ASSESSING THE POTENTIAL OF RAINWATER HARVESTING SYSTEM AT THE MIDDLE EAST TECHNICAL UNIVERSITY – NORTHERN CYPRUS CAMPUS

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SUSTAINABLE ENVIRONMENT AND ENERGY SYSTEMS
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RAYAAN HARB

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Approval of the Board of Graduate Programs

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ETHICAL DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

ASSESSING THE POTENTIAL OF RAINWATER HARVESTING SYSTEM AT THE MIDDLE EAST TECHNICAL UNIVERSITY – NORTHERN CYPRUS CAMPUS

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Rainwater harvesting system (RWHS), where runoff from roofs and impervious areas is collected and utilized, is a prominent solution to deal with water scarcity by conserving available water resources and the energy needed to deliver water to the water supply system. The impact of climate change on water resources can also be reduced by rainwater harvesting. RWH is becoming an important part of the sustainable water management around the world. The Eastern Mediterranean countries with semi-arid climate obtain low precipitation and high temperature. Therefore, applying RWHS will be very beneficial in these areas to provide non-potable uses such as irrigation and household use. This study investigates the potential of RWH in the METU-NCC. Two approaches for runoff calculation were compared, the traditional Soil Conservation Service (SCS) method and the Storm Water Management Model (SWMM) using monthly and hourly rainfall data from 1978 to 2009. A RWHS was proposed to assess the potential of rainwater harvesting. The reservoir locations of the system were chosen with their relative irrigation areas and their volumes were calculated after computing the irrigation consumption of the campus. The study was not aimed at optimizing the system rather the system serves the purpose to show if there is a potential in RWH. The tank volumes were found to be 2300 m^3, 3500 m^3 and 1100 m^3 with efficiencies of 37.8%, 41.3% and 90.5% respectively and 41.2% of the campus irrigation was met. According to the findings, there is potential for collecting rainwater for irrigation purposes on the campus.

Keywords: Rainwater Harvesting System, Reservoir Volume, Rainfall, Northern Cyprus

ÖZ

ORTA DOĞU TEKNİK ÜNİVERSİTESİ - KUZEY KIBRIS KAMPUSU'NDA YAĞMURSUYU TOPLAMA SİSTEMİ POTANSİYELİNİN İNCELENMESİ

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Çatılardan ve geçirimsiz yüzeylerden akışa geçen yağmur suyunun toplanarak kullanılmasını sağlayan yağmursuyu toplama sistemleri, su kıtlığıyla mücadele kapsamında mevcut su kaynaklarının korunacak olmasından ve ayrıca içme suyu sağlayan sistemler için gerekli enerjin azaltılacak olmasından dolayı etkin çözüm sağlamaktadır. Yağmursuyu toplama sistemleri iklim değişikliğinin su kaynakları üzerindeki etkisinin azaltılmasına da katkı sağlamaktadır. Yağmursuyu toplama sistemleri dünya genelinde sürdürülebilir su yönetiminin önemli bir parçası olmaktadır. Yarı kurak iklime sahip Doğu Akdeniz ülkelerinde düşük yağışlar ve yüksek sıcaklıklar gözlenmektedir. Bu bölgelerde yağmur suyu toplama sistemlerinin uygulanmaya başlamasıyla depolanan su, kullanım ve sulama suyu ihtiyacına katkıda bulunacaktır. Bu çalışmada ODTÜ-KKK'de yağmursuyu toplama sistemi kurmak için yeterli potansiyel olup olmadığı araştırılmıştır. Yüzey akışının hesaplanmasında 1978-2009 yıllarına ait aylık ve günlük yağış değerleri kullanılarak geleneksel Amerikan Toprak Muhafaza Kurumunun yöntemi ve Yağmursuyu Yönetimi Modeli (Storm Water Management Model – SWMM) yazılımı kullanılmıştır. Yağmursuyu toplama depolarının konumu mevcut yağmursuyu drenaj hatlarına ve her bir depodan hangi yeşil alanın sulanacağına bakılarak karar verilmiştir. Bu çalışma kapsamında en uygun sistem ve depo hacmini bulmak için herhangi bir optimizasyon çalışması yapılmamıştır. Sadece böyle bir sistemin kurulması için yeterli potansiyel olup olmadığına bakılmıştır. Yapılan çalışma sonucunda kamusa yapılması önerilen 2300 m^3, 3500 m^3 ve 1100 m^3 hacimlerdeki depoların verimlilik oranları sırasıyla %37.8, %41.3 ve %90.5 olarak elde edilmiştir. Bu çalışmadan elde edilen sonuçlara göre sulama amaçlı kullanım için kampusa yağmursuyu toplama sisteminin kurulması için yeterli potansiyel olduğu ortaya çıkmıştır.

Anahtar Kelimeler: Yağmursuyu Toplama Sistemi; Depo Hacmi; Yağış; Kuzey Kıbrıs.

To My Beloved Parents,

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LIST OF SYMBOLS AND ABBREVIATIONS

A_i	Area of each surface in a sub-catchment
A_T	Total area of sub-catchment
AHP	Analytical Hierarchy Process
CAS	Chinese Academy of Sciences
CCC	Culture and Convention Center
CN	Curve Number
CN_N	Normalized Curve Number
CS	Cumulative Surplus
D	Water demand
DM	Demand Met
E	Water saving efficiency
EPA	Environmental Protection Agency
f	Actual rate of infiltration
f_p	Infiltration capacity
FAO	Food and Agriculture Organization of the United Nations
HWSD	Harmonized World Soil Database
i	Rate of precipitation
I_a	Initial abstraction
IIASA	International Institute for Applied Systems Analysis
IT	Information Technology
ISRIC	International Soil Reference and Information Centre
JRC	Joint Centre of the European Commission
METU-NCC	Middle East Technical University- Northern Cyprus Campus
P	Precipitation
R	Rainfall runoff
RWHS	Rainwater Harvesting System
S_D	Soil moisture deficit at time of runoff

SC	Storage Capacity
SCS	Soil Conservation Service
SP	Spillage
V	Volume of rainwater
WS	Water Storage

CHAPTER I

INTRODUCTION

1.1 Statement of the Problem

Cyprus is the third largest island in the Mediterranean Sea with an area of 9,251 km², the island experiences hot and dry summers while winters are mild (T.C. Başbakanlık Yayınları, 2000). The island witnesses a problem of water scarcity mainly due to low annual precipitation and unfavorable distribution of annual rainfall. Moreover, groundwater is being depleted and the quality of groundwater has reduced due to over-pumping of the aquifers leading to the entry of saltwater (Priscoli and Wolf, 2009). Therefore, an approach of supplying water from Turkey was adopted (Priscoli and Wolf, 2009). An approach to collect and utilize the rainwater that is discarded by urban drainage systems can provide an annual supply of water to sustain the irrigation demands in a specific area. The hydraulic system that applies this approach is called rainwater harvesting system (RWHS). Conventionally, urban rainwater management considered rainwater runoff as a waste to be guided away in a controlled manner. Collection of rainfall runoff grants an adequate supply of water for ample uses whether outdoor or indoor. Moreover, rainwater harvesting system reduces effects of urbanization such as flooding, erosion and pollution problems. This leads to the statement that rainwater is a resource that can be stored and used.

Rainwater harvesting is not a new concept, it was applied as early as 4500 B.C. by the inhabitants of southern Mesopotamia (present day Iraq) and by other inhabitants of different regions in the Middle East. The Romans later developed the primitive rainwater harvesting systems into more sophisticated systems in order to irrigate their lands (Sivanappan, 2006). Moreover, rainwater harvesting systems were also employed in ancient Persia, where large underground cisterns were deployed to store the surface runoff; remains of these cisterns are still visible (Pazwash, 2011). There are ample objectives of rainwater harvesting systems that include directing storm water runoff to natural depressions or reservoirs. Moreover, this water can be used for irrigation, supplying household water, supplying drinking water and injecting this water into the ground to replenish groundwater supply (Pazwash, 2011). Furthermore, in-situ rainwater harvesting systems may reduce the carbon footprint of water collection and the distribution cycle, as well as reducing the cost of water transportation (Zuberi et al., 2013).

1.2 Objective of the study

The main objective of this study is to assess the potential of rainwater harvesting on the campus of the Middle East Technical University - Northern Cyprus (METU-NCC) and to propose a rainwater harvesting system that can provide water for irrigation. Moreover, this system should easily be integrated with the existing system. Although this study focuses on the METU-NCC, the findings of this work may be implemented in different locations of Cyprus as well as countries with similar climate as Cyprus.

1.3 Organization of the thesis

The study commences with an introduction including a statement of the problem, objectives and purpose as well as the methods used in the study. The second chapter comprises of the background literature. Then, the third chapter describes the site of METU-NCC; the area, existing water consumption and the systems used to supply non-potable water. In the fourth chapter, the methodology of the study, and data used to calculate the monthly rainwater runoff and the water tank calculations will be presented. The fifth chapter discusses the results of the runoff and the water tank volumes as well as the location of the tanks and the integration of the rainwater harvesting system with the existing system. Finally, the paper is concluded including the future modifications to the rainwater harvesting system and the future research possibilities are addressed.

CHAPTER II
LITERATURE REVIEW

2.1 Rainwater harvesting systems

Rainwater harvesting is defined as collecting from catchment areas such as roofs or other urban structures to meet demand for domestic, industry, agriculture, and environmental purposes when water sources are becoming scarce or low quality (Aladenola and Adeboye, 2009; Hamid and Nordin, 2011; Worm and Hattum, 2006). This process has been used by ancient civilizations for agricultural irrigation and as a source of drinking water and this allowed those civilizations to flourish in semi-arid regions. Nowadays, RWHS are being used in water-limited locations, such as western U.S. regions and in some African countries in order to provide potable water, household water as well as for irrigation (Ling and Benham, 2014). Moreover, RWH is used as a method of urban flood control through redirecting the rainwater away from regions of low water drainage.

Collecting and using rainwater may decrease the use of municipal and groundwater. Since the rainwater collected from roofs is relatively cleaner than the rainwater collected from other impermeable surfaces such as roads, roofs are the largest impervious surface in residential areas to be used as catchment areas and allow the harvest of water that would otherwise enter into the storm-water drainage system. This may reduce storm-water runoff and the necessity for downstream storm-water management and treatment. Rainwater is clean as it falls, but the surface that this water is collected from contains the contaminants, therefore necessary treatment and filtration is needed before storing this water. Harvested rainwater is used mainly for irrigation and toilet flushing (Ling and Benham, 2014).

According to Hamid and Nordin (2011), there are six components of any RWHS:

I. Catchment area
II. Gutters and downspouts
III. Filtration system
IV. Storage system
V. Delivery system
VI. Treatment system

The quantity of rainwater that can be collected from a surface such as a roof is dependent on its size and texture. Moreover, the material of the catchment surface will affect the rainwater quality through the contaminants that might be present on the surface (Ling and Benham, 2014).

The gutters and downspouts will lead the rainwater from the catchment surfaces to the storage system. The purpose of the filtration system is to prevent the flow of debris from the surfaces to the pipes of the storage system. This can be done by installing screens that can accumulate the debris and may be cleaned manually. The size and material of the debris will dictate the size of the screens. Moreover, leaf guards can be installed to prevent the entry of leaves to the pipes. An important part of the filtration system is the first "flush" removal. The first flush of rainwater will contain material that has collected on the catchment surface since the last rainfall event, which may include dust, pollen, leaves, insects, bird feces, and other residues (Ling and Benham, 2014). It is recommended to divert from 0.2 mm to 2 mm of the runoff as first flush depending on the quality of water (Doyle, 2008).

The storage system is usually the largest investment aspect of the rainwater harvesting system. Therefore it requires careful analysis to provide the optimal storage capacity and structural durability at the lowest possible cost. Storage reservoirs are in two categories: surface and sub-surface storage tanks (Worm and Hattum, 2006). The water reservoir may be constructed from many different materials that include fiberglass, polypropylene, concrete or metal. Cisterns should be made to inhibit algal growth and they should be screened to prevent mosquito breeding. Furthermore, they should be cleaned regularly to ensure the cleanliness of the stored water (Ling and Benham, 2014).

In the systems intended for non-potable uses such as irrigation and toilet flushing, screens and first flush diverters are sufficient for treatment thereby reducing the cost of the system. On the other hand, potable use of the collected rainwater will require treatment and disinfection to remove contaminants and toxins in order to meet drinking water standards (Ling and Benham, 2014).

2.2 Studies about Rainwater Harvesting Systems

In a study conducted by Zuberi et al. (2013), the theoretical potential of rainfall at METU-NCC was studied to supply water for toilet flushing in the dormitories. It was found that a RWHS installed to collect rainwater from the roof areas of the three dormitories present would be sufficient for the flushing consumption of the second dormitory. 2831 m^3 of water can be collected annually with a reliability of 93%. This study showed that there is an opportunity for water scarce areas to utilize their limited resources in an efficient way.

A study was conducted by Dwivedi et al. (2013) to estimate the rooftop harvesting potential of the buildings as well as the planning and designing of the RWHS, the delivery system, and the groundwater recharge system. This study is performed for the Dhule town in India and a 50 mm/hr rainfall intensity was assumed for the modelling of this system. Moreover, the cost of different components of the system was studied and an annual equivalent capital cost was estimated. The unit cost of water appeared to be high in comparison to the market price, however, the environmental benefits of the groundwater recharging with good quality water validates such projects.

Hamid and Nordin (2011) selected a male residential college in Malaysia to perform their case study in order to determine the reliability of rainwater harvesting system installation. Malaysia receives about 3000 mm of rainfall annually. Moreover, this study illustrates that 90% reliability may be achieved based on the rainfall data and roof catchment area of the college and it was estimated that the system would save RM 10460 (3275.40 USD) annually on the water bill.

In another research conducted for Abeokuta, Nigeria, by Aladenola and Adeboye (2009) showed that rainwater harvesting systems can satisfy the monthly water consumption for toilet flushing and laundry except for the months from November till February. Abeokuta has a mean annual rainfall of 1156 mm. Moreover, provided there is sufficient rainfall, the excess rainwater stored during September and October is adequate to supply water during the dry months.

