench	200.98	12	68.78	0	6.43	126.64
64	57B	InfiltrationTrench	199.45	12	68.14	0	6.43	125.75
65	192B	InfiltrationTrench	190.36	12	58.03	0	6.43	126.76
66	48B	InfiltrationTrench	184.18	12	54.04	0	6.43	124.58
67	47B	InfiltrationTrench	200.03	12	69.21	0	6.43	125.26
68	45B	InfiltrationTrench	194.39	12	61.17	0	6.43	127.66
69	22B	InfiltrationTrench	189.95	12	59.49	0	6.43	124.89
70	21B	InfiltrationTrench	199.98	12	69	0	6.43	125.42
71	20B	InfiltrationTrench	196.67	12	65.69	0	6.43	125.41
72	23B	InfiltrationTrench	197.83	12	64.15	0	6.43	128.11
73	65B	InfiltrationTrench	198.72	12	66.81	0	6.43	126.34
74	59B	InfiltrationTrench	187.54	12	53.22	0	6.43	128.75
75	83B	InfiltrationTrench	201.46	12	70.33	0	6.43	125.57
76	97B	InfiltrationTrench	201.01	12	68.87	0	6.43	126.58
77	78B	InfiltrationTrench	180.7	12	50.71	0	6.43	124.43
78	74B	InfiltrationTrench	194.63	12	62.48	0	6.43	126.58
79	450B	InfiltrationTrench	201.02	12	68.9	0	6.43	126.56
80	54B	InfiltrationTrench	191.71	12	61.59	0	6.43	124.56
81	40B	InfiltrationTrench	195.48	12	63.98	0	6.43	125.94
82	42B	InfiltrationTrench	199.63	12	66.93	0	6.43	127.14
83	38B	InfiltrationTrench	200.74	12	68.8	0	6.43	126.38
84	13B	InfiltrationTrench	201.51	12	70.54	0	6.43	125.4
85	15B	InfiltrationTrench	191.67	12	59.96	0	6.43	126.14
86	11B	InfiltrationTrench	199.71	12	68.89	0	6.43	125.25
87	14B	InfiltrationTrench	197.92	12	65.51	0	6.43	126.84
88	79B	InfiltrationTrench	198.21	12	66.92	0	6.43	125.73
89	67B	InfiltrationTrench	198.01	12	67.06	0	6.43	125.39
90	66B	InfiltrationTrench	201.33	12	69.85	0	6.43	125.92
91	301B	InfiltrationTrench	184.34	12	54.8	0	6.43	123.98
92	99B	InfiltrationTrench	179.96	12	47.84	0	6.43	126.56
93	26B	InfiltrationTrench	198.95	12	67.82	0	6.43	125.57
94	27B	InfiltrationTrench	200.09	12	68.91	0	6.43	125.62
95	447B	InfiltrationTrench	193.58	12	59.78	0	6.43	128.23

Table 4.12 (Continued): LID operation summary-2nd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
96	101B	InfiltrationTrench	201.01	12	68.88	0	6.43	126.57
97	64B	InfiltrationTrench	201.83	12	72.01	0	6.43	124.26
98	88B	InfiltrationTrench	181.27	12	49.75	0	6.43	125.95
99	89B	InfiltrationTrench	195.1	12	62.86	0	6.43	126.68
100	44B	InfiltrationTrench	198.19	12	67.3	0	6.43	125.33
101	1B	InfiltrationTrench	192.2	12	63.19	0	6.43	123.44

Table 4.13 : Instantaneous discharge time series of drainage system- 2nd scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0
1:30:00	0	0
1:45:00	0	0
2:00:00	31.74	0
2:15:00	0	0.05
2:30:00	0	0.01
2:45:00	0	0.01
3:00:00	23.34	0.01
3:15:00	0	0.07
3:30:00	0	0.08
3:45:00	0	0.1
4:00:00	0	0.09
4:15:00	0	0.1
4:30:00	0	0.09
4:45:00	0	0.08
5:00:00	0	0.08
5:15:00	0	0.07
5:30:00	0	0.07
5:45:00	0	0.07
6:00:00	39.6	0.06
6:15:00	0	1.09
6:30:00	0	0.57
6:45:00	0	0.36

Table 4.13 (Continued): Instantaneous discharge time series of drainage system- 2nd scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
7:00:00	0	0.27
7:15:00	0	0.21
7:30:00	0	0.17
7:45:00	0	0.14
8:00:00	0	0.12
8:15:00	0	0.11
8:30:00	0	0.09
8:45:00	0	0.08
9:00:00	0	0.07
9:15:00	0	0.07
9:30:00	0	0.06
9:45:00	0	0.06
10:00:00	0	0.05
10:15:00	0	0.05
10:30:00	0	0.04
10:45:00	0	0.04
11:00:00	0	0.04
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.03
12:00:00	30	0.03
12:15:00	0	0.74
12:30:00	0	0.4
12:45:00	0	0.28
13:00:00	0	0.21
13:15:00	0	0.17
13:30:00	0	0.14
13:45:00	0	0.12
14:00:00	0	0.11
14:15:00	0	0.1
14:30:00	0	0.09
14:45:00	0	0.08
15:00:00	0	0.07
15:15:00	0	0.07
15:30:00	0	0.06
15:45:00	0	0.06
16:00:00	0	0.06

Table 4.13 (Continued): Instantaneous discharge time series of drainage system- 2nd scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
16:15:00	0	0.05
16:30:00	0	0.05
16:45:00	0	0.05
17:00:00	0	0.05
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.04
19:00:00	0	0.04
19:15:00	0	0.04
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.03
23:30:00	0	0.03
23:45:00	0	0.02
0:00:00	0	0.02

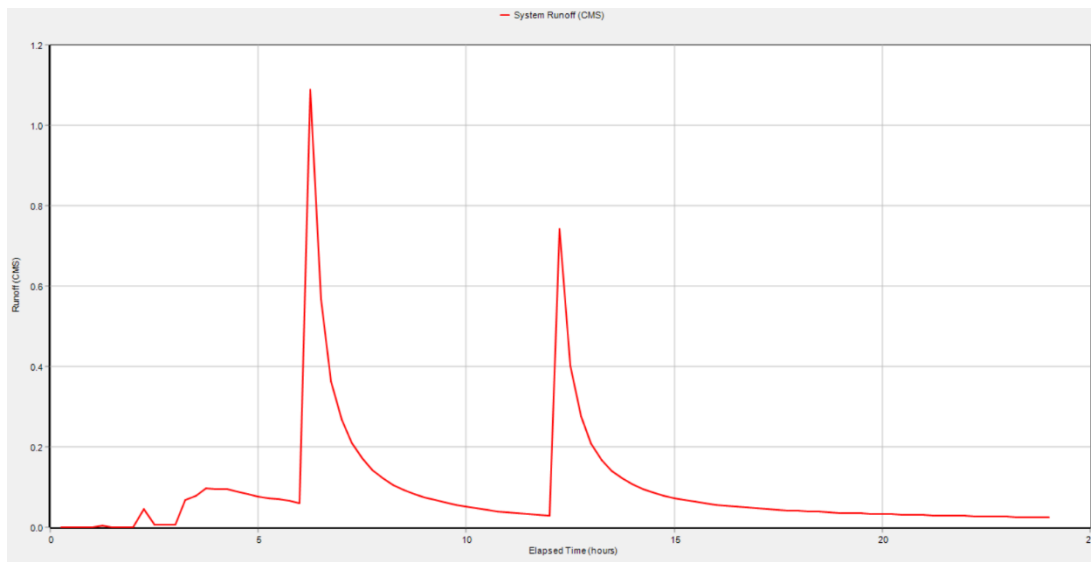


Figure 4.36 : 10 year return period hydrograph- 2nd scenario.

4.2.5 3rd scenario results - Bio-retention cells LID-5%

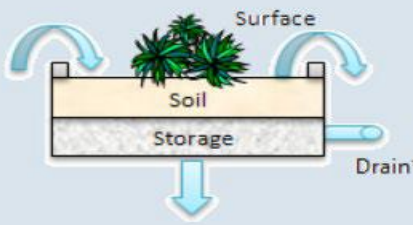
Figures 4.37 through 4.40 show SWMM model input data in 3rd scenario (Bio-retention cells). Table 4.14 shows the hydrologic calculations results of the under study subcatchments while Table 4.15 shows implemented LID's operation summary on them. Table 4.16 shows instantaneous discharge time series of drainage system. Figure 4.41 depicts 10 year return period hydrograph.

Figure 4.37 : SWMM model input data- 3rd scenario-1.

LID Control Editor

Control Name:

LID Type:



*Optional

OK Cancel Help

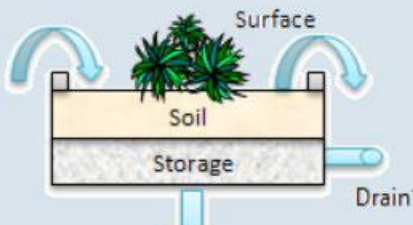
Surface	Soil	Storage	Drain
Thickness (in. or mm)		200	
Porosity (volume fraction)		0.5	
Field Capacity (volume fraction)		0.2	
Wilting Point (volume fraction)		0.1	
Conductivity (in/hr or mm/hr)		0.5	
Conductivity Slope		10.0	
Suction Head (in. or mm)		3.5	

Figure 4.38 : SWMM model input data- 3rd scenario-2.

LID Control Editor

Control Name:

LID Type:



*Optional

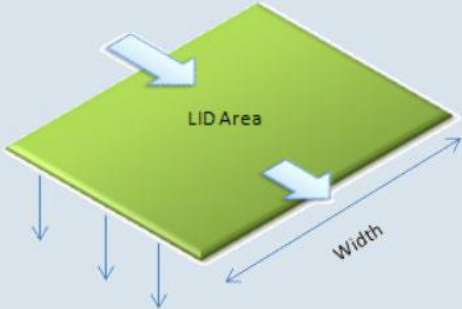
OK Cancel Help

Surface	Soil	Storage	Drain
Thickness (in. or mm)		200	
Void Ratio (Voids / Solids)		0.75	
Seepage Rate (in/hr or mm/hr)		0.5	
Clogging Factor		0	

Figure 4.39 : SWMM model input data- 3rd scenario-3.

LID Usage Editor

LID Control Name: **Bio-RetentionCell**



Area of Each Unit (sq ft or sq m): 25

Number of Units: 65

% of Subcatchment Occupied: 5.015

Surface Width per Unit (ft or m): 5

% Initially Saturated: 5

% of Impervious Area Treated: 100

Send Drain Flow To:
(Leave blank to use outlet of current subcatchment)

☐ **Return all Outflow to Pervious Area**

Detailed Report File (Optional)

OK Cancel Help

Figure 4.40 : SWMM model input data- 3rd scenario-4.

Table 4.14 : Hydrologic calculation results of the subcatchments- 3rd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	9.61	16.21	0.04	0	0.462
2	299B	35.1	14.91	14.14	0.06	0.01	0.403
3	29B	35.1	19.2	10.81	0.08	0.02	0.308
4	28B	35.1	17.87	12.44	0.08	0.02	0.355
5	25B	35.1	24.96	5.61	0.07	0.02	0.16
6	16B	35.1	9.64	10.71	0.08	0.01	0.305
7	17B	35.1	20.77	5.75	0.35	0.05	0.164
8	300B	35.1	15.6	11.87	0.01	0	0.338
9	33B	35.1	19.93	8.68	0.24	0.04	0.247
10	93B	35.1	19.73	9.36	0.12	0.03	0.267
11	96B	35.1	20.11	8.37	0.18	0.03	0.239
12	12B	35.1	19.24	11.01	0.08	0.02	0.314
13	52B	35.1	22.05	7.8	0.07	0.01	0.222
14	53B	35.1	22.02	7.67	0.07	0.01	0.218
15	51B	35.1	20.1	8.29	0.12	0.02	0.236
16	58B	35.1	24.96	5.18	0.09	0.02	0.147
17	302B	35.1	15.63	10.81	0.02	0	0.308
18	34B	35.1	19.92	8.87	0.14	0.03	0.253
19	10B	35.1	20.31	7.49	0.19	0.03	0.213

Table 4.14 (Continued): Hydrologic calculation results of the subcatchments- 3rd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
20	18B	35.1	20.68	6.41	0.13	0.02	0.183
21	19B	35.1	19.55	9.77	0.12	0.02	0.278
22	85B	35.1	17.4	12.86	0.07	0.02	0.366
23	71B	35.1	21.27	8.69	0.03	0	0.248
24	72B	35.1	19.2	10.79	0.07	0.01	0.307
25	73B	35.1	20.69	6.26	0.13	0.02	0.178
26	195B	35.1	20.11	8.2	0.22	0.04	0.234
27	46B	35.1	20.3	7.64	0.14	0.02	0.218
28	91B	35.1	24.95	5.57	0.08	0.02	0.159
29	60B	35.1	24.97	4.99	0.05	0.01	0.142
30	61B	35.1	20.12	8.26	0.15	0.03	0.235
31	269B	35.1	9.64	16.62	0.1	0.01	0.474
32	298B	35.1	14.4	15.53	0.07	0.01	0.442
33	95B	35.1	20.35	7.35	0.47	0.08	0.209
34	37B	35.1	20.47	6.92	1.03	0.16	0.197
35	194B	35.1	17.78	12.7	0.06	0.01	0.362
36	193B	35.1	21.72	8.21	0.06	0.01	0.234
37	191B	35.1	20.49	7.04	0.08	0.01	0.201
38	32B	35.1	19.12	11.12	0.08	0.01	0.317
39	94B	35.1	20.77	5.99	0.33	0.05	0.171
40	49B	35.1	18.1	12.26	0.07	0.02	0.349
41	92B	35.1	24.97	5.63	0.06	0.02	0.16
42	393B	35.1	24.9	5.46	0.03	0.01	0.155
43	196B	35.1	21.34	8.4	0.05	0.01	0.239
44	197B	35.1	17.54	12.88	0.05	0.01	0.367
45	198B	35.1	19.2	10.81	0.08	0.02	0.308
46	30B	35.1	18.65	11.47	0.1	0.02	0.327
47	31B	35.1	18.79	11.51	0.1	0.02	0.328
48	56B	35.1	19.72	9.37	0.15	0.03	0.267
49	24B	35.1	20.48	6.81	0.1	0.02	0.194
50	35B	35.1	19.35	9.99	0.16	0.03	0.285
51	43B	35.1	24.97	5.69	0.06	0.02	0.162
52	9B	35.1	20.12	8.12	0.21	0.04	0.231
53	81B	35.1	18.67	11.59	0.06	0.01	0.33
54	82B	35.1	18.67	11.62	0.08	0.02	0.331
55	80B	35.1	20.18	7.85	0.25	0.04	0.224

Table 4.14 (Continued): Hydrologic calculation results of the subcatchments- 3rd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
56	90B	35.1	20.47	6.59	0.08	0.01	0.188
57	86B	35.1	21.36	8.48	0.03	0.01	0.242
58	87B	35.1	21.77	7.86	0.03	0.01	0.224
59	70B	35.1	20.45	9.47	0.09	0.01	0.27
60	84B	35.1	18.45	11.89	0.06	0.01	0.339
61	69B	35.1	19.53	9.63	0.11	0.02	0.274
62	63B	35.1	18.9	11.39	0.09	0.02	0.325
63	62B	35.1	20.31	7.67	0.12	0.02	0.218
64	57B	35.1	24.97	5.57	0.15	0.04	0.159
65	192B	35.1	21.56	8.17	0.04	0.01	0.233
66	48B	35.1	17.82	12.17	0.04	0.01	0.347
67	47B	35.1	19.54	9.64	0.11	0.02	0.275
68	45B	35.1	20.47	6.54	0.08	0.01	0.186
69	22B	35.1	24.9	5.49	0.03	0.01	0.157
70	21B	35.1	19.73	9.29	0.11	0.02	0.265
71	20B	35.1	19.72	9.2	0.13	0.03	0.262
72	23B	35.1	20.57	6.23	0.24	0.04	0.177
73	65B	35.1	20.3	7.88	0.11	0.02	0.224
74	59B	35.1	23.96	5.04	0.03	0.01	0.144
75	83B	35.1	19.93	9.01	0.18	0.04	0.257
76	97B	35.1	24.98	5.5	0.21	0.05	0.157
77	78B	35.1	17.57	12.37	0.03	0.01	0.353
78	74B	35.1	21.24	8.58	0.05	0.01	0.245
79	450B	35.1	9.64	16.28	0.11	0.01	0.464
80	54B	35.1	17.74	12.47	0.04	0.01	0.355
81	40B	35.1	9.47	17.66	0.05	0	0.503
82	42B	35.1	20.5	7.09	0.26	0.04	0.202
83	38B	35.1	20.31	7.89	0.37	0.06	0.225
84	13B	35.1	19.47	10.8	0.05	0.01	0.308
85	15B	35.1	20.66	9.17	0.05	0.01	0.261
86	11B	35.1	19.12	11.09	0.1	0.02	0.316
87	14B	35.1	21.6	8.32	0.05	0.01	0.237
88	79B	35.1	19.92	8.75	0.09	0.02	0.249
89	67B	35.1	19.45	10.72	0.11	0.02	0.306
90	66B	35.1	20.26	9.86	0.05	0.01	0.281
91	301B	35.1	13.75	16.25	0.01	0	0.463

Table 4.14 (Continued): Hydrologic calculation results of the subcatchments- 3rd scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
92	99B	35.1	9.61	15.31	0.03	0	0.436
93	26B	35.1	19.92	8.94	0.12	0.02	0.255
94	27B	35.1	24.97	5.59	0.07	0.02	0.159
95	447B	35.1	9.63	11.24	0.11	0.01	0.32
96	101B	35.1	9.64	16.24	0.06	0.01	0.463
97	64B	35.1	24.98	5.82	0.02	0.01	0.166
98	88B	35.1	20.49	9.1	0.03	0	0.259
99	89B	35.1	21.36	8.47	0.05	0.01	0.241
100	44B	35.1	19.72	9.34	0.1	0.02	0.266
101	1B	35.1	24.92	5.82	0.04	0.02	0.166

Table 4.15 : LID operation summary- 3rd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	BioRetentionCell	177.83	5.12	87.04	0	28.29	113.96
2	299B	BioRetentionCell	186.08	5.13	97.45	0	28.29	111.78
3	29B	BioRetentionCell	192.77	5.13	103.3	0	28.29	112.63
4	28B	BioRetentionCell	196.32	5.13	107.91	0	28.29	111.56
5	25B	BioRetentionCell	198.93	5.13	109.32	0	28.29	112.77
6	16B	BioRetentionCell	196.04	5.1	100.75	0	28.29	118.47
7	17B	BioRetentionCell	196.37	5.09	100.65	0	28.29	118.91
8	300B	BioRetentionCell	201.25	5.13	110.32	0	28.29	114.09
9	33B	BioRetentionCell	201.35	5.13	110.82	0	28.29	113.68
10	93B	BioRetentionCell	198.93	5.13	109.34	0	28.29	112.75
11	96B	BioRetentionCell	198.05	5.13	107.42	0	28.29	113.79
12	12B	BioRetentionCell	201.54	5.13	111.96	0	28.29	112.73
13	52B	BioRetentionCell	198.54	5.12	105.7	0	28.29	116.01
14	53B	BioRetentionCell	193.13	5.11	100.39	0	28.29	115.91
15	51B	BioRetentionCell	197.66	5.13	106.92	0	28.29	113.9
16	58B	BioRetentionCell	196.25	5.1	101.64	0	28.29	117.79
17	302B	BioRetentionCell	187.06	5.12	95.77	0	28.29	114.47
18	34B	BioRetentionCell	199.17	5.13	109.05	0	28.29	113.28
19	10B	BioRetentionCell	200.19	5.12	108.1	0	28.29	115.25
20	18B	BioRetentionCell	197.11	5.11	103.19	0	28.29	117.1
21	19B	BioRetentionCell	201.58	5.13	112.22	0	28.29	112.51
22	85B	BioRetentionCell	192.2	5.13	104.2	0	28.29	111.16

Table 4.15 (Continued): LID operation summary- 3rd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
23	71B	BioRetentionCell	200.97	5.12	109.16	0	28.29	114.97
24	72B	BioRetentionCell	191.52	5.13	102.06	0	28.29	112.61
25	73B	BioRetentionCell	199.23	5.11	104.71	0	28.29	117.69
26	195B	BioRetentionCell	199.95	5.13	108.93	0	28.29	114.18
27	46B	BioRetentionCell	198.16	5.12	106.47	0	28.29	114.85
28	91B	BioRetentionCell	196.86	5.13	107.3	0	28.29	112.72
29	60B	BioRetentionCell	194.99	5.09	98.82	0	28.29	119.36
30	61B	BioRetentionCell	200.27	5.13	109.35	0	28.29	114.08
31	269B	BioRetentionCell	198.21	5.13	106.89	0	28.29	114.48
32	298B	BioRetentionCell	191.29	5.13	103.57	0	28.29	110.87
33	95B	BioRetentionCell	199.71	5.12	107.45	0	28.29	115.42
34	37B	BioRetentionCell	199.91	5.12	106.86	0	28.29	116.22
35	194B	BioRetentionCell	201.74	5.13	113.39	0	28.29	111.49
36	193B	BioRetentionCell	200.73	5.12	108.34	0	28.29	115.55
37	191B	BioRetentionCell	198.96	5.12	106.22	0	28.29	115.9
38	32B	BioRetentionCell	199.06	5.13	109.66	0	28.29	112.55
39	94B	BioRetentionCell	197.32	5.1	102.27	0	28.29	118.23
40	49B	BioRetentionCell	198.77	5.13	110.18	0	28.29	111.74
41	92B	BioRetentionCell	199.94	5.13	110.33	0	28.29	112.76
42	393B	BioRetentionCell	188.86	5.13	99.88	0	28.29	112.14
43	196B	BioRetentionCell	192.85	5.12	101.06	0	28.29	114.95
44	197B	BioRetentionCell	197.38	5.13	109.3	0	28.29	111.24
45	198B	BioRetentionCell	192.77	5.13	103.3	0	28.29	112.63
46	30B	BioRetentionCell	193.83	5.13	104.84	0	28.29	112.15
47	31B	BioRetentionCell	201.6	5.13	112.42	0	28.29	112.34
48	56B	BioRetentionCell	197.29	5.13	107.79	0	28.29	112.66
49	24B	BioRetentionCell	196.92	5.11	103.8	0	28.29	116.29
50	35B	BioRetentionCell	199.48	5.13	110.3	0	28.29	112.33
51	43B	BioRetentionCell	200.12	5.13	111.22	0	28.29	112.05
52	9B	BioRetentionCell	200.5	5.13	109.33	0	28.29	114.33
53	81B	BioRetentionCell	198.44	5.13	109.42	0	28.29	112.18
54	82B	BioRetentionCell	199.12	5.13	110.12	0	28.29	112.16
55	80B	BioRetentionCell	200.5	5.12	108.93	0	28.29	114.73
56	90B	BioRetentionCell	194.46	5.11	101	0	28.29	116.64
57	86B	BioRetentionCell	196.55	5.12	104.69	0	28.29	115.02
58	87B	BioRetentionCell	189.04	5.12	96.79	0	28.29	115.42
59	70B	BioRetentionCell	194.27	5.13	103.57	0	28.29	113.87

Table 4.15 (Continued): LID operation summary- 3rd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
60	84B	BioRetentionCell	201.65	5.13	112.76	0	28.29	112.05
61	69B	BioRetentionCell	197.18	5.13	107.81	0	28.29	112.53
62	63B	BioRetentionCell	199.41	5.13	110.23	0	28.29	112.34
63	62B	BioRetentionCell	200.98	5.12	109.18	0	28.29	114.95
64	57B	BioRetentionCell	199.45	5.13	109.15	0	28.29	113.46
65	192B	BioRetentionCell	190.36	5.12	98.45	0	28.29	115.08
66	48B	BioRetentionCell	184.18	5.13	95.91	0	28.29	111.42
67	47B	BioRetentionCell	200.03	5.13	110.54	0	28.29	112.64
68	45B	BioRetentionCell	194.39	5.11	100.83	0	28.29	116.74
69	22B	BioRetentionCell	189.95	5.13	101.12	0	28.29	111.98
70	21B	BioRetentionCell	199.98	5.13	110.23	0	28.29	112.9
71	20B	BioRetentionCell	196.67	5.13	106.94	0	28.29	112.88
72	23B	BioRetentionCell	197.83	5.1	103.27	0	28.29	117.74
73	65B	BioRetentionCell	198.72	5.13	107.44	0	28.29	114.45
74	59B	BioRetentionCell	187.54	5.06	90.22	0	28.29	120.53
75	83B	BioRetentionCell	201.46	5.13	111.45	0	28.29	113.17
76	97B	BioRetentionCell	201.01	5.12	109.32	0	28.29	114.85
77	78B	BioRetentionCell	180.7	5.13	92.71	0	28.29	111.14
78	74B	BioRetentionCell	194.63	5.12	102.98	0	28.29	114.81
79	450B	BioRetentionCell	201.02	5.12	109.36	0	28.29	114.82
80	54B	BioRetentionCell	191.71	5.13	103.44	0	28.29	111.42
81	40B	BioRetentionCell	195.48	5.13	104.89	0	28.29	113.75
82	42B	BioRetentionCell	199.63	5.12	106.98	0	28.29	115.82
83	38B	BioRetentionCell	200.74	5.13	109.38	0	28.29	114.53
84	13B	BioRetentionCell	201.51	5.13	111.78	0	28.29	112.89
85	15B	BioRetentionCell	191.67	5.12	100.77	0	28.29	114.05
86	11B	BioRetentionCell	199.71	5.13	110.24	0	28.29	112.63
87	14B	BioRetentionCell	197.92	5.12	105.81	0	28.29	115.27
88	79B	BioRetentionCell	198.21	5.13	107.96	0	28.29	113.41
89	67B	BioRetentionCell	198.01	5.13	108.31	0	28.29	112.85
90	66B	BioRetentionCell	201.33	5.13	110.73	0	28.29	113.76
91	301B	BioRetentionCell	184.34	5.13	97.11	0	28.29	110.39
92	99B	BioRetentionCell	179.96	5.12	88.48	0	28.29	114.65
93	26B	BioRetentionCell	198.95	5.13	108.95	0	28.29	113.15
94	27B	BioRetentionCell	200.09	5.13	110.01	0	28.29	113.24
95	447B	BioRetentionCell	193.58	5.1	98.78	0	28.29	117.98
96	101B	BioRetentionCell	201.01	5.12	109.32	0	28.29	114.85

Table 4.15 (Continued): LID operation summary- 3rd scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
97	64B	BioRetentionCell	201.83	5.13	114.04	0	28.29	110.94
98	88B	BioRetentionCell	181.27	5.12	90.78	0	28.29	113.65
99	89B	BioRetentionCell	195.1	5.12	103.29	0	28.29	114.97
100	44B	BioRetentionCell	198.19	5.13	108.6	0	28.29	112.75
101	1B	BioRetentionCell	192.2	5.13	105.91	0	28.29	109.44

Table 4.16 : Instantaneous discharge time series of drainage system- 3rd scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0.01
1:30:00	0	0.09
1:45:00	0	0.08
2:00:00	31.74	0.06
2:15:00	0	0.8
2:30:00	0	0.41
2:45:00	0	0.26
3:00:00	23.34	0.18
3:15:00	0	0.7
3:30:00	0	0.41
3:45:00	0	0.28
4:00:00	0	0.21
4:15:00	0	0.16
4:30:00	0	0.13
4:45:00	0	0.11
5:00:00	0	0.09
5:15:00	0	0.08
5:30:00	0	0.07
5:45:00	0	0.06
6:00:00	39.6	0.06
6:15:00	0	1.01
6:30:00	0	0.53
6:45:00	0	0.33
7:00:00	0	0.24

Table 4.16 (Continued): Instantaneous discharge time series of drainage system- 3rd scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
7:15:00	0	0.18
7:30:00	0	0.15
7:45:00	0	0.12
8:00:00	0	0.1
8:15:00	0	0.09
8:30:00	0	0.07
8:45:00	0	0.06
9:00:00	0	0.06
9:15:00	0	0.05
9:30:00	0	0.05
9:45:00	0	0.04
10:00:00	0	0.04
10:15:00	0	0.04
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.03
12:00:00	30	0.03
12:15:00	0	0.65
12:30:00	0	0.37
12:45:00	0	0.25
13:00:00	0	0.19
13:15:00	0	0.15
13:30:00	0	0.12
13:45:00	0	0.1
14:00:00	0	0.09
14:15:00	0	0.08
14:30:00	0	0.07
14:45:00	0	0.07
15:00:00	0	0.06
15:15:00	0	0.06
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.05
16:15:00	0	0.05

Table 4.16 (Continued): Instantaneous discharge time series of drainage system- 3rd scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
16:30:00	0	0.05
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.04
19:00:00	0	0.03
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.03
23:30:00	0	0.03
23:45:00	0	0.02
0:00:00	0	0.02

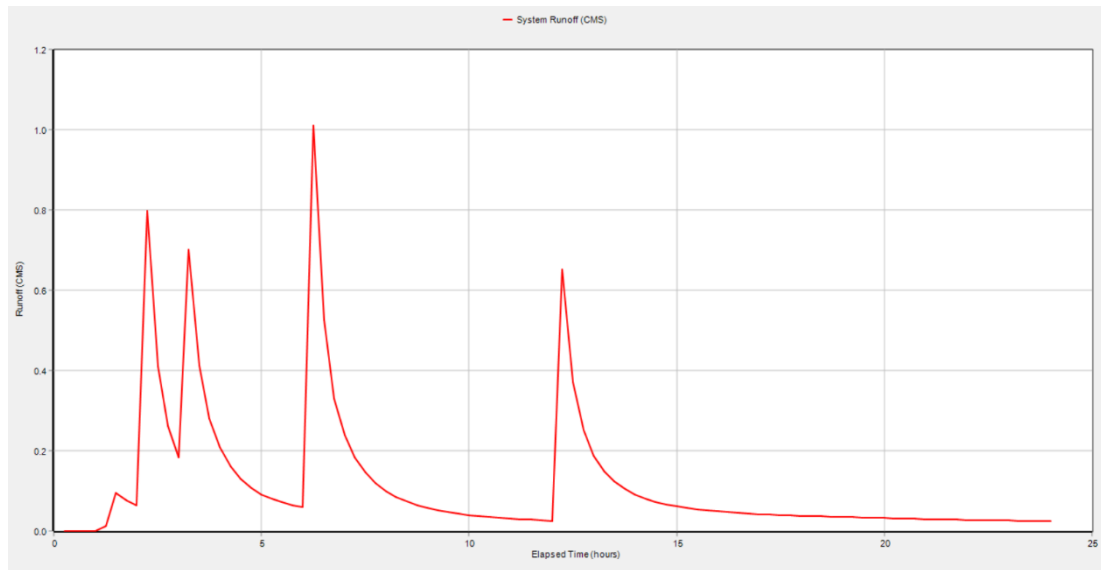


Figure 4.41 : 10 year return period hydrograph- 3rd scenario.