Furumai et al. (2008) conducted a study to explain the trend of promotion of rainwater storage and harvesting in Japan with an estimated average annual total precipitation of 640 billion m^3, after evapotranspiration leaving a potential of 410 billion

m^3 of water to be utilized for industry, household and agriculture. Moreover, this paper further emphasizes that there are different uses of this water. A new type of rainwater use, which is water supply to heated road surface, is highlighted. This was introduced to diminish the urban heat-island phenomena. Moreover, this paper introduces research on detailed land-cover classification of rooftops using satellite image and GIS data, this is beneficial for advanced urban runoff simulation and for estimation of potential of rainwater storage and harvesting facilities.

In a research conducted by Jothiprakash and Sath (2009) different RWH techniques were evaluated to identify the most appropriate method for a large-scale industrial area in Maharashtra, India, to satisfy its daily water demand. The industry is located in an area that receives an average annual rainfall of 2983 mm. Moreover, the volume of water to be stored was determined through mass balance method, Ripple diagram method, analytical method and sequent peak algorithm method. Then Analytical Hierarchy Process (AHP) was used to determine the most appropriate type of RWH technique and the required number of RWH structures. The results showed that AHP can be a useful tool to evaluate RWH methods and structures.

The Department of Water in Perth, Australia, conducted a study to evaluate the potential use of storm water in Perth. The storm water discharge was estimated as rainfall over the percentage of impervious surface that drains to the environment. The study indicated that a significant volume of water is generated in the region and could be harvested as a potable or non-potable water supply. The water can be pumped to infiltrate or injected into the superficial aquifer for storage (Department of Water, 2008).

In a study performed in Tehran, Iran by Mehrabadi and Motevalli (2012) on the operation of rooftop rainwater harvesting systems to reduce urban flood, have found that by collecting the rainfall runoff from residential rooftops, urban flood control can be attained. Tehran has an average annual rainfall of 238.9 mm, and by modelling different tank volumes to collect rooftop runoff, it was found that with increasing tank size and subsequently the volume of collected water, the urban flood frequency decreased.

Tobin et al. (2013) performed a study on the assessment of rainwater harvesting systems in the rural area of Edo State in Nigeria. They collected data using quantitative data collection methods such as a survey questionnaire, checklist and bacteriological assessment of water quality. The data was analyzed using the statistical package for social sciences and the results showed that the rooftop rainwater harvesting was used by over 80% of the households. The stored water was mainly utilized for personal hygiene purposes. The water samples tested showed an unacceptable levels of coliforms and E. coli bacteria.

Nafisah and Matsushita (2009) conducted a comparative study on the metropolis rainwater harvesting practices Sumida-Ku in Tokyo, Japan and Selangor, Malaysia. The paper states that the rainwater harvesting systems in Tokyo are well developed and this technique has started few decades ago, while in Malaysia they are behind in implementing the rainwater harvesting systems. The paper discusses and compares the policy and planning, design and social issues attributed to the rainwater harvesting systems in Japan and Malaysia. Moreover, the aspects implemented in Japan that Malaysia should work on to improve and adopt are shown.

A research conducted by Grady and Younos (2008) analyzed the water and energy conservation of rainwater harvesting system on a single family house. They have analyzed and compared the efficiency of two water systems, a local groundwater and rainwater harvesting systems. This residence is located in Montgomery County, Virginia in the United States. The rainwater harvesting system collects water from the rooftop runoff and stores this water in an underground storage tank. The rainwater is utilized for outdoor and indoor purposes as well as for potable use. The rainwater harvesting system exhibited a supply of 84% of the water consumption of the household with an average annual rainfall of 987.6 mm. Moreover, the study showed that for this case the groundwater system was more efficient and cost-effective but both systems were more cost-effective and energy effective than extending a public water line to the residence.

A field study performed by Strand (2013) to show how rainwater harvesting systems in the urban areas of Colombo, Sri Lanka, can act as a solution for sustainable water management issue and that this system might lead to economic and environmental advances. The aim of this study was to find solutions to improve the water management in Sri Lanka. Moreover, the annual rainfall in Sri Lanka is between 2500 to 5800 mm in the south west region of the island and about 1250 mm in the other regions of the island. The rain often comes in short heavy bursts causing floods. Furthermore, the result of the field study showed that the economic and environmental benefits associated with rainwater harvesting systems are possible sustainable solutions to the water issues on the island. In addition, this study opts to illustrate the areas where the rainwater harvesting systems have the best potential with the highest impact.

A report prepared by the Maryland Department of the Environment provides a summary on the development and calibration of a watershed model for the Patapsco/Back River Watershed using the SWMM software. This report includes sections on the watershed properties, model structure, development and calibration. The report discusses the watershed from the hydrological and water quality perspectives. Two precipitation gauges were used and the simulation was performed from 1/1/1992 to 9/31/2001 and results showed the infiltration rate and runoffs in the basin as well as pollutant transport such as heavy metals in the watershed (Maryland Department of the Environment, 2002).

Nnaji and Mama (2014) conducted a study to assess the potential for rainwater harvesting in Nigeria to focus on flood mitigation and domestic water supply. This work was done by using 26 locations in the major ecological zones of Nigeria and classifying residential buildings into different classes with different amounts of water consumption. A water balance approach was utilized for each class to evaluate the fraction of water demand that can be satisfied by the rainwater and so defining the minimum water storage capacity to be used. Results illustrated that for the reliability of system was over 80 % for the rainforest and guinea savanna zone. Monthly precipitation data between 17 and 30 years were used for each location and the average coefficient of variation of this was calculated and the results showed that the rainwater harvesting potential was a power function of rainfall coefficient of variation.

Zura, a village in India has scarce water resources that are under threat due to droughts, increasing ground water salinity and groundwater over-exploitation. A study was conducted as an attempt to assess the potential of rainwater harvesting in this village with an average annual rainfall of 332 mm. The results found in this research is that a decentralized management strategy of the rainwater is greatly needed in order to make the people self-dependent in obtaining their drinking water requirements (Tripathi and Pandey, 2005).

Another study in Kanai, Mali, was performed to determine the rate of water consumption and current water sources in order to estimate the volume of rainwater that can be collected using questionnaires administered to households. Questions related to the socio-economic state of households, source of water, methods of rainwater harvesting and purpose of use of the water were asked in the questionnaires. A survey suggested that more than half of the households depend on sources that are susceptible to drought while only 3 % of them utilize rainwater. The study area has an average annual rainfall of 1064 mm and the amount could not satisfy the water consumption if the present techniques are not improved by increasing the involvement of the villagers (Lekwot et al., 2012).

Ward et al. (2010) evaluated the design of two different rainwater harvesting systems using an advanced continuous simulation model. The systems illustrated between 36% and 46% of the WC demand. Moreover, the simple tank design methods resulted in larger tank sizes compared to the simulation model. This has led to an over-sizing in the tanks installed. The catchment size, a parameter neglected in the simple method, was found to be important in tank sizing. Furthermore, a cost analysis was conducted and it was found that the rainwater harvesting systems are more feasible in large commercial buildings compared to smaller domestic systems.

Rahman et al. (2012) investigated the water savings potential of rainwater tanks installed in 10 houses in different locations in Sydney, Australia. Three different tank sizes were studied, 2 kL, 3 kL and 5 kL, using a water balance simulation model. The analysis was conducted on a daily time scale and the water saving, reliability and cost feasibility were observed. The findings of the study showed that the average annual water saving was correlated with the average annual rainfall, while the benefit cost ratios for the rainwater tanks were less than 1.00 without government support. The study noted that the 5 kL tank was a better option than the 2 kL and 3 kL tanks. The rainwater tanks should be supply water to the toilet, laundry and outdoor irrigation to attain the best financial outcome for the users. The results of this study propose that government authorities should maintain or increase the financial support for rainwater tanks.

Since the water balance of RWHS is dominated by the stochastic nature of precipitation. Unami et al. (2015) developed a mathematical model containing stochastic differential equations, with model parameters that can be recognized from observed data to explain the dynamics of RWHS for irrigation. Stochastic control problems were expressed and then solved to find the optimal irrigation approaches during the dry season. The same procedure may be inversely applied to design the system dimensions. The model parameters were identified with the observed data in an experimental micro RWHS in Japan and in the semi-arid savanna in Ghana. Finally, a real life RWHS that will be employed in the Jordan Rift Valley was discussed.

Imteaz et al. (2012) developed a simple spreadsheet based daily water balance model to assess the performance and design of rainwater tanks. Daily rainfall data, roof catchment area, rainfall loss factor, available storage volume, tank overflow and water demand were used in the analysis. Moreover, this model was used to design the optimum size of domestic rainwater reservoir in southwest Nigeria for the dry months. Two demand situations were evaluated, the first was toilet flushing only and the second was toilet flushing and laundry use. The results of this study were compared with results from earlier studies, which used monthly average rainfall data. It was found that the analysis using monthly average rainfall data over-estimates the rainwater tank volume. This study showed 100% reliability with a tank volume of 7 m^3 during low demand, however, during higher demand a larger tank volume of 10 m^3 was required to obtain 100% reliability. Furthermore, the large quantities of water was lost as overflow, with a tank size of 10 m^3, therefore, the collected rainwater could be used for other purposes if large tanks were to be installed.

Imteaz et al. (2011) conducted a study on the evaluation and design of rainwater tank for large roof areas in Melbourne, Australia, using daily rainfall data representing three different climatic scenarios dry, average and wet years. The average annual rainfall in Melbourne is 650 mm. A spreadsheet-based daily water balance model was developed considering the daily rainfall data, the roof areas, the rainfall loss factor, the available storage volume, the tank overflow and the irrigation demand. Two underground rainwater tanks were considered, 185 m^3 and 110 m^3. Using the model, the reliability of each tank under different climatic regimes was examined. The results showed that both the tanks were reliable in wet and average years but less effective during the dry years. A payback period analysis showed that the total construction cost of the tanks can be recovered within 15 to 21 years taking into account the tank size, climatic conditions and future water price.

Moreover, a correlation between the water price increase rates and payback periods was developed. The study emphasizes the importance of optimization and cost analysis for large rainwater tanks in order to maximize the benefits.

Al-Ansari et al. (2012) conducted a study on the Sinjar area of northwest Iraq, with an average annual rainfall of 320 mm, by applying RWH modeling methods for agricultural purposes. Linear Programming optimization and Watershed Modeling System methods were used to increase the irrigated area. The methods employed demonstrated to be effective for solving large-scale water demand issues with multiple parameters. Two scenarios were studied, the first scenario was that each reservoir operated as an individual unit while, the second was that all reservoirs in the basin operated as one system. The two scenarios illustrated positive results but the second scenario provided better results than the first.

The utilization of non-dimensional parameters was proposed in a study conducted by Palla et al. (2011) in order to investigate the optimum performance of RWHS. A model was applied to evaluate the inflow, outflow and change in storage volume of a RWHS using a daily mass balance equation; the water-saving efficiency, over-flow ratio and detention time were determined and utilized to measure the system performance over a long-term simulation period. Different scenarios were examined to test the system performance, three precipitation regimes, three levels of water demand and ten storage capacity levels. The demand fraction and the storage fraction were the two non-dimensional parameters used to investigate the optimum sizing of the RWHS. The demand fraction was found to affect the water-saving efficiency and the overflow ratio, while the storage fraction affects the detention time which influences the water quality degradation in the system. A sensitivity analysis was conducted to examine the effect of the length of the time series climate records on the reliability of the selected performance indices. The results showed that 30 years of daily rainfall records are adequate for assessment of the system performance.

Since there is a great variation in average annual rainfall between the east and west of Greater Melbourne, ranging from 1050 mm in the east and 450 mm in the east, then there is a difference in rainwater tank size to satisfy similar demands and to provide the same supply reliability. Khastagir and Jayasuriya (2010) presented a novel procedure and a correlation for the optimal sizing of rainwater tanks taking into account the annual rainfall, the demand for rainwater, the catchment area and the supply reliability. The developed dimensionless curve reflects these variables and sets the path for developing a web-based interactive tool for choosing the optimum rainwater tank size.

Basinger et al. (2010) assessed the reliability of using harvested rainwater as a means of flushing toilets, irrigating gardens, and topping off air-conditioner in residential buildings in New York City by utilizing a new RWHS reliability model. The model can be is not case specific since it is based on a non-parametric rainfall generation method using a bootstrapped Markov chain. The RWHS reliability is determined for user-specified catchment area and tank volume ranges using precipitation generated using the stochastic procedure. The reliability with which backyard gardens and air conditioning units are supplied with rainwater exceeded 80% and 90%, respectively, while toilet flushing demand can be met with a 7–40% reliability. When the reliability curves developed were utilized to size RWHS to flush the low flow toilets, it was found that the rooftop runoff to the sewer system was reduced by about 28% over an average rainfall year, and the potable water demand was decreased by about 53%.

Abdulla and Al-Shareef (2009) evaluated the potential for potable water savings by using rainwater in residential areas of the twelve Jordanian districts and proposed methods to improve both quality and quantity of harvested rainwater. The rainfall varies from 600 mm to less than 200 mm annually over the twelve districts. The results showed that a maximum of 15.5 Mm^3/y of rainwater can be collected from the roofs of residential buildings assuming that all surfaces are utilized and all the rainfall on the surfaces is collected. The estimated collected rainwater is equivalent to 5.6% of the total domestic water supply of the year 2005. The potential for RWH varies between the districts, ranging from 0.023×10^6 m^3 to 6.45×10^6 m^3, while the estimated potential for potable water savings, ranged from 0.27% to 19.7%. Samples of harvested rainwater from residential roofs were analyzed; the measure of inorganic compounds matched the World Health Organization standards for drinking water, while fecal coliform, an important bacteriological parameter, exceeded the limits for drinking water.

Ghisi (2009) analyzed the effect of rainfall, roof area, number of residents, potable water demand and rainwater demand on rainwater tank sizing. Computer simulation was used for the analysis, considering daily rainfall data for three cities in the state of São Paulo, Brazil. The roof areas considered were 50, 100, 200 and 400 m^2, the potable water demands were 50, 100, 150, 200, 250 and 300 L per capita per day, while the rainwater demands were taken as a percentage of the potable water demand and the number of residents was considered to be two or four. The results showed a broad variation of rainwater tank sizes for each city and for each parameter. Hence, the conclusion of the study is that rainwater tank sizing for houses must be performed for each specific situation, taking into account the local rainfall, roof area, potable water demand, rainwater demand and number of residents.

Santos and Taveira-Pinto (2013) carried out a study to describe and analyze six different calculation methods for rainwater tank sizing. In order to apply these methods, two cases of RWHS were utilized, a dwelling and a public building. The results indicated that the methods based on the maximum rainwater demand and 100% efficiency conditions lead to an over-estimation of the rainwater storage tanks, thus need long payback periods. Moreover, daily simulation at 80% efficiency was the most suitable condition to size the RWHS, since it led to the best ratio of economic savings/installation cost. Furthermore, the Rippl method and the 80% efficiency condition lead to similar tank volumes.

Campisano and Modica (2012) presented a dimensionless methodology for the optimal design of domestic RWHS. The procedure was based on the results of daily water balance simulations conducted for 17 rainfall gauging stations in Sicily, Italy. The average annual rainfall is 720 mm concentrated in the months from October to March in Sicily. A novel dimensionless parameter to illustrate the intra-annual rainfall patterns was introduced and regional regressive models were developed to estimate the water savings and overflows from the RWHS. A cost-based method and the obtained regressive models were used to evaluate the optimal domestic RWH tank size. The results showed that the economic feasibility of large tanks decreases as rainfall decreases.

In another study Tam et al. (2010) investigated the cost effectiveness of RWHS in Australian residential areas. Seven cities are studied Gold Coast, Brisbane, Melbourne, Sydney, Adelaide, Perth and Canberra. The cost of installation and operation of the RWHS and the cost of alternative water sources, such as constructing additional dams and desalination plants were compared. The results indicated that using RWHS is an economic option for households in Gold Coast, Brisbane, and Sydney. Moreover, suitable tank sizes for various household areas were proposed.

Bocanerga-Martinez et al. (2014) proposed an optimization-based approach for designing domestic RWHS. The model considers the installation of RWH devices, pipes and reservoirs for the optimal collection, storage and distribution of the harvested rainwater. In addition, the model functions to satisfy the domestic water demands taking into consideration the reduction of the total annual cost of utilizing fresh water, the capital costs for the catchment areas, storages and pumps, and the cost of pumping, maintenance and treatment. This model was applied in Morelia, Mexico, under various scenarios. The results indicate the possibility to meet a high percentage of the water demands while reducing the cost of employing the system in the long-run.

In a study conducted by Sample and Liu (2014) decentralized RWHS for different land uses and locations in Virginia, USA were evaluated for water supply and runoff collection, using the Rainwater Analysis and Simulation Program (RASP) model. RASP simulates the RWHS using storage volume, roof area, irrigated area, and indoor non-potable demand as input data. A lifecycle cost-benefit model of the RWHS was developed. Near-optimal solutions were found for each case and location using a nonlinear metaheuristic algorithm. On the other hand, positive net benefits were not attained in any of the cases or locations. The net benefits were found to be sensitive to water and wastewater charges.

Villarreal and Dixon (2005) provided possibilities for applying a RWHS in Ringdansen, Sweden. Four scenarios were analyzed for using rainwater in a dual water supply system to supplement potable water. A computer model was generated to quantify the water saving potential of the RWHS. The performance of the RWHS was defined by the water saving efficiency. Rainwater tank sizes were computed according to the analysis. Assuming that all the roof area at Ringdansen is utilized and the rainwater is used only for

WC flushing, a 40 m^3 tank would be appropriate, saving more than 60% of the main water supply. Moreover, if a combination of WC flushing and laundry use is to be supplied with rainwater, a 40 m^3 tank would save about 30% of the water demand. On the other hand, an 80 m^3 rainwater tank with a catchment area of 20,000 m^2 would supply about 60% of the irrigation demand of the central area in each residential block during the summer months.

2.3 Rainfall Runoff Methods

The rainfall runoff is required to be calculated in order to design the suitable rainwater harvesting system. There are ample methods to compute the runoff. When rain falls on a certain area, some of the water is intercepted by vegetation, some will infiltrate the soil and some will evaporate before reaching the ground. The remaining amount of water will flow on the surface as runoff. Those losses in rainwater quantity that do not appear as runoff are called abstractions. Abstractions comprise of interception, surface depression storage (puddles), evaporation, transpiration (loss of water from plants) and infiltration. Unless there are prominent vegetation areas, evaporation and transpiration are considered to be negligible in design-storm conditions in urban regions. Rainfall runoff in urban areas is caused by the rainfall excess or effective rainfall. The rainfall excess is calculated by subtracting the abstraction from the total rainfall. Moreover, the rate of rainfall excess is the depth of runoff per unit time. Hence, the total volume of rainfall excess is the total volume of runoff (Akan and Houghtalen, 2003).

In urban areas, interception and infiltration are assumed to be the main forms of abstraction. Interception storage is defined as the amount of rainwater which is intercepted by the vegetation before reaching the ground, however, this water later evaporates into the atmosphere. This occurs at the start of rainfall events and after the maximum holding capacity of the plants is reached this form of abstraction does not affect the runoff. The amount of interception depends on the type and density of the vegetation and the amount of precipitation (Akan and Houghtalen, 2003). Furthermore, it is suggested that losses in the form of interception may be significant for long-term models but may be assumed negligible in heavy rainfalls during individual rainfall events (Viessman et al., 1989).

Infiltration refers to the entry of the rainwater through the ground surface filling the pores of the soil. This process accounts for most of the abstraction that occurs in a rainfall event. Infiltration is affected by the surface and sub-surface conditions, where surface characteristics affect the availability of water and the sub-surface characteristics influence the water infiltration. The maximum rate of water infiltration is the infiltration capacity. If the rate of rainfall is lower than the infiltration capacity then the rate of infiltration is equal to the rate of the rainfall (Akan and Houghtalen, 2003).

$$f = i \quad \text{if} \;\; f_p > i \tag{2.1}$$

$$f = f_p \;\text{if} \;\; f_p < i \tag{2.2}$$

where, f_p is the infiltration capacity; f is the actual rate of infiltration; i is the rate of precipitation.

Depression storage is the amount of rainwater trapped in puddles on the surface and is prevented to flow with the runoff. The fate of this water is evaporation on impervious layers while on pervious layers the water will infiltrate until the soil reaches saturation then it will evaporate into the atmosphere. It is complex to model the depression storage, however, depression storage is negligible compared to other forms of abstraction, and therefore it may be neglected (Akan and Houghtalen, 2003). The following methods are the general techniques used in the engineering practices to calculate the abstractions of rainwater in order to compute the rainfall runoff. These methods differ in parameters needed to be collected to calculate the runoff.

The Φ-index model is the simplest method to calculate rainfall runoff. The infiltration capacity is assumed to be a constant index Φ that is projected using measured rainfall-runoff data. This method is a simple estimation of the losses due to infiltration. The amount of precipitation lower than the value of the Φ-index is loss due to infiltration and the amount of precipitation above the value of the Φ-index is rainfall runoff (Akan and Houghtalen, 2003).

The Green and Ampt model is an algebraic method to compute infiltration. The parameters used in this model are physical and can be computed from the soil texture and land use. In order to further comprehend this model, assume a rain event on a pervious surface, and this surface has a uniform degree of saturation at the beginning of the rain event. The degree of saturation ranges from 0 which means dry to 1.0 which is fully saturated. Furthermore, as the rain infiltrates the surface, the degree of saturation increases, but the increase of saturation will be the greatest near the ground surface and will decrease with depth. The model claims that two different zones separated by a wetting front exist in the sub-surface. The zone closer to the ground surface is called the saturated zone while the dry zone is below the wetting front and it has unlimited depth and the saturation of the dry zone is the same as the initial saturation level. The saturated zone will increase in depth as more water infiltrates the soil. In dry soil or below the wetting front, the infiltration capacity is higher than in moist soil, but this capacity will diminish as the rainwater infiltrates the soil (Akan and Houghtalen, 2003).

The Horton method is an exponential decay function based on experimental data, expressing the infiltration capacity in terms of the initial and final infiltration capacity, rainfall time and an exponential decay constant. By fitting the equation to measured infiltration data one will be able to determine the initial and final infiltration capacity and the exponential decay constant (Akan and Houghtalen, 2003).

Horton method has a drawback, because the infiltration capacity only depends on time and the infiltrated water is not considered. If the rate of rainfall is smaller than the infiltration capacity between time 0 and t then the Horton method will cause an underestimation of the infiltration capacity. Therefore, Akan (1992) manipulated the Horton method equation to express the infiltration capacity as a function of the water infiltrated and this method was named the Modified Horton method (Akan and Houghtalen, 2003).

On the other hand, the Holtan method is based on the idea that the infiltration capacity is proportional to the soil's available water holding capacity. As the water infiltrates the soil this holding capacity decreases and so the infiltration capacity decreases accordingly. This method was developed for agricultural areas but it may be used for wooded areas and areas covered by grass in urban regions.

The Soil Conservation Service method (SCS) is often referred to as the runoff curve number method. This method accounts for interception, depression storage, evaporation and infiltration in the abstraction to calculate the rainfall runoff. In order to use this method, the soil in the region being studied should be classified according its permeability into four different groups (A, B, C and D). Group A includes the soil textures sand, loamy sand and sandy loam, while group B includes silt loam and loam textures. Group C consists of sandy clay loam, while clay loam, silty clay loam, sandy loam, silty clay and clay belong to group D. Group A soils have a low runoff potential and high infiltration rate, while group B soils have moderate infiltration rates. On the other hand, group C soils have low infiltration rates and high runoff potential, while group D soils have the highest runoff potential between the four different soil groups (Cronshey, 1986).

Table 2.1. The hydrologic soil group and the corresponding soil textures (Cronshey, 1986)

Hydrologic Soil Group	Soil Texture
A	Sand, loamy sand or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay or clay

The runoff curve number (CN) is a basin parameter that ranges from 0 to 100 and is dependent on the hydrologic soil group, the soil cover type, the land conditions, percentage of impervious areas in the basin, and the moisture level of the soil, as shown in Table 2.2. In the case of an area having sub-catchments with different CNs, then a weighted average should be computed to form a composite CN for the whole area. The SCS runoff expression is shown in Equation 4.4 (Akan and Houghtalen, 2003).

The initial abstraction consists of the water intercepted by vegetation, the water retained in the surface depressions, evaporation and infiltration before the runoff begins. Moreover, this equation can only be used if the precipitation is greater than the initial abstraction. In addition, this method may be used in order to compute the total rainfall runoff given the total precipitation and it may be used to determine the rate of rainfall runoff given the rainfall hyetograph (Akan and Houghtalen, 2003).

Table 2.2. Runoff Curve Numbers for urban land uses (Cronshey, 1986).

Cover description		**Curve numbers for hydrologic soil group**			
Cover type and hydrologic condition	**Average percent impervious area**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover >75%)		39	61	74	80
Impervious areas					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas					
Natural desert landscaping (pervious areas only)		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1 to 2 inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	98	79	84
2 acres	12	46	65	77	82

2.4 Water Storage Tanks

Storage tanks come in different materials and specifications. They may be placed above the ground level or underground, depending on the size and material of the tanks and the purpose of use of the water. Polyethylene, fiber glass and the modular system are ordered from the manufacturer and assembled on site, while concrete tanks are constructed on site. When designing water tanks, the hydrostatic pressure should be studied in order to construct a durable tank. Hydrostatic pressure force is a force exerted by a fluid on a solid surface in contact with the fluid. This force is normal to the solid force (Som and Biswas, 2004). The pressure due to the fluid is directly proportional to the depth of fluid, hence at the surface the pressure is zero while at the bottom it is expressed in Equation 2.3. Moreover, Figure 2.1 illustrates the previous statement (Young et al., 2011).

$$P = \gamma h \tag{2.3}$$

where, P is the pressure; γ is the specific weight of the fluid; h is the height of the tank

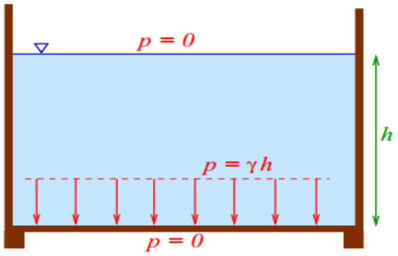


Figure 2.1. Pressure at the bottom of a tank (Young et al., 2011).

Applying this concept on the vertical walls of the tank leads to the principle of the pressure prism. The applied force to the interior surface of the tank increases with depth. Moreover, the resultant force acts on the centroid, which is $h/3$ over the base, as shown in Figure 2.2 (Young et al., 2011).

$$F_R = P * A \tag{2.4}$$

where, F_R is the resultant force; P is the pressure; A is the area in contact with the fluid

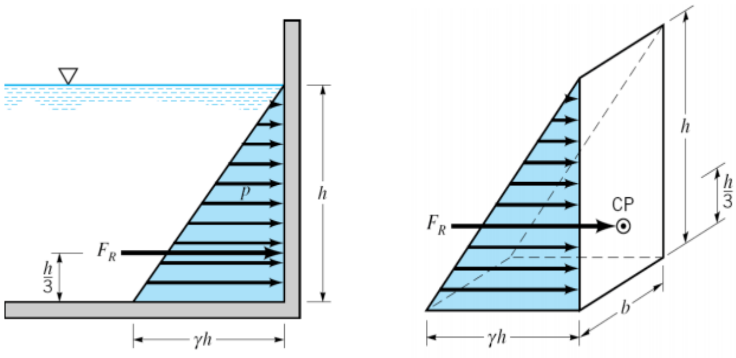


Figure 2.2. Pressure distribution and 3-D representation on a vertical wall respectively (Young et al., 2011).