4.2.6 4th scenario results - Permeable Pavements LID-5%

Figures 4.42 through 4.46 illustrate SWMM model input data in 4th scenario (permeable pavements). Table 4.17 shows the hydrologic calculations results of the under study subcatchments while Table 4.18 shows implemented LID's operation summary on them. Table 4.19 shows the instantaneous discharge time series of the drainage system and Figure 4.47 depicts 10 year return period hydrograph.

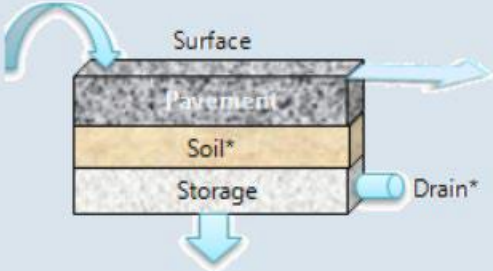
Soil Surface	Storage Pavement
Berm Height (in. or mm)	0.0
Vegetation Volume Fraction	0.0
Surface Roughness (Mannings n)	0.1
Surface Slope (percent)	1.0

Figure 4.42 : SWMM model input data- 4th scenario-1.

LID Control Editor

Control Name:

LID Type:



*Optional

OK Cancel Help

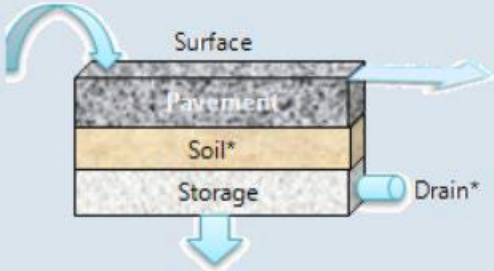
Soil	Storage	Drain
Surface	Pavement	
Thickness (in. or mm)	10	
Void Ratio (Voids / Solids)	0.15	
Impervious Surface Fraction	0	
Permeability (in/hr or mm/hr)	100	
Clogging Factor	0	

Figure 4.43 : SWMM model input data- 4th scenario-2.

LID Control Editor

Control Name:

LID Type:



*Optional

OK Cancel Help

Surface	Storage	Drain
Soil	Pavement	
Thickness (in. or mm)	200	
Porosity (volume fraction)	0.5	
Field Capacity (volume fraction)	0.2	
Wilting Point (volume fraction)	0.1	
Conductivity (in/hr or mm/hr)	0.5	
Conductivity Slope	10.0	
Suction Head (in. or mm)	3.5	

Figure 4.44 : SWMM model input data- 4th scenario-3.

LID Control Editor

Control Name:

LID Type:

*Optional

Surface	Pavement
Soil	Storage
Drain	
Thickness (in. or mm)	200
Void Ratio (Voids / Solids)	0.75
Seepage Rate (in/hr or mm/hr)	0.5
Clogging Factor	0

OK Cancel Help

Figure 4.45 : SWMM model input data- 4th scenario-4.

LID Usage Editor

LID Control Name:

LID Area

Width

☐ LID Occupies Full Subcatchment

Area of Each Unit (sq ft or sq m)

Number of Units

% of Subcatchment Occupied

Surface Width per Unit (ft or m)

% Initially Saturated

% of Impervious Area Treated

Send Drain Flow To:
(Leave blank to use outlet of current subcatchment)

☐ Return all Outflow to Pervious Area

Detailed Report File (Optional)

OK Cancel Help

Figure 4.46 : SWMM model input data- 4th scenario-5.

Table 4.17 : Hydrologic calculation results of the subcatchments- 4th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	10	16.49	0.04	0	0.47
2	299B	35.1	15.29	14.35	0.06	0.01	0.409
3	29B	35.1	19.57	11.04	0.08	0.01	0.314
4	28B	35.1	18.22	12.64	0.08	0.02	0.36
5	25B	35.1	25.31	5.83	0.08	0.02	0.166
6	16B	35.1	9.93	12.66	0.1	0.01	0.361
7	17B	35.1	21.12	6.14	0.37	0.05	0.175
8	300B	35.1	15.94	12.11	0.01	0	0.345
9	33B	35.1	20.27	8.91	0.25	0.04	0.254
10	93B	35.1	20.08	9.58	0.13	0.02	0.273
11	96B	35.1	20.46	8.61	0.18	0.03	0.245
12	12B	35.1	19.59	11.23	0.08	0.01	0.32
13	52B	35.1	22.4	8.09	0.07	0.01	0.23
14	53B	35.1	22.38	7.97	0.07	0.01	0.227
15	51B	35.1	20.45	8.54	0.12	0.02	0.243
16	58B	35.1	25.31	5.52	0.1	0.02	0.157
17	302B	35.1	16	11.09	0.03	0	0.316
18	34B	35.1	20.27	9.1	0.14	0.03	0.259
19	10B	35.1	20.65	7.76	0.2	0.03	0.221
20	18B	35.1	21.03	6.74	0.13	0.02	0.192
21	19B	35.1	19.89	9.98	0.12	0.02	0.284
22	85B	35.1	17.77	13.06	0.07	0.01	0.372
23	71B	35.1	21.62	8.96	0.03	0	0.255
24	72B	35.1	19.56	11.01	0.07	0.01	0.314
25	73B	35.1	21.03	6.6	0.13	0.02	0.188
26	195B	35.1	20.46	8.44	0.23	0.04	0.241
27	46B	35.1	20.65	7.9	0.14	0.02	0.225
28	91B	35.1	25.3	5.79	0.08	0.02	0.165
29	60B	35.1	25.32	5.4	0.06	0.01	0.154
30	61B	35.1	20.46	8.51	0.15	0.03	0.242
31	269B	35.1	9.99	16.88	0.1	0.01	0.481
32	298B	35.1	14.76	15.72	0.07	0.01	0.448
33	95B	35.1	20.7	7.63	0.49	0.07	0.217
34	37B	35.1	20.82	7.21	1.08	0.16	0.205
35	194B	35.1	18.12	12.89	0.06	0.01	0.367
36	193B	35.1	22.07	8.49	0.06	0.01	0.242
37	191B	35.1	20.84	7.33	0.08	0.01	0.209

Table 4.17 (Continued): Hydrologic calculation results of the subcatchments- 4th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
38	32B	35.1	19.47	11.33	0.08	0.01	0.323
39	94B	35.1	21.12	6.35	0.35	0.05	0.181
40	49B	35.1	18.45	12.46	0.07	0.01	0.355
41	92B	35.1	25.32	5.84	0.06	0.02	0.166
42	393B	35.1	25.27	5.68	0.03	0.01	0.162
43	196B	35.1	21.7	8.67	0.05	0.01	0.247
44	197B	35.1	17.89	13.07	0.05	0.01	0.372
45	198B	35.1	19.57	11.04	0.08	0.01	0.314
46	30B	35.1	19.01	11.68	0.1	0.02	0.333
47	31B	35.1	19.14	11.72	0.11	0.02	0.334
48	56B	35.1	20.07	9.59	0.15	0.03	0.273
49	24B	35.1	20.84	7.11	0.11	0.02	0.202
50	35B	35.1	19.7	10.2	0.17	0.03	0.291
51	43B	35.1	25.32	5.89	0.07	0.02	0.168
52	9B	35.1	20.46	8.37	0.22	0.04	0.238
53	81B	35.1	19.02	11.8	0.06	0.01	0.336
54	82B	35.1	19.02	11.82	0.08	0.02	0.337
55	80B	35.1	20.52	8.11	0.26	0.04	0.231
56	90B	35.1	20.83	6.9	0.08	0.01	0.197
57	86B	35.1	21.72	8.76	0.03	0	0.249
58	87B	35.1	22.14	8.15	0.03	0	0.232
59	70B	35.1	20.81	9.71	0.09	0.01	0.277
60	84B	35.1	18.8	12.09	0.06	0.01	0.344
61	69B	35.1	19.88	9.84	0.12	0.02	0.28
62	63B	35.1	19.24	11.6	0.09	0.02	0.33
63	62B	35.1	20.92	9.67	0.15	0.01	0.275
64	57B	35.1	25.31	5.8	0.15	0.04	0.165
65	192B	35.1	21.92	8.46	0.04	0.01	0.241
66	48B	35.1	18.2	12.38	0.04	0.01	0.353
67	47B	35.1	19.33	12.38	0.14	0.02	0.353
68	45B	35.1	20.83	6.86	0.08	0.01	0.195
69	22B	35.1	25.27	5.71	0.03	0.01	0.163
70	21B	35.1	20.08	9.51	0.11	0.02	0.271
71	20B	35.1	20.07	9.43	0.13	0.03	0.269
72	23B	35.1	20.92	6.57	0.26	0.04	0.187
73	65B	35.1	20.65	8.13	0.12	0.02	0.232

Table 4.17 (Continued): Hydrologic calculation results of the subcatchments- 4th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
74	59B	35.1	24.31	5.52	0.04	0.01	0.157
75	83B	35.1	20.27	9.23	0.19	0.03	0.263
76	97B	35.1	25.32	5.76	0.22	0.04	0.164
77	78B	35.1	17.97	12.58	0.03	0.01	0.358
78	74B	35.1	21.6	8.85	0.05	0.01	0.252
79	450B	35.1	9.99	16.54	0.12	0.01	0.471
80	54B	35.1	18.1	12.67	0.04	0.01	0.361
81	40B	35.1	9.82	17.9	0.05	0	0.51
82	42B	35.1	20.84	7.38	0.27	0.04	0.21
83	38B	35.1	20.65	8.15	0.38	0.06	0.232
84	13B	35.1	19.81	11.02	0.05	0.01	0.314
85	15B	35.1	21.03	9.42	0.05	0.01	0.268
86	11B	35.1	19.47	11.3	0.11	0.02	0.322
87	14B	35.1	21.95	8.59	0.05	0.01	0.245
88	79B	35.1	20.27	8.99	0.1	0.02	0.256
89	67B	35.1	19.8	10.94	0.11	0.02	0.312
90	66B	35.1	20.6	10.09	0.06	0.01	0.288
91	301B	35.1	14.13	16.44	0.01	0	0.468
92	99B	35.1	10	15.6	0.03	0	0.445
93	26B	35.1	20.27	9.17	0.13	0.02	0.261
94	27B	35.1	25.32	5.82	0.08	0.02	0.166
95	447B	35.1	9.99	11.6	0.11	0.01	0.33
96	101B	35.1	9.99	16.5	0.07	0.01	0.47
97	64B	35.1	25.32	6.01	0.02	0.01	0.171
98	88B	35.1	20.88	9.36	0.03	0	0.267
99	89B	35.1	21.71	8.74	0.05	0.01	0.249
100	44B	35.1	20.07	9.56	0.1	0.02	0.272
101	1B	35.1	25.28	5.99	0.04	0.02	0.171

Table 4.18 : LID operation summary- 4th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	PermeablePavement	177.83	12	91.85	0	28.29	102.3
2	299B	PermeablePavement	186.08	12	101.36	0	28.29	101.06
3	29B	PermeablePavement	192.77	12	107.53	0	28.29	101.56
4	28B	PermeablePavement	196.32	12	111.74	0	28.29	100.93

Table 4.18 (Continued): LID operation summary- 4th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
5	25B	PermeablePavement	198.93	12	113.61	0	28.29	101.65
6	16B	PermeablePavement	365.33	12	276.68	0	28.29	104.95
7	17B	PermeablePavement	196.37	12	108.32	0	28.29	104.34
8	300B	PermeablePavement	201.25	12	115.18	0	28.29	102.37
9	33B	PermeablePavement	201.35	12	115.5	0	28.29	102.15
10	93B	PermeablePavement	198.93	12	113.61	0	28.29	101.64
11	96B	PermeablePavement	198.05	12	112.17	0	28.29	102.21
12	12B	PermeablePavement	201.54	12	116.22	0	28.29	101.63
13	52B	PermeablePavement	198.54	12	111.47	0	28.29	103.37
14	53B	PermeablePavement	193.13	12	106.1	0	28.29	103.32
15	51B	PermeablePavement	197.66	12	111.7	0	28.29	102.26
16	58B	PermeablePavement	196.25	12	108.44	0	28.29	104.1
17	302B	PermeablePavement	187.06	12	100.81	0	28.29	102.57
18	34B	PermeablePavement	199.17	12	113.59	0	28.29	101.93
19	10B	PermeablePavement	200.19	12	113.52	0	28.29	102.98
20	18B	PermeablePavement	197.11	12	109.55	0	28.29	103.85
21	19B	PermeablePavement	201.58	12	116.37	0	28.29	101.51
22	85B	PermeablePavement	192.2	12	107.83	0	28.29	100.68
23	71B	PermeablePavement	200.97	12	114.42	0	28.29	102.84
24	72B	PermeablePavement	191.52	12	106.29	0	28.29	101.55
25	73B	PermeablePavement	199.23	12	111.44	0	28.29	104.07
26	195B	PermeablePavement	199.95	12	113.83	0	28.29	102.42
27	46B	PermeablePavement	198.16	12	111.7	0	28.29	102.78
28	91B	PermeablePavement	196.86	12	111.58	0	28.29	101.62
29	60B	PermeablePavement	194.99	12	106.92	0	28.29	104.35
30	61B	PermeablePavement	200.27	12	114.21	0	28.29	102.37
31	269B	PermeablePavement	198.21	12	111.93	0	28.29	102.58
32	298B	PermeablePavement	191.29	12	107.1	0	28.29	100.5
33	95B	PermeablePavement	199.71	12	112.94	0	28.29	103.07
34	37B	PermeablePavement	199.91	12	112.73	0	28.29	103.47
35	194B	PermeablePavement	201.74	12	117.18	0	28.29	100.89
36	193B	PermeablePavement	200.73	12	113.89	0	28.29	103.14
37	191B	PermeablePavement	198.96	12	111.94	0	28.29	103.31
38	32B	PermeablePavement	199.06	12	113.86	0	28.29	101.53
39	94B	PermeablePavement	197.32	12	109.38	0	28.29	104.22
40	49B	PermeablePavement	198.77	12	114.07	0	28.29	101.05
41	92B	PermeablePavement	199.94	12	114.61	0	28.29	101.65

Table 4.18 (Continued): LID operation summary- 4th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
42	393B	PermeablePavement	188.86	12	103.93	0	28.29	101.27
43	196B	PermeablePavement	192.85	12	106.33	0	28.29	102.83
44	197B	PermeablePavement	197.38	12	112.98	0	28.29	100.73
45	198B	PermeablePavement	192.77	12	107.53	0	28.29	101.56
46	30B	PermeablePavement	193.83	12	108.85	0	28.29	101.29
47	31B	PermeablePavement	201.6	12	116.52	0	28.29	101.41
48	56B	PermeablePavement	197.29	12	112.03	0	28.29	101.58
49	24B	PermeablePavement	196.92	12	109.72	0	28.29	103.5
50	35B	PermeablePavement	199.48	12	114.38	0	28.29	101.4
51	43B	PermeablePavement	200.12	12	115.19	0	28.29	101.24
52	9B	PermeablePavement	200.5	12	114.3	0	28.29	102.5
53	81B	PermeablePavement	198.44	12	113.45	0	28.29	101.31
54	82B	PermeablePavement	199.12	12	114.15	0	28.29	101.3
55	80B	PermeablePavement	200.5	12	114.09	0	28.29	102.71
56	90B	PermeablePavement	194.46	12	107.1	0	28.29	103.65
57	86B	PermeablePavement	196.55	12	110	0	28.29	102.87
58	87B	PermeablePavement	189.04	12	102.26	0	28.29	103.07
59	70B	PermeablePavement	194.27	12	108.33	0	28.29	102.25
60	84B	PermeablePavement	201.65	12	116.74	0	28.29	101.24
61	69B	PermeablePavement	197.18	12	112.01	0	28.29	101.51
62	63B	PermeablePavement	199.41	12	114.31	0	28.29	101.4
63	62B	PermeablePavement	442.66	12	354.54	0	28.29	104.42
64	57B	PermeablePavement	199.45	12	113.74	0	28.29	102.03
65	192B	PermeablePavement	190.36	12	103.76	0	28.29	102.9
66	48B	PermeablePavement	184.18	12	99.68	0	28.29	100.84
67	47B	PermeablePavement	35.1	0.95	0	0	20	54.16
68	45B	PermeablePavement	194.39	12	106.98	0	28.29	103.7
69	22B	PermeablePavement	189.95	12	105.1	0	28.29	101.18
70	21B	PermeablePavement	199.98	12	114.58	0	28.29	101.73
71	20B	PermeablePavement	196.67	12	111.27	0	28.29	101.71
72	23B	PermeablePavement	197.83	12	110.04	0	28.29	104.08
73	65B	PermeablePavement	198.72	12	112.47	0	28.29	102.56
74	59B	PermeablePavement	187.54	12	99.66	0	28.29	104.16
75	83B	PermeablePavement	201.46	12	115.89	0	28.29	101.87
76	97B	PermeablePavement	201.01	12	114.53	0	28.29	102.78
77	78B	PermeablePavement	180.7	12	96.38	0	28.29	100.67
78	74B	PermeablePavement	194.63	12	108.19	0	28.29	102.76

Table 4.18 (Continued): LID operation summary- 4th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
79	450B	PermeablePavement	201.02	12	114.56	0	28.29	102.76
80	54B	PermeablePavement	191.71	12	107.2	0	28.29	100.84
81	40B	PermeablePavement	195.48	12	109.6	0	28.29	102.18
82	42B	PermeablePavement	199.63	12	112.65	0	28.29	103.27
83	38B	PermeablePavement	200.74	12	114.45	0	28.29	102.61
84	13B	PermeablePavement	201.51	12	116.13	0	28.29	101.72
85	15B	PermeablePavement	191.67	12	105.63	0	28.29	102.35
86	11B	PermeablePavement	199.71	12	114.48	0	28.29	101.57
87	14B	PermeablePavement	197.92	12	111.22	0	28.29	103
88	79B	PermeablePavement	198.21	12	112.53	0	28.29	102
89	67B	PermeablePavement	198.01	12	112.64	0	28.29	101.69
90	66B	PermeablePavement	201.33	12	115.44	0	28.29	102.19
91	301B	PermeablePavement	184.34	12	100.58	0	28.29	100.18
92	99B	PermeablePavement	179.96	12	93.59	0	28.29	102.67
93	26B	PermeablePavement	198.95	12	113.41	0	28.29	101.86
94	27B	PermeablePavement	200.09	12	114.51	0	28.29	101.91
95	447B	PermeablePavement	193.58	12	105.72	0	28.29	104.14
96	101B	PermeablePavement	201.01	12	114.53	0	28.29	102.78
97	64B	PermeablePavement	201.83	12	117.65	0	28.29	100.54
98	88B	PermeablePavement	181.27	12	95.44	0	28.29	102.13
99	89B	PermeablePavement	195.1	12	108.57	0	28.29	102.84
100	44B	PermeablePavement	198.19	12	112.89	0	28.29	101.64
101	1B	PermeablePavement	192.2	12	108.97	0	28.29	99.54

Table 4.19 : Instantaneous discharge time series of drainage system- 4th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0.01
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0.03
1:30:00	0	0.01
1:45:00	0	0.01
2:00:00	31.74	0
2:15:00	0	0.63
2:30:00	0	0.42

Table 4.19 (Continued): Instantaneous discharge time series of drainage system- 4th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:45:00	0	0.27
3:00:00	23.34	0.2
3:15:00	0	0.8
3:30:00	0	0.47
3:45:00	0	0.33
4:00:00	0	0.25
4:15:00	0	0.2
4:30:00	0	0.16
4:45:00	0	0.14
5:00:00	0	0.12
5:15:00	0	0.11
5:30:00	0	0.09
5:45:00	0	0.08
6:00:00	39.6	0.08
6:15:00	0	1.12
6:30:00	0	0.57
6:45:00	0	0.36
7:00:00	0	0.27
7:15:00	0	0.21
7:30:00	0	0.17
7:45:00	0	0.14
8:00:00	0	0.12
8:15:00	0	0.11
8:30:00	0	0.09
8:45:00	0	0.08
9:00:00	0	0.07
9:15:00	0	0.07
9:30:00	0	0.06
9:45:00	0	0.06
10:00:00	0	0.05
10:15:00	0	0.05
10:30:00	0	0.04
10:45:00	0	0.04
11:00:00	0	0.04
11:15:00	0	0.04
11:30:00	0	0.03
11:45:00	0	0.03

Table 4.19 (Continued): Instantaneous discharge time series of drainage system- 4th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
12:00:00	30	0.03
12:15:00	0	0.74
12:30:00	0	0.4
12:45:00	0	0.28
13:00:00	0	0.21
13:15:00	0	0.17
13:30:00	0	0.14
13:45:00	0	0.12
14:00:00	0	0.11
14:15:00	0	0.1
14:30:00	0	0.09
14:45:00	0	0.08
15:00:00	0	0.07
15:15:00	0	0.07
15:30:00	0	0.06
15:45:00	0	0.06
16:00:00	0	0.06
16:15:00	0	0.05
16:30:00	0	0.05
16:45:00	0	0.05
17:00:00	0	0.05
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.04
19:00:00	0	0.04
19:15:00	0	0.04
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03

Table 4.19 (Continued): Instantaneous discharge time series of drainage system- 4th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.03
23:30:00	0	0.03
23:45:00	0	0.02
0:00:00	0	0.02

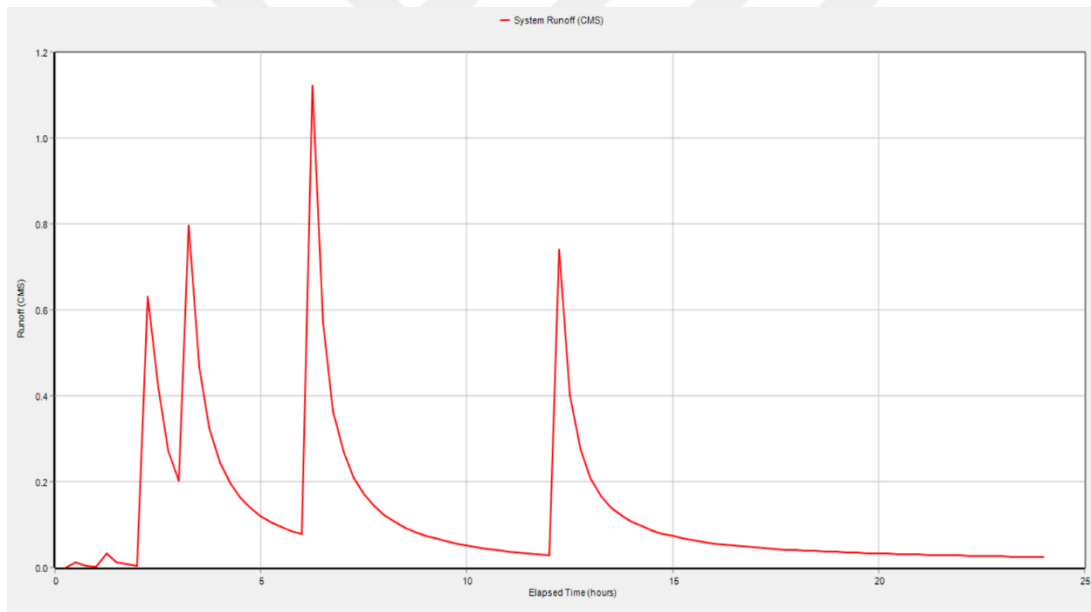


Figure 4.47 : 10 year return period hydrograph- 4th scenario.

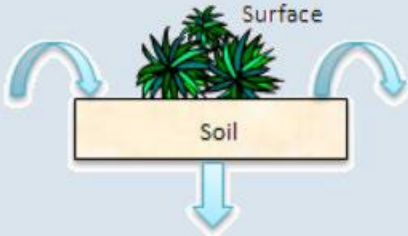
4.2.7 5th scenario modeling results - Rain Gardens LID-5%

Figures 4.48 through 4.50 illustrate SWMM model input data in 5th scenario (rain gardens). Table 4.20 shows the hydrologic calculations results of the under study subcatchments while Table 4.21 shows implemented LID's operation summary on them. Table 4.22 shows instantaneous discharge time series of drainage system, whereas Figure 4.52 depicts 10 year return period hydrograph.

LID Control Editor

Control Name:

LID Type:



Surface Soil Storage

Berm Height (in. or mm)

Vegetation Volume Fraction

Surface Roughness (Mannings n)

Surface Slope (percent)

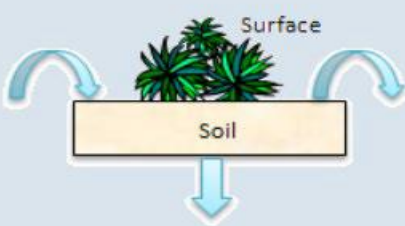
OK Cancel Help

Figure 4.48 : SWMM model input data- 5th scenario-1.

LID Control Editor

Control Name:

LID Type:



Surface Soil Storage

Thickness (in. or mm)

Porosity (volume fraction)

Field Capacity (volume fraction)

Wilting Point (volume fraction)

Conductivity (in/hr or mm/hr)

Conductivity Slope

Suction Head (in. or mm)

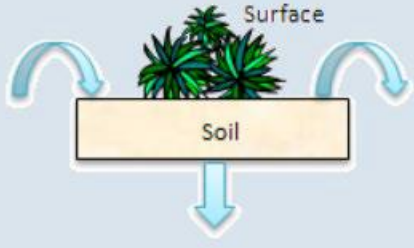
OK Cancel Help

Figure 4.49 : SWMM model input data- 5th scenario-2.

LID Control Editor

Control Name:

LID Type:



Surface Soil Storage

Thickness (in. or mm)

Void Ratio (Voids / Solids)

Seepage Rate (in/hr or mm/hr)

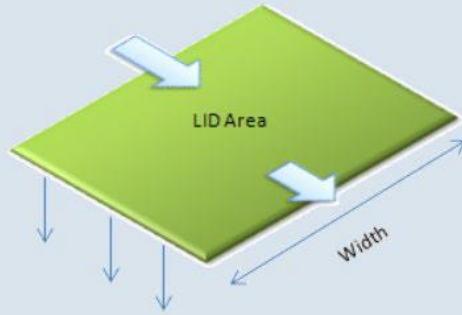
Clogging Factor

OK Cancel Help

Figure 4.50 : SWMM model input data- 5th scenario-3.

LID Usage Editor

LID Control Name:



LID Area

Width

☐ LID Occupies Full Subcatchment

Area of Each Unit (sq ft or sq m)

Number of Units

% of Subcatchment Occupied

Surface Width per Unit (ft or m)

% Initially Saturated

% of Impervious Area Treated

Send Drain Flow To:
(Leave blank to use outlet of current subcatchment)

☐ Return all Outflow to Pervious Area

Detailed Report File (Optional)

OK Cancel Help

Figure 4.51 : SWMM model input data- 5th scenario-4.

Table 4.20 : Hydrologic calculation results of the subcatchments- 5th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	9.32	16.78	0.04	0	0.478
2	299B	35.1	14.64	14.68	0.06	0.01	0.418
3	29B	35.1	18.94	11.34	0.09	0.02	0.323
4	28B	35.1	17.61	12.96	0.08	0.02	0.369
5	25B	35.1	24.71	6.11	0.08	0.02	0.174
6	16B	35.1	9.39	11.2	0.09	0.01	0.319
7	17B	35.1	20.52	6.25	0.38	0.05	0.178
8	300B	35.1	15.35	12.36	0.01	0	0.352
9	33B	35.1	19.68	9.17	0.25	0.04	0.261
10	93B	35.1	19.48	9.87	0.13	0.03	0.281
11	96B	35.1	19.85	8.88	0.19	0.03	0.253
12	12B	35.1	19	11.51	0.09	0.02	0.328
13	52B	35.1	21.8	8.29	0.07	0.01	0.236
14	53B	35.1	21.76	8.18	0.07	0.01	0.233
15	51B	35.1	19.85	8.8	0.12	0.02	0.251
16	58B	35.1	24.71	5.68	0.1	0.02	0.162
17	302B	35.1	15.36	11.35	0.03	0	0.323
18	34B	35.1	19.67	9.37	0.14	0.03	0.267
19	10B	35.1	20.06	7.99	0.21	0.03	0.227
20	18B	35.1	20.43	6.91	0.14	0.02	0.197
21	19B	35.1	19.3	10.27	0.12	0.02	0.292
22	85B	35.1	17.14	13.39	0.07	0.02	0.381
23	71B	35.1	21.02	9.19	0.03	0	0.262
24	72B	35.1	18.94	11.31	0.07	0.01	0.322
25	73B	35.1	20.44	6.75	0.14	0.02	0.192
26	195B	35.1	19.86	8.7	0.24	0.04	0.248
27	46B	35.1	20.04	8.14	0.15	0.02	0.232
28	91B	35.1	24.69	6.08	0.09	0.02	0.173
29	60B	35.1	24.72	5.49	0.06	0.01	0.156
30	61B	35.1	19.87	8.76	0.16	0.03	0.25
31	269B	35.1	9.39	17.13	0.1	0.01	0.488
32	298B	35.1	14.13	16.06	0.08	0.01	0.458
33	95B	35.1	20.1	7.85	0.51	0.08	0.224
34	37B	35.1	20.22	7.41	1.11	0.16	0.211
35	194B	35.1	17.53	13.2	0.06	0.01	0.376
36	193B	35.1	21.48	8.7	0.07	0.01	0.248
37	191B	35.1	20.24	7.53	0.08	0.01	0.215

Table 4.20 (Continued): Hydrologic calculation results of the subcatchments- 5th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
38	32B	35.1	18.87	11.62	0.08	0.01	0.331
39	94B	35.1	20.52	6.49	0.35	0.05	0.185
40	49B	35.1	17.85	12.77	0.08	0.02	0.364
41	92B	35.1	24.72	6.13	0.07	0.02	0.175
42	393B	35.1	24.63	5.99	0.03	0.01	0.171
43	196B	35.1	21.08	8.91	0.06	0.01	0.254
44	197B	35.1	17.28	13.39	0.05	0.01	0.382
45	198B	35.1	18.94	11.34	0.09	0.02	0.323
46	30B	35.1	18.39	11.99	0.1	0.02	0.342
47	31B	35.1	18.54	12.01	0.11	0.02	0.342
48	56B	35.1	19.47	9.88	0.16	0.03	0.282
49	24B	35.1	20.23	7.31	0.11	0.02	0.208
50	35B	35.1	19.1	10.5	0.17	0.04	0.299
51	43B	35.1	24.72	6.19	0.07	0.02	0.176
52	9B	35.1	19.87	8.62	0.22	0.04	0.246
53	81B	35.1	18.41	12.1	0.07	0.01	0.345
54	82B	35.1	18.42	12.12	0.08	0.02	0.345
55	80B	35.1	19.93	8.35	0.27	0.04	0.238
56	90B	35.1	20.22	7.09	0.09	0.01	0.202
57	86B	35.1	21.11	8.99	0.04	0.01	0.256
58	87B	35.1	21.51	8.39	0.04	0.01	0.239
59	70B	35.1	20.19	9.98	0.1	0.02	0.284
60	84B	35.1	18.21	12.39	0.06	0.01	0.353
61	69B	35.1	19.28	10.14	0.12	0.02	0.289
62	63B	35.1	18.64	11.9	0.09	0.02	0.339
63	62B	35.1	20.06	8.16	0.13	0.02	0.233
64	57B	35.1	24.72	6.07	0.16	0.04	0.173
65	192B	35.1	21.29	8.7	0.04	0.01	0.248
66	48B	35.1	17.54	12.72	0.05	0.01	0.363
67	47B	35.1	19.29	10.14	0.12	0.02	0.289
68	45B	35.1	20.22	7.05	0.09	0.01	0.201
69	22B	35.1	24.64	6.03	0.03	0.01	0.172
70	21B	35.1	19.48	9.79	0.11	0.02	0.279
71	20B	35.1	19.46	9.71	0.14	0.03	0.277
72	23B	35.1	20.32	6.72	0.26	0.04	0.192
73	65B	35.1	20.05	8.38	0.12	0.02	0.239

Table 4.20 (Continued): Hydrologic calculation results of the subcatchments- 5th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
74	59B	35.1	23.71	5.54	0.04	0.01	0.158
75	83B	35.1	19.68	9.5	0.19	0.04	0.271
76	97B	35.1	24.73	5.99	0.23	0.05	0.171
77	78B	35.1	17.29	12.94	0.03	0.01	0.369
78	74B	35.1	20.98	9.09	0.05	0.01	0.259
79	450B	35.1	9.39	16.77	0.12	0.01	0.478
80	54B	35.1	17.47	13	0.04	0.01	0.37
81	40B	35.1	9.21	18.17	0.05	0.01	0.518
82	42B	35.1	20.25	7.59	0.28	0.04	0.216
83	38B	35.1	20.06	8.39	0.39	0.06	0.239
84	13B	35.1	19.22	11.3	0.05	0.01	0.322
85	15B	35.1	20.4	9.69	0.05	0.01	0.276
86	11B	35.1	18.87	11.59	0.11	0.02	0.33
87	14B	35.1	21.34	8.82	0.05	0.01	0.251
88	79B	35.1	19.66	9.26	0.1	0.02	0.264
89	67B	35.1	19.2	11.23	0.11	0.02	0.32
90	66B	35.1	20.01	10.35	0.06	0.01	0.295
91	301B	35.1	13.47	16.8	0.02	0	0.479
92	99B	35.1	9.33	15.87	0.03	0	0.452
93	26B	35.1	19.67	9.45	0.13	0.02	0.269
94	27B	35.1	24.72	6.09	0.08	0.02	0.174
95	447B	35.1	9.38	11.75	0.11	0.01	0.335
96	101B	35.1	9.39	16.73	0.07	0.01	0.477
97	64B	35.1	24.73	6.32	0.02	0.01	0.18
98	88B	35.1	20.21	9.66	0.03	0	0.275
99	89B	35.1	21.1	8.97	0.05	0.01	0.256
100	44B	35.1	19.48	9.87	0.1	0.02	0.281
101	1B	35.1	24.65	6.35	0.04	0.02	0.181

Table 4.21 : LID operation summary- 5th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	RainGarden	177.83	0.16	96.88	0	48	128.79
2	299B	RainGarden	186.08	0.16	107.39	0	48	126.53
3	29B	RainGarden	192.77	0.16	113.22	0	48	127.39
4	28B	RainGarden	196.32	0.16	117.85	0	48	126.3

Table 4.21 (Continued): LID operation summary- 5th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
5	25B	RainGarden	198.93	0.16	119.24	0	48	127.53
6	16B	RainGarden	196.04	0.15	110.58	0	48	133.3
7	17B	RainGarden	196.37	0.15	110.46	0	48	133.75
8	300B	RainGarden	201.25	0.16	120.22	0	48	128.87
9	33B	RainGarden	201.35	0.16	120.73	0	48	128.45
10	93B	RainGarden	198.93	0.16	119.27	0	48	127.5
11	96B	RainGarden	198.05	0.16	117.32	0	48	128.57
12	12B	RainGarden	201.54	0.16	121.89	0	48	127.49
13	52B	RainGarden	198.54	0.16	115.54	0	48	130.84
14	53B	RainGarden	193.13	0.16	110.22	0	48	130.74
15	51B	RainGarden	197.66	0.16	116.82	0	48	128.68
16	58B	RainGarden	196.25	0.16	111.47	0	48	132.61
17	302B	RainGarden	187.06	0.16	105.61	0	48	129.29
18	34B	RainGarden	199.17	0.16	118.96	0	48	128.04
19	10B	RainGarden	200.19	0.16	117.96	0	48	130.06
20	18B	RainGarden	197.11	0.16	113.02	0	48	131.93
21	19B	RainGarden	201.58	0.16	122.15	0	48	127.26
22	85B	RainGarden	192.2	0.16	114.14	0	48	125.9
23	71B	RainGarden	200.97	0.16	119.03	0	48	129.78
24	72B	RainGarden	191.52	0.16	111.98	0	48	127.38
25	73B	RainGarden	199.23	0.16	114.55	0	48	132.52
26	195B	RainGarden	199.95	0.16	118.82	0	48	128.96
27	46B	RainGarden	198.16	0.16	116.34	0	48	129.66
28	91B	RainGarden	196.86	0.16	117.22	0	48	127.47
29	60B	RainGarden	194.99	0.15	108.62	0	48	134.21
30	61B	RainGarden	200.27	0.16	119.24	0	48	128.87
31	269B	RainGarden	198.21	0.16	116.77	0	48	129.28
32	298B	RainGarden	191.29	0.16	113.52	0	48	125.61
33	95B	RainGarden	199.71	0.16	117.31	0	48	130.24
34	37B	RainGarden	199.91	0.16	116.69	0	48	131.05
35	194B	RainGarden	201.74	0.16	123.34	0	48	126.24
36	193B	RainGarden	200.73	0.16	118.2	0	48	130.37
37	191B	RainGarden	198.96	0.16	116.07	0	48	130.73
38	32B	RainGarden	199.06	0.16	119.59	0	48	127.31
39	94B	RainGarden	197.32	0.15	112.1	0	48	133.05
40	49B	RainGarden	198.77	0.16	120.12	0	48	126.49
41	92B	RainGarden	199.94	0.16	120.25	0	48	127.52

Table 4.21 (Continued): LID operation summary- 5th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
42	393B	RainGarden	188.86	0.16	109.81	0	48	126.89
43	196B	RainGarden	192.85	0.16	110.91	0	48	129.77
44	197B	RainGarden	197.38	0.16	119.24	0	48	125.98
45	198B	RainGarden	192.77	0.16	113.22	0	48	127.39
46	30B	RainGarden	193.83	0.16	114.77	0	48	126.9
47	31B	RainGarden	201.6	0.16	122.35	0	48	127.09
48	56B	RainGarden	197.29	0.16	117.72	0	48	127.42
49	24B	RainGarden	196.92	0.16	113.64	0	48	131.12
50	35B	RainGarden	199.48	0.16	120.23	0	48	127.09
51	43B	RainGarden	200.12	0.16	121.16	0	48	126.8
52	9B	RainGarden	200.5	0.16	119.22	0	48	129.12
53	81B	RainGarden	198.44	0.16	119.35	0	48	126.93
54	82B	RainGarden	199.12	0.16	120.05	0	48	126.91
55	80B	RainGarden	200.5	0.16	118.81	0	48	129.53
56	90B	RainGarden	194.46	0.16	110.83	0	48	131.47
57	86B	RainGarden	196.55	0.16	114.55	0	48	129.84
58	87B	RainGarden	189.04	0.16	106.63	0	48	130.25
59	70B	RainGarden	194.27	0.16	113.46	0	48	128.66
60	84B	RainGarden	201.65	0.16	122.69	0	48	126.8
61	69B	RainGarden	197.18	0.16	117.74	0	48	127.28
62	63B	RainGarden	199.41	0.16	120.16	0	48	127.09
63	62B	RainGarden	200.98	0.16	119.06	0	48	129.76
64	57B	RainGarden	199.45	0.16	119.06	0	48	128.23
65	192B	RainGarden	190.36	0.16	108.29	0	48	129.91
66	48B	RainGarden	184.18	0.16	105.85	0	48	126.16
67	47B	RainGarden	200.03	0.16	120.47	0	48	127.4
68	45B	RainGarden	194.39	0.16	110.66	0	48	131.57
69	22B	RainGarden	189.95	0.16	111.05	0	48	126.73
70	21B	RainGarden	199.98	0.16	120.15	0	48	127.66
71	20B	RainGarden	196.67	0.16	116.86	0	48	127.65
72	23B	RainGarden	197.83	0.16	113.11	0	48	132.56
73	65B	RainGarden	198.72	0.16	117.32	0	48	129.24
74	59B	RainGarden	187.54	0.14	99.98	0	48	135.4
75	83B	RainGarden	201.46	0.16	121.37	0	48	127.93
76	97B	RainGarden	201.01	0.16	119.2	0	48	129.65
77	78B	RainGarden	180.7	0.16	102.65	0	48	125.89
78	74B	RainGarden	194.63	0.16	112.84	0	48	129.63

Table 4.21 (Continued): LID operation summary- 5th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
79	450B	RainGarden	201.02	0.16	119.24	0	48	129.62
80	54B	RainGarden	191.71	0.16	113.38	0	48	126.16
81	40B	RainGarden	195.48	0.16	114.78	0	48	128.53
82	42B	RainGarden	199.63	0.16	116.82	0	48	130.65
83	38B	RainGarden	200.74	0.16	119.26	0	48	129.32
84	13B	RainGarden	201.51	0.16	121.7	0	48	127.65
85	15B	RainGarden	191.67	0.16	110.65	0	48	128.85
86	11B	RainGarden	199.71	0.16	120.16	0	48	127.38
87	14B	RainGarden	197.92	0.16	115.66	0	48	130.09
88	79B	RainGarden	198.21	0.16	117.87	0	48	128.19
89	67B	RainGarden	198.01	0.16	118.24	0	48	127.61
90	66B	RainGarden	201.33	0.16	120.64	0	48	128.53
91	301B	RainGarden	184.34	0.16	107.07	0	48	125.12
92	99B	RainGarden	179.96	0.16	98.31	0	48	129.48
93	26B	RainGarden	198.95	0.16	118.87	0	48	127.92
94	27B	RainGarden	200.09	0.16	119.92	0	48	128.01
95	447B	RainGarden	193.58	0.15	108.61	0	48	132.81
96	101B	RainGarden	201.01	0.16	119.2	0	48	129.65
97	64B	RainGarden	201.83	0.16	123.99	0	48	125.68
98	88B	RainGarden	181.27	0.16	100.64	0	48	128.47
99	89B	RainGarden	195.1	0.16	113.15	0	48	129.79
100	44B	RainGarden	199.84	0.16	120.17	0	48	127.51
101	1B	RainGarden	192.2	0.16	115.89	0	48	124.15

Table 4.22 : Instantaneous discharge time series of drainage system- 5th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0.26
1:30:00	0	0.27
1:45:00	0	0.18
2:00:00	31.74	0.14
2:15:00	0	0.87
2:30:00	0	0.45

Table 4.22 (Continued): Instantaneous discharge time series of drainage system- 5th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:45:00	0	0.28
3:00:00	23.34	0.18
3:15:00	0	0.69
3:30:00	0	0.41
3:45:00	0	0.28
4:00:00	0	0.21
4:15:00	0	0.16
4:30:00	0	0.13
4:45:00	0	0.11
5:00:00	0	0.09
5:15:00	0	0.08
5:30:00	0	0.07
5:45:00	0	0.06
6:00:00	39.6	0.06
6:15:00	0	0.99
6:30:00	0	0.52
6:45:00	0	0.33
7:00:00	0	0.24
7:15:00	0	0.18
7:30:00	0	0.14
7:45:00	0	0.12
8:00:00	0	0.1
8:15:00	0	0.08
8:30:00	0	0.07
8:45:00	0	0.06
9:00:00	0	0.06
9:15:00	0	0.05
9:30:00	0	0.05
9:45:00	0	0.04
10:00:00	0	0.04
10:15:00	0	0.04
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.03

Table 4.22 (Continued): Instantaneous discharge time series of drainage system- 5th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
12:00:00	30	0.03
12:15:00	0	0.63
12:30:00	0	0.37
12:45:00	0	0.25
13:00:00	0	0.19
13:15:00	0	0.15
13:30:00	0	0.12
13:45:00	0	0.1
14:00:00	0	0.09
14:15:00	0	0.08
14:30:00	0	0.07
14:45:00	0	0.07
15:00:00	0	0.06
15:15:00	0	0.06
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.05
16:15:00	0	0.05
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.04
19:00:00	0	0.03
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03

Table 4.22 (Continued): Instantaneous discharge time series of drainage system- 5th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.03
23:30:00	0	0.03
23:45:00	0	0.02
0:00:00	0	0.02

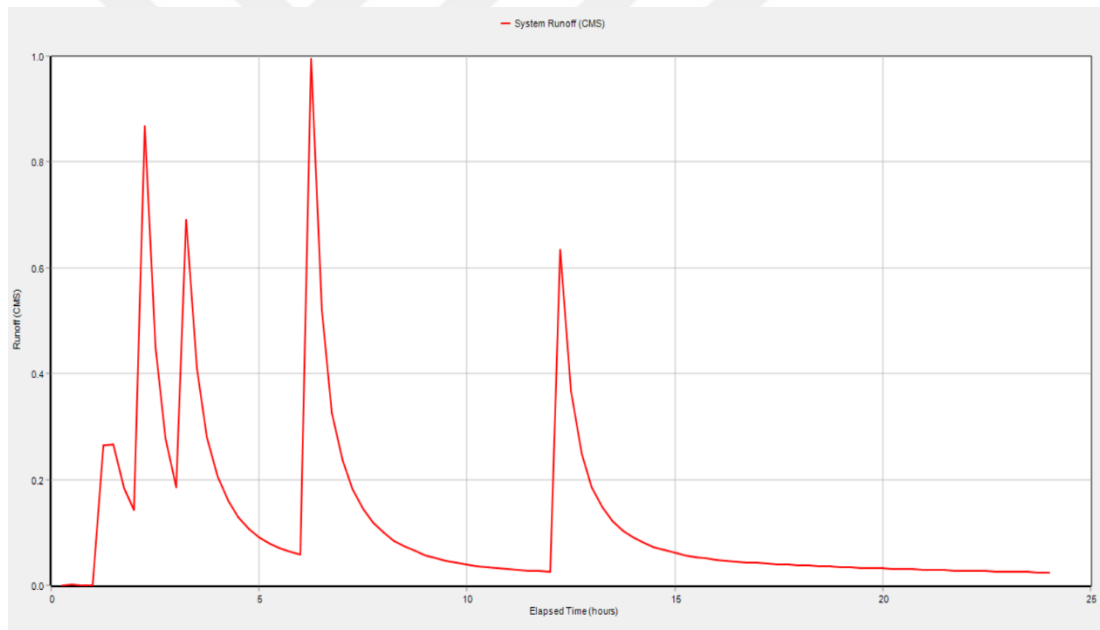


Figure 4.52 : 10 year return period hydrograph- 5th scenario.

4.2.8 6th scenario modeling results - Rain Barrels LID-1%

Figure 4.53 and Figure 4.54 illustrate SWMM model input data in 6th scenario (rain barrels). Table 4.23 shows the hydrologic calculations results of the under study subcatchments while Table 4.24 shows implemented LID's operation summary on them. Table 4.25 shows the instantaneous discharge time series of drainage system whereas Figure 4.55 depicts 10 year return period hydrograph.

LID Control Editor

Control Name:

LID Type:



Storage Drain

Barrel Height (in. or mm)

OK Cancel Help

Figure 4.53 : SWMM model input data- 6th scenario-1.

LID Usage Editor

LID Control Name



Detailed Report File (Optional)

☐ LID Occupies Full Subcatchment

Area of Each Unit (sq ft or sq m)

Number of Units

% of Subcatchment Occupied

Surface Width per Unit (ft or m)

% Initially Saturated

% of Impervious Area Treated

Send Drain Flow To:
(Leave blank to use outlet of current subcatchment)

☐ Return all Outflow to Pervious Area

OK Cancel Help

Figure 4.54 : SWMM model input data- 6th scenario-2.

Table 4.23 : Hydrologic calculation results of the subcatchments- 6th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	9.78	11.57	0.03	0	0.329
2	299B	35.1	15.43	9.02	0.04	0	0.257
3	29B	35.1	19.9	5.5	0.04	0	0.157
4	28B	35.1	18.49	7.06	0.04	0	0.201
5	25B	35.1	25.76	0.06	0	0	0.002
6	16B	35.1	9.78	5.68	0.04	0	0.162
7	17B	35.1	21.38	0.69	0.04	0	0.02
8	300B	35.1	15.96	6.51	0.01	0	0.185
9	33B	35.1	20.7	3.06	0.08	0.01	0.087
10	93B	35.1	20.3	3.92	0.05	0	0.112
11	96B	35.1	20.7	2.96	0.06	0	0.084
12	12B	35.1	19.9	5.53	0.04	0	0.158
13	52B	35.1	22.72	2.49	0.02	0	0.071
14	53B	35.1	22.84	2.45	0.02	0	0.07
15	51B	35.1	20.7	2.9	0.04	0	0.083
16	58B	35.1	25.76	0.01	0	0	0
17	302B	35.1	16.07	5.75	0.01	0	0.164
18	34B	35.1	20.5	3.43	0.05	0	0.098
19	10B	35.1	20.9	2.1	0.05	0	0.06
20	18B	35.1	21.29	1.19	0.02	0	0.034
21	19B	35.1	20.11	4.28	0.05	0	0.122
22	85B	35.1	18.02	7.57	0.04	0	0.216
23	71B	35.1	22.01	3.27	0.01	0	0.093
24	72B	35.1	19.9	5.5	0.04	0	0.157
25	73B	35.1	21.29	1.03	0.02	0	0.029
26	195B	35.1	20.7	2.77	0.08	0	0.079
27	46B	35.1	20.9	2.27	0.04	0	0.065
28	91B	35.1	25.76	0.06	0	0	0.002
29	60B	35.1	25.76	0.01	0	0	0
30	61B	35.1	20.7	2.82	0.05	0	0.08
31	269B	35.1	9.78	11.51	0.07	0	0.328
32	298B	35.1	14.76	10.44	0.05	0	0.297
33	95B	35.1	20.95	1.97	0.13	0.01	0.056
34	37B	35.1	21.07	1.58	0.24	0.01	0.045
35	194B	35.1	18.26	7.29	0.03	0	0.208
36	193B	35.1	22.49	2.82	0.02	0	0.08
37	191B	35.1	21.09	1.7	0.02	0	0.048

Table 4.23 (Continued): Hydrologic calculation results of the subcatchments- 6th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
38	32B	35.1	19.79	5.68	0.04	0	0.162
39	94B	35.1	21.39	0.85	0.05	0	0.024
40	49B	35.1	18.84	6.7	0.04	0	0.191
41	92B	35.1	25.76	0.06	0	0	0.002
42	393B	35.1	25.76	0.07	0	0	0.002
43	196B	35.1	22.13	3.14	0.02	0	0.089
44	197B	35.1	18.02	7.56	0.03	0	0.215
45	198B	35.1	19.9	5.5	0.04	0	0.157
46	30B	35.1	19.31	6.13	0.05	0	0.175
47	31B	35.1	19.43	6.02	0.05	0	0.172
48	56B	35.1	20.3	3.96	0.06	0	0.113
49	24B	35.1	21.1	1.53	0.02	0	0.044
50	35B	35.1	20.1	4.37	0.07	0.01	0.124
51	43B	35.1	25.76	0.08	0	0	0.002
52	9B	35.1	20.7	2.68	0.07	0	0.076
53	81B	35.1	19.32	6.16	0.03	0	0.176
54	82B	35.1	19.32	6.18	0.04	0	0.176
55	80B	35.1	20.97	2.31	0.07	0	0.066
56	90B	35.1	21.09	1.38	0.02	0	0.039
57	86B	35.1	22.14	3.15	0.01	0	0.09
58	87B	35.1	22.61	2.7	0.01	0	0.077
59	70B	35.1	21.2	4.14	0.04	0	0.118
60	84B	35.1	19.08	6.4	0.03	0	0.182
61	69B	35.1	20.3	4.04	0.05	0	0.115
62	63B	35.1	19.43	6	0.05	0	0.171
63	62B	35.1	20.9	2.25	0.03	0	0.064
64	57B	35.1	25.76	0.05	0	0	0.001
65	192B	35.1	22.25	2.99	0.01	0	0.085
66	48B	35.1	18.49	7.05	0.03	0	0.201
67	47B	35.1	20.3	4	0.05	0	0.114
68	45B	35.1	21.09	1.35	0.02	0	0.038
69	22B	35.1	25.76	0.08	0	0	0.002
70	21B	35.1	20.3	3.83	0.04	0	0.109
71	20B	35.1	20.3	3.81	0.05	0	0.108
72	23B	35.1	21.39	0.97	0.04	0	0.028
73	65B	35.1	20.9	2.48	0.04	0	0.071

Table 4.23 (Continued): Hydrologic calculation results of the subcatchments- 6th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
74	59B	35.1	24.71	0.46	0	0	0.013
75	83B	35.1	20.5	3.52	0.07	0.01	0.1
76	97B	35.1	25.76	0.03	0	0	0.001
77	78B	35.1	18.24	7.33	0.02	0	0.209
78	74B	35.1	22.01	3.28	0.02	0	0.093
79	450B	35.1	9.78	11.1	0.08	0	0.316
80	54B	35.1	18.38	7.19	0.02	0	0.205
81	40B	35.1	9.78	12.46	0.04	0	0.355
82	42B	35.1	21.1	1.74	0.06	0	0.05
83	38B	35.1	20.9	2.46	0.11	0.01	0.07
84	13B	35.1	20.02	5.36	0.02	0	0.153
85	15B	35.1	21.42	3.9	0.02	0	0.111
86	11B	35.1	19.78	5.63	0.05	0	0.161
87	14B	35.1	22.25	2.99	0.02	0	0.085
88	79B	35.1	20.5	3.33	0.04	0	0.095
89	67B	35.1	20.02	5.36	0.05	0	0.153
90	66B	35.1	20.95	4.39	0.02	0	0.125
91	301B	35.1	12.83	10.37	0.01	0	0.295
92	99B	35.1	9.77	10.59	0.02	0	0.302
93	26B	35.1	20.5	3.5	0.05	0	0.1
94	27B	35.1	25.76	0.05	0	0	0.001
95	447B	35.1	9.78	6.24	0.06	0	0.178
96	101B	35.1	9.78	11.06	0.04	0	0.315
97	64B	35.1	25.76	0.12	0	0	0.004
98	88B	35.1	21.3	4.05	0.01	0	0.115
99	89B	35.1	22.13	3.16	0.02	0	0.09
100	44B	35.1	20.3	3.91	0.04	0	0.111
101	1B	35.1	25.76	0.21	0	0	0.006