When discussing water tank design, Ajagbe et al. (2012) deduced that with the increase of tank volume, the amount of material used for the structure increases. In addition, the quantity of material was verified at different volumes (10, 30, 90, 140 and 170 m^3) of the rectangular and cylindrical water tanks and it was found that the quantity of material used for the rectangular water tank is more than the cylindrical water tank with the same volumes. The material studied, consists of steel reinforcement, concrete, and formwork, all of these materials were found to be used more in the rectangular water tank design than the cylindrical water tank, as presented in Figure 2.3, 2.4, and 2.5 respectively (Ajagbe et al., 2012).

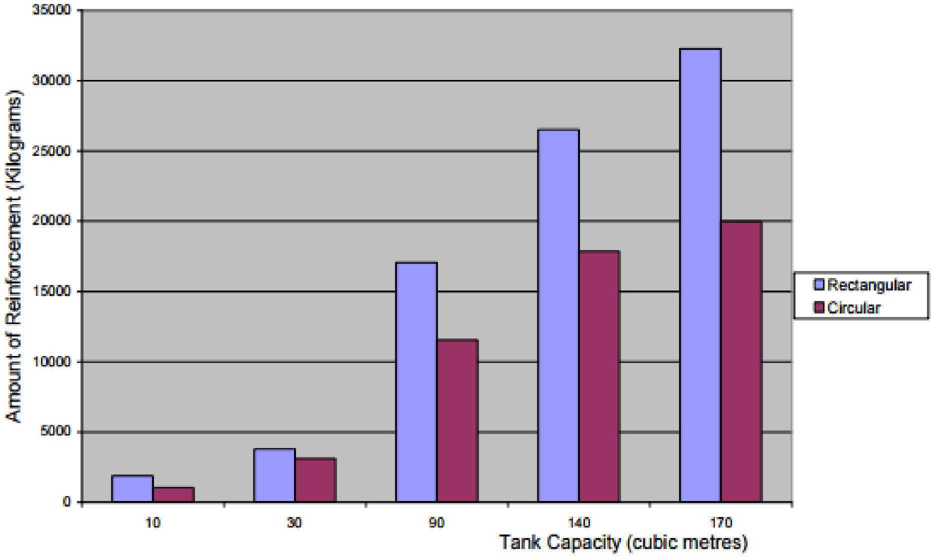


Figure 2.3. Amount of reinforcement against tank capacity (Ajagbe et al., 2012).

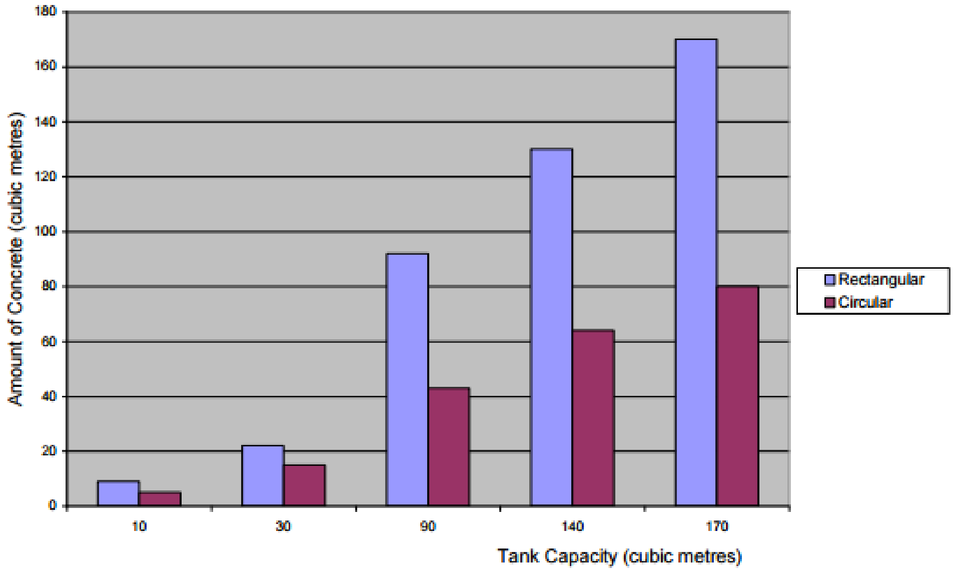


Figure 2.4. Amount of concrete against tank capacity (Ajagbe et al., 2012).

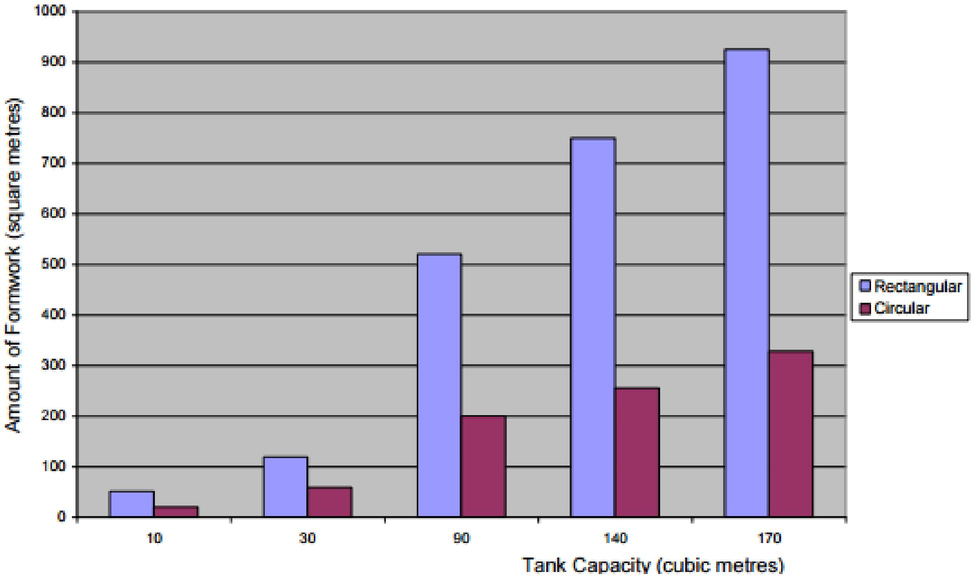


Figure 2.5. Amount of formwork against tank capacity (Ajagbe et al., 2012).

In another study performed Xiao et al. (2014) a rectangular concrete tank and a cylindrical concrete tank were modelled to assess the tensile stress on the walls of the different design of tanks. The tanks were constructed from the same concrete with equal volumes and the walls had the same thickness. The maximum tensile stress on the walls in the rectangular design was found to be 8 MPa, as shown in Figure 2.6, while the maximum tensile stress on the walls in the cylindrical design was found to be negligible when the tank is full of water as shown in Figure 2.7. The tensile stress in the rectangular tank was concentrated on the corner between the wall and the bottom of the tank. Therefore, the cylindrical tank can withstand higher hydraulic pressure than the rectangular tank leading to less deformation will occur in the cylindrical tank.

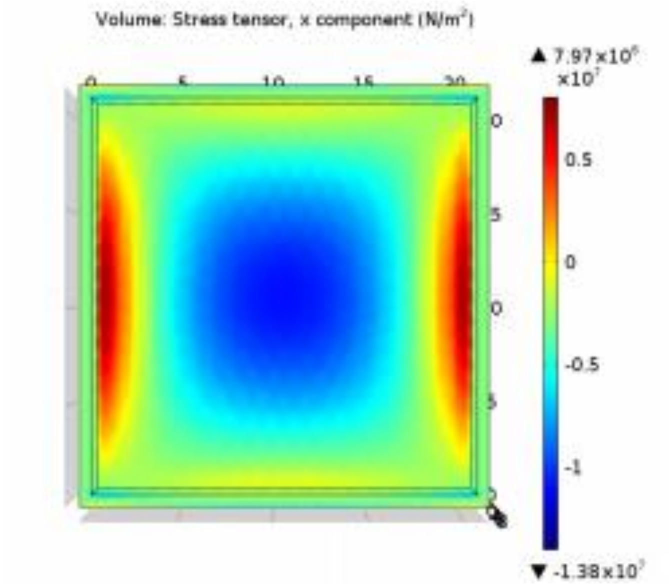


Figure 2.6. Tensile stress in the rectangular concrete tank (Xiao et al., 2014).

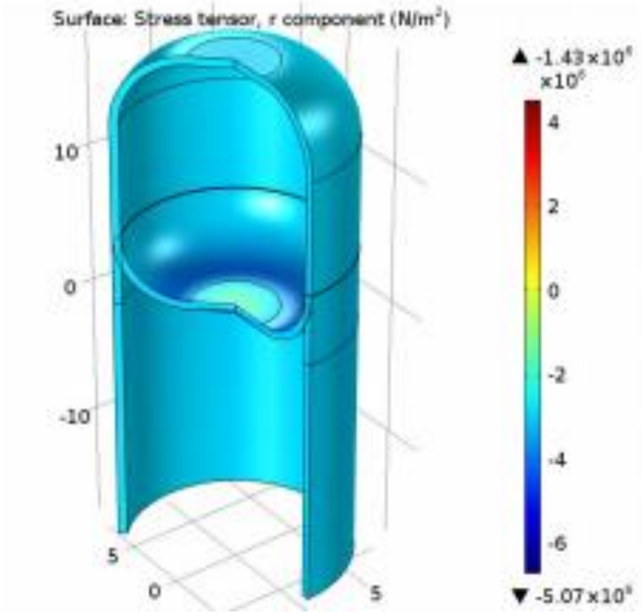


Figure 2.7. Tensile stress in the cylindrical configuration (Xiao et al., 2014)

Whether to place the tanks above-ground or underground is also another issue. This issue is mainly related to the size of tanks to be installed and the space available on the site (UNEP and CEHI, 2009). Moreover, each case has its own advantages and disadvantages shown in the Table 2.3. The two cases are suitable with different tank materials and sizes (UNEP and CEHI, 2009). Above-ground storage tanks must be UV and impact resistant, as well as opaque to prevent algal growth and they should be screened to prevent mosquito breeding (Hoffmann et al., 2012). On the other hand, underground storage tanks should be constructed to withstand certain loads, as well as having a manhole to facilitate cleaning, inspection and maintenance (Hoffmann et al., 2012). Moreover, if the RWHS is connected to a backup water supply, then it should have a back-flow prevention device in order to keep the rainwater separated from the regular supply (Hoffmann et al., 2012).

Table 2.3. The pros and cons of above-ground versus underground water tanks (UNEP and CEHI, 2009).

	Advantages	**Disadvantages**
Under-ground	• Surrounding ground lends structural support allowing lower wall thickness and lower installation costs. • Can form part of the building foundation. • Unobtrusive – require little or no space above ground; useful where large volume storage is required.	• For relatively small storage requirements, is relatively more expensive. • Water extraction is more problematic, requiring a pump. • Leaks or failures are difficult to detect; pose risk to building foundation failure if constructed on a slope. • Possible contamination of the tank from groundwater intrusion or floodwaters. • Possibility of undetected structural damage by tree roots; allows for entry of contaminants or vermin.
Above-ground	• Allows for easy inspection for cracks (masonry structures) or leakage. • Cheaper to install and maintain; particularly the case for small volume household supply needs. • Water extraction can be done by gravity with extraction by tap; allows for easy draining if needed. • Tank(s) can be raised above ground to increase water pressure.	• Requires space for installation, particularly if large storage volume is needed; case for commercial and industrial uses. • Masonry works exposed to deterioration from weathering. • Failure of elevated support structures can be dangerous. • Requires the construction of a solid foundation which may be costly.

Table 2.4. The advantages and disadvantages of different storage tank materials (Hoffmann et al., 2012).

Tank Material	**Advantages**	**Disadvantages**
Polyethylene	Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application.	Can be UV-degradable; must be painted or tinted for above-ground installation; pressure-proof for below-ground installation.
Modular Storage	Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive.	Longevity may be less than other materials; higher risk of puncturing of watertight membrane during construction.
Ferro-Concrete	Durable, immoveable, versatile; suitable for above or below ground installation; neutralizes acid rain.	Potential to crack and leak; expensive.
Cast in Place Concrete	Durable, immoveable, versatile; suitable for above or below ground installation; neutralizes acid rain.	Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils.
Stone or Concrete Block	Durable and immoveable; keeps water cool in summer months.	Difficult to maintain; expensive to build.

When constructing a RWHS, tank-sizing is an important step, in order to achieve optimal effectiveness of the storage tank (SOPAC, 2004). There are four methods mainly used to compute the minimum storage capacity. A rule-of-thumb is that 20% more than the computed storage capacity should be added to ensure air space above the stored water and dead storage at the bottom of the tank (SOPAC, 2004). There are ample methods of calculating the size of the water storage tanks depending on the intended use of the water and the period of time the water is to be stored in order to satisfy the demand.

2.4.1 Dry Period Demand Method

In this approach, the longest average period without rainfall for the specific geographic area is estimated; it is called the dry season. Then the average monthly demand is multiplied by the period in months of the dry season and the resulting volume is the minimum storage capacity. The tanks sized using this method are mainly aimed at supplying water for household use (SOPAC, 2004).

2.4.2 Simple Method

In the simple method, the average annual water consumption is found and the dry season is expressed in days and found as a ratio of the whole year (365 days). The ratio is multiplied by the annual consumption to find the minimum storage capacity of water. This method is mainly utilized for the calculation of water reservoirs aimed at supplying water for household use such as toilet flushing and washing (UNEP and CEHI, 2009).

2.4.3 Simple Tabular Method

This method is utilized in the tank sizing based on precipitation and water consumption variability over the course of a year. The tanks sized using the simple tabular method are mainly aimed for household use or irrigation purposes. There are four steps (UNEP and CEHI, 2009):

1. Obtain the monthly rainfall data of a year.
2. Estimate the volume of monthly runoff and volume of water harvested.
3. Obtain the monthly volume of water consumption of a year

4. Use the monthly volume of water harvested and consumed to calculate the minimum storage required. This data is assembled in a tabular form and changes to the cumulative volume harvested and stored, the cumulative consumption and the total amount stored in one month. The difference between the highest volume stored and the amount left in the tank at the end of the year is the minimum storage volume.

2.4.4 Graphical Method

The fourth method states that the monthly rainfall runoff and the monthly water consumption should be represented graphically. For more accurate assessment, daily or weekly rainfall data is required. This method is employed to compute the tank size for household or irrigation purposes. There are three main steps (Worm and Hattum, 2006):

1. Plot a bar graph for the mean monthly runoff and add a line for the average monthly water consumption.
2. Plot a graph of the cumulative monthly runoff and add a line showing the cumulative monthly water use.
3. In a month, the greatest difference between the cumulative monthly runoff and water use is the minimum storage capacity.

Moreover, the reliability of the system should be computed to figure out if the system is worth constructing or not. This is done by finding the Water Saving Efficiency, "E", which is a percentage measure of water conserved in relation to total demand. It is calculated by dividing the total volume of rainwater stored by the total demand. The water saving efficiency is expressed as follows (Ward et al., 2011),

$$E = \left(\frac{V}{D}\right) * 100 \tag{2.5}$$

where, E is the water saving efficiency; V is the rainwater stored; D is the water demand.

CHAPTER III

DESCRIPTION OF STUDY AREA

3.1 Overview of the Case Study

METU-NCC is located on the west of Northern Cyprus about 50 km west of Lefkosa (Nicosia) and 6 km north of Guzelyurt (Morphou), as shown in Figure 3.1. The campus is built on an area of 339 hectares and holds about 2500 people from students and staff (METU-NCC, 2014). Since every year the population living on campus is increasing, the energy and water consumption is also increasing accordingly.

At the moment, the university pumps water, for potable and non-potable use (cooking, toilets, washing and irrigation), from three wells in Guzelyurt and stores this water in a concrete reservoir with a capacity of 4000 m^3 near the EBI dormitory building. These wells are owned by the university and so the cost of pumping is the main cost for providing water for the campus. Water on Cyprus is a very precious commodity and water scarcity is a vital problem here (Maden, 2014). This has led to development constraints in North Cyprus as about 90% of the water supplies go to irrigation. As water is being pumped from wells above the safe yield capacity of the aquifer, seawater along the coast enters and contaminates the aquifer (Maden, 2014). Ergil (2000) identifies this problem in the Guzelyurt aquifer and Maden (2014) states that the saltwater intrusion in the Guzelyurt Basin has caused the quality of water to deteriorate. Maden (2014) states that over-pumping has forced the groundwater table to sink which resulted in saltwater intrusion (Maden, 2014). Moreover, there are other factors polluting the groundwater, such as, contamination by industries, pollution due to ore beds and discharging wastes into reception basins of water resources and into the sea. Therefore, groundwater is damaged in terms of quantity and quality (Maden, 2014). The decrease in groundwater pumping is expected to have a positive effect along with the project of transferring water from Turkey (Maden, 2014). Therefore, a system such as the rainwater harvesting will provide an additional source of water that may be used safely for irrigation and decrease the pressure on the aquifer in Guzelyurt.

The water consumption data acquired from the University administration showed that water used for irrigation was 99,066 m^3 in the year 2013 and the water consumption from the buildings had a total of 55475 m^3 during the months from January to June in 2013. This shows that a large amount of water is being pumped to the campus for irrigation in comparison to water utilized for household use. Rainwater harvesting will provide an adequate amount of water without the need for treatment and by that reducing the pressure caused by the campus on the groundwater in Guzelyurt.

A system that will store the rainwater and utilize it later should be connected to the rainwater drainage system. An operational drainage system exists on campus and so only connections between the drainage system and a storage system are needed.

Figure 3.1. Map of Cyprus (Doeleman, 2007).

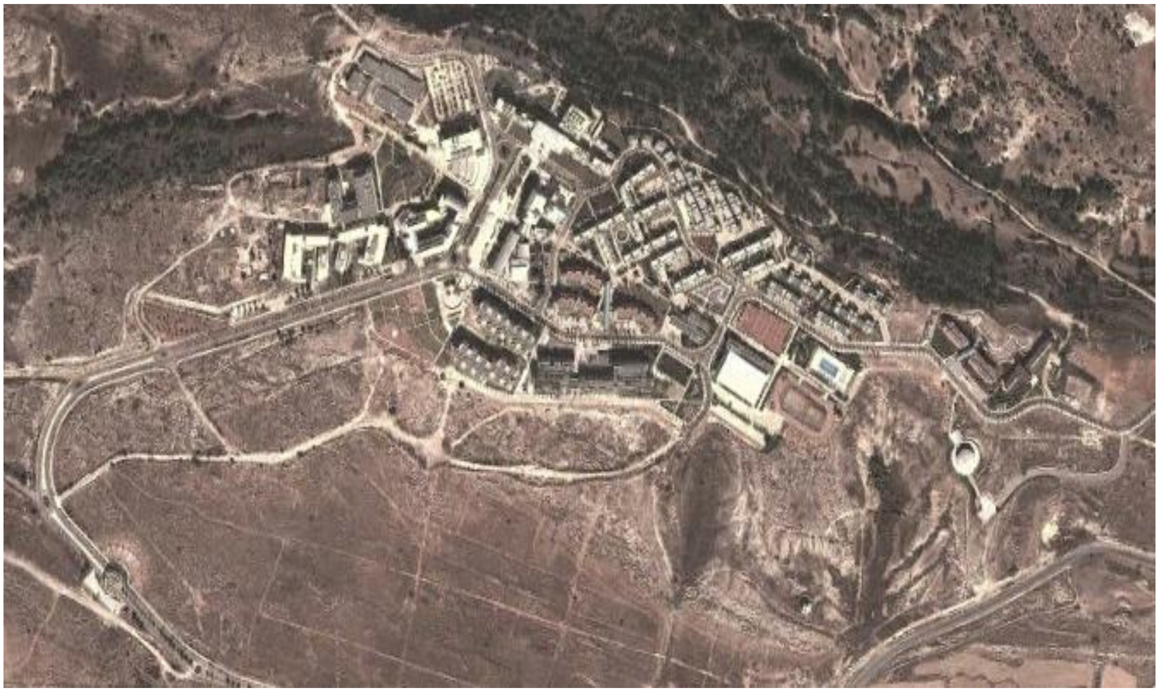


Figure 3.2. Top view of METU-NCC (Google Earth, 2014)

3.2 Description of the Site

There are two entrances for the campus, the A1 Entrance is located to the south of the campus at the bottom of the hill and the second entrance is located to the east of the campus; the town of Kalkanli is a walking distance from this gate. Moving along the road from the A1 Entrance, there are three Academic Blocks and the Preparatory School building situated to the left of the road. North of this complex, the Culture and Convention Center (CCC) and the Engineering Laboratories are located. The Administration building and IT building are directly east of the CCC, and going north of the Administration building, the Library is located. Going south from the Information Technology (IT) building one will find the Cafeteria building and further south the shopping area is located. On campus there are four dormitory complexes, Dorm 1 complex is located to the east of the shopping area buildings, while Dorm 2 complex is located to the south of the shopping area buildings, on the other hand, Dorm 3 complex is to the east of the Dorm 2 complex and to the south of the Dorm 1 complex. East of the Dorm 1 complex the Health Center is located. Directly south of the Health Center and east of the Dorm 3 complex the artificial turf football field is located. Going east from the Health Center one can find the Sports Center along with outdoor basketball and tennis courts consisting of rubber grounds, an outdoor swimming pool and a beach volleyball field surrounded by a running track. The staff residences are located in the area east of the IT building, north of the Dorm 1 complex and the Health Center and extending to the north of the Sports Center complex. Along the road east of the staff residences towards the east entrance of the campus the Guest House will be to the left of the road while the Science and Technology Center will be to the right below the road, in addition, the EBI dormitory is located to the east of the Guest House. Before reaching the east entrance from the EBI dormitory the water reservoir is located to the left of the road. Figure 3.2 and 3.4 show the top view and the plan of the campus where the structures and topography of the campus can be seen. There are many different surfaces on the campus which are presented in Figure 3.3. Since each surface has a different runoff coefficient that will be used to calculate the volume of rainfall runoff, those surfaces should be distinguished. Asphalt, rooftops and granite have the lowest absorption coefficient while sand has the greatest. The surfaces are characterized into eight groups as follows:

1. Asphalt
2. Rooftops
3. Granite
4. Interlocking tiles (parking lots and pavement)
5. Planted vegetation and Grass areas
6. Natural Environment
7. Rubber (basketball, tennis courts and running track)
8. Artificial compacted sand (Children’s playground sand pit, sand volleyball)

A.

B.

C.

D.

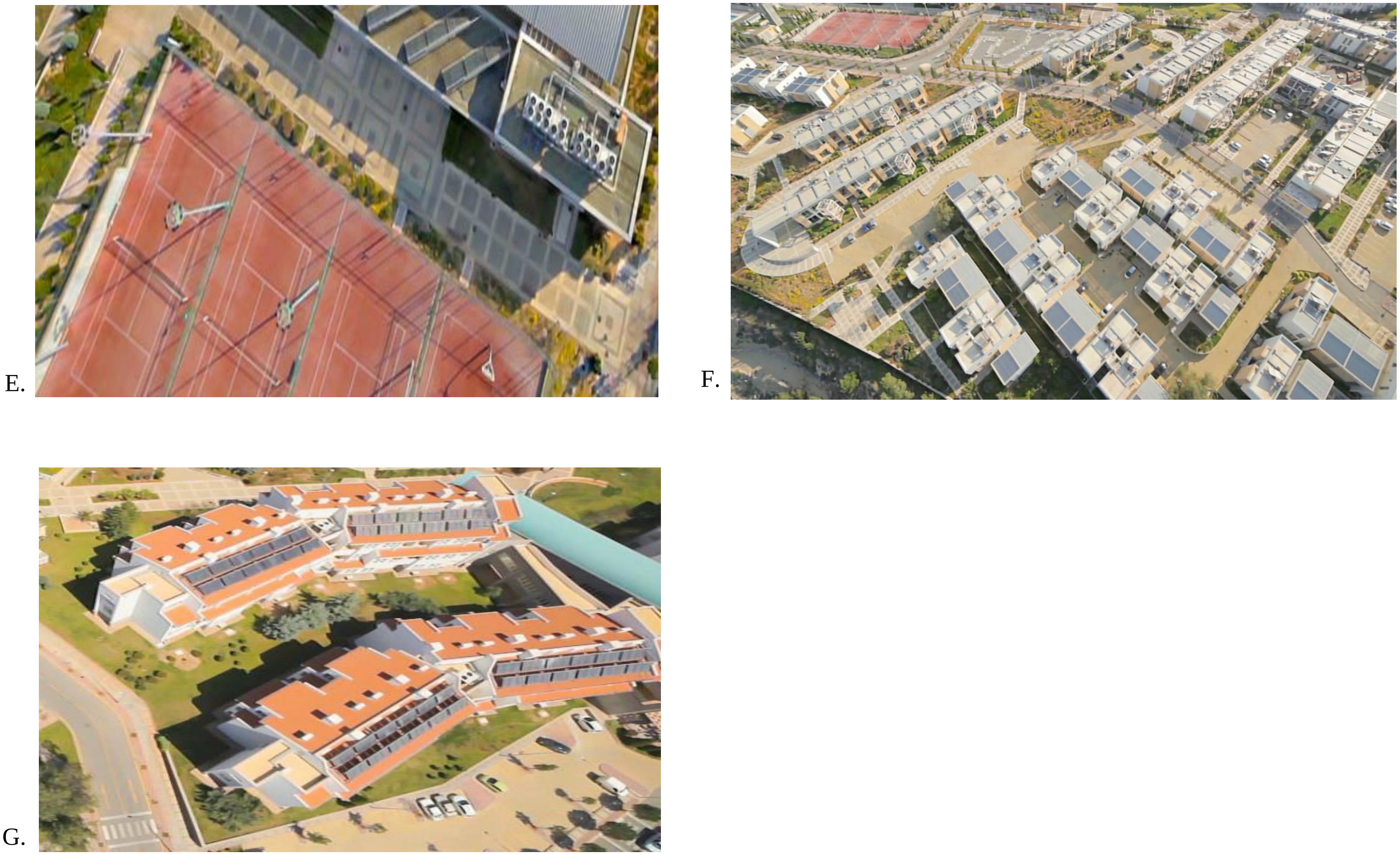

E.
F.
G.

Figure 3.3. The different surfaces present on campus. A. Artificial sand area. B. Rooftop, interlocking tiles, asphalt, and grass areas. C. Granite D. Natural Environment E. Rubber area. F. Rooftop and interlocking tiles. G. Rooftop and grass areas (METU NCC, 2014).

Figure 3.4. Plan of METU-NCC

3.3 Soil Characteristics

The Harmonized World Soil Database Viewer (HWSD) version 1.2 was used to find the general soil characteristics of this region of Cyprus. This software is adopted by the Food and Agriculture Organization of the United Nations (FAO), the Chinese Academy of Sciences (CAS), the International Institute for Applied Systems Analysis (IIASA), the International Soil Reference and Information Centre (ISRIC) and the Joint Centre of the European Commission (JRC). When the HWSD software is opened the window shown in Figure 3.5 is seen.