Table 4.24 : LID operation summary- 6th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	RainBarrel	867.66	0	0	0	75	942.66
2	299B	RainBarrel	882.02	0	0	0	75	957.02
3	29B	RainBarrel	879.76	0	0	0	75	954.75
4	28B	RainBarrel	903.19	0	0	0	75	978.19

Table 4.24 (Continued): LID operation summary- 6th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
5	25B	RainBarrel	889.2	0	0	0	75	964.2
6	16B	RainBarrel	862.74	0	0	0	75	937.71
7	17B	RainBarrel	877.36	0	0	0	75	952.33
8	300B	RainBarrel	754.96	0	0	0	75	829.96
9	33B	RainBarrel	898.05	0	0	0	75	973.05
10	93B	RainBarrel	889.23	0	0	0	75	964.22
11	96B	RainBarrel	892.79	0	0	0	75	967.79
12	12B	RainBarrel	902.25	0	0	0	75	977.25
13	52B	RainBarrel	886.77	0	0	0	75	961.76
14	53B	RainBarrel	877.61	0	0	0	75	952.59
15	51B	RainBarrel	888.7	0	0	0	75	963.69
16	58B	RainBarrel	883.89	0	0	0	75	958.86
17	302B	RainBarrel	863.12	0	0	0	75	938.11
18	34B	RainBarrel	901.66	0	0	0	75	976.65
19	10B	RainBarrel	891.84	0	0	0	75	966.83
20	18B	RainBarrel	887.89	0	0	0	75	962.87
21	19B	RainBarrel	902.46	0	0	0	75	977.46
22	85B	RainBarrel	871	0	0	0	75	946
23	71B	RainBarrel	874.9	0	0	0	75	949.9
24	72B	RainBarrel	902.21	0	0	0	75	977.21
25	73B	RainBarrel	885.31	0	0	0	75	960.29
26	195B	RainBarrel	900.51	0	0	0	75	975.5
27	46B	RainBarrel	894.49	0	0	0	75	969.49
28	91B	RainBarrel	896.24	0	0	0	75	971.24
29	60B	RainBarrel	859.61	0	0	0	75	934.57
30	61B	RainBarrel	895.79	0	0	0	75	970.79
31	269B	RainBarrel	885.39	0	0	0	75	960.39
32	298B	RainBarrel	885.46	0	0	0	75	960.45
33	95B	RainBarrel	895.41	0	0	0	75	970.4
34	37B	RainBarrel	895.3	0	0	0	75	970.29
35	194B	RainBarrel	903.3	0	0	0	75	978.3
36	193B	RainBarrel	897.83	0	0	0	75	972.82
37	191B	RainBarrel	881.1	0	0	0	75	956.09
38	32B	RainBarrel	902.38	0	0	0	75	977.38
39	94B	RainBarrel	886	0	0	0	75	960.97
40	49B	RainBarrel	888.46	0	0	0	75	963.46
41	92B	RainBarrel	886.42	0	0	0	75	961.41

Table 4.24 (Continued): LID operation summary- 6th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
42	393B	RainBarrel	902.61	0	0	0	75	977.61
43	196B	RainBarrel	884.94	0	0	0	75	959.93
44	197B	RainBarrel	903.47	0	0	0	75	978.47
45	198B	RainBarrel	879.76	0	0	0	75	954.75
46	30B	RainBarrel	892.6	0	0	0	75	967.6
47	31B	RainBarrel	902.61	0	0	0	75	977.61
48	56B	RainBarrel	896.85	0	0	0	75	971.85
49	24B	RainBarrel	889.73	0	0	0	75	964.72
50	35B	RainBarrel	891.96	0	0	0	75	966.96
51	43B	RainBarrel	902.83	0	0	0	75	977.83
52	9B	RainBarrel	893.58	0	0	0	75	968.58
53	81B	RainBarrel	902.71	0	0	0	75	977.7
54	82B	RainBarrel	902.73	0	0	0	75	977.72
55	80B	RainBarrel	894.15	0	0	0	75	969.14
56	90B	RainBarrel	879.81	0	0	0	75	954.79
57	86B	RainBarrel	898.83	0	0	0	75	973.82
58	87B	RainBarrel	897.42	0	0	0	75	972.41
59	70B	RainBarrel	900.79	0	0	0	75	975.78
60	84B	RainBarrel	885.66	0	0	0	75	960.66
61	69B	RainBarrel	902.38	0	0	0	75	977.38
62	63B	RainBarrel	880.95	0	0	0	75	955.94
63	62B	RainBarrel	893.59	0	0	0	75	968.58
64	57B	RainBarrel	901.46	0	0	0	75	976.45
65	192B	RainBarrel	880.19	0	0	0	75	955.18
66	48B	RainBarrel	903.18	0	0	0	75	978.18
67	47B	RainBarrel	902.32	0	0	0	75	977.32
68	45B	RainBarrel	879.4	0	0	0	75	954.39
69	22B	RainBarrel	887.39	0	0	0	75	962.39
70	21B	RainBarrel	902.06	0	0	0	75	977.06
71	20B	RainBarrel	902.03	0	0	0	75	977.03
72	23B	RainBarrel	886.94	0	0	0	75	961.92
73	65B	RainBarrel	893.96	0	0	0	75	968.96
74	59B	RainBarrel	814.98	0	0	0	75	889.9
75	83B	RainBarrel	893.36	0	0	0	75	968.36
76	97B	RainBarrel	899.38	0	0	0	75	974.38
77	78B	RainBarrel	830.29	0	0	0	75	905.29
78	74B	RainBarrel	883.01	0	0	0	75	958

Table 4.24 (Continued): LID operation summary- 6th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
79	450B	RainBarrel	875.19	0	0	0	75	950.18
80	54B	RainBarrel	903.26	0	0	0	75	978.26
81	40B	RainBarrel	871.84	0	0	0	75	946.83
82	42B	RainBarrel	897.05	0	0	0	75	972.04
83	38B	RainBarrel	898.09	0	0	0	75	973.08
84	13B	RainBarrel	902.1	0	0	0	75	977.1
85	15B	RainBarrel	868.05	0	0	0	75	943.04
86	11B	RainBarrel	884.07	0	0	0	75	959.07
87	14B	RainBarrel	883.8	0	0	0	75	958.8
88	79B	RainBarrel	901.48	0	0	0	75	976.48
89	67B	RainBarrel	893.24	0	0	0	75	968.24
90	66B	RainBarrel	870.43	0	0	0	75	945.43
91	301B	RainBarrel	114.12	0	0	0	75	189.12
92	99B	RainBarrel	826.05	0	0	0	75	901.04
93	26B	RainBarrel	901.79	0	0	0	75	976.79
94	27B	RainBarrel	901.72	0	0	0	75	976.71
95	447B	RainBarrel	869.56	0	0	0	75	944.53
96	101B	RainBarrel	857.82	0	0	0	75	932.81
97	64B	RainBarrel	903.78	0	0	0	75	978.78
98	88B	RainBarrel	847.69	0	0	0	75	922.68
99	89B	RainBarrel	869.78	0	0	0	75	944.77
100	44B	RainBarrel	885.51	0	0	0	75	960.5
101	1B	RainBarrel	905.96	0	0	0	75	980.96

Table 4.25 : Instantaneous discharge time series of drainage system- 6th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0
1:30:00	0	0
1:45:00	0	0
2:00:00	31.74	0
2:15:00	0	0.05
2:30:00	0	0.01

Table 4.25 (Continued): Instantaneous discharge time series of drainage system- 6th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:45:00	0	0.01
3:00:00	23.34	0.01
3:15:00	0	0.07
3:30:00	0	0.06
3:45:00	0	0.06
4:00:00	0	0.06
4:15:00	0	0.06
4:30:00	0	0.05
4:45:00	0	0.05
5:00:00	0	0.05
5:15:00	0	0.05
5:30:00	0	0.05
5:45:00	0	0.05
6:00:00	39.6	0.05
6:15:00	0	0.18
6:30:00	0	0.1
6:45:00	0	0.07
7:00:00	0	0.06
7:15:00	0	0.06
7:30:00	0	0.06
7:45:00	0	0.05
8:00:00	0	0.05
8:15:00	0	0.05
8:30:00	0	0.05
8:45:00	0	0.04
9:00:00	0	0.04
9:15:00	0	0.04
9:30:00	0	0.04
9:45:00	0	0.04
10:00:00	0	0.04
10:15:00	0	0.03
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.03

Table 4.25 (Continued): Instantaneous discharge time series of drainage system- 6th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
12:00:00	30	0.03
12:15:00	0	0.11
12:30:00	0	0.08
12:45:00	0	0.07
13:00:00	0	0.06
13:15:00	0	0.06
13:30:00	0	0.06
13:45:00	0	0.06
14:00:00	0	0.06
14:15:00	0	0.05
14:30:00	0	0.05
14:45:00	0	0.05
15:00:00	0	0.05
15:15:00	0	0.05
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.05
16:15:00	0	0.04
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.04
19:00:00	0	0.04
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03

Table 4.25 (Continued): Instantaneous discharge time series of drainage system- 6th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.03
23:30:00	0	0.03
23:45:00	0	0.03
0:00:00	0	0.03

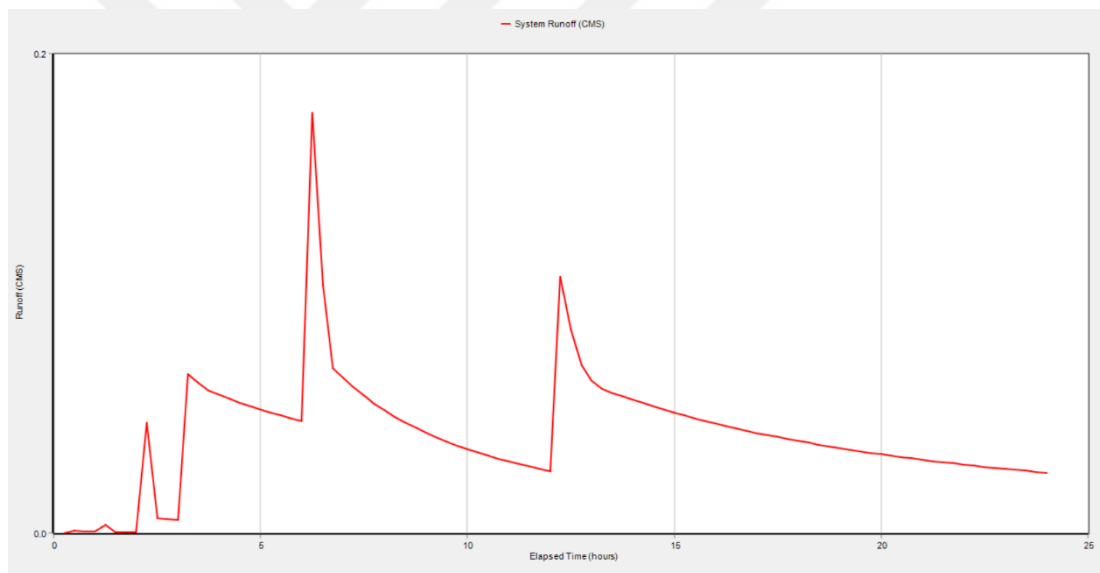


Figure 4.55 : 10 year return period hydrograph- 6th scenario.

After completion of calculations of 1st set of developed LID-included scenarios (scenario 2 ~ scenario 6) in SWMM, next set of LID-included scenarios (scenario 7 ~ scenario 11) is modeled and results is presented below. Results of 11 scenarios should be analyzed and compared to each other to determine the best choice.

4.2.9 7th scenario modeling results – Infiltration trenches LID-10%

Table 4.26 shows the hydrologic calculations results of the under study subcatchments while Table 4.27 shows implemented LID's operation summary on them. Table 4.28

shows the instantaneous discharge time series of drainage system whereas Figure 4.56 depicts 10 year return period hydrograph.

Table 4.26 : Hydrologic calculation results of the subcatchments- 7th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	10.1	10.79	0.03	0	0.307
2	299B	35.1	15.12	8.41	0.03	0	0.239
3	29B	35.1	19.07	5.22	0.04	0	0.149
4	28B	35.1	17.78	6.62	0.04	0	0.189
5	25B	35.1	24.6	0.06	0	0	0.002
6	16B	35.1	10.1	5.5	0.04	0	0.157
7	17B	35.1	20.64	0.68	0.04	0	0.019
8	300B	35.1	15.73	6.14	0.01	0	0.175
9	33B	35.1	19.84	3.04	0.08	0.01	0.087
10	93B	35.1	19.47	3.84	0.05	0	0.109
11	96B	35.1	19.83	2.95	0.06	0	0.084
12	12B	35.1	19.08	5.25	0.04	0	0.15
13	52B	35.1	21.74	2.42	0.02	0	0.069
14	53B	35.1	21.73	2.4	0.02	0	0.068
15	51B	35.1	20.02	2.76	0.04	0	0.079
16	58B	35.1	24.62	0.01	0	0	0
17	302B	35.1	15.77	5.43	0.01	0	0.155
18	34B	35.1	19.83	3.24	0.05	0	0.092
19	10B	35.1	20.19	2.02	0.05	0	0.058
20	18B	35.1	20.38	1.23	0.02	0	0.035
21	19B	35.1	19.3	4.16	0.05	0	0.119
22	85B	35.1	17.47	7.02	0.04	0	0.2
23	71B	35.1	21	3.18	0.01	0	0.091
24	72B	35.1	19.06	5.22	0.03	0	0.149
25	73B	35.1	20.56	1.01	0.02	0	0.029
26	195B	35.1	20.01	2.64	0.07	0	0.075
27	46B	35.1	20.2	2.18	0.04	0	0.062
28	91B	35.1	24.61	0.06	0	0	0.002
29	60B	35.1	24.61	0.01	0	0	0
30	61B	35.1	20.01	2.69	0.05	0	0.077
31	269B	35.1	10.1	10.78	0.06	0	0.307
32	298B	35.1	14.52	9.66	0.05	0	0.275
33	95B	35.1	20.24	1.91	0.12	0.01	0.054
34	37B	35.1	20.35	1.54	0.23	0.01	0.044

Table 4.26 (Continued): Hydrologic calculation results of the subcatchments- 7th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
35	194B	35.1	17.69	6.78	0.03	0	0.193
36	193B	35.1	21.43	2.75	0.02	0	0.078
37	191B	35.1	20.37	1.65	0.02	0	0.047
38	32B	35.1	18.96	5.38	0.04	0	0.153
39	94B	35.1	20.64	0.84	0.05	0	0.024
40	49B	35.1	18	6.42	0.04	0	0.183
41	92B	35.1	24.61	0.06	0	0	0.002
42	393B	35.1	24.58	0.07	0	0	0.002
43	196B	35.1	21.1	3.05	0.02	0	0.087
44	197B	35.1	17.46	7	0.03	0	0.199
45	198B	35.1	19.07	5.22	0.04	0	0.149
46	30B	35.1	18.53	5.79	0.05	0	0.165
47	31B	35.1	18.65	5.7	0.05	0	0.162
48	56B	35.1	19.47	3.88	0.06	0	0.11
49	24B	35.1	20.38	1.49	0.02	0	0.042
50	35B	35.1	19.29	4.24	0.07	0.01	0.121
51	43B	35.1	24.61	0.08	0	0	0.002
52	9B	35.1	20.01	2.57	0.07	0	0.073
53	81B	35.1	18.53	5.82	0.03	0	0.166
54	82B	35.1	18.54	5.83	0.04	0	0.166
55	80B	35.1	20.07	2.33	0.07	0	0.066
56	90B	35.1	20.37	1.35	0.02	0	0.038
57	86B	35.1	21.08	3.06	0.01	0	0.087
58	87B	35.1	21.53	2.64	0.01	0	0.075
59	70B	35.1	20.24	3.98	0.04	0	0.113
60	84B	35.1	18.33	6.04	0.03	0	0.172
61	69B	35.1	19.47	3.95	0.05	0	0.113
62	63B	35.1	18.64	5.68	0.04	0	0.162
63	62B	35.1	20.2	2.16	0.03	0	0.062
64	57B	35.1	24.62	0.05	0	0	0.001
65	192B	35.1	21.31	2.89	0.01	0	0.082
66	48B	35.1	17.77	6.61	0.02	0	0.188
67	47B	35.1	19.47	3.91	0.04	0	0.111
68	45B	35.1	20.37	1.32	0.02	0	0.038
69	22B	35.1	24.58	0.08	0	0	0.002
70	21B	35.1	19.65	3.6	0.04	0	0.103

Table 4.26 (Continued): Hydrologic calculation results of the subcatchments- 7th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
71	20B	35.1	19.65	3.58	0.05	0	0.102
72	23B	35.1	20.45	1.02	0.04	0	0.029
73	65B	35.1	20.01	2.49	0.04	0	0.071
74	59B	35.1	23.65	0.46	0	0	0.013
75	83B	35.1	19.66	3.47	0.07	0	0.099
76	97B	35.1	24.62	0.03	0	0	0.001
77	78B	35.1	17.57	6.87	0.02	0	0.196
78	74B	35.1	20.97	3.18	0.02	0	0.091
79	450B	35.1	10.09	10.43	0.07	0	0.297
80	54B	35.1	17.65	6.71	0.02	0	0.191
81	40B	35.1	9.94	11.73	0.03	0	0.334
82	42B	35.1	20.37	1.68	0.06	0	0.048
83	38B	35.1	20.02	2.47	0.11	0.01	0.07
84	13B	35.1	19.19	5.11	0.02	0	0.145
85	15B	35.1	20.46	3.76	0.02	0	0.107
86	11B	35.1	18.97	5.34	0.05	0	0.152
87	14B	35.1	21.31	2.89	0.02	0	0.082
88	79B	35.1	19.82	3.15	0.03	0	0.09
89	67B	35.1	19.17	5.09	0.05	0	0.145
90	66B	35.1	20.04	4.22	0.02	0	0.12
91	301B	35.1	13.91	10.34	0.01	0	0.295
92	99B	35.1	10.1	9.97	0.02	0	0.284
93	26B	35.1	19.65	3.45	0.05	0	0.098
94	27B	35.1	24.61	0.05	0	0	0.001
95	447B	35.1	10.09	6.03	0.06	0	0.172
96	101B	35.1	10.09	10.4	0.04	0	0.296
97	64B	35.1	24.62	0.12	0	0	0.003
98	88B	35.1	20.32	3.89	0.01	0	0.111
99	89B	35.1	21.08	3.07	0.02	0	0.087
100	44B	35.1	19.64	3.67	0.04	0	0.105
101	1B	35.1	24.59	0.2	0	0	0.006

Table 4.27 : LID operation summary- 7th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	InfiltrationTrench	109	12	0	0	6.43	103.44
2	299B	InfiltrationTrench	110.91	12	0	0	6.43	105.35
3	29B	InfiltrationTrench	112.25	12	0	0	6.43	106.69
4	28B	InfiltrationTrench	111.33	12	0	0	6.43	105.77
5	25B	InfiltrationTrench	112.65	12	0	0	6.43	107.08
6	16B	InfiltrationTrench	111.38	12	0	0	6.43	105.82
7	17B	InfiltrationTrench	111.94	12	0	0	6.43	106.37
8	300B	InfiltrationTrench	113.82	12	0	0	6.43	108.26
9	33B	InfiltrationTrench	113.86	12	0	0	6.43	108.3
10	93B	InfiltrationTrench	112.65	12	0	0	6.43	107.08
11	96B	InfiltrationTrench	113.23	12	0	0	6.43	107.67
12	12B	InfiltrationTrench	113.95	12	0	0	6.43	108.39
13	52B	InfiltrationTrench	112.51	12	0	0	6.43	106.94
14	53B	InfiltrationTrench	112.05	12	0	0	6.43	106.49
15	51B	InfiltrationTrench	113.53	12	0	0	6.43	107.96
16	58B	InfiltrationTrench	112.6	12	0	0	6.43	107.04
17	302B	InfiltrationTrench	106.74	12	0	0	6.43	101.18
18	34B	InfiltrationTrench	112.77	12	0	0	6.43	107.21
19	10B	InfiltrationTrench	113.31	12	0	0	6.43	107.75
20	18B	InfiltrationTrench	112.92	12	0	0	6.43	107.35
21	19B	InfiltrationTrench	113.97	12	0	0	6.43	108.4
22	85B	InfiltrationTrench	113.22	12	0	0	6.43	107.66
23	71B	InfiltrationTrench	113.7	12	0	0	6.43	108.13
24	72B	InfiltrationTrench	112	12	0	0	6.43	106.44
25	73B	InfiltrationTrench	112.92	12	0	0	6.43	107.36
26	195B	InfiltrationTrench	113.17	12	0	0	6.43	107.61
27	46B	InfiltrationTrench	113.47	12	0	0	6.43	107.9
28	91B	InfiltrationTrench	113.05	12	0	0	6.43	107.49
29	60B	InfiltrationTrench	110.95	12	0	0	6.43	105.38
30	61B	InfiltrationTrench	113.33	12	0	0	6.43	107.77
31	269B	InfiltrationTrench	112.3	12	0	0	6.43	106.74
32	298B	InfiltrationTrench	113.15	12	0	0	6.43	107.59
33	95B	InfiltrationTrench	113.41	12	0	0	6.43	107.84
34	37B	InfiltrationTrench	113.34	12	0	0	6.43	107.78
35	194B	InfiltrationTrench	114.04	12	0	0	6.43	108.48
36	193B	InfiltrationTrench	113.59	12	0	0	6.43	108.02
37	191B	InfiltrationTrench	112.71	12	0	0	6.43	107.15

Table 4.27 (Continued): LID operation summary- 7th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
38	32B	InfiltrationTrench	112.71	12	0	0	6.43	107.15
39	94B	InfiltrationTrench	112.39	12	0	0	6.43	106.83
40	49B	InfiltrationTrench	112.56	12	0	0	6.43	106.99
41	92B	InfiltrationTrench	113.15	12	0	0	6.43	107.58
42	393B	InfiltrationTrench	111.48	12	0	0	6.43	105.91
43	196B	InfiltrationTrench	112.97	12	0	0	6.43	107.4
44	197B	InfiltrationTrench	111.86	12	0	0	6.43	106.3
45	198B	InfiltrationTrench	112.25	12	0	0	6.43	106.69
46	30B	InfiltrationTrench	112.48	12	0	0	6.43	106.92
47	31B	InfiltrationTrench	113.98	12	0	0	6.43	108.42
48	56B	InfiltrationTrench	113.14	12	0	0	6.43	107.58
49	24B	InfiltrationTrench	113.11	12	0	0	6.43	107.54
50	35B	InfiltrationTrench	112.91	12	0	0	6.43	107.35
51	43B	InfiltrationTrench	113.24	12	0	0	6.43	107.67
52	9B	InfiltrationTrench	113.45	12	0	0	6.43	107.89
53	81B	InfiltrationTrench	112.39	12	0	0	6.43	106.83
54	82B	InfiltrationTrench	112.74	12	0	0	6.43	107.17
55	80B	InfiltrationTrench	113.46	12	0	0	6.43	107.89
56	90B	InfiltrationTrench	112.21	12	0	0	6.43	106.64
57	86B	InfiltrationTrench	111.49	12	0	0	6.43	105.92
58	87B	InfiltrationTrench	112.53	12	0	0	6.43	106.97
59	70B	InfiltrationTrench	112.48	12	0	0	6.43	106.92
60	84B	InfiltrationTrench	114	12	0	0	6.43	108.44
61	69B	InfiltrationTrench	113.59	12	0	0	6.43	108.02
62	63B	InfiltrationTrench	112.88	12	0	0	6.43	107.32
63	62B	InfiltrationTrench	113.7	12	0	0	6.43	108.13
64	57B	InfiltrationTrench	113.72	12	0	0	6.43	108.16
65	192B	InfiltrationTrench	112.71	12	0	0	6.43	107.15
66	48B	InfiltrationTrench	110.52	12	0	0	6.43	104.96
67	47B	InfiltrationTrench	113.19	12	0	0	6.43	107.63
68	45B	InfiltrationTrench	112.18	12	0	0	6.43	106.61
69	22B	InfiltrationTrench	111.71	12	0	0	6.43	106.14
70	21B	InfiltrationTrench	113.17	12	0	0	6.43	107.61
71	20B	InfiltrationTrench	113.01	12	0	0	6.43	107.45
72	23B	InfiltrationTrench	112.77	12	0	0	6.43	107.21
73	65B	InfiltrationTrench	112.56	12	0	0	6.43	107
74	59B	InfiltrationTrench	107.56	12	0	0	6.43	101.99

Table 4.27 (Continued): LID operation summary- 7th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
75	83B	InfiltrationTrench	113.91	12	0	0	6.43	108.35
76	97B	InfiltrationTrench	113.71	12	0	0	6.43	108.15
77	78B	InfiltrationTrench	112.1	12	0	0	6.43	106.53
78	74B	InfiltrationTrench	110.52	12	0	0	6.43	104.96
79	450B	InfiltrationTrench	113.72	12	0	0	6.43	108.16
80	54B	InfiltrationTrench	109.02	12	0	0	6.43	103.46
81	40B	InfiltrationTrench	110.93	12	0	0	6.43	105.37
82	42B	InfiltrationTrench	113.05	12	0	0	6.43	107.48
83	38B	InfiltrationTrench	113.57	12	0	0	6.43	108.01
84	13B	InfiltrationTrench	113.94	12	0	0	6.43	108.37
85	15B	InfiltrationTrench	112.97	12	0	0	6.43	107.4
86	11B	InfiltrationTrench	113.03	12	0	0	6.43	107.47
87	14B	InfiltrationTrench	112.18	12	0	0	6.43	106.61
88	79B	InfiltrationTrench	112.29	12	0	0	6.43	106.73
89	67B	InfiltrationTrench	112.18	12	0	0	6.43	106.62
90	66B	InfiltrationTrench	113.86	12	0	0	6.43	108.29
91	301B	InfiltrationTrench	105.34	12	0	0	6.43	99.78
92	99B	InfiltrationTrench	111.72	12	0	0	6.43	106.16
93	26B	InfiltrationTrench	112.66	12	0	0	6.43	107.1
94	27B	InfiltrationTrench	113.23	12	0	0	6.43	107.67
95	447B	InfiltrationTrench	112.26	12	0	0	6.43	106.7
96	101B	InfiltrationTrench	113.71	12	0	0	6.43	108.15
97	64B	InfiltrationTrench	114.08	12	0	0	6.43	108.52
98	88B	InfiltrationTrench	109.78	12	0	0	6.43	104.22
99	89B	InfiltrationTrench	110.76	12	0	0	6.43	105.2
100	44B	InfiltrationTrench	112.28	12	0	0	6.43	106.71
101	1B	InfiltrationTrench	112.33	12	0	0	6.43	106.77

Table 4.28 : Instantaneous discharge time series of drainage system- 7th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0
1:30:00	0	0

Table 4.28 (Continued): Instantaneous discharge time series of drainage system- 7th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
1:45:00	0	0
2:00:00	31.74	0
2:15:00	0	0.05
2:30:00	0	0.01
2:45:00	0	0.01
3:00:00	23.34	0.01
3:15:00	0	0.07
3:30:00	0	0.06
3:45:00	0	0.06
4:00:00	0	0.06
4:15:00	0	0.06
4:30:00	0	0.05
4:45:00	0	0.05
5:00:00	0	0.05
5:15:00	0	0.05
5:30:00	0	0.05
5:45:00	0	0.05
6:00:00	39.6	0.05
6:15:00	0	0.17
6:30:00	0	0.1
6:45:00	0	0.07
7:00:00	0	0.06
7:15:00	0	0.06
7:30:00	0	0.05
7:45:00	0	0.05
8:00:00	0	0.05
8:15:00	0	0.05
8:30:00	0	0.04
8:45:00	0	0.04
9:00:00	0	0.04
9:15:00	0	0.04
9:30:00	0	0.04
9:45:00	0	0.03
10:00:00	0	0.03
10:15:00	0	0.03
10:30:00	0	0.03
10:45:00	0	0.03

Table 4.28 (Continued): Instantaneous discharge time series of drainage system- 7th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.02
12:00:00	30	0.02
12:15:00	0	0.1
12:30:00	0	0.08
12:45:00	0	0.07
13:00:00	0	0.06
13:15:00	0	0.06
13:30:00	0	0.06
13:45:00	0	0.06
14:00:00	0	0.05
14:15:00	0	0.05
14:30:00	0	0.05
14:45:00	0	0.05
15:00:00	0	0.05
15:15:00	0	0.05
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.04
16:15:00	0	0.04
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.03
19:00:00	0	0.03
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03

Table 4.28 (Continued): Instantaneous discharge time series of drainage system- 7th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.02
23:30:00	0	0.02
23:45:00	0	0.02
0:00:00	0	0.02

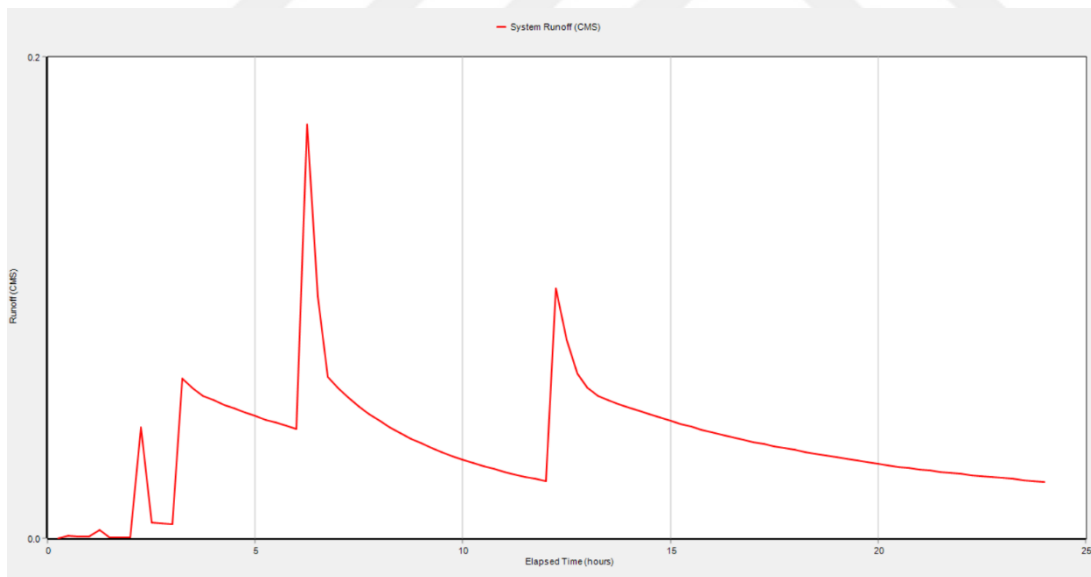


Figure 4.56 : 10 year return period hydrograph- 7th scenario.