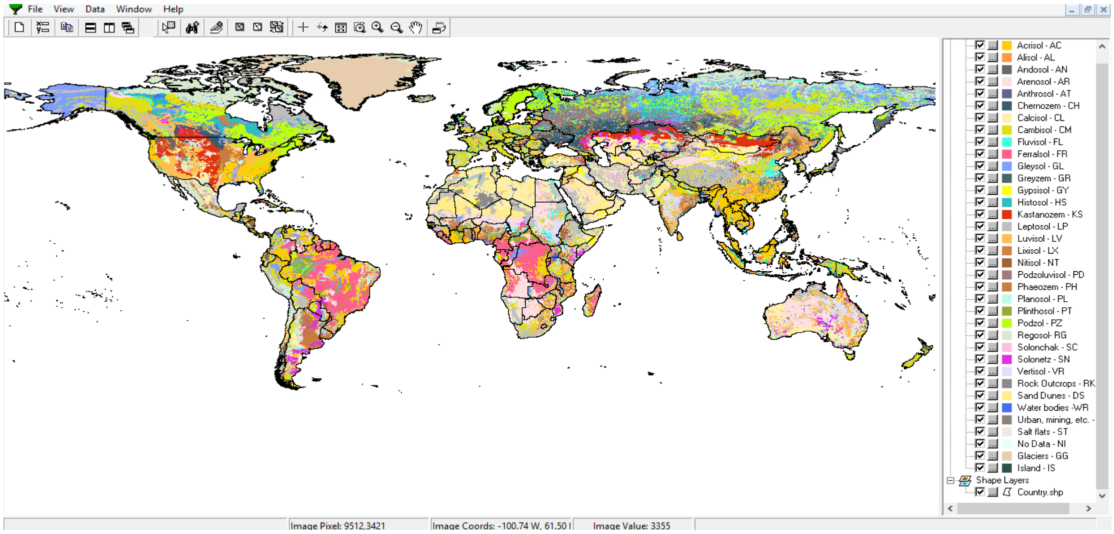


Image Pixel: 9512,3421
Image Coords: -100.74 W, 61.50 I
Image Value: 3355

Figure 3.5. HWSD viewer window

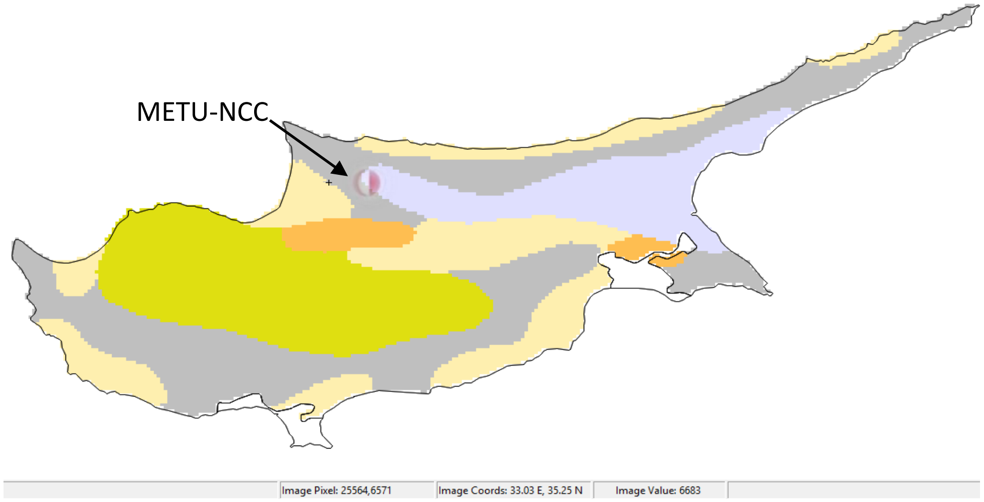


Image Pixel: 25564,6571
Image Coords: 33.03 E, 35.25 N
Image Value: 6683

Figure 3.6. Map of Cyprus in the HWSD viewer.

The program is equipped by a coordinate system; moreover, the coordinates of the university campus are determined using Google Earth. They were found to be 35.25 N, 33.03 E and the same location is chosen on the HWSD viewer software as in Figure 3.6 and the soil characteristics are displayed. The dominant soil group was found to be Calcisols with 50% loam and 50% clay to be the most prominent soil textures. Therefore, the dominant soil texture is clay loam and hence this satisfies the Hydrologic Soil Group D. Table 3.1 shows the soil characteristics information obtained from HWSD viewer.

Table 3.1. Soil data from the HWSD viewer of the location specified on the map.

Cover	**Dominant Soil**	**Associated Soil**	**Associated Soil**	**Associated Soil**
Soil Mapping Unit	6683			
Dominant Soil Group	CL - Calcisols			
Share in Soil Mapping Unit (%)	40	40	10	10
Soil Unit Name (FAO74)	Calcic Cambisols	Calcic Cambisols	Chromic Luvisols	Vertic Cambisols
Topsoil Texture	Medium	Fine	Medium	Fine
Reference Soil Depth (cm)	100	100	100	100
Drainage class (0-0.5% slope)	Imperfectly	Imperfectly	Moderately Well	Moderately Well
AWC (mm)	50	50	150	150
Topsoil Sand Fraction (%)	38	19	47	21
Topsoil Silt Fraction (%)	41	33	29	28
Topsoil Clay Fraction (%)	21	48	24	51
Topsoil USDA Texture Classification	loam	clay (light)	loam	clay (light)
Topsoil Reference Bulk Density (kg/dm^3)	1.4	1.24	1.39	1.23
Topsoil Bulk Density (kg/dm^3)	1.42	1.3	1.54	1.43
Topsoil Gravel Content (%)	10	8	9	5
Subsoil Sand Fraction (%)	36	23	39	18
Subsoil Silt Fraction (%)	41	34	27	28
Subsoil Clay Fraction (%)	23	43	34	54
Subsoil USDA Texture Classification	loam	clay (light)	clay loam	clay (light)
Subsoil Reference Bulk Density (kg/dm3)	1.38	1.26	1.33	1.22
Subsoil Bulk Density (kg/dm3)	1.46	1.34	1.52	1.46
Subsoil Gravel Content (%)	10	6	8	5

CHAPTER IV

DATA AND METHODOLOGY

4.1 Precipitation Data

The daily precipitation data for Guzelyurt from 1978 to 2009 was obtained from the Meteorological Department of Northern Cyprus. The monthly and annual rainfall are obtained from the daily rainfall. As seen in Figure 4.1 the average monthly rainfall from 1978-2009 is the highest during the months of February, December and January while the lowest rainfall is witnessed during the months July, September, June and August. On the other hand, the maximum annual rainfall of 494 mm occurred during the water year 2002-2003 while the lowest annual rainfall of 132 mm occurred during the water year 2007-2008 as shown in Figure 4.2.

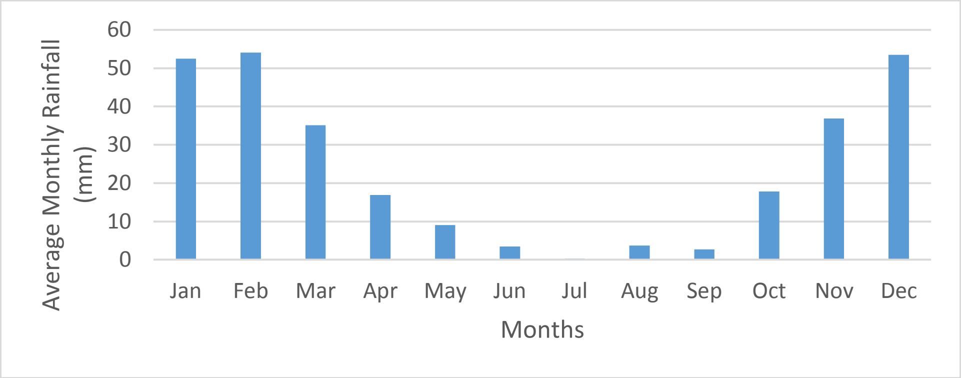


Figure 4.1. Average monthly rainfall from Guzelyurt station.

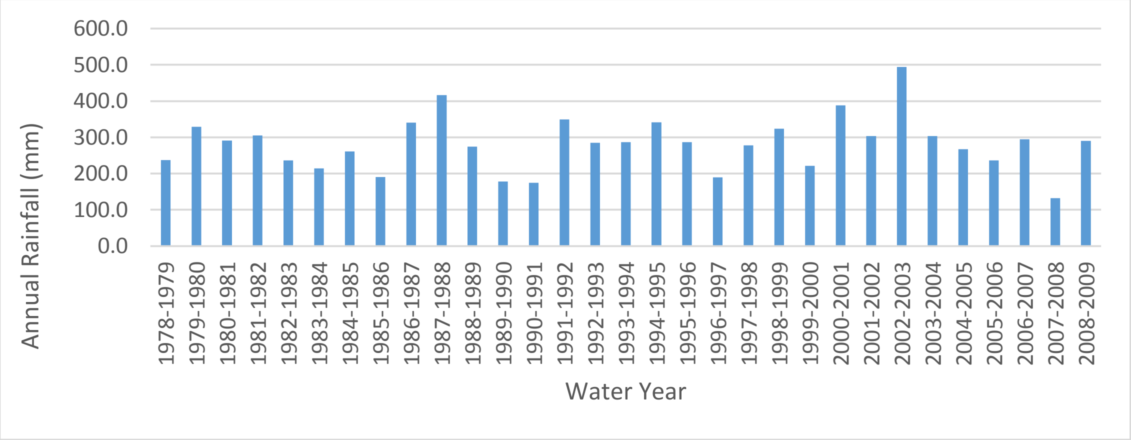


Figure 4.2. Annual rainfall versus water year from the Guzelyurt station.

Since the SWMM software needs the input data in a specific format of hourly rainfall, the daily data was disaggregated into hourly data. Using 2000-2009 hourly rainfall data of the Guzelyurt station Şahin (2013) found that the Guzelyurt daily rainfall follows a pattern of four six-hour periods as shown in Figure 4.3.

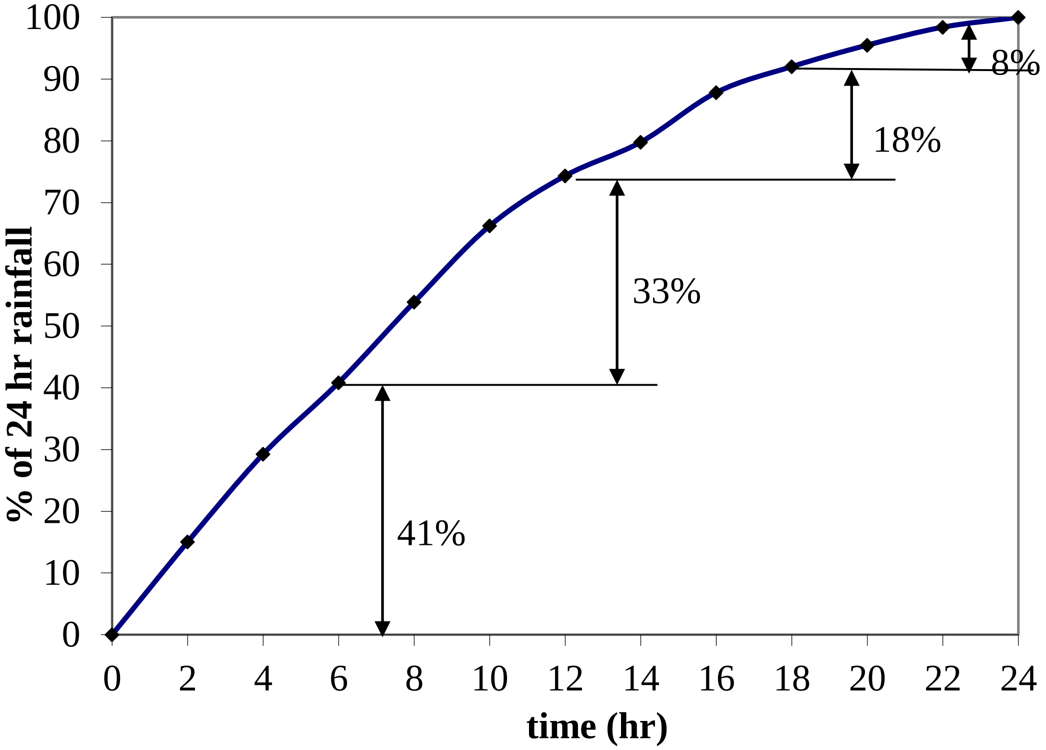


Figure 4.3. The percent distribution of daily rainfall in Guzelyurt (Şahin, 2013).

According to Şahin (2013) the distribution of daily rainfall was found to be 41% during the first six hours of rainfall in a day, while the second six hours constitute 33% of the total daily rainfall, the third six hours are 18% of the total daily rainfall and the last six hours are 8% of the total daily rainfall. Using the daily rainfall data (1978-2009) the hourly rainfall data was obtained. For instance, the first six hours of rainfall in a day constitute 41% of the total daily rainfall, therefore by dividing the obtained depth of daily rainfall in the six hours by six, the hourly rainfall in the first six hours would be obtained. This operation is performed to the 1978-2009 period daily rainfall and, the hourly data were acquired.

4.2 Catchment Area

In order to compute the amount of runoff that will be obtained on campus, the catchment characteristics of the campus should be studied. The existing rainwater drainage system is built to collect the rainwater from the campus from seven areas. Using the elevation differences and the suspected movement of rainwater runoff into the drainage system towards the existing discharge outlets, those seven sub-catchments were drawn. Each sub-catchment contains a separate discharge outlet and specific surface characteristics. Computing the areas in each sub-catchment was performed with the aid of a plan of the campus showing the route of the drainage system, as well as, the software AutoCAD 2011 to outline the areas of the sub-catchments and Google Earth to view the different surfaces. Moreover, the area of the different surfaces was found in order to estimate the runoff. The sub-catchments can be seen in Figure 4.4.

The seven sub-catchments are as follows:

1. 2nd Lodgment Complex. (Yellow)
2. A-Types Lodgments, B-Types Lodgments, Guest House, EBI Dormitory and section of the CD-Types Lodgments. (Green)
3. 1st Lodgment Complex, IT Building, Administration Building and section of the Culture and Convention Center. (Blue)
4. Engineering Laboratories, T-Block, Culture and Convention Center and section of the School of Foreign Languages Building. (Red)
5. Cafeteria Building, Market Area Buildings (Çarşı), 1st Dormitory, Health Center Building, S-Block, R-Block, School of Foreign Languages Building and section of the CD-Types Lodgments. (Purple)
6. Swimming Pool, Sports Complex Building, 2nd Dormitory and 3rd Dormitory. (Orange)
7. Library (Pink)

Figure 4.4. Plan of METU-NCC with different sub-catchments colored.

4.3 Traditional SCS Method

From the methods discussed previously, one of the runoff methods should be chosen according to the available parameters and the suitability of the method. Moreover, the other methods require data that is not available or parameters that need long experimental work to be determined before applying the method. Since the Soil Conservation Service (SCS) method includes all types of abstractions in the runoff calculation and the parameters needed to compute the runoff are available, it is the most suitable method for this case.

The curve number (CN) of the surface is dependent on the hydrologic soil group in the study area which is classified according to Table 2.1, the CN of the surfaces present in sub-catchments can be established using Table 2.2. The hydrologic soil group of the soil present in the campus region is closest to soil group D. The description in Table 2.1 defines the type of surface present in the region of study. Moreover, looking at Table 2.2 one can deduce that the CN of impervious areas with soil group D is 98 while grass areas with up to 75% grass cover is 84 and areas with more than 75% grass cover is 80. On the other hand, the CN of open areas with less than 50% grass cover such as natural forest areas on campus is 89. The greater the CN, the more the runoff produced by the surface, in other words, the impervious areas have the greatest runoff potential.

After the CN of each surface is determined, a normalized CN of the sub-catchment as a whole should be determined by multiplying each specific area with its corresponding CN, summing the result and dividing that by the total area of the sub-catchment.

$$CN_N = \sum_{i=1}^{n} \left(\frac{A_i * CN_i}{A_T}\right) \tag{4.1}$$

where, CN_N is the normalized CN of a sub-catchment; A_i is the area of each surface in a sub-catchment (m^2); CN_i is the CN of each surface in the sub-catchment; A_T is the total area of the sub-catchment (m^2); n is the total number of surfaces in the sub-catchment.

After finding “CN_N”, the soil moisture deficit is needed to found using the Equation 4.2 (Akan and Houghtalen, 2003),

$$S_D = \frac{25400 - 254CN_N}{CN_N} \quad (4.2)$$

where, S_D is the soil moisture deficit at the time of runoff (mm); CN_N is the normalized runoff curve number.

The initial abstraction consisting of the water intercepted by vegetation, retained in the surface depressions, evaporated or infiltrated before the runoff begins is calculated by Equation 4.3. Moreover, this equation can only be used if the precipitation is greater than the initial abstraction (Akan and Houghtalen, 2003),

$$I_a = 0.2S_D \quad (4.3)$$

where, I_a is the initial abstraction (mm); S_D is the soil moisture deficit at the time of runoff (mm).

Finally all after those parameters are computed the SCS runoff expression shown in Equation 4.4 can be employed to compute the runoff (Akan and Houghtalen, 2003).

$$R = \frac{(P - I_a)^2}{(P - I_a) + S_D} \quad (4.4)$$

where, R is the rainfall runoff (mm); P is the precipitation (mm); I_a is the initial abstraction (mm); S_D is the soil moisture deficit at the time of runoff (mm).

After the runoff is calculated, the volume of the runoff from each sub-catchment is computed using Equation 4.5.

$$V = R * A_T \quad (4.5)$$

where, V is the volume of runoff (m^3); R is the rainfall runoff (m); A_T is the area of the sub-catchment (m^2).

4.4 SWMM Model

The Environmental Protection Agency (EPA) developed the Storm Water Management Model (SWMM), which is a software that is capable of presenting a dynamic rainfall-runoff simulation model for single storm event simulation or continuous simulation of runoff quantity and quality from mainly urban sub-catchment areas (Rossman, 2010). SWMM generates runoff and pollutant concentrations by operating on a group of sub-catchment areas that receive precipitation. There is a routing section in SWMM capable of simulating the transport of this runoff through pipes, channels, storage or treatment devices, pumps and regulators (Rossman, 2010). Moreover, SWMM is able to track the quantity and quality of runoff produced in each sub-catchment, the flow rate, the flow depth in each pipe and channel during a simulation period. SWMM is widely used for planning, analysis and design of storm-water runoff, sewers and other drainage systems in urban areas.

SWMM 5.1 provides an integrated environment for controlling study area input data as well as running hydrologic, hydraulic and water quality simulations. Furthermore, SWMM allows to view the results in many different formats. SWMM accounts for various hydrologic processes that contribute to runoff in urban areas, such as, time- fluctuating rainfall, evaporation, snow accumulation and melting and infiltration (Rossman, 2010). Dividing the study area into smaller sub-catchment zones, each exhibiting different characteristics will lead to spatial variability in these processes. Moreover, this software possesses a collection of hydraulic modeling options that may be utilized to route runoff and external inflows through the transport systems. In addition, SWMM can also estimate the accumulation of pollutant loads related to the runoff. SWMM has ample applications which include designing and sizing of drainage system components for flood control, sizing of detention facilities and their accessories for flood control and water quality protection, flood mapping of natural channel systems and evaluating the effect of inflow and infiltration on sewer overflows (Rossman, 2010).

This software works by creating a conceptual drainage system where water and pollutants flow through different environmental sections. SWMM has characterized these sections into various objects in the following form (Rossman, 2010):

- The Atmosphere, where the precipitation input data is inserted using the falls Rain Gage object.
- The Land Surface, where the different components and parameters of the basin area is inserted in the Sub-catchment object. It receives precipitation from the Atmospheric section and outflow is simulated in the form of infiltration and surface runoff.
- The Groundwater section receives the infiltration output from the previous section and transfers a part of it to the Transport section. The Aquifer object is used to model this compartment.
- The Transport subdivision, contains a network of transport elements such as channels, pipes, pumps, and regulators, as well as, storage and treatment units that carry water to outfalls. The input of this section may come from surface runoff, groundwater interflow, or from user-defined hydrographs. The Node and Link objects are used to model the components of this section.

Infiltration of rainfall in a sub-catchment into the unsaturated top soil zone can be modelled using three different methods (Rossman, 2010):

- Horton infiltration
- Green-Ampt infiltration
- SCS Curve Number infiltration

Moreover, in order to model snow melting or accumulation, the Snow Pack object should be used, while modelling pollutant accumulation and wash-off the Land Uses should be managed. Some other important input parameters that are used in the Sub-catchment object include the appointed rain gage, the outlet node, the land uses, the imperviousness layer fraction, the sub-catchment slope, the width of overland flow, the Manning's n for both the pervious and impervious areas and the depression storage in the pervious and impervious areas (Rossman, 2010).

The reason why the SWMM model is chosen is its wide recognition by engineering consultants around the world, it is free to download and therefore readily available to the public, as well as, it provides output for detailed analysis. SWMM 5.0 is a physically based, deterministic model, which depends on the estimation of initial parameters (Vargas, 2009). It can provide either single-event or continuous-storm-event simulations when analyzing the rainfall/runoff relationship (Rossman, 2010). SWMM can simulate hydrologic processes as infiltration and overland flow in a sub-catchment areas while directing this runoff through a drainage system such as pipes, channels, storage/treatment devices, pumps and regulators (Vargas, 2009). Figure 4.5 shows how the SWMM model operates, the rainwater infiltrates into the surface and then runoff emerges the saturation of the surface then the water is collected by the specified drainage system.

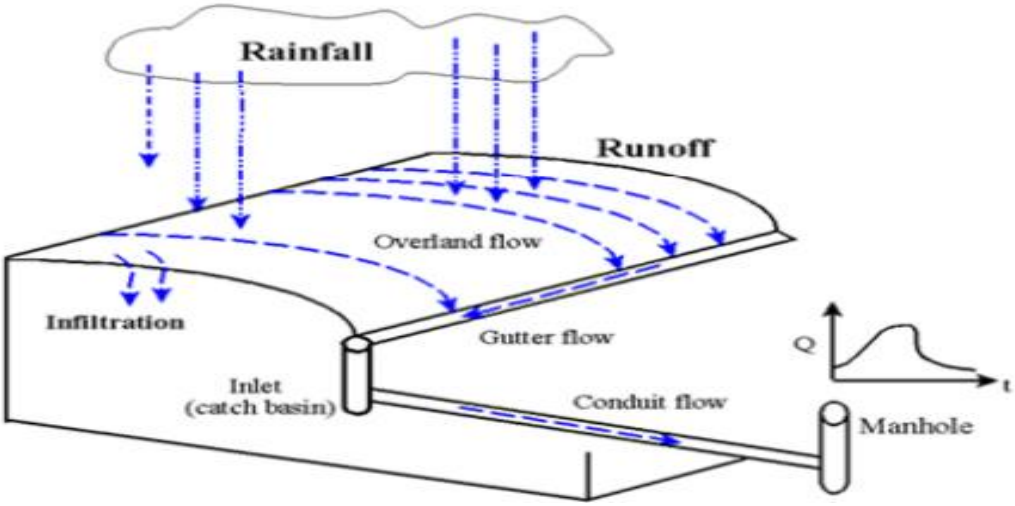
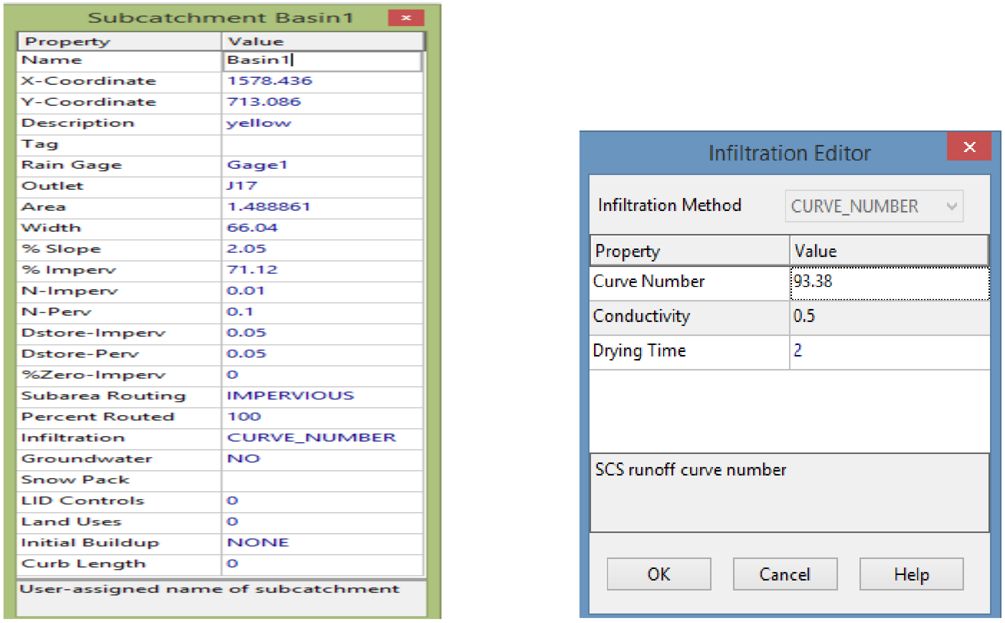


Figure 4.5. The SWMM runoff/routing flow in a sub-catchment (Vargas, 2009).

When using SWMM, the first action to be performed is choosing the appropriate units of the project. In this case, meters (m) as the length unit, millimeters (mm) as the rainfall depth, hectares (ha) as the sub-catchment area unit and liters (L) as the runoff volume unit were chosen as the units of the project. The method of simulation is chosen to be the SCS method. Moreover, the default routing method is the steady flow, since in this study the flow rates are not our concern. A screen-shot of the campus region from Google Earth was placed as the background in order to fit the areas to be drawn on SWMM.

Sub-catchments were drawn on the map using the drawing object in the toolbar. In each sub-catchment the total area of the sub-catchment is added, along with the impervious layer percentage, the percent slope of the area and the width of overland flow path. The impervious layer percentage is calculated by dividing the area of interlocking tiles and concrete by the total area of the sub-catchment. The percent slope of the area is determined by subtracting the highest elevation in the sub-catchment area by the outlet elevation and dividing that by the distance between these two points (Rossman, 2010). While the width of overland flow path is determined by dividing the area of the sub-catchment by the farthest distance to the outlet in the sub-catchment area (Rossman, 2010). The routing in the sub-catchment is chosen to be through the impervious areas since the rainwater gutters and collection system is found in the impervious region of the sub-catchment. The percent of routed rainwater is assumed to be 100 %, in order to find the maximum runoff that will result from the rainfall present. This data is filed in the Sub-catchment Editor such as in Figure 4.6. A rain gage holding the rainfall data is assigned in the Rain Gage tab as such as Figure 4.8. The rest of the parameters are kept as the default values since the information about these parameters is not available and these parameters do not affect this specific analysis.