4.2.10 8th scenario modeling results – Bio-retention cells LID-10%

Table 4.29 shows the hydrologic calculations results of the under study subcatchments while Table 4.30 shows implemented LID's operation summary on them. Table 4.31

shows the instantaneous discharge time series of drainage system whereas Figure 4.57 depicts 10 year return period hydrograph.

Table 4.29 : Hydrologic calculation results of the subcatchments- 8th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	9.37	12.98	0.03	0.01	0.37
2	299B	35.1	14.4	10.91	0.04	0.01	0.311
3	29B	35.1	18.36	7.76	0.06	0.02	0.221
4	28B	35.1	17.06	9.18	0.06	0.02	0.261
5	25B	35.1	23.9	2.62	0.03	0.03	0.075
6	16B	35.1	9.39	7.55	0.06	0.01	0.215
7	17B	35.1	19.94	2.72	0.16	0.06	0.078
8	300B	35.1	15.04	8.69	0.01	0	0.248
9	33B	35.1	19.15	5.62	0.15	0.06	0.16
10	93B	35.1	18.76	6.4	0.09	0.03	0.182
11	96B	35.1	19.13	5.48	0.12	0.04	0.156
12	12B	35.1	18.39	7.91	0.06	0.02	0.225
13	52B	35.1	21.04	4.74	0.04	0.01	0.135
14	53B	35.1	21.03	4.68	0.04	0.01	0.133
15	51B	35.1	19.32	5.3	0.08	0.03	0.151
16	58B	35.1	23.92	2.19	0.04	0.03	0.063
17	302B	35.1	15.02	7.43	0.02	0	0.212
18	34B	35.1	19.13	5.77	0.09	0.03	0.164
19	10B	35.1	19.5	4.45	0.12	0.04	0.127
20	18B	35.1	19.68	3.49	0.07	0.03	0.099
21	19B	35.1	18.61	6.83	0.08	0.03	0.195
22	85B	35.1	16.77	9.73	0.05	0.02	0.277
23	71B	35.1	20.31	5.66	0.02	0.01	0.161
24	72B	35.1	18.36	7.74	0.05	0.02	0.22
25	73B	35.1	19.86	3.23	0.06	0.03	0.092
26	195B	35.1	19.31	5.14	0.14	0.05	0.146
27	46B	35.1	19.5	4.64	0.08	0.03	0.132
28	91B	35.1	23.91	2.65	0.04	0.03	0.076
29	60B	35.1	23.9	1.92	0.02	0.01	0.055
30	61B	35.1	19.32	5.2	0.09	0.04	0.148
31	269B	35.1	9.39	13.19	0.08	0.01	0.376
32	298B	35.1	13.82	12.38	0.06	0.02	0.353
33	95B	35.1	19.55	4.33	0.28	0.11	0.123
34	37B	35.1	19.66	3.9	0.58	0.24	0.111

Table 4.29 (Continued): Hydrologic calculation results of the subcatchments- 8th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
35	194B	35.1	17	9.52	0.04	0.01	0.271
36	193B	35.1	20.74	5.18	0.04	0.01	0.148
37	191B	35.1	19.67	3.99	0.04	0.02	0.114
38	32B	35.1	18.26	7.97	0.05	0.02	0.227
39	94B	35.1	19.94	2.97	0.16	0.07	0.085
40	49B	35.1	17.3	9.05	0.05	0.02	0.258
41	92B	35.1	23.91	2.66	0.03	0.02	0.076
42	393B	35.1	23.87	2.59	0.01	0.01	0.074
43	196B	35.1	20.4	5.47	0.03	0.01	0.156
44	197B	35.1	16.75	9.61	0.04	0.01	0.274
45	198B	35.1	18.36	7.76	0.06	0.02	0.221
46	30B	35.1	17.83	8.38	0.07	0.02	0.239
47	31B	35.1	17.96	8.39	0.08	0.02	0.239
48	56B	35.1	18.77	6.48	0.1	0.04	0.185
49	24B	35.1	19.68	3.82	0.06	0.02	0.109
50	35B	35.1	18.59	6.85	0.11	0.04	0.195
51	43B	35.1	23.91	2.73	0.03	0.03	0.078
52	9B	35.1	19.32	5.07	0.13	0.05	0.144
53	81B	35.1	17.83	8.4	0.05	0.01	0.239
54	82B	35.1	17.83	8.44	0.06	0.02	0.241
55	80B	35.1	19.38	4.81	0.15	0.06	0.137
56	90B	35.1	19.66	3.59	0.04	0.02	0.102
57	86B	35.1	20.37	5.38	0.02	0.01	0.153
58	87B	35.1	20.82	4.99	0.02	0.01	0.142
59	70B	35.1	19.54	6.45	0.06	0.02	0.184
60	84B	35.1	17.64	8.75	0.04	0.01	0.249
61	69B	35.1	18.78	6.59	0.08	0.03	0.188
62	63B	35.1	17.94	8.29	0.07	0.02	0.236
63	62B	35.1	19.51	4.64	0.07	0.03	0.132
64	57B	35.1	23.93	2.63	0.07	0.05	0.075
65	192B	35.1	20.61	5.28	0.02	0.01	0.15
66	48B	35.1	17.05	9.1	0.03	0.01	0.259
67	47B	35.1	18.77	6.52	0.07	0.03	0.186
68	45B	35.1	19.66	3.55	0.04	0.02	0.101
69	22B	35.1	23.87	2.62	0.01	0.01	0.075
70	21B	35.1	18.95	6.19	0.07	0.03	0.176

Table 4.29 (Continued): Hydrologic calculation results of the subcatchments- 8th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
71	20B	35.1	18.95	6.16	0.09	0.03	0.175
72	23B	35.1	19.76	3.22	0.13	0.06	0.092
73	65B	35.1	19.3	4.92	0.07	0.03	0.14
74	59B	35.1	22.94	1.89	0.01	0.01	0.054
75	83B	35.1	18.97	6.09	0.12	0.05	0.174
76	97B	35.1	23.93	2.52	0.1	0.07	0.072
77	78B	35.1	16.86	9.5	0.02	0.01	0.271
78	74B	35.1	20.25	5.44	0.03	0.01	0.155
79	450B	35.1	9.4	12.92	0.09	0.01	0.368
80	54B	35.1	16.92	9.11	0.03	0.01	0.26
81	40B	35.1	9.22	14.1	0.04	0.01	0.402
82	42B	35.1	19.68	4.06	0.15	0.06	0.116
83	38B	35.1	19.32	4.97	0.23	0.09	0.142
84	13B	35.1	18.5	7.75	0.03	0.01	0.221
85	15B	35.1	19.76	6.24	0.03	0.01	0.178
86	11B	35.1	18.27	7.94	0.07	0.02	0.226
87	14B	35.1	20.6	5.24	0.03	0.01	0.149
88	79B	35.1	19.12	5.64	0.06	0.02	0.161
89	67B	35.1	18.47	7.61	0.07	0.02	0.217
90	66B	35.1	19.35	6.79	0.04	0.01	0.193
91	301B	35.1	13.14	12.53	0.01	0	0.357
92	99B	35.1	9.39	12.3	0.03	0	0.35
93	26B	35.1	18.94	5.98	0.08	0.03	0.17
94	27B	35.1	23.91	2.62	0.03	0.03	0.075
95	447B	35.1	9.39	8.17	0.08	0.01	0.233
96	101B	35.1	9.4	12.89	0.05	0.01	0.367
97	64B	35.1	23.93	2.91	0.01	0.01	0.083
98	88B	35.1	19.59	6.16	0.02	0.01	0.176
99	89B	35.1	20.36	5.34	0.03	0.01	0.152
100	44B	35.1	18.94	6.21	0.06	0.02	0.177
101	1B	35.1	23.88	2.97	0.02	0.02	0.085

Table 4.30 : LID operation summary- 8th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	BioRetentionCell	109	5.07	20.7	0	28.29	111.52
2	299B	BioRetentionCell	110.91	5.08	24.12	0	28.29	109.99

Table 4.30 (Continued): LID operation summary- 8th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
3	29B	BioRetentionCell	112.25	5.08	24.89	0	28.29	110.56
4	28B	BioRetentionCell	111.33	5.08	24.77	0	28.29	109.76
5	25B	BioRetentionCell	112.65	5.08	25.24	0	28.29	110.61
6	16B	BioRetentionCell	111.38	5.04	20.15	0	28.29	114.48
7	17B	BioRetentionCell	111.94	5.03	20.32	0	28.29	114.87
8	300B	BioRetentionCell	113.82	5.08	25.5	0	28.29	111.53
9	33B	BioRetentionCell	113.86	5.08	25.82	0	28.29	111.25
10	93B	BioRetentionCell	112.65	5.08	25.26	0	28.29	110.59
11	96B	BioRetentionCell	113.23	5.08	25.1	0	28.29	111.34
12	12B	BioRetentionCell	113.95	5.08	26.55	0	28.29	110.6
13	52B	BioRetentionCell	112.51	5.06	22.94	0	28.29	112.79
14	53B	BioRetentionCell	112.05	5.06	22.49	0	28.29	112.79
15	51B	BioRetentionCell	113.53	5.08	25.3	0	28.29	111.43
16	58B	BioRetentionCell	112.6	5.05	21.77	0	28.29	114.07
17	302B	BioRetentionCell	106.74	5.06	18.42	0	28.29	111.54
18	34B	BioRetentionCell	112.77	5.08	25.02	0	28.29	110.95
19	10B	BioRetentionCell	113.31	5.07	24.21	0	28.29	112.32
20	18B	BioRetentionCell	112.92	5.06	22.56	0	28.29	113.59
21	19B	BioRetentionCell	113.97	5.08	26.72	0	28.29	110.45
22	85B	BioRetentionCell	113.22	5.09	26.84	0	28.29	109.58
23	71B	BioRetentionCell	113.7	5.08	24.77	0	28.29	112.14
24	72B	BioRetentionCell	112	5.08	24.65	0	28.29	110.56
25	73B	BioRetentionCell	112.92	5.05	22.19	0	28.29	113.96
26	195B	BioRetentionCell	113.17	5.08	24.8	0	28.29	111.58
27	46B	BioRetentionCell	113.47	5.08	24.59	0	28.29	112.08
28	91B	BioRetentionCell	113.05	5.08	25.65	0	28.29	110.61
29	60B	BioRetentionCell	110.95	5.02	18.99	0	28.29	115.21
30	61B	BioRetentionCell	113.33	5.08	25.02	0	28.29	111.52
31	269B	BioRetentionCell	112.3	5.08	23.75	0	28.29	111.77
32	298B	BioRetentionCell	113.15	5.09	26.96	0	28.29	109.39
33	95B	BioRetentionCell	113.41	5.07	24.18	0	28.29	112.45
34	37B	BioRetentionCell	113.34	5.07	23.59	0	28.29	112.97
35	194B	BioRetentionCell	114.04	5.09	27.48	0	28.29	109.76
36	193B	BioRetentionCell	113.59	5.07	24.27	0	28.29	112.53
37	191B	BioRetentionCell	112.71	5.07	23.2	0	28.29	112.73
38	32B	BioRetentionCell	112.71	5.08	25.45	0	28.29	110.46
39	94B	BioRetentionCell	112.39	5.04	21.29	0	28.29	114.35

Table 4.30 (Continued): LID operation summary- 8th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
40	49B	BioRetentionCell	112.56	5.09	25.85	0	28.29	109.91
41	92B	BioRetentionCell	113.15	5.08	25.74	0	28.29	110.61
42	393B	BioRetentionCell	111.48	5.08	24.45	0	28.29	110.23
43	196B	BioRetentionCell	112.97	5.07	23.97	0	28.29	112.21
44	197B	BioRetentionCell	111.86	5.08	25.51	0	28.29	109.55
45	198B	BioRetentionCell	112.25	5.08	24.89	0	28.29	110.56
46	30B	BioRetentionCell	112.48	5.08	25.46	0	28.29	110.23
47	31B	BioRetentionCell	113.98	5.09	26.85	0	28.29	110.33
48	56B	BioRetentionCell	113.14	5.08	25.78	0	28.29	110.57
49	24B	BioRetentionCell	113.11	5.06	23.28	0	28.29	113.05
50	35B	BioRetentionCell	112.91	5.08	25.8	0	28.29	110.31
51	43B	BioRetentionCell	113.24	5.08	26.31	0	28.29	110.13
52	9B	BioRetentionCell	113.45	5.08	24.97	0	28.29	111.69
53	81B	BioRetentionCell	112.39	5.08	25.4	0	28.29	110.2
54	82B	BioRetentionCell	112.74	5.08	25.75	0	28.29	110.19
55	80B	BioRetentionCell	113.46	5.08	24.7	0	28.29	111.97
56	90B	BioRetentionCell	112.21	5.06	22.17	0	28.29	113.26
57	86B	BioRetentionCell	111.49	5.07	22.61	0	28.29	112.1
58	87B	BioRetentionCell	112.53	5.07	23.19	0	28.29	112.56
59	70B	BioRetentionCell	112.48	5.08	24.28	0	28.29	111.41
60	84B	BioRetentionCell	114	5.09	27.06	0	28.29	110.14
61	69B	BioRetentionCell	113.59	5.08	26.29	0	28.29	110.5
62	63B	BioRetentionCell	112.88	5.08	25.77	0	28.29	110.31
63	62B	BioRetentionCell	113.7	5.08	24.78	0	28.29	112.12
64	57B	BioRetentionCell	113.72	5.08	25.81	0	28.29	111.11
65	192B	BioRetentionCell	112.71	5.07	23.6	0	28.29	112.33
66	48B	BioRetentionCell	110.52	5.08	23.98	0	28.29	109.75
67	47B	BioRetentionCell	113.19	5.08	25.87	0	28.29	110.53
68	45B	BioRetentionCell	112.18	5.06	22.07	0	28.29	113.33
69	22B	BioRetentionCell	111.71	5.08	24.79	0	28.29	110.12
70	21B	BioRetentionCell	113.17	5.08	25.67	0	28.29	110.71
71	20B	BioRetentionCell	113.01	5.08	25.49	0	28.29	110.72
72	23B	BioRetentionCell	112.77	5.05	22	0	28.29	114.01
73	65B	BioRetentionCell	112.56	5.08	24.02	0	28.29	111.75
74	59B	BioRetentionCell	107.56	4.99	14.1	0	28.29	116.75
75	83B	BioRetentionCell	113.91	5.08	26.22	0	28.29	110.9
76	97B	BioRetentionCell	113.71	5.08	24.87	0	28.29	112.05

Table 4.30 (Continued): LID operation summary- 8th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
77	78B	BioRetentionCell	112.1	5.08	25.66	0	28.29	109.64
78	74B	BioRetentionCell	110.52	5.07	21.82	0	28.29	111.92
79	450B	BioRetentionCell	113.72	5.08	24.89	0	28.29	112.04
80	54B	BioRetentionCell	109.02	5.08	22.61	0	28.29	109.62
81	40B	BioRetentionCell	110.93	5.08	22.9	0	28.29	111.23
82	42B	BioRetentionCell	113.05	5.07	23.58	0	28.29	112.69
83	38B	BioRetentionCell	113.57	5.08	24.96	0	28.29	111.83
84	13B	BioRetentionCell	113.94	5.08	26.43	0	28.29	110.71
85	15B	BioRetentionCell	112.97	5.08	24.57	0	28.29	111.61
86	11B	BioRetentionCell	113.03	5.08	25.72	0	28.29	110.52
87	14B	BioRetentionCell	112.18	5.07	23.1	0	28.29	112.29
88	79B	BioRetentionCell	112.29	5.08	24.46	0	28.29	111.04
89	67B	BioRetentionCell	112.18	5.08	24.74	0	28.29	110.65
90	66B	BioRetentionCell	113.86	5.08	25.76	0	28.29	111.3
91	301B	BioRetentionCell	105.34	5.08	19.72	0	28.29	108.83
92	99B	BioRetentionCell	111.72	5.07	22.8	0	28.29	112.14
93	26B	BioRetentionCell	112.66	5.08	25	0	28.29	110.87
94	27B	BioRetentionCell	113.23	5.08	25.5	0	28.29	110.94
95	447B	BioRetentionCell	112.26	5.04	21.27	0	28.29	114.23
96	101B	BioRetentionCell	113.71	5.08	24.87	0	28.29	112.05
97	64B	BioRetentionCell	114.08	5.09	27.89	0	28.29	109.39
98	88B	BioRetentionCell	109.78	5.07	21.69	0	28.29	111.3
99	89B	BioRetentionCell	110.76	5.07	21.95	0	28.29	112.04
100	44B	BioRetentionCell	112.28	5.08	24.9	0	28.29	110.58
101	1B	BioRetentionCell	112.33	5.09	27.15	0	28.29	108.38

Table 4.31 : Instantaneous discharge time series of drainage system- 8th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0
1:30:00	0	0
1:45:00	0	0
2:00:00	31.74	0

Table 4.31 (Continued): Instantaneous discharge time series of drainage system- 8th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:15:00	0	0.05
2:30:00	0	0.01
2:45:00	0	0.01
3:00:00	23.34	0.01
3:15:00	0	0.08
3:30:00	0	0.13
3:45:00	0	0.1
4:00:00	0	0.08
4:15:00	0	0.06
4:30:00	0	0.06
4:45:00	0	0.05
5:00:00	0	0.05
5:15:00	0	0.05
5:30:00	0	0.05
5:45:00	0	0.05
6:00:00	39.6	0.05
6:15:00	0	1
6:30:00	0	0.47
6:45:00	0	0.28
7:00:00	0	0.19
7:15:00	0	0.14
7:30:00	0	0.11
7:45:00	0	0.08
8:00:00	0	0.07
8:15:00	0	0.06
8:30:00	0	0.05
8:45:00	0	0.05
9:00:00	0	0.04
9:15:00	0	0.04
9:30:00	0	0.04
9:45:00	0	0.03
10:00:00	0	0.03
10:15:00	0	0.03
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03

Table 4.31 (Continued): Instantaneous discharge time series of drainage system- 8th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
11:30:00	0	0.03
11:45:00	0	0.02
12:00:00	30	0.02
12:15:00	0	0.67
12:30:00	0	0.34
12:45:00	0	0.22
13:00:00	0	0.16
13:15:00	0	0.12
13:30:00	0	0.1
13:45:00	0	0.08
14:00:00	0	0.07
14:15:00	0	0.06
14:30:00	0	0.06
14:45:00	0	0.05
15:00:00	0	0.05
15:15:00	0	0.05
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.04
16:15:00	0	0.04
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.03
19:00:00	0	0.03
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03

Table 4.31 (Continued): Instantaneous discharge time series of drainage system- 8th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
20:45:00	0	0.03
21:00:00	0	0.03
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.02
23:30:00	0	0.02
23:45:00	0	0.02
0:00:00	0	0.02

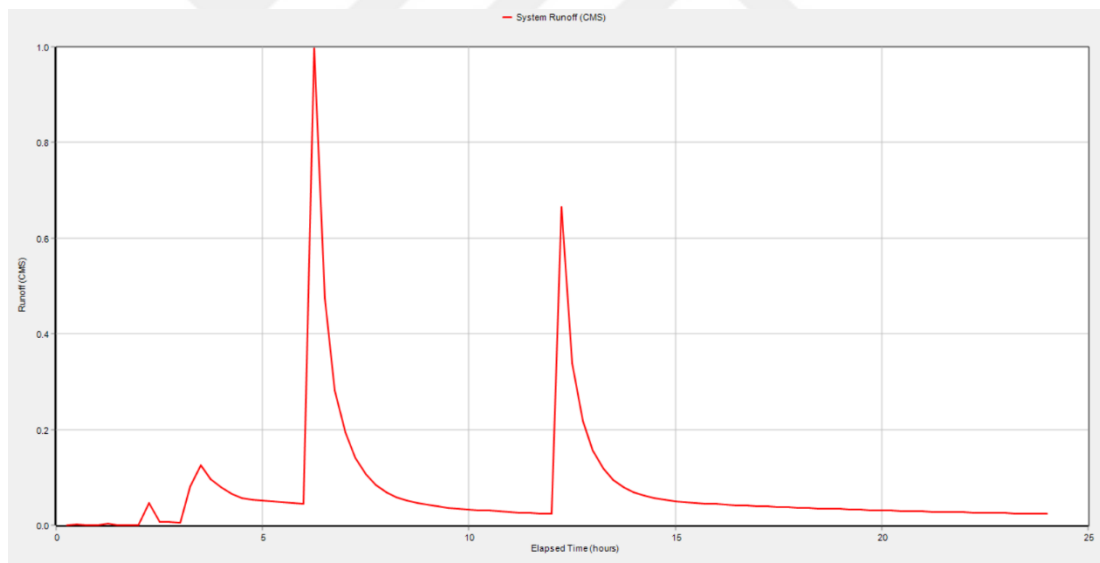


Figure 4.57 : 10 year return period hydrograph- 8th scenario.

4.2.11 9th scenario modeling results – Permeable pavements LID-10%

Table 4.32 shows the hydrologic calculations results of the under study subcatchments while Table 4.33 shows implemented LID's operation summary on them. Table 4.34 shows the instantaneous discharge time series of drainage system whereas Figure 4.58 depicts 10 year return period hydrograph.

Table 4.32 : Hydrologic calculation results of the subcatchments- 9th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	10.1	13.41	0.03	0	0.382
2	299B	35.1	15.12	11.25	0.05	0.01	0.321
3	29B	35.1	19.07	8.12	0.06	0.02	0.231
4	28B	35.1	17.78	9.51	0.06	0.02	0.271
5	25B	35.1	24.6	2.99	0.04	0.02	0.085
6	16B	35.1	9.99	11.08	0.09	0.01	0.316
7	17B	35.1	20.64	3.28	0.2	0.06	0.093
8	300B	35.1	15.73	9.09	0.01	0	0.259
9	33B	35.1	19.84	6.01	0.17	0.05	0.171
10	93B	35.1	19.47	6.77	0.09	0.03	0.193
11	96B	35.1	19.83	5.87	0.12	0.04	0.167
12	12B	35.1	19.08	8.26	0.06	0.02	0.235
13	52B	35.1	21.74	5.2	0.05	0.01	0.148
14	53B	35.1	21.73	5.15	0.05	0.01	0.147
15	51B	35.1	20.02	5.69	0.08	0.02	0.162
16	58B	35.1	24.62	2.71	0.05	0.02	0.077
17	302B	35.1	15.77	7.87	0.02	0	0.224
18	34B	35.1	19.83	6.15	0.09	0.03	0.175
19	10B	35.1	20.19	4.89	0.13	0.03	0.139
20	18B	35.1	20.38	3.98	0.08	0.02	0.113
21	19B	35.1	19.3	7.18	0.09	0.03	0.205
22	85B	35.1	17.47	10.04	0.05	0.02	0.286
23	71B	35.1	21	6.08	0.02	0	0.173
24	72B	35.1	19.06	8.1	0.05	0.01	0.231
25	73B	35.1	20.56	3.74	0.07	0.02	0.107
26	195B	35.1	20.01	5.54	0.15	0.04	0.158
27	46B	35.1	20.2	5.07	0.09	0.03	0.144
28	91B	35.1	24.61	3.01	0.04	0.03	0.086
29	60B	35.1	24.61	2.5	0.03	0.01	0.071
30	61B	35.1	20.01	5.61	0.1	0.03	0.16
31	269B	35.1	10.1	13.61	0.08	0.01	0.388
32	298B	35.1	14.52	12.69	0.06	0.02	0.362
33	95B	35.1	20.24	4.77	0.31	0.08	0.136
34	37B	35.1	20.35	4.36	0.65	0.16	0.124
35	194B	35.1	17.69	9.84	0.04	0.01	0.28
36	193B	35.1	21.43	5.62	0.04	0.01	0.16
37	191B	35.1	20.37	4.45	0.05	0.01	0.127

Table 4.32 (Continued): Hydrologic calculation results of the subcatchments- 9th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
38	32B	35.1	18.96	8.32	0.06	0.02	0.237
39	94B	35.1	20.64	3.5	0.19	0.05	0.1
40	49B	35.1	18	9.38	0.06	0.02	0.267
41	92B	35.1	24.61	3.02	0.03	0.02	0.086
42	393B	35.1	24.58	2.94	0.02	0.01	0.084
43	196B	35.1	21.1	5.9	0.04	0.01	0.168
44	197B	35.1	17.46	9.94	0.04	0.01	0.283
45	198B	35.1	19.07	8.12	0.06	0.02	0.231
46	30B	35.1	18.53	8.73	0.08	0.02	0.249
47	31B	35.1	18.65	8.73	0.08	0.02	0.249
48	56B	35.1	19.47	6.84	0.11	0.04	0.195
49	24B	35.1	20.38	4.29	0.07	0.02	0.122
50	35B	35.1	19.29	7.2	0.12	0.04	0.205
51	43B	35.1	24.61	3.07	0.03	0.02	0.087
52	9B	35.1	20.01	5.48	0.14	0.04	0.156
53	81B	35.1	18.53	8.75	0.05	0.01	0.249
54	82B	35.1	18.54	8.79	0.06	0.02	0.25
55	80B	35.1	20.07	5.23	0.17	0.05	0.149
56	90B	35.1	20.37	4.08	0.05	0.01	0.116
57	86B	35.1	21.08	5.82	0.02	0	0.166
58	87B	35.1	21.53	5.44	0.02	0	0.155
59	70B	35.1	20.24	6.85	0.07	0.02	0.195
60	84B	35.1	18.33	9.08	0.05	0.01	0.259
61	69B	35.1	19.47	6.94	0.08	0.03	0.198
62	63B	35.1	18.64	8.64	0.07	0.02	0.246
63	62B	35.1	20.2	5.06	0.08	0.02	0.144
64	57B	35.1	24.62	3.01	0.08	0.05	0.086
65	192B	35.1	21.31	5.72	0.03	0.01	0.163
66	48B	35.1	17.77	9.44	0.03	0.01	0.269
67	47B	35.1	18.36	11.79	0.13	0.02	0.336
68	45B	35.1	20.37	4.04	0.05	0.01	0.115
69	22B	35.1	24.58	2.97	0.02	0.01	0.085
70	21B	35.1	19.65	6.55	0.07	0.02	0.187
71	20B	35.1	19.65	6.52	0.09	0.03	0.186
72	23B	35.1	20.45	3.73	0.15	0.04	0.106
73	65B	35.1	20.01	5.34	0.08	0.02	0.152

Table 4.32 (Continued): Hydrologic calculation results of the subcatchments- 9th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
74	59B	35.1	23.65	2.6	0.02	0.01	0.074
75	83B	35.1	19.66	6.46	0.13	0.04	0.184
76	97B	35.1	24.62	2.94	0.11	0.05	0.084
77	78B	35.1	17.57	9.82	0.02	0.01	0.28
78	74B	35.1	20.97	5.88	0.03	0.01	0.168
79	450B	35.1	10.09	13.34	0.09	0.01	0.38
80	54B	35.1	17.65	9.46	0.03	0.01	0.269
81	40B	35.1	9.94	14.51	0.04	0	0.413
82	42B	35.1	20.37	4.51	0.16	0.04	0.128
83	38B	35.1	20.02	5.39	0.25	0.07	0.153
84	13B	35.1	19.19	8.11	0.04	0.01	0.231
85	15B	35.1	20.46	6.65	0.03	0.01	0.189
86	11B	35.1	18.97	8.3	0.08	0.02	0.236
87	14B	35.1	21.31	5.68	0.03	0.01	0.162
88	79B	35.1	19.82	6.03	0.07	0.02	0.172
89	67B	35.1	19.17	7.98	0.08	0.02	0.227
90	66B	35.1	20.04	7.18	0.04	0.01	0.205
91	301B	35.1	13.91	12.88	0.01	0	0.367
92	99B	35.1	10.1	12.74	0.03	0	0.363
93	26B	35.1	19.65	6.36	0.09	0.03	0.181
94	27B	35.1	24.61	3	0.04	0.02	0.085
95	447B	35.1	10.09	8.7	0.08	0.01	0.248
96	101B	35.1	10.09	13.31	0.05	0.01	0.379
97	64B	35.1	24.62	3.21	0.01	0.01	0.091
98	88B	35.1	20.32	6.58	0.02	0	0.187
99	89B	35.1	21.08	5.78	0.03	0.01	0.165
100	44B	35.1	19.64	6.57	0.07	0.02	0.187
101	1B	35.1	24.59	3.28	0.02	0.02	0.093

Table 4.33 : LID operation summary- 9th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	PermeablePavement	109	12	24.77	0	28.29	100.53
2	299B	PermeablePavement	110.91	12	27.48	0	28.29	99.73
3	29B	PermeablePavement	112.25	12	28.47	0	28.29	100.08
4	28B	PermeablePavement	111.33	12	28.01	0	28.29	99.62

Table 4.33 (Continued): LID operation summary- 9th scenario

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
5	25B	PermeablePavement	112.65	12	28.83	0	28.29	100.11
6	16B	PermeablePavement	196.04	12	108.06	0	28.29	104.27
7	17B	PermeablePavement	111.94	12	25.88	0	28.29	102.35
8	300B	PermeablePavement	113.82	12	29.47	0	28.29	100.64
9	33B	PermeablePavement	113.86	12	29.66	0	28.29	100.5
10	93B	PermeablePavement	112.65	12	28.84	0	28.29	100.1
11	96B	PermeablePavement	113.23	12	29	0	28.29	100.52
12	12B	PermeablePavement	113.95	12	30.09	0	28.29	100.16
13	52B	PermeablePavement	112.51	12	27.5	0	28.29	101.3
14	53B	PermeablePavement	112.05	12	27.06	0	28.29	101.29
15	51B	PermeablePavement	113.53	12	29.24	0	28.29	100.58
16	58B	PermeablePavement	112.6	12	26.92	0	28.29	101.98
17	302B	PermeablePavement	106.74	12	22.51	0	28.29	100.52
18	34B	PermeablePavement	112.77	12	28.76	0	28.29	100.3
19	10B	PermeablePavement	113.31	12	28.56	0	28.29	101.04
20	18B	PermeablePavement	112.92	12	27.48	0	28.29	101.73
21	19B	PermeablePavement	113.97	12	30.18	0	28.29	100.08
22	85B	PermeablePavement	113.22	12	29.97	0	28.29	99.6
23	71B	PermeablePavement	113.7	12	29.03	0	28.29	100.96
24	72B	PermeablePavement	112	12	28.23	0	28.29	100.06
25	73B	PermeablePavement	112.92	12	27.29	0	28.29	101.93
26	195B	PermeablePavement	113.17	12	28.82	0	28.29	100.64
27	46B	PermeablePavement	113.47	12	28.84	0	28.29	100.92
28	91B	PermeablePavement	113.05	12	29.22	0	28.29	100.13
29	60B	PermeablePavement	110.95	12	24.75	0	28.29	102.49
30	61B	PermeablePavement	113.33	12	29.01	0	28.29	100.62
31	269B	PermeablePavement	112.3	12	27.88	0	28.29	100.72
32	298B	PermeablePavement	113.15	12	30.01	0	28.29	99.49
33	95B	PermeablePavement	113.41	12	28.59	0	28.29	101.12
34	37B	PermeablePavement	113.34	12	28.23	0	28.29	101.41
35	194B	PermeablePavement	114.04	12	30.64	0	28.29	99.72
36	193B	PermeablePavement	113.59	12	28.72	0	28.29	101.17
37	191B	PermeablePavement	112.71	12	27.74	0	28.29	101.26
38	32B	PermeablePavement	112.71	12	28.97	0	28.29	100.04
39	94B	PermeablePavement	112.39	12	26.57	0	28.29	102.11
40	49B	PermeablePavement	112.56	12	29.12	0	28.29	99.74
41	92B	PermeablePavement	113.15	12	29.31	0	28.29	100.13

Table 4.33 (Continued): LID operation summary- 9th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
42	393B	PermeablePavement	111.48	12	27.89	0	28.29	99.88
43	196B	PermeablePavement	112.97	12	28.28	0	28.29	100.98
44	197B	PermeablePavement	111.86	12	28.66	0	28.29	99.53
45	198B	PermeablePavement	112.25	12	28.47	0	28.29	100.08
46	30B	PermeablePavement	112.48	12	28.87	0	28.29	99.91
47	31B	PermeablePavement	113.98	12	30.25	0	28.29	100.02
48	56B	PermeablePavement	113.14	12	29.33	0	28.29	100.11
49	24B	PermeablePavement	113.11	12	27.95	0	28.29	101.45
50	35B	PermeablePavement	112.91	12	29.24	0	28.29	99.97
51	43B	PermeablePavement	113.24	12	29.65	0	28.29	99.88
52	9B	PermeablePavement	113.45	12	29.03	0	28.29	100.71
53	81B	PermeablePavement	112.39	12	28.8	0	28.29	99.89
54	82B	PermeablePavement	112.74	12	29.13	0	28.29	99.9
55	80B	PermeablePavement	113.46	12	28.89	0	28.29	100.86
56	90B	PermeablePavement	112.21	12	26.95	0	28.29	101.55
57	86B	PermeablePavement	111.49	12	26.89	0	28.29	100.89
58	87B	PermeablePavement	112.53	12	27.65	0	28.29	101.17
59	70B	PermeablePavement	112.48	12	28.24	0	28.29	100.54
60	84B	PermeablePavement	114	12	30.38	0	28.29	99.92
61	69B	PermeablePavement	113.59	12	29.79	0	28.29	100.09
62	63B	PermeablePavement	112.88	12	29.21	0	28.29	99.97
63	62B	PermeablePavement	113.7	12	29.04	0	28.29	100.95
64	57B	PermeablePavement	113.72	12	29.6	0	28.29	100.42
65	192B	PermeablePavement	112.71	12	27.97	0	28.29	101.04
66	48B	PermeablePavement	110.52	12	27.24	0	28.29	99.58
67	47B	PermeablePavement	35.1	0.95	0	0	20	54.16
68	45B	PermeablePavement	112.18	12	26.88	0	28.29	101.59
69	22B	PermeablePavement	111.71	12	28.17	0	28.29	99.83
70	21B	PermeablePavement	113.17	12	29.28	0	28.29	100.18
71	20B	PermeablePavement	113.01	12	29.11	0	28.29	100.19
72	23B	PermeablePavement	112.77	12	27.11	0	28.29	101.95
73	65B	PermeablePavement	112.56	12	28.14	0	28.29	100.72
74	59B	PermeablePavement	107.56	12	21.12	0	28.29	102.73
75	83B	PermeablePavement	113.91	12	29.9	0	28.29	100.31
76	97B	PermeablePavement	113.71	12	29.09	0	28.29	100.91
77	78B	PermeablePavement	112.1	12	28.83	0	28.29	99.58
78	74B	PermeablePavement	110.52	12	26.04	0	28.29	100.78

Table 4.33 (Continued): LID operation summary- 9th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
79	450B	PermeablePavement	113.72	12	29.11	0	28.29	100.9
80	54B	PermeablePavement	109.02	12	25.86	0	28.29	99.47
81	40B	PermeablePavement	110.93	12	26.83	0	28.29	100.4
82	42B	PermeablePavement	113.05	12	28.1	0	28.29	101.25
83	38B	PermeablePavement	113.57	12	29.08	0	28.29	100.79
84	13B	PermeablePavement	113.94	12	30.02	0	28.29	100.21
85	15B	PermeablePavement	112.97	12	28.61	0	28.29	100.65
86	11B	PermeablePavement	113.03	12	29.25	0	28.29	100.08
87	14B	PermeablePavement	112.18	12	27.46	0	28.29	101.01
88	79B	PermeablePavement	112.29	12	28.26	0	28.29	100.33
89	67B	PermeablePavement	112.18	12	28.36	0	28.29	100.12
90	66B	PermeablePavement	113.86	12	29.63	0	28.29	100.52
91	301B	PermeablePavement	105.34	12	22.81	0	28.29	98.94
92	99B	PermeablePavement	111.72	12	27.1	0	28.29	100.92
93	26B	PermeablePavement	112.66	12	28.7	0	28.29	100.25
94	27B	PermeablePavement	113.23	12	29.22	0	28.29	100.31
95	447B	PermeablePavement	112.26	12	26.5	0	28.29	102.06
96	101B	PermeablePavement	113.71	12	29.1	0	28.29	100.91
97	64B	PermeablePavement	114.08	12	30.91	0	28.29	99.52
98	88B	PermeablePavement	109.78	12	25.66	0	28.29	100.42
99	89B	PermeablePavement	110.76	12	26.21	0	28.29	100.85
100	44B	PermeablePavement	112.28	12	28.48	0	28.29	100.09
101	1B	PermeablePavement	112.33	12	30.11	0	28.29	98.7

Table 4.34 : Instantaneous discharge time series of drainage system- 9th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0.01
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0.01
1:30:00	0	0
1:45:00	0	0
2:00:00	31.74	0
2:15:00	0	0.05
2:30:00	0	0.01

Table 4.34 (Continued): Instantaneous discharge time series of drainage system- 9th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:45:00	0	0.01
3:00:00	23.34	0.01
3:15:00	0	0.08
3:30:00	0	0.07
3:45:00	0	0.06
4:00:00	0	0.06
4:15:00	0	0.06
4:30:00	0	0.06
4:45:00	0	0.05
5:00:00	0	0.05
5:15:00	0	0.05
5:30:00	0	0.05
5:45:00	0	0.05
6:00:00	39.6	0.05
6:15:00	0	1.08
6:30:00	0	0.53
6:45:00	0	0.34
7:00:00	0	0.25
7:15:00	0	0.19
7:30:00	0	0.15
7:45:00	0	0.13
8:00:00	0	0.11
8:15:00	0	0.09
8:30:00	0	0.08
8:45:00	0	0.07
9:00:00	0	0.06
9:15:00	0	0.06
9:30:00	0	0.05
9:45:00	0	0.05
10:00:00	0	0.04
10:15:00	0	0.04
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.03
12:00:00	30	0.02

Table 4.34 (Continued): Instantaneous discharge time series of drainage system- 9th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
12:15:00	0	0.86
12:30:00	0	0.39
12:45:00	0	0.26
13:00:00	0	0.19
13:15:00	0	0.15
13:30:00	0	0.13
13:45:00	0	0.11
14:00:00	0	0.09
14:15:00	0	0.08
14:30:00	0	0.08
14:45:00	0	0.07
15:00:00	0	0.06
15:15:00	0	0.06
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.05
16:15:00	0	0.05
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.03
19:00:00	0	0.03
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03
21:15:00	0	0.03

Table 4.34 (Continued): Instantaneous discharge time series of drainage system- 9th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.02
23:30:00	0	0.02
23:45:00	0	0.02
0:00:00	0	0.02

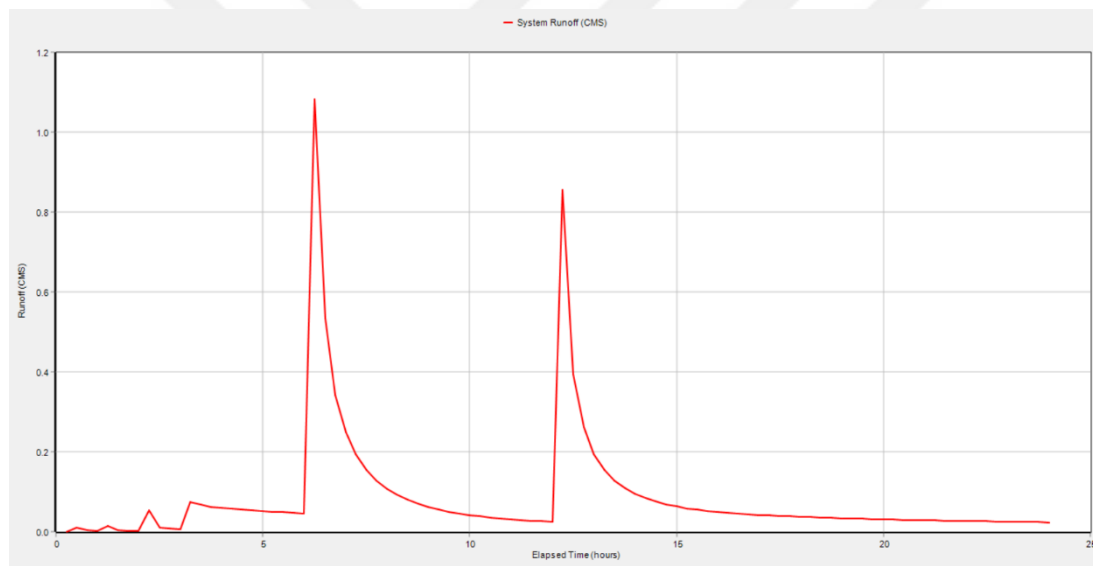


Figure 4.58 : 10 year return period hydrograph- 9th scenario.

4.2.12 10th scenario modeling results – Rain gardens LID-10%

Table 4.35 shows the hydrologic calculations results of the under study subcatchments while Table 4.36 shows implemented LID's operation summary on them. Table 4.37 shows the instantaneous discharge time series of drainage system whereas Figure 4.59 depicts 10 year return period hydrograph.

Table 4.35 : Hydrologic calculation results of the subcatchments- 10th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	8.85	14	0.04	0.01	0.399
2	299B	35.1	13.89	11.91	0.05	0.01	0.339
3	29B	35.1	17.86	8.75	0.07	0.02	0.249
4	28B	35.1	16.56	10.18	0.06	0.02	0.29
5	25B	35.1	23.4	3.61	0.05	0.03	0.103
6	16B	35.1	8.89	8.5	0.07	0.01	0.242
7	17B	35.1	19.45	3.67	0.22	0.08	0.104
8	300B	35.1	14.55	9.66	0.01	0	0.275
9	33B	35.1	18.65	6.59	0.18	0.06	0.188
10	93B	35.1	18.26	7.39	0.1	0.03	0.211
11	96B	35.1	18.64	6.45	0.14	0.04	0.184
12	12B	35.1	17.9	8.88	0.07	0.02	0.253
13	52B	35.1	20.54	5.71	0.05	0.01	0.163
14	53B	35.1	20.53	5.66	0.05	0.02	0.161
15	51B	35.1	18.83	6.27	0.09	0.03	0.179
16	58B	35.1	23.43	3.15	0.06	0.03	0.09
17	302B	35.1	14.49	8.47	0.02	0	0.241
18	34B	35.1	18.63	6.76	0.1	0.03	0.192
19	10B	35.1	19	5.42	0.14	0.05	0.155
20	18B	35.1	19.19	4.45	0.09	0.03	0.127
21	19B	35.1	18.11	7.81	0.09	0.03	0.222
22	85B	35.1	16.28	10.71	0.06	0.02	0.305
23	71B	35.1	19.82	6.63	0.02	0.01	0.189
24	72B	35.1	17.85	8.73	0.06	0.02	0.249
25	73B	35.1	19.37	4.19	0.08	0.03	0.119
26	195B	35.1	18.82	6.11	0.17	0.05	0.174
27	46B	35.1	19.01	5.62	0.1	0.03	0.16
28	91B	35.1	23.41	3.63	0.05	0.03	0.104
29	60B	35.1	23.41	2.87	0.03	0.01	0.082
30	61B	35.1	18.82	6.18	0.11	0.04	0.176
31	269B	35.1	8.89	14.18	0.08	0.01	0.404
32	298B	35.1	13.32	13.37	0.06	0.02	0.381
33	95B	35.1	19.05	5.3	0.34	0.11	0.151
34	37B	35.1	19.16	4.86	0.73	0.24	0.138
35	194B	35.1	16.51	10.5	0.05	0.01	0.299
36	193B	35.1	20.25	6.15	0.05	0.01	0.175
37	191B	35.1	19.17	4.96	0.05	0.02	0.141

Table 4.35 (Continued): Hydrologic calculation results of the subcatchments-10th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
38	32B	35.1	17.76	8.95	0.06	0.02	0.255
39	94B	35.1	19.45	3.92	0.21	0.08	0.112
40	49B	35.1	16.8	10.04	0.06	0.02	0.286
41	92B	35.1	23.41	3.64	0.04	0.02	0.104
42	393B	35.1	23.36	3.59	0.02	0.01	0.102
43	196B	35.1	19.91	6.44	0.04	0.01	0.184
44	197B	35.1	16.25	10.61	0.04	0.01	0.302
45	198B	35.1	17.86	8.75	0.07	0.02	0.249
46	30B	35.1	17.33	9.37	0.08	0.02	0.267
47	31B	35.1	17.47	9.36	0.08	0.02	0.267
48	56B	35.1	18.27	7.46	0.12	0.04	0.213
49	24B	35.1	19.19	4.79	0.07	0.02	0.136
50	35B	35.1	18.09	7.84	0.13	0.04	0.223
51	43B	35.1	23.41	3.71	0.04	0.03	0.106
52	9B	35.1	18.82	6.05	0.16	0.05	0.172
53	81B	35.1	17.33	9.39	0.05	0.01	0.268
54	82B	35.1	17.33	9.43	0.07	0.02	0.269
55	80B	35.1	18.88	5.78	0.18	0.06	0.165
56	90B	35.1	19.17	4.56	0.06	0.02	0.13
57	86B	35.1	19.87	6.37	0.02	0.01	0.181
58	87B	35.1	20.33	5.96	0.03	0.01	0.17
59	70B	35.1	19.04	7.43	0.07	0.02	0.212
60	84B	35.1	17.15	9.72	0.05	0.01	0.277
61	69B	35.1	18.28	7.57	0.09	0.03	0.216
62	63B	35.1	17.44	9.27	0.07	0.02	0.264
63	62B	35.1	19.01	5.61	0.09	0.03	0.16
64	57B	35.1	23.43	3.61	0.1	0.05	0.103
65	192B	35.1	20.11	6.25	0.03	0.01	0.178
66	48B	35.1	16.54	10.12	0.04	0.01	0.288
67	47B	35.1	18.27	7.5	0.09	0.03	0.214
68	45B	35.1	19.17	4.52	0.05	0.02	0.129
69	22B	35.1	23.37	3.62	0.02	0.01	0.103
70	21B	35.1	18.45	7.17	0.08	0.03	0.204
71	20B	35.1	18.45	7.14	0.1	0.03	0.203
72	23B	35.1	19.26	4.17	0.16	0.06	0.119
73	65B	35.1	18.8	5.91	0.08	0.03	0.168

Table 4.35 (Continued): Hydrologic calculation results of the subcatchments-10th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
74	59B	35.1	22.45	2.85	0.02	0.01	0.081
75	83B	35.1	18.47	7.06	0.14	0.05	0.201
76	97B	35.1	23.44	3.49	0.14	0.07	0.099
77	78B	35.1	16.36	10.49	0.02	0.01	0.299
78	74B	35.1	19.74	6.44	0.03	0.01	0.184
79	450B	35.1	8.91	13.89	0.1	0.01	0.396
80	54B	35.1	16.4	10.14	0.03	0.01	0.289
81	40B	35.1	8.71	15.1	0.04	0.01	0.43
82	42B	35.1	19.18	5.03	0.18	0.06	0.143
83	38B	35.1	18.83	5.94	0.28	0.09	0.169
84	13B	35.1	18	8.72	0.04	0.01	0.248
85	15B	35.1	19.26	7.22	0.04	0.01	0.206
86	11B	35.1	17.77	8.93	0.08	0.02	0.254
87	14B	35.1	20.1	6.22	0.04	0.01	0.177
88	79B	35.1	18.61	6.63	0.07	0.02	0.189
89	67B	35.1	17.96	8.6	0.08	0.02	0.245
90	66B	35.1	18.86	7.76	0.04	0.01	0.221
91	301B	35.1	12.59	13.61	0.01	0	0.388
92	99B	35.1	8.88	13.29	0.03	0	0.379
93	26B	35.1	18.44	6.97	0.1	0.03	0.199
94	27B	35.1	23.42	3.6	0.05	0.03	0.103
95	447B	35.1	8.9	9.13	0.09	0.01	0.26
96	101B	35.1	8.91	13.86	0.06	0.01	0.395
97	64B	35.1	23.44	3.88	0.01	0.01	0.111
98	88B	35.1	19.07	7.18	0.02	0.01	0.204
99	89B	35.1	19.85	6.33	0.04	0.01	0.18
100	44B	35.1	18.45	7.25	0.07	0.03	0.206
101	1B	35.1	23.38	3.98	0.03	0.02	0.113

Table 4.36 : LID operation summary- 10th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	RainGarden	109	0.14	30.32	0	48	126.53
2	299B	RainGarden	110.91	0.15	33.84	0	48	124.93
3	29B	RainGarden	112.25	0.15	34.6	0	48	125.5
4	28B	RainGarden	111.33	0.15	34.5	0	48	124.69

Table 4.36 (Continued): LID operation summary- 10th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
5	25B	RainGarden	112.65	0.15	34.96	0	48	125.54
6	16B	RainGarden	111.38	0.14	29.6	0	48	129.64
7	17B	RainGarden	111.94	0.14	29.76	0	48	130.05
8	300B	RainGarden	113.82	0.15	35.2	0	48	126.47
9	33B	RainGarden	113.86	0.15	35.53	0	48	126.19
10	93B	RainGarden	112.65	0.15	34.98	0	48	125.53
11	96B	RainGarden	113.23	0.15	34.8	0	48	126.28
12	12B	RainGarden	113.95	0.15	36.27	0	48	125.53
13	52B	RainGarden	112.51	0.14	32.56	0	48	127.8
14	53B	RainGarden	112.05	0.14	32.1	0	48	127.81
15	51B	RainGarden	113.53	0.15	35.01	0	48	126.37
16	58B	RainGarden	112.6	0.14	31.29	0	48	129.17
17	302B	RainGarden	106.74	0.14	27.98	0	48	126.62
18	34B	RainGarden	112.77	0.15	34.73	0	48	125.89
19	10B	RainGarden	113.31	0.14	33.89	0	48	127.27
20	18B	RainGarden	112.92	0.14	32.12	0	48	128.65
21	19B	RainGarden	113.97	0.15	36.44	0	48	125.38
22	85B	RainGarden	113.22	0.15	36.58	0	48	124.49
23	71B	RainGarden	113.7	0.14	34.46	0	48	127.09
24	72B	RainGarden	112	0.15	34.36	0	48	125.5
25	73B	RainGarden	112.92	0.14	31.72	0	48	129.06
26	195B	RainGarden	113.17	0.15	34.5	0	48	126.52
27	46B	RainGarden	113.47	0.14	34.29	0	48	127.03
28	91B	RainGarden	113.05	0.15	35.37	0	48	125.54
29	60B	RainGarden	110.95	0.13	28.4	0	48	130.41
30	61B	RainGarden	113.33	0.15	34.73	0	48	126.46
31	269B	RainGarden	112.3	0.14	33.44	0	48	126.72
32	298B	RainGarden	113.15	0.15	36.71	0	48	124.3
33	95B	RainGarden	113.41	0.14	33.86	0	48	127.41
34	37B	RainGarden	113.34	0.14	33.22	0	48	127.98
35	194B	RainGarden	114.04	0.15	37.22	0	48	124.67
36	193B	RainGarden	113.59	0.14	33.95	0	48	127.49
37	191B	RainGarden	112.71	0.14	32.84	0	48	127.73
38	32B	RainGarden	112.71	0.15	35.17	0	48	125.39
39	94B	RainGarden	112.39	0.14	30.77	0	48	129.48
40	49B	RainGarden	112.56	0.15	35.58	0	48	124.83
41	92B	RainGarden	113.15	0.15	35.46	0	48	125.55

Table 4.36 (Continued): LID operation summary- 10th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
42	393B	RainGarden	111.48	0.15	34.16	0	48	125.17
43	196B	RainGarden	112.97	0.14	33.65	0	48	127.17
44	197B	RainGarden	111.86	0.15	35.25	0	48	124.47
45	198B	RainGarden	112.25	0.15	34.6	0	48	125.5
46	30B	RainGarden	112.48	0.15	35.18	0	48	125.16
47	31B	RainGarden	113.98	0.15	36.57	0	48	125.26
48	56B	RainGarden	113.14	0.15	35.5	0	48	125.5
49	24B	RainGarden	113.11	0.14	32.9	0	48	128.07
50	35B	RainGarden	112.91	0.15	35.53	0	48	125.24
51	43B	RainGarden	113.24	0.15	36.04	0	48	125.05
52	9B	RainGarden	113.45	0.15	34.67	0	48	126.63
53	81B	RainGarden	112.39	0.15	35.12	0	48	125.13
54	82B	RainGarden	112.74	0.15	35.47	0	48	125.12
55	80B	RainGarden	113.46	0.15	34.4	0	48	126.91
56	90B	RainGarden	112.21	0.14	31.75	0	48	128.32
57	86B	RainGarden	111.49	0.14	32.26	0	48	127.08
58	87B	RainGarden	112.53	0.14	32.83	0	48	127.55
59	70B	RainGarden	112.48	0.15	33.98	0	48	126.36
60	84B	RainGarden	114	0.15	36.8	0	48	125.06
61	69B	RainGarden	113.59	0.15	36.02	0	48	125.42
62	63B	RainGarden	112.88	0.15	35.49	0	48	125.24
63	62B	RainGarden	113.7	0.14	34.48	0	48	127.07
64	57B	RainGarden	113.72	0.15	35.52	0	48	126.05
65	192B	RainGarden	112.71	0.14	33.27	0	48	127.3
66	48B	RainGarden	110.52	0.14	33.7	0	48	124.68
67	47B	RainGarden	113.19	0.15	35.59	0	48	125.46
68	45B	RainGarden	112.18	0.14	31.64	0	48	128.39
69	22B	RainGarden	111.71	0.15	34.5	0	48	125.06
70	21B	RainGarden	113.17	0.15	35.38	0	48	125.64
71	20B	RainGarden	113.01	0.15	35.2	0	48	125.66
72	23B	RainGarden	112.77	0.14	31.52	0	48	129.11
73	65B	RainGarden	112.56	0.15	33.72	0	48	126.7
74	59B	RainGarden	107.56	0.12	23.5	0	48	131.94
75	83B	RainGarden	113.91	0.15	35.93	0	48	125.83
76	97B	RainGarden	113.71	0.15	34.57	0	48	127
77	78B	RainGarden	112.1	0.15	35.39	0	48	124.56
78	74B	RainGarden	110.52	0.14	31.46	0	48	126.92

Table 4.36 (Continued): LID operation summary- 10th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
79	450B	RainGarden	113.72	0.15	34.59	0	48	126.98
80	54B	RainGarden	109.02	0.14	32.32	0	48	124.56
81	40B	RainGarden	110.93	0.14	32.6	0	48	126.19
82	42B	RainGarden	113.05	0.14	33.23	0	48	127.68
83	38B	RainGarden	113.57	0.15	34.66	0	48	126.77
84	13B	RainGarden	113.94	0.15	36.15	0	48	125.64
85	15B	RainGarden	112.97	0.15	34.27	0	48	126.55
86	11B	RainGarden	113.03	0.15	35.44	0	48	125.45
87	14B	RainGarden	112.18	0.14	32.76	0	48	127.27
88	79B	RainGarden	112.29	0.15	34.17	0	48	125.98
89	67B	RainGarden	112.18	0.15	34.45	0	48	125.59
90	66B	RainGarden	113.86	0.15	35.47	0	48	126.24
91	301B	RainGarden	105.34	0.14	29.4	0	48	123.8
92	99B	RainGarden	111.72	0.14	32.45	0	48	127.13
93	26B	RainGarden	112.66	0.15	34.71	0	48	125.81
94	27B	RainGarden	113.23	0.15	35.21	0	48	125.87
95	447B	RainGarden	112.26	0.14	30.76	0	48	129.36
96	101B	RainGarden	113.71	0.15	34.57	0	48	127
97	64B	RainGarden	114.08	0.15	37.65	0	48	124.29
98	88B	RainGarden	109.78	0.14	31.35	0	48	126.29
99	89B	RainGarden	110.76	0.14	31.58	0	48	127.04
100	44B	RainGarden	113.1	0.15	35.42	0	48	125.54
101	1B	RainGarden	112.33	0.14	36.94	0	48	123.25

Table 4.37 : Instantaneous discharge time series of drainage system- 10th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0
1:30:00	0	0
1:45:00	0	0
2:00:00	31.74	0
2:15:00	0	0.05
2:30:00	0	0.03

Table 4.37 (Continued): Instantaneous discharge time series of drainage system- 10th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:45:00	0	0.03
3:00:00	23.34	0.02
3:15:00	0	0.55
3:30:00	0	0.3
3:45:00	0	0.2
4:00:00	0	0.14
4:15:00	0	0.1
4:30:00	0	0.09
4:45:00	0	0.07
5:00:00	0	0.06
5:15:00	0	0.06
5:30:00	0	0.05
5:45:00	0	0.05
6:00:00	39.6	0.05
6:15:00	0	0.96
6:30:00	0	0.47
6:45:00	0	0.28
7:00:00	0	0.19
7:15:00	0	0.14
7:30:00	0	0.11
7:45:00	0	0.09
8:00:00	0	0.07
8:15:00	0	0.06
8:30:00	0	0.05
8:45:00	0	0.05
9:00:00	0	0.04
9:15:00	0	0.04
9:30:00	0	0.04
9:45:00	0	0.03
10:00:00	0	0.03
10:15:00	0	0.03
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.02

Table 4.37 (Continued): Instantaneous discharge time series of drainage system- 10th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
12:00:00	30	0.02
12:15:00	0	0.63
12:30:00	0	0.33
12:45:00	0	0.22
13:00:00	0	0.15
13:15:00	0	0.12
13:30:00	0	0.09
13:45:00	0	0.08
14:00:00	0	0.07
14:15:00	0	0.06
14:30:00	0	0.06
14:45:00	0	0.05
15:00:00	0	0.05
15:15:00	0	0.05
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.04
16:15:00	0	0.04
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.03
19:00:00	0	0.03
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03

Table 4.37 (Continued): Instantaneous discharge time series of drainage system- 10th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
21:15:00	0	0.03
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.02
23:30:00	0	0.02
23:45:00	0	0.02
0:00:00	0	0.02

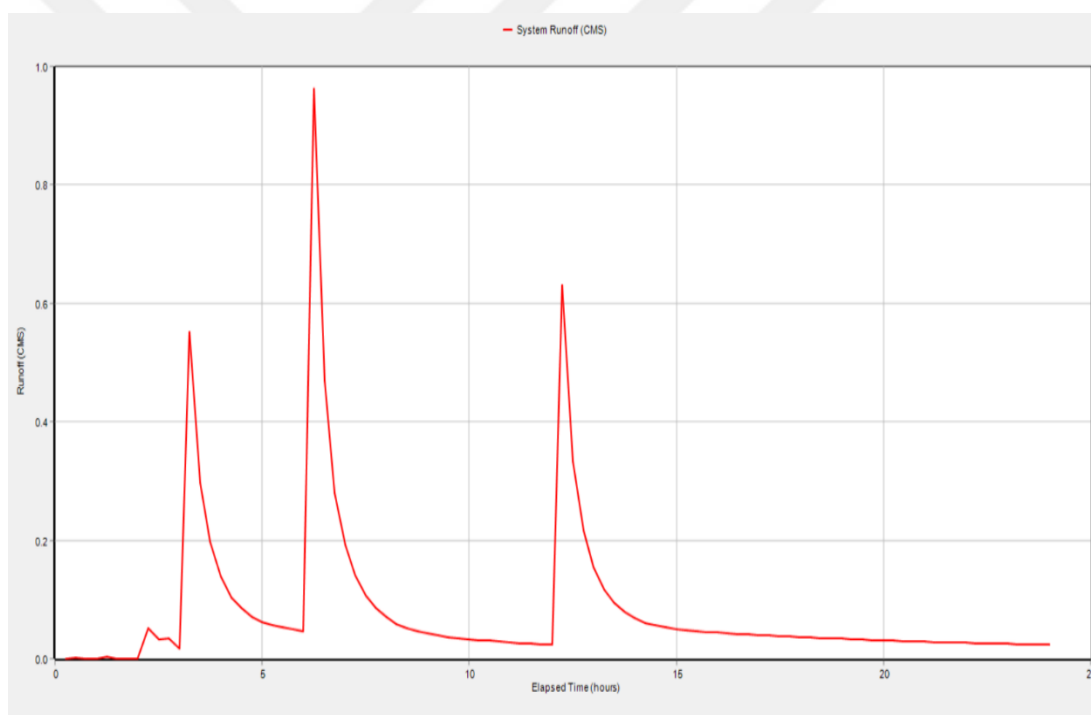


Figure 4.59 : 10 year return period hydrograph- 10th scenario.

4.2.13 11th scenario modeling results – Rain barrels LID-2%

Table 4.38 shows the hydrologic calculations results of the under study subcatchments while Table 4.39 shows implemented LID's operation summary on them. Table 4.40 shows the instantaneous discharge time series of drainage system whereas Figure 4.60 depicts 10 year return period hydrograph.

Table 4.38 : Hydrologic calculation results of the subcatchments- 11th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
1	452B	35.1	9.68	11.48	0.03	0	0.327
2	299B	35.1	15.27	8.94	0.04	0	0.255
3	29B	35.1	19.7	5.46	0.04	0	0.156
4	28B	35.1	18.31	7	0.04	0	0.199
5	25B	35.1	25.5	0.06	0	0	0.002
6	16B	35.1	9.68	5.66	0.04	0	0.161
7	17B	35.1	21.17	0.69	0.04	0	0.02
8	300B	35.1	15.81	6.47	0.01	0	0.184
9	33B	35.1	20.49	3.04	0.08	0.01	0.087
10	93B	35.1	20.1	3.89	0.05	0	0.111
11	96B	35.1	20.49	2.95	0.06	0	0.084
12	12B	35.1	19.7	5.49	0.04	0	0.156
13	52B	35.1	22.49	2.48	0.02	0	0.071
14	53B	35.1	22.61	2.44	0.02	0	0.069
15	51B	35.1	20.49	2.88	0.04	0	0.082
16	58B	35.1	25.5	0.01	0	0	0
17	302B	35.1	15.9	5.71	0.01	0	0.163
18	34B	35.1	20.29	3.41	0.05	0	0.097
19	10B	35.1	20.69	2.09	0.05	0	0.06
20	18B	35.1	21.08	1.18	0.02	0	0.034
21	19B	35.1	19.9	4.25	0.05	0	0.121
22	85B	35.1	17.84	7.5	0.04	0	0.214
23	71B	35.1	21.78	3.26	0.01	0	0.093
24	72B	35.1	19.7	5.46	0.04	0	0.155
25	73B	35.1	21.08	1.03	0.02	0	0.029
26	195B	35.1	20.49	2.75	0.08	0	0.078
27	46B	35.1	20.68	2.26	0.04	0	0.064
28	91B	35.1	25.5	0.06	0	0	0.002
29	60B	35.1	25.5	0.01	0	0	0
30	61B	35.1	20.49	2.81	0.05	0	0.08
31	269B	35.1	9.68	11.43	0.07	0	0.326
32	298B	35.1	14.61	10.34	0.05	0	0.295
33	95B	35.1	20.74	1.97	0.13	0.01	0.056
34	37B	35.1	20.85	1.57	0.24	0.01	0.045
35	194B	35.1	18.07	7.23	0.03	0	0.206
36	193B	35.1	22.15	2.83	0.02	0	0.081
37	191B	35.1	20.88	1.69	0.02	0	0.048

Table 4.38 (Continued): Hydrologic calculation results of the subcatchments-11th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
38	32B	35.1	19.47	5.69	0.04	0	0.162
39	94B	35.1	21.17	0.85	0.05	0	0.024
40	49B	35.1	18.53	6.71	0.04	0	0.191
41	92B	35.1	25.5	0.06	0	0	0.002
42	393B	35.1	25.5	0.07	0	0	0.002
43	196B	35.1	21.91	3.12	0.02	0	0.089
44	197B	35.1	17.84	7.49	0.03	0	0.213
45	198B	35.1	19.7	5.46	0.04	0	0.156
46	30B	35.1	19.12	6.09	0.05	0	0.173
47	31B	35.1	19.24	5.98	0.05	0	0.17
48	56B	35.1	20.1	3.93	0.06	0	0.112
49	24B	35.1	20.88	1.53	0.02	0	0.043
50	35B	35.1	19.9	4.34	0.07	0.01	0.124
51	43B	35.1	25.5	0.08	0	0	0.002
52	9B	35.1	20.49	2.67	0.07	0	0.076
53	81B	35.1	19.12	6.11	0.03	0	0.174
54	82B	35.1	19.12	6.13	0.04	0	0.175
55	80B	35.1	20.76	2.3	0.07	0	0.065
56	90B	35.1	20.88	1.38	0.02	0	0.039
57	86B	35.1	21.91	3.14	0.01	0	0.089
58	87B	35.1	22.26	2.71	0.01	0	0.077
59	70B	35.1	20.98	4.12	0.04	0	0.117
60	84B	35.1	18.88	6.35	0.03	0	0.181
61	69B	35.1	19.9	4.19	0.05	0	0.119
62	63B	35.1	19.24	5.96	0.05	0	0.17
63	62B	35.1	20.68	2.24	0.03	0	0.064
64	57B	35.1	25.5	0.05	0	0	0.001
65	192B	35.1	22.02	2.98	0.01	0	0.085
66	48B	35.1	18.31	6.99	0.03	0	0.199
67	47B	35.1	20.1	3.97	0.05	0	0.113
68	45B	35.1	20.88	1.35	0.02	0	0.038
69	22B	35.1	25.49	0.08	0	0	0.002
70	21B	35.1	20.1	3.8	0.04	0	0.108
71	20B	35.1	20.1	3.78	0.05	0	0.108
72	23B	35.1	21.17	0.97	0.04	0	0.028
73	65B	35.1	20.68	2.47	0.04	0	0.07

Table 4.38 (Continued): Hydrologic calculation results of the subcatchments-11th scenario.

No.	Subcatchment	Total Precip mm	Total Infil mm	Total Runoff mm	Total Runoff 10 ⁶ lit	Peak Runoff CMS	Runoff Coeff
74	59B	35.1	24.47	0.46	0	0	0.013
75	83B	35.1	20.29	3.5	0.07	0.01	0.1
76	97B	35.1	25.5	0.03	0	0	0.001
77	78B	35.1	17.95	7.35	0.02	0	0.209
78	74B	35.1	21.79	3.26	0.02	0	0.093
79	450B	35.1	9.68	11.03	0.08	0	0.314
80	54B	35.1	18.19	7.12	0.02	0	0.203
81	40B	35.1	9.68	12.36	0.04	0	0.352
82	42B	35.1	20.88	1.73	0.06	0	0.049
83	38B	35.1	20.69	2.45	0.11	0.01	0.07
84	13B	35.1	19.82	5.33	0.02	0	0.152
85	15B	35.1	21.21	3.88	0.02	0	0.11
86	11B	35.1	19.58	5.59	0.05	0	0.159
87	14B	35.1	22.02	2.97	0.02	0	0.085
88	79B	35.1	20.29	3.31	0.04	0	0.094
89	67B	35.1	19.82	5.32	0.05	0	0.151
90	66B	35.1	20.75	4.36	0.02	0	0.124
91	301B	35.1	11.24	9.44	0.01	0	0.269
92	99B	35.1	9.68	10.53	0.02	0	0.3
93	26B	35.1	20.29	3.48	0.05	0	0.099
94	27B	35.1	25.5	0.05	0	0	0.001
95	447B	35.1	9.68	6.22	0.06	0	0.177
96	101B	35.1	9.68	10.99	0.04	0	0.313
97	64B	35.1	25.5	0.12	0	0	0.004
98	88B	35.1	20.98	4.06	0.01	0	0.116
99	89B	35.1	21.91	3.14	0.02	0	0.09
100	44B	35.1	20.1	3.88	0.04	0	0.111
101	1B	35.1	25.5	0.21	0	0	0.006

Table 4.39 : LID operation summary- 11th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
1	452B	RainBarrel	447.04	0	0	0	75	522.03
2	299B	RainBarrel	454.19	0	0	0	75	529.19
3	29B	RainBarrel	461.43	0	0	0	75	536.42
4	28B	RainBarrel	464.77	0	0	0	75	539.77

Table 4.39 (Continued): LID operation summary- 11th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
5	25B	RainBarrel	462.63	0	0	0	75	537.63
6	16B	RainBarrel	452.63	0	0	0	75	527.62
7	17B	RainBarrel	453.16	0	0	0	75	528.14
8	300B	RainBarrel	442.72	0	0	0	75	517.72
9	33B	RainBarrel	462.22	0	0	0	75	537.22
10	93B	RainBarrel	462.64	0	0	0	75	537.64
11	96B	RainBarrel	462.66	0	0	0	75	537.66
12	12B	RainBarrel	464.31	0	0	0	75	539.31
13	52B	RainBarrel	456.63	0	0	0	75	531.62
14	53B	RainBarrel	459.02	0	0	0	75	534.02
15	51B	RainBarrel	462.08	0	0	0	75	537.08
16	58B	RainBarrel	455.27	0	0	0	75	530.26
17	302B	RainBarrel	444.77	0	0	0	75	519.77
18	34B	RainBarrel	464.02	0	0	0	75	539.01
19	10B	RainBarrel	461.64	0	0	0	75	536.64
20	18B	RainBarrel	457.23	0	0	0	75	532.22
21	19B	RainBarrel	464.41	0	0	0	75	539.41
22	85B	RainBarrel	460.74	0	0	0	75	535.74
23	71B	RainBarrel	450.67	0	0	0	75	525.66
24	72B	RainBarrel	464.29	0	0	0	75	539.29
25	73B	RainBarrel	455.97	0	0	0	75	530.96
26	195B	RainBarrel	463.45	0	0	0	75	538.45
27	46B	RainBarrel	460.46	0	0	0	75	535.46
28	91B	RainBarrel	461.3	0	0	0	75	536.3
29	60B	RainBarrel	448.98	0	0	0	75	523.96
30	61B	RainBarrel	461.09	0	0	0	75	536.09
31	269B	RainBarrel	455.9	0	0	0	75	530.9
32	298B	RainBarrel	455.9	0	0	0	75	530.9
33	95B	RainBarrel	461.94	0	0	0	75	536.93
34	37B	RainBarrel	460.9	0	0	0	75	535.89
35	194B	RainBarrel	464.82	0	0	0	75	539.82
36	193B	RainBarrel	462.14	0	0	0	75	537.14
37	191B	RainBarrel	459.65	0	0	0	75	534.64
38	32B	RainBarrel	464.37	0	0	0	75	539.37
39	94B	RainBarrel	456.36	0	0	0	75	531.34
40	49B	RainBarrel	457.4	0	0	0	75	532.4
41	92B	RainBarrel	462.28	0	0	0	75	537.28

Table 4.39 (Continued): LID operation summary- 11th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
42	393B	RainBarrel	464.48	0	0	0	75	539.48
43	196B	RainBarrel	455.69	0	0	0	75	530.68
44	197B	RainBarrel	464.91	0	0	0	75	539.91
45	198B	RainBarrel	461.43	0	0	0	75	536.42
46	30B	RainBarrel	459.48	0	0	0	75	534.48
47	31B	RainBarrel	464.48	0	0	0	75	539.48
48	56B	RainBarrel	461.61	0	0	0	75	536.61
49	24B	RainBarrel	458.12	0	0	0	75	533.11
50	35B	RainBarrel	463.13	0	0	0	75	538.13
51	43B	RainBarrel	464.59	0	0	0	75	539.59
52	9B	RainBarrel	462.5	0	0	0	75	537.5
53	81B	RainBarrel	464.53	0	0	0	75	539.53
54	82B	RainBarrel	464.54	0	0	0	75	539.54
55	80B	RainBarrel	462.32	0	0	0	75	537.32
56	90B	RainBarrel	458.44	0	0	0	75	533.43
57	86B	RainBarrel	462.63	0	0	0	75	537.63
58	87B	RainBarrel	461.94	0	0	0	75	536.94
59	70B	RainBarrel	463.59	0	0	0	75	538.59
60	84B	RainBarrel	456.01	0	0	0	75	531.01
61	69B	RainBarrel	464.37	0	0	0	75	539.37
62	63B	RainBarrel	461.71	0	0	0	75	536.71
63	62B	RainBarrel	460.01	0	0	0	75	535
64	57B	RainBarrel	463.92	0	0	0	75	538.92
65	192B	RainBarrel	453.32	0	0	0	75	528.31
66	48B	RainBarrel	464.76	0	0	0	75	539.76
67	47B	RainBarrel	464.34	0	0	0	75	539.34
68	45B	RainBarrel	458.24	0	0	0	75	533.23
69	22B	RainBarrel	456.87	0	0	0	75	531.87
70	21B	RainBarrel	464.21	0	0	0	75	539.21
71	20B	RainBarrel	464.2	0	0	0	75	539.2
72	23B	RainBarrel	456.79	0	0	0	75	531.78
73	65B	RainBarrel	460.18	0	0	0	75	535.18
74	59B	RainBarrel	430.48	0	0	0	75	505.44
75	83B	RainBarrel	463.03	0	0	0	75	538.03
76	97B	RainBarrel	462.9	0	0	0	75	537.9
77	78B	RainBarrel	455.11	0	0	0	75	530.11
78	74B	RainBarrel	454.72	0	0	0	75	529.71

Table 4.39 (Continued): LID operation summary- 11th scenario.

No.	Subcatchment	LID Control	Total Inflow mm	Infil Loss mm	Surface Outflow mm	Drain Outflow mm	Initial Storage mm	Final Storage mm
79	450B	RainBarrel	459.83	0	0	0	75	534.83
80	54B	RainBarrel	464.8	0	0	0	75	539.8
81	40B	RainBarrel	449.11	0	0	0	75	524.11
82	42B	RainBarrel	461.76	0	0	0	75	536.76
83	38B	RainBarrel	462.25	0	0	0	75	537.24
84	13B	RainBarrel	464.23	0	0	0	75	539.23
85	15B	RainBarrel	459.25	0	0	0	75	534.24
86	11B	RainBarrel	462.02	0	0	0	75	537.02
87	14B	RainBarrel	455.12	0	0	0	75	530.12
88	79B	RainBarrel	463.93	0	0	0	75	538.93
89	67B	RainBarrel	459.8	0	0	0	75	534.8
90	66B	RainBarrel	459.82	0	0	0	75	534.81
91	301B	RainBarrel	70.23	0	0	0	75	145.23
92	99B	RainBarrel	452.9	0	0	0	75	527.89
93	26B	RainBarrel	464.08	0	0	0	75	539.08
94	27B	RainBarrel	464.04	0	0	0	75	539.04
95	447B	RainBarrel	454.61	0	0	0	75	529.6
96	101B	RainBarrel	457.52	0	0	0	75	532.51
97	64B	RainBarrel	465.06	0	0	0	75	540.06
98	88B	RainBarrel	456.6	0	0	0	75	531.59
99	89B	RainBarrel	458.92	0	0	0	75	533.91
100	44B	RainBarrel	462.16	0	0	0	75	537.16
101	1B	RainBarrel	466.14	0	0	0	75	541.14

Table 4.40 : Instantaneous discharge time series of drainage system- 11th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
0:15:00	43.26	0
0:30:00	0	0
0:45:00	0	0
1:00:00	42.66	0
1:15:00	0	0
1:30:00	0	0
1:45:00	0	0
2:00:00	31.74	0
2:15:00	0	0.05
2:30:00	0	0.01

Table 4.40 (Continued): Instantaneous discharge time series of drainage system- 11th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
2:45:00	0	0.01
3:00:00	23.34	0.01
3:15:00	0	0.07
3:30:00	0	0.06
3:45:00	0	0.06
4:00:00	0	0.06
4:15:00	0	0.06
4:30:00	0	0.05
4:45:00	0	0.05
5:00:00	0	0.05
5:15:00	0	0.05
5:30:00	0	0.05
5:45:00	0	0.05
6:00:00	39.6	0.05
6:15:00	0	0.18
6:30:00	0	0.1
6:45:00	0	0.07
7:00:00	0	0.06
7:15:00	0	0.06
7:30:00	0	0.06
7:45:00	0	0.05
8:00:00	0	0.05
8:15:00	0	0.05
8:30:00	0	0.05
8:45:00	0	0.04
9:00:00	0	0.04
9:15:00	0	0.04
9:30:00	0	0.04
9:45:00	0	0.04
10:00:00	0	0.04
10:15:00	0	0.03
10:30:00	0	0.03
10:45:00	0	0.03
11:00:00	0	0.03
11:15:00	0	0.03
11:30:00	0	0.03
11:45:00	0	0.03

Table 4.40 (Continued): Instantaneous discharge time series of drainage system- 11th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
12:00:00	30	0.03
12:15:00	0	0.11
12:30:00	0	0.08
12:45:00	0	0.07
13:00:00	0	0.06
13:15:00	0	0.06
13:30:00	0	0.06
13:45:00	0	0.06
14:00:00	0	0.06
14:15:00	0	0.05
14:30:00	0	0.05
14:45:00	0	0.05
15:00:00	0	0.05
15:15:00	0	0.05
15:30:00	0	0.05
15:45:00	0	0.05
16:00:00	0	0.05
16:15:00	0	0.04
16:30:00	0	0.04
16:45:00	0	0.04
17:00:00	0	0.04
17:15:00	0	0.04
17:30:00	0	0.04
17:45:00	0	0.04
18:00:00	0	0.04
18:15:00	0	0.04
18:30:00	0	0.04
18:45:00	0	0.04
19:00:00	0	0.04
19:15:00	0	0.03
19:30:00	0	0.03
19:45:00	0	0.03
20:00:00	0	0.03
20:15:00	0	0.03
20:30:00	0	0.03
20:45:00	0	0.03
21:00:00	0	0.03
21:15:00	0	0.03

Table 4.40 (Continued): Instantaneous discharge time series of drainage system- 11th scenario.

Elapsed Time	Precipitation (mm/hr)	Runoff (CMS)
21:30:00	0	0.03
21:45:00	0	0.03
22:00:00	0	0.03
22:15:00	0	0.03
22:30:00	0	0.03
22:45:00	0	0.03
23:00:00	0	0.03
23:15:00	0	0.03
23:30:00	0	0.03
23:45:00	0	0.03
0:00:00	0	0.03

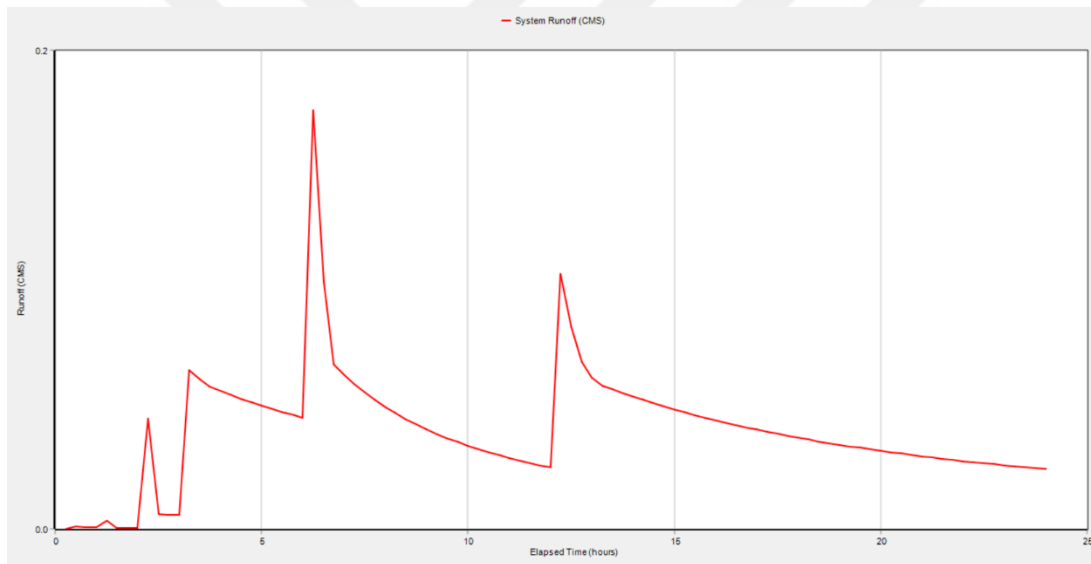


Figure 4.60 : 10 year return period hydrograph- 11th scenario.

4.3 Results Comparison and Conclusion

Hydrographs obtained from 11 scenarios (as defined in Table 4.10) simulation for Bastam city drainage system are shown through several Figures. In Figure 4.61 Hydrographs of 1st set of LID-included scenarios are compared to each other and non-LID scenario, Same is done to 2nd set of LID-included scenarios in Figure 4.62. Hydrographs of all 11 scenarios are shown in Figure 4.63. In considered 24-hour storm event, graph lines are densely distributed and since runoff amounts are almost the same and close to zero after 18th hour, graphs are shown for the elapsed time interval of 0

~ 18 hours in order to have clearer visualization. Table 4.41 displays peak flow as well as flow volume of drainage system for all the scenarios. Each of Figures 4.64 through 4.68 depicts 3 hydrographs for any LID practice, one of them is for the LID scenario occupying 5% of subcatchments area, one is for occupying 10% of subcatchments area, and one is for Non-LID scenario. As it is shown in Table 4.7 discharge from external watersheds is relatively a high value, so it is not logical and recommended to let it enter the city, because it would lead to bigger cross sections of conduits and also it would increase the flooding risk. It is recommended to control this external flow and transfer it to the out of the city by some engineering measure such as earth fill channels and dikes.

Table 4.41 : SWMM output results comparison for 11 scenarios.

Scenario	LID	Max. Flow CMS	Flow Vol. 10 ⁶ ltr	Max. Flow Ratio	Max. Flow Vol. Ratio
1st	Non-LID	1.18	16.13	100%	100%
2nd	Infiltration Trenches -5	1.09	8.44	92%	52%
3rd	Bio-Retention Cells-5	1.01	11.29	86%	70%
4th	Permeable Pavements-5	1.12	11.78	95%	73%
5th	Rain Gardens-5	0.99	12.1	84%	75%
6th	Rain Barrels-1	0.18	3.66	15%	23%
7th	Infiltration Trenches -10	0.17	3.54	14%	22%
8th	Bio-Retention Cells-10	1	6.96	85%	43%
9th	Permeable Pavements-10	1.08	7.73	92%	48%
10th	Rain Gardens-10	0.96	8.42	81%	52%
11th	Rain Barrels-10	0.17	3.66	14%	23%

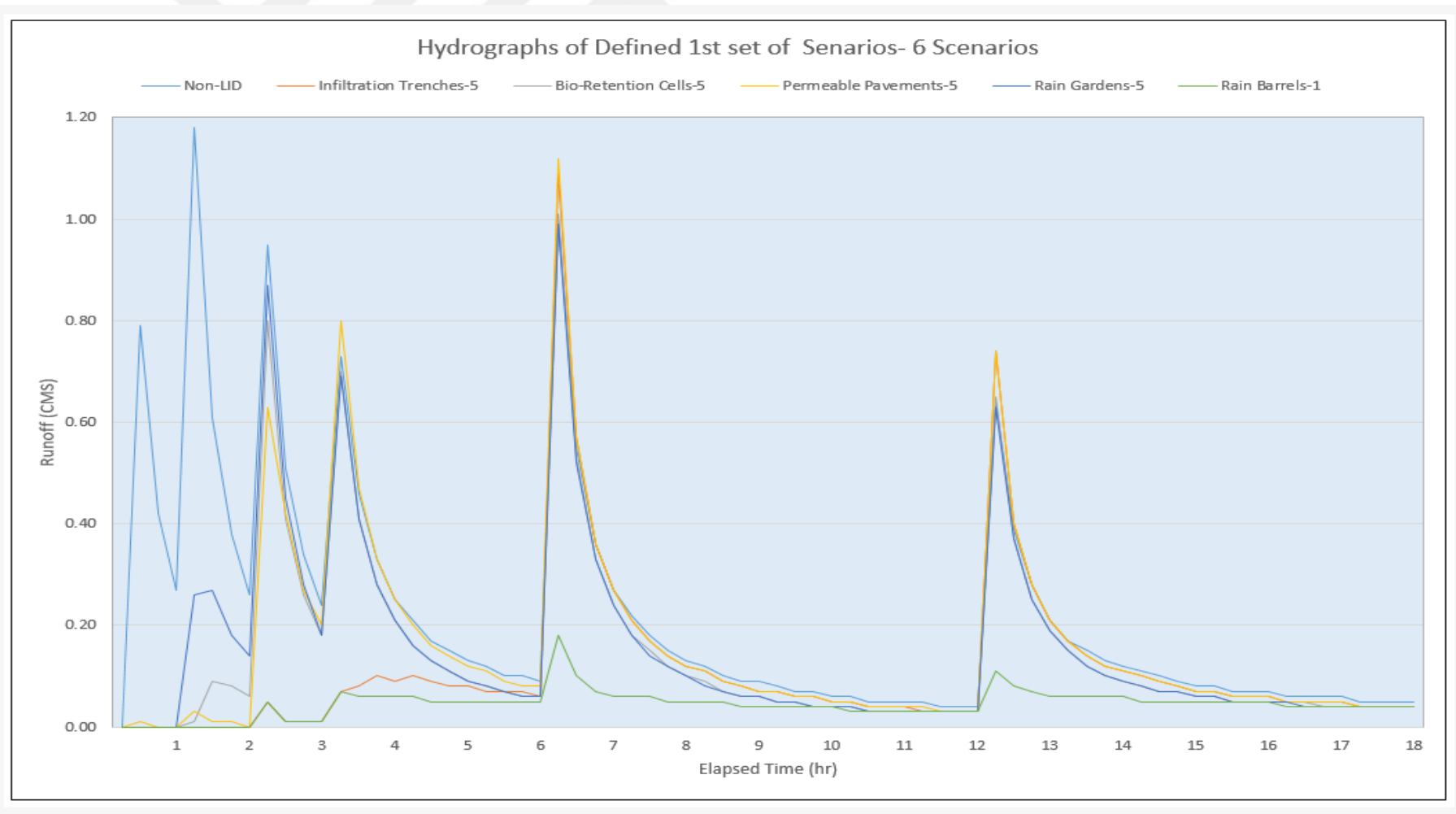


Figure 4.61 : Drainage system hydrographs of 1st set of LID-included scenarios.

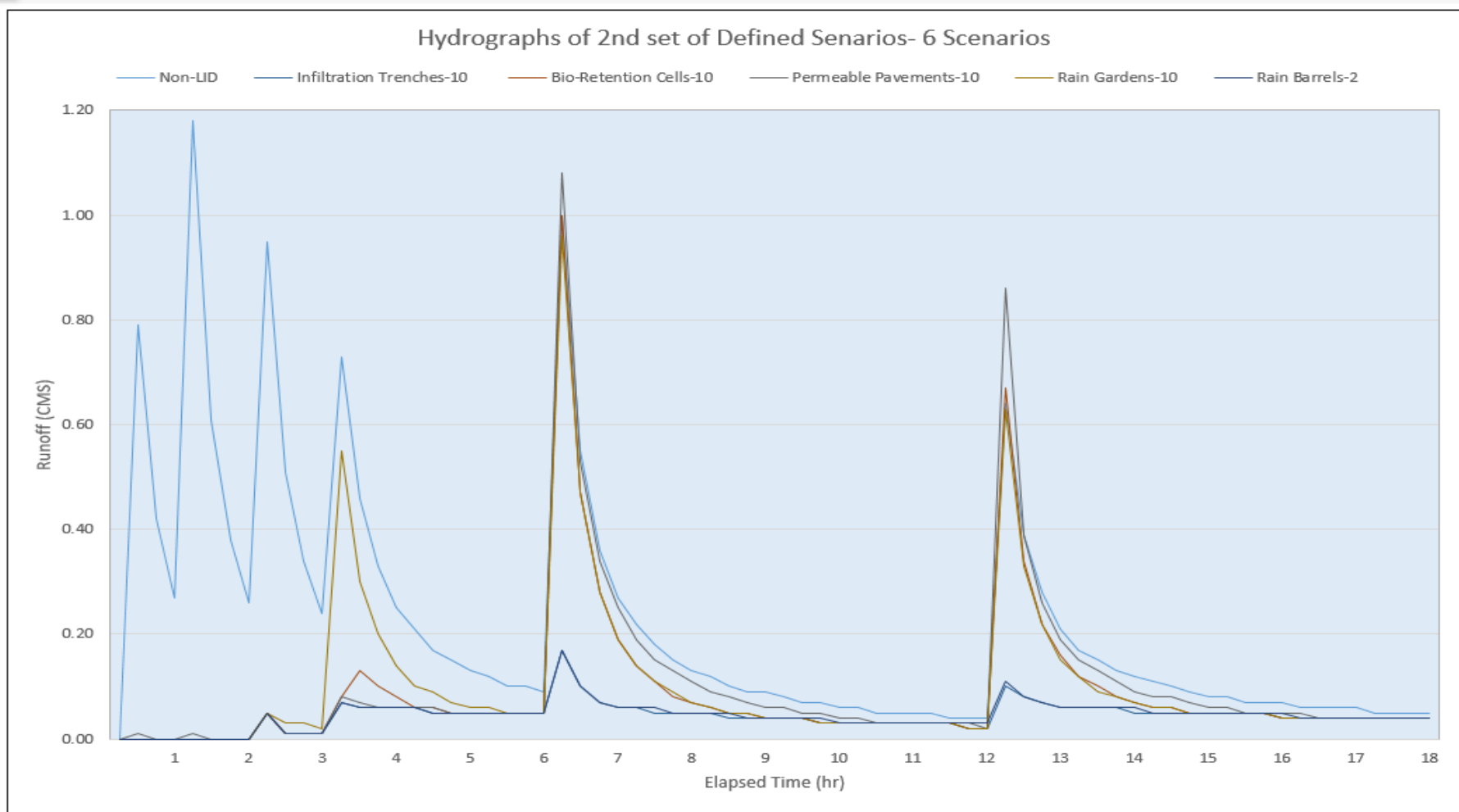


Figure 4.62 : Drainage system hydrographs of 2nd set of LID-included scenarios

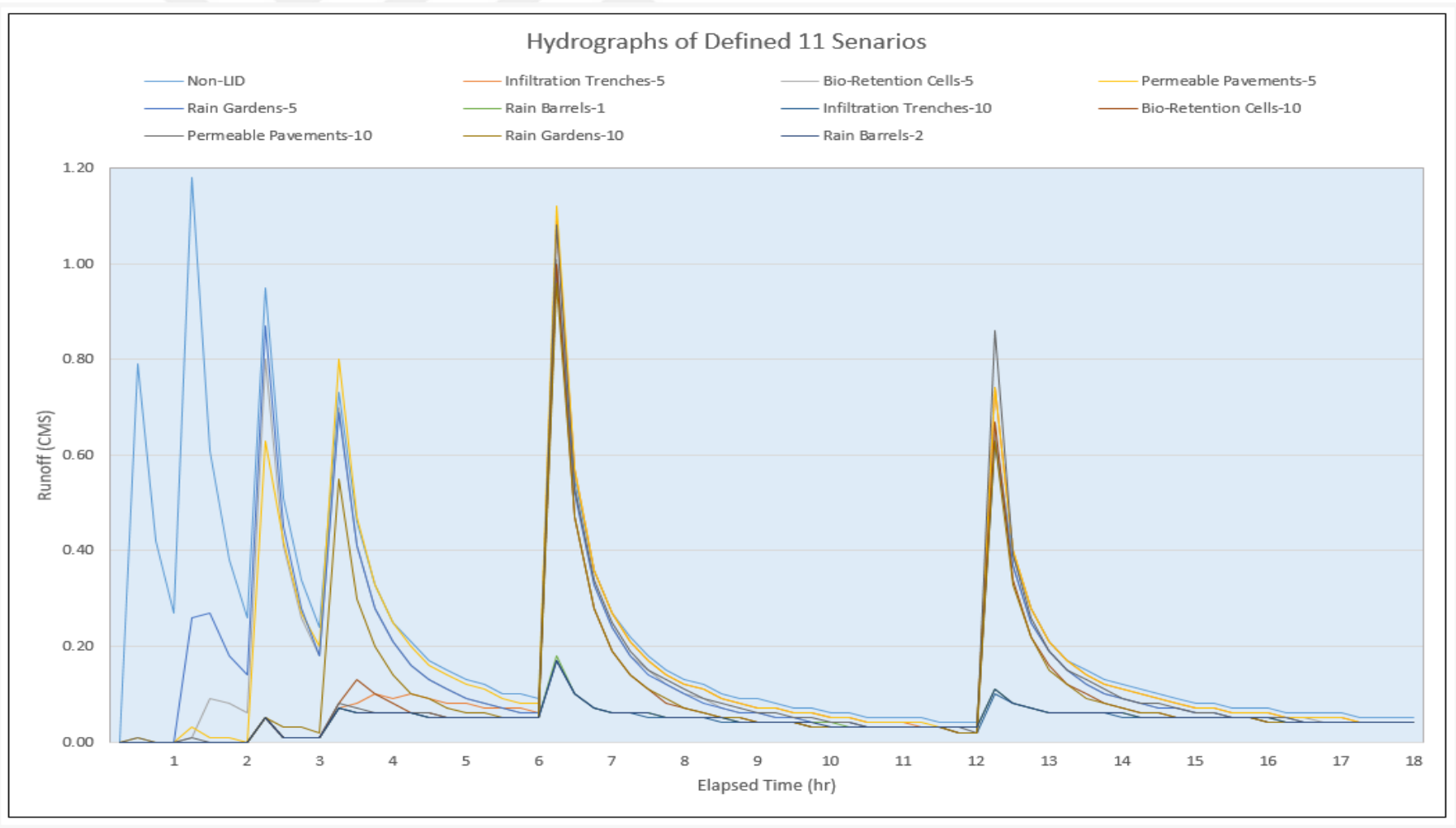


Figure 4.63 : Drainage system hydrographs of all 11 scenarios.

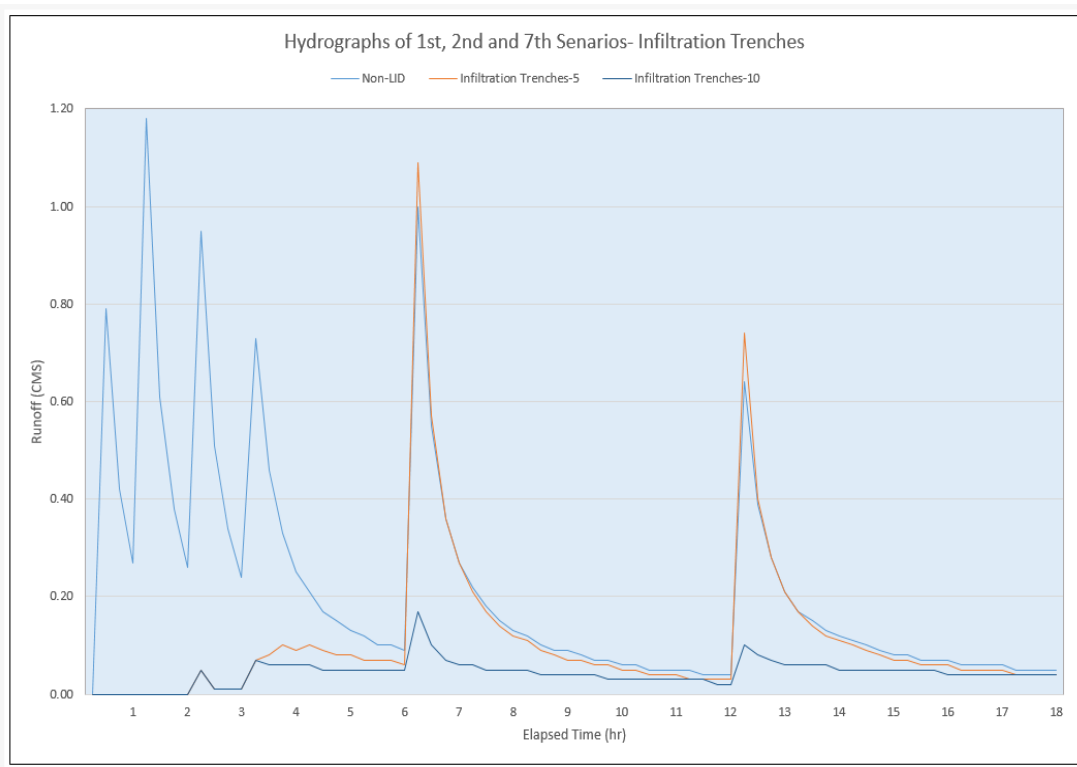


Figure 4.64 : Hydrographs of 1st, 2nd and 7th Scenarios- Infiltration Trenches.

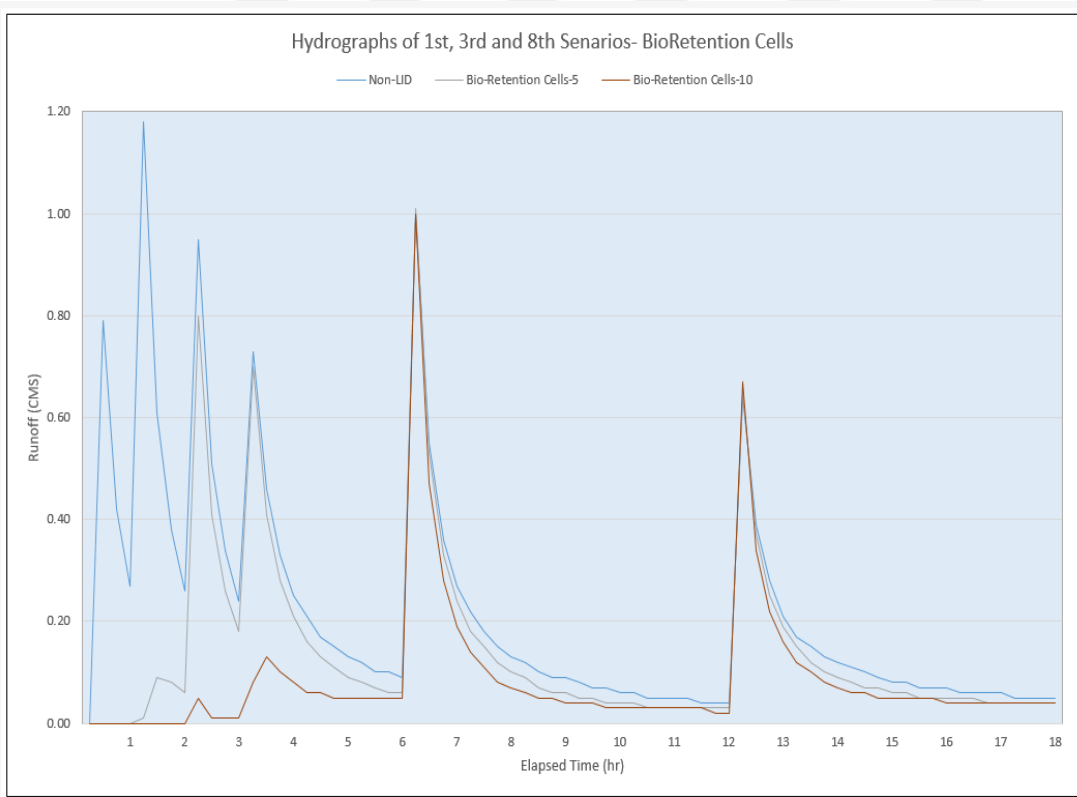


Figure 4.65 : Hydrographs of 1st, 3rd and 8th Scenarios- Bio-Retention Cells.

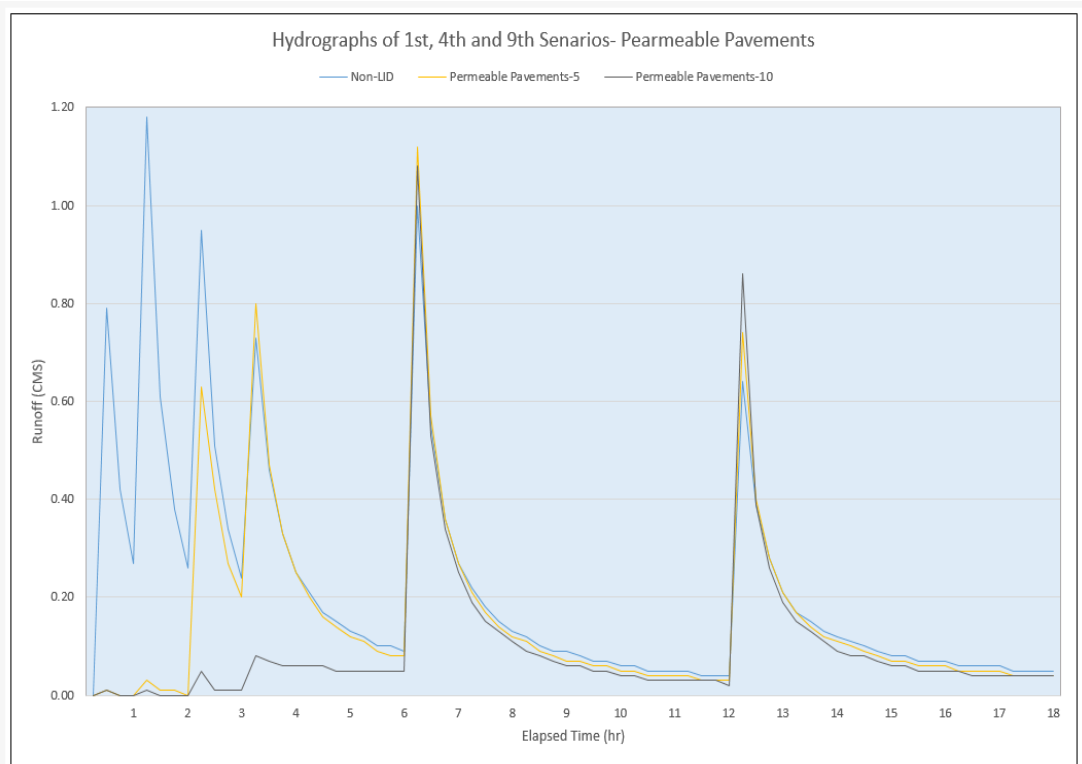


Figure 4.66 : Hydrographs of 1st, 4th and 9th Scenarios- Permeable Pavements.

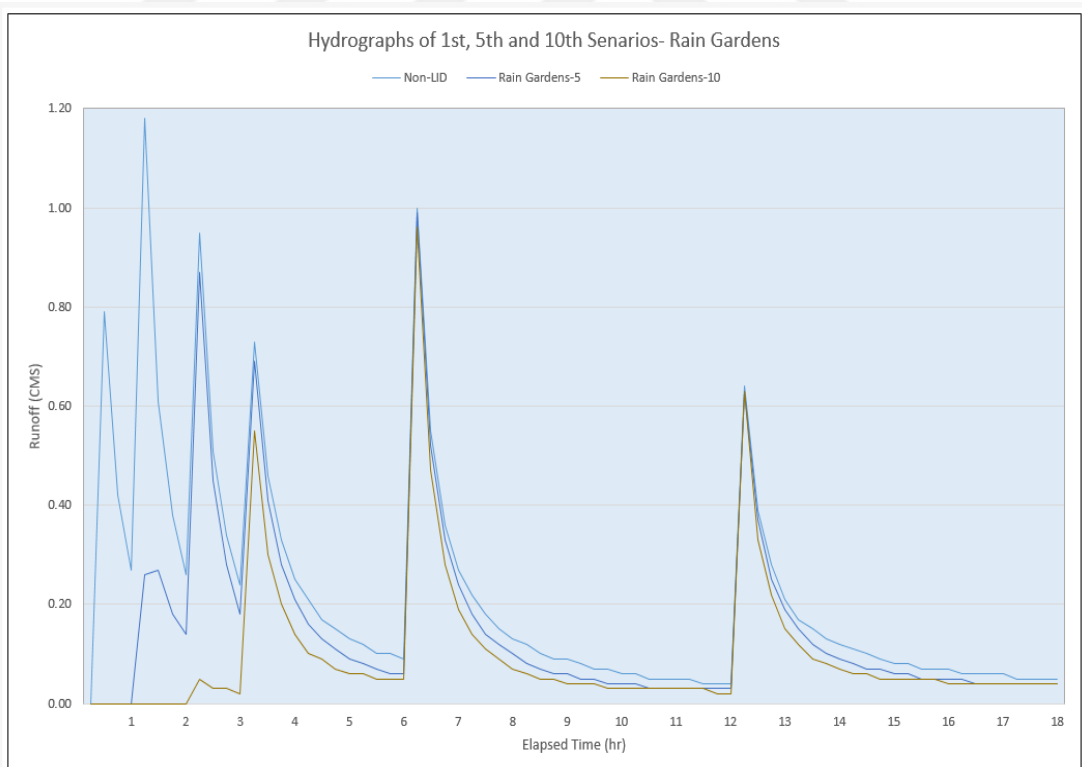


Figure 4.67 : Hydrographs of 1st, 5th and 10th Scenarios- Rain Gardens.

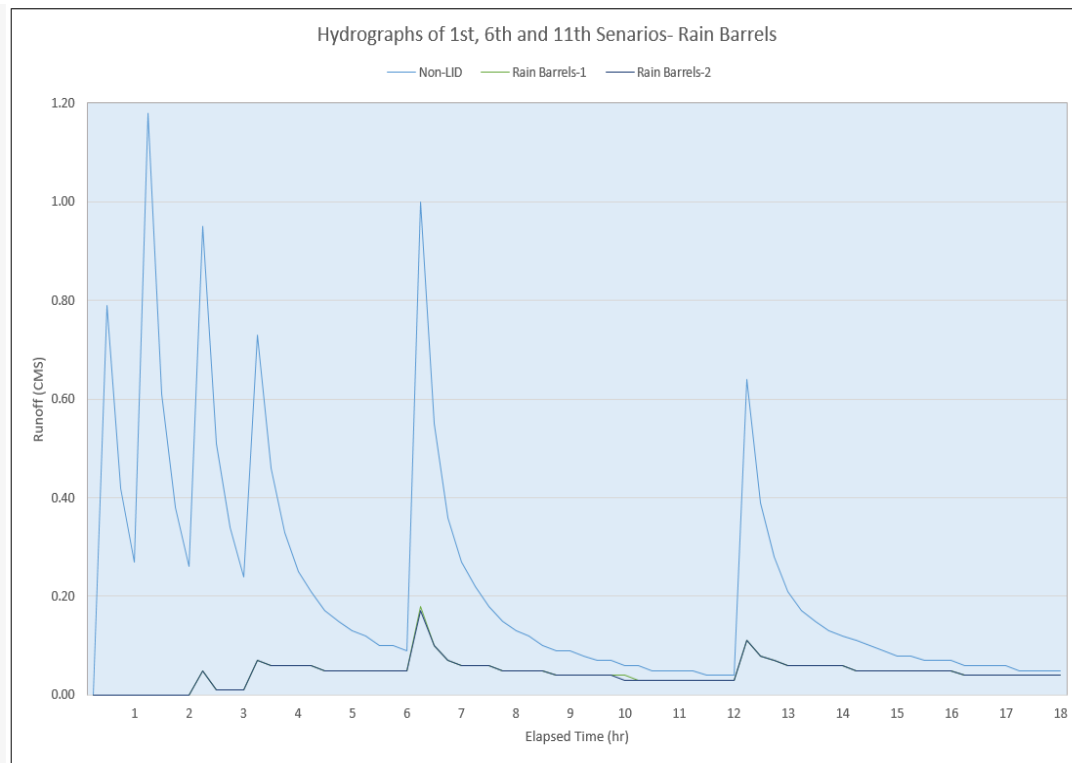


Figure 4.68 : Hydrographs of 1st, 6th and 11th Scenarios- Rain Barrels.

As stated earlier, we will compare the peak discharge amounts of each set of scenarios and also take in to account the total runoff volume values in our comparisons. We will contrast the values with each other and with non-LID scenario. We will also examine the effect of area occupancy of each LID practice.

According to Table 4.41 and Figure 4.61, in 1st set of LID included scenarios (LID coverage rate is 5% over subcatchments of area) rain Barrel LID reduces the peak discharge with a considerable amount i.e. 85% while other 4 LID's only 8% to 16%. Considering runoff volume, rain barrel LID reduces it by 77% whereas infiltration trenches LID is more efficient between other 4 with a reduction amount of 48%.

In 2nd set of LID included scenarios (LID coverage rate is 10% over subcatchments of area) rain Barrel and infiltration trenches LIDs both reduce the peak discharge with a considerable amount i.e. 86% while other 4 LID's only 8% to 19%. Considering runoff volume, interestingly rain Barrels and infiltration trenches LIDs reduce this value by 77% and 78%. Bio-retention cell LID is more efficient between other 3 with a reduction amount of 57%.

In this research, considering all the factors taken into account of the Bastam city case study, it is concluded that infiltration trenches-10%, rain barrels-2% and rain barrels-

1% are the most effective scenarios due to peak flow and flow volume reduction criteria by far comparing to other LID included scenarios. Additionally, it has been noticed that peak flow and flow volume reduction rates of the 3 top ranked scenarios are very close. It is also seen that after a certain percent of LID occupancy of the subcatchments, increasing the LID coverage does not have a substantial positive effect on peak flow and flow volume reduction in Rain Barrel LID scenario as resulted hydrograph is almost identical for 1% and 2% LID practice coverage.

Table 4.42 sorts efficient scenarios due to criterion of peak discharge reduction value descending. The 2nd criterion here is flow volume reduction ratio for equal maximum flow reduction ratios.

Table 4.42 : Ranks of 11 developed scenarios.

Rank	Scenario	LID	Max. Flow CMS	Flow Vol. 10 ⁶ ltr	Max. Flow Reduction Ratio	Max. Flow Vol. Reduction Ratio
1	7th	Infiltration Trenches -10	0.17	3.54	86%	78%
2	11th	Rain Barrels-2	0.17	3.66	86%	77%
3	6th	Rain Barrels-1	0.18	3.66	85%	77%
4	10th	Rain Gardens-10	0.96	8.42	19%	48%
5	5th	Rain Gardens-5	0.99	12.1	16%	25%
6	8th	Bio-Retention Cells-10	1	6.96	15%	57%
7	3rd	Bio-Retention Cells-5	1.01	11.29	14%	30%
8	9th	Permeable Pavements-10	1.08	7.73	8%	52%
9	2nd	Infiltration Trenches -5	1.09	8.44	8%	48%
10	4th	Permeable Pavements-5	1.12	11.78	5%	27%
11	1st	Non-LID	1.18	16.13	0%	0%

From discharge reduction point of view Infiltration Trenches and Rain Barrels (7th and 11th scenarios) were discovered to be best LID practices according to Table 4.42. In this study, LID practices were modeled independently in each scenario. It is recommended to consider combinations of 2 or more LID practices in each scenario in next researches. It was seen that selecting optimal LID coverage percent is a crucial matter in practical LID applications, some studies could be done regarding to this matter. It is also recommended to use spatial analysis to optimally locate the LID

implementations. Quality control of runoff as another aspect of SWMM ca be studied in future researches.



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