Property	Value
Name	Basin1
X-Coordinate	1578.436
Y-Coordinate	713.086
Description	yellow
Tag	
Rain Gage	Gage1
Outlet	J17
Area	1.488861
Width	66.04
% Slope	2.05
% Imperv	71.12
N-Imperv	0.01
N-Perv	0.1
Dstore-Imperv	0.05
Dstore-Perv	0.05
%Zero-Imperv	0
Subarea Routing	IMPERVIOUS
Percent Routed	100
Infiltration	CURVE_NUMBER
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0

User-assigned name of subcatchment

Infiltration Method: CURVE_NUMBER

Property	Value
Curve Number	93.38
Conductivity	0.5
Drying Time	2

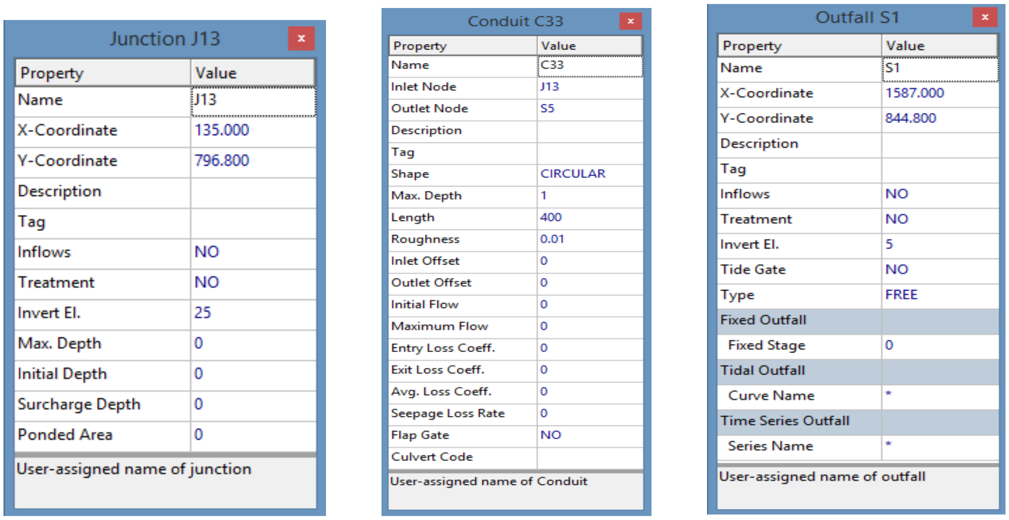
SCS runoff curve number

Figure 4.6. The sub-catchment editor window and infiltration editor window in SWMM.

In the Infiltration Editor window the normalized CN is entered, as well as the soil drying time which has a range from 2 to 14 days. The hydraulic conductivity is not considered and its value is ignored in this method. The previous is done for each sub-catchment.

Moreover, an outfall for each sub-catchment is added on the map, from the Node object under the Hydraulic tab, corresponding to the outlet present in reality. In addition, a junction is created between each sub-catchment and its respective outfall, this is done to keep space for the combination of the outlets of different sub-catchments. The tag or name of each junction is added in the Outlet tab in the sub-catchment editor of the respective sub-catchment as shown in Figure 4.6. The junction is connected to the outfall by a conduit or pipe and this added from the Link tab. When adding the junction and outfall one must make sure that the elevation of the outfall is lower than that of the junction which is in turn lower than that of the lowest point in the sub-catchment, in order for the rainwater to flow in the direction of the outfall. The exact elevations are not necessary since we are not concerned with the flow rates, the only concern in this study is the volume of outflow. Figure 4.7 shows the junction, conduit and outfall editor windows.

Furthermore, a legend showing the different areas of the sub-catchments can be added from the Map tab on the left on the window. The next step is to add the rainfall data, the rain gage tab is used to add the data. The hourly rainfall data is added in a specific format either in the table present in the Time Series tab or uploaded as an external file in the same window. The model finally should appear as Figure 4.9. Before simulating the data, the dates to be simulated should be chosen, in other words, the start and end of the desired simulation dates should be selected from the Dates tab under the Options tab; Figure 4.10 shows the simulation dates window.


Junction J13

Property	Value
Name	J13
X-Coordinate	135.000
Y-Coordinate	796.800
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	25
Max. Depth	0
Initial Depth	0
Surcharge Depth	0
Ponded Area	0

User-assigned name of junction

Conduit C33

Property	Value
Name	C33
Inlet Node	J13
Outlet Node	S5
Description	
Tag	
Shape	CIRCULAR
Max. Depth	1
Length	400
Roughness	0.01
Inlet Offset	0
Outlet Offset	0
Initial Flow	0
Maximum Flow	0
Entry Loss Coeff.	0
Exit Loss Coeff.	0
Avg. Loss Coeff.	0
Seepage Loss Rate	0
Flap Gate	NO
Culvert Code	

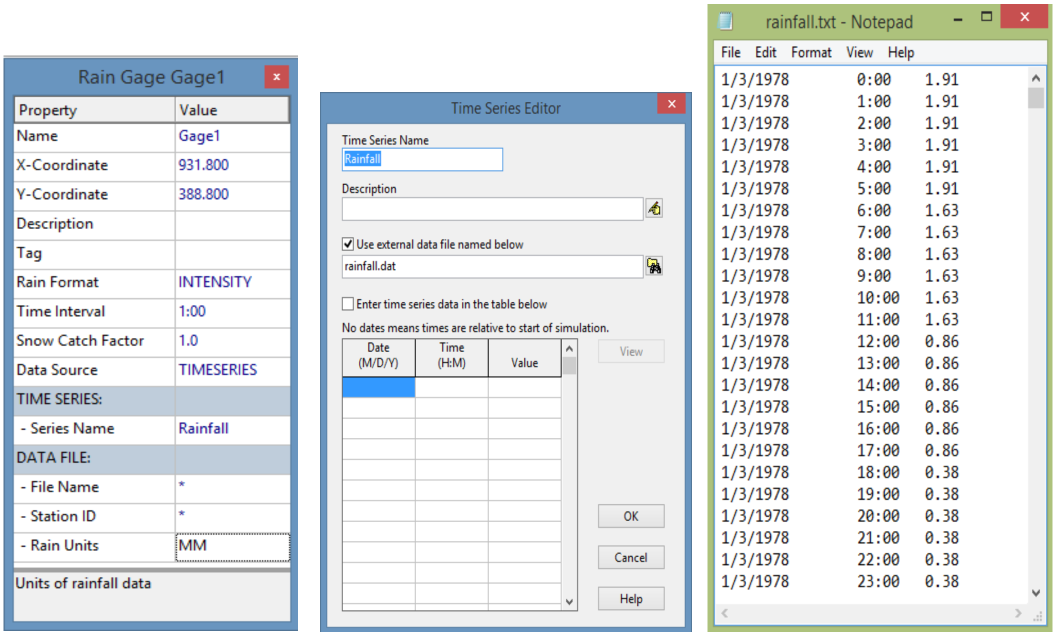
User-assigned name of Conduit

Outfall S1

Property	Value
Name	S1
X-Coordinate	1587.000
Y-Coordinate	844.800
Description	
Tag	
Inflows	NO
Treatment	NO
Invert El.	5
Tide Gate	NO
Type	FREE
Fixed Outfall	
Fixed Stage	0
Tidal Outfall	
Curve Name	*
Time Series Outfall	
Series Name	*

User-assigned name of outfall

Figure 4.7. The junction, conduit and outfall editor windows on SWMM respectively.


Rain Gage Gage1

Property	Value
Name	Gage1
X-Coordinate	931.800
Y-Coordinate	388.800
Description	
Tag	
Rain Format	INTENSITY
Time Interval	1:00
Snow Catch Factor	1.0
Data Source	TIMESERIES
TIME SERIES:	
- Series Name	Rainfall
DATA FILE:	
- File Name	*
- Station ID	*
- Rain Units	MM

Units of rainfall data

Time Series Editor

Time Series Name: Rainfall

Description:

☑ Use external data file named below: rainfall.dat

☐ Enter time series data in the table below

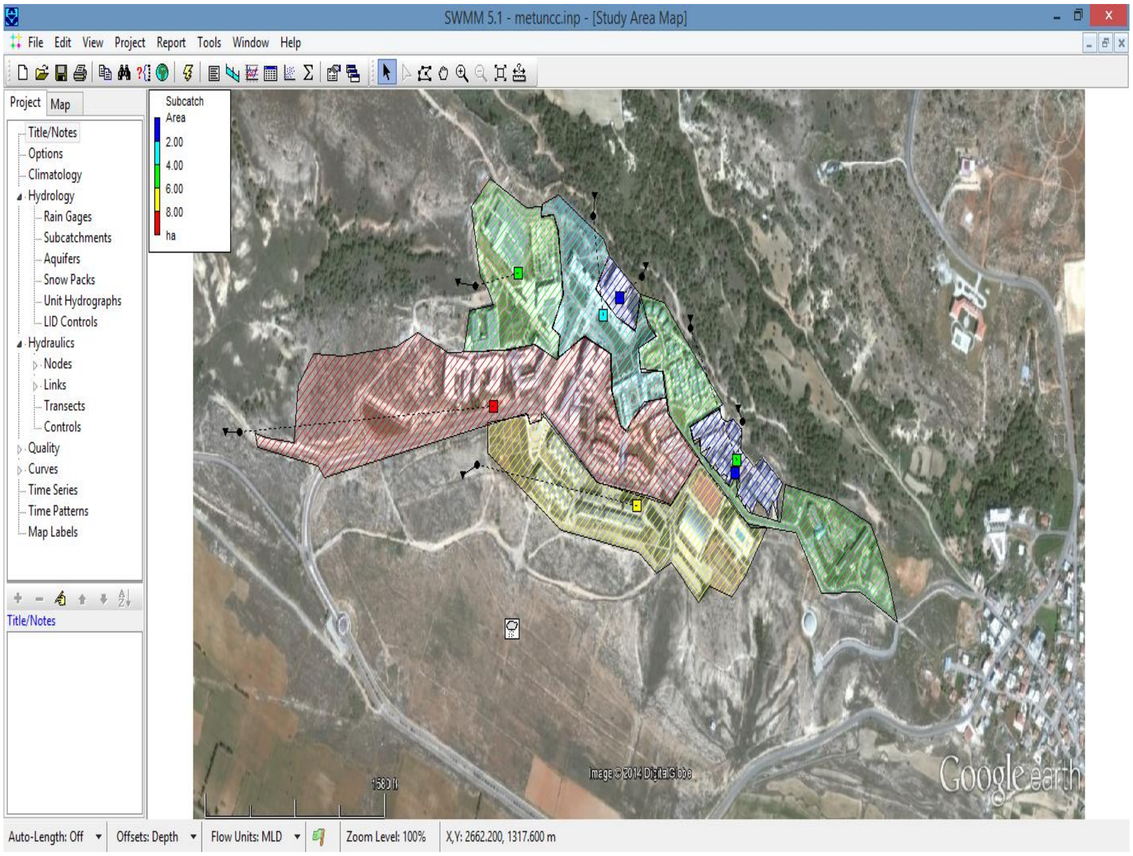
No dates means times are relative to start of simulation.

Date (M/D/Y)	Time (H:M)	Value

rainfall.txt - Notepad

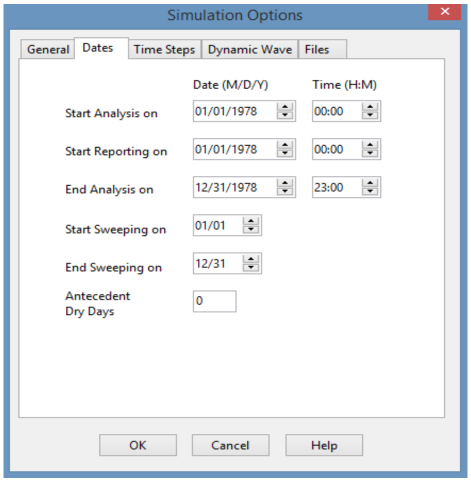
```
1/3/1978        0:00    1.91
1/3/1978        1:00    1.91
1/3/1978        2:00    1.91
1/3/1978        3:00    1.91
1/3/1978        4:00    1.91
1/3/1978        5:00    1.91
1/3/1978        6:00    1.63
1/3/1978        7:00    1.63
1/3/1978        8:00    1.63
1/3/1978        9:00    1.63
1/3/1978        10:00   1.63
1/3/1978        11:00   1.63
1/3/1978        12:00   0.86
1/3/1978        13:00   0.86
1/3/1978        14:00   0.86
1/3/1978        15:00   0.86
1/3/1978        16:00   0.86
1/3/1978        17:00   0.86
1/3/1978        18:00   0.38
1/3/1978        19:00   0.38
1/3/1978        20:00   0.38
1/3/1978        21:00   0.38
1/3/1978        22:00   0.38
1/3/1978        23:00   0.38
```

Figure 4.8. The rain gage and time series editor and the rainfall data format.



Auto-Length: Off
Offsets: Depth
Flow Units: MLD
Zoom Level: 100%
X,Y: 2662.200, 1317.600 m

Figure 4.9. The appearance of the SWMM model.



	Date (M/D/Y)	Time (H:M)
Start Analysis on	01/01/1978	00:00
Start Reporting on	01/01/1978	00:00
End Analysis on	12/31/1978	23:00
Start Sweeping on	01/01	
End Sweeping on	12/31	
Antecedent Dry Days	0	

Figure 4.10. The simulation dates options window.

4.5 Irrigation Demand

After the runoff volumes of the sub-catchments are computed, the tank volumes and locations along with the rainwater harvesting system as a whole can be discussed. The first step is to determine the consumption of water in the sub-catchments and decide how to distribute the water tanks in order to meet the irrigation demand in the seven sub-catchments. The vegetation on campus which needs irrigation was divided into three groups, as ground cover, trees and bushes, and lawn area. Figure 4.11 shows the three groups of vegetation. The amount of water supplied to each group of vegetation and the map, shown in Figure 4.12, showing all the vegetation on the campus was provided by the Directorate of Administrative Affairs at the METU-NCC in Table 4.1. In order to find the water consumed in each sub-catchment, the areas of each vegetation group in each sub-catchment are calculated using the map.

Figure 4.11. The three groups of vegetation on campus.

A. Ground cover. B. Trees and bushes. C. Lawn area.

Table 4.1. The crop type along with the irrigation requirements.

Crop Type	Months of Irrigation	Duration (months)	Irrigation Period (day/week)	Required Water per m^2 (L/day)	Total Water per m^2 (L/month)
Ground Cover	Jan-Dec	12	2	0.87	6.96
Trees and Bushes	Jan-Dec	12	1	20	80
Lawn Area	May-Oct	6	6	12	288
Lawn Area	Nov-Apr	6	5	10	200
Fruit Trees	Mar-Oct	8	3	1.88	22.6

Figure 4.12. The AutoCAD map showing the vegetation on the campus.

4.6 Location of Reservoirs

Deciding the location and the number of water reservoirs, as well as the areas to be irrigated by those reservoirs will be the last step before calculating the volumes of the water tanks. Since the collection of water is occurring at the lowest elevations of the campus then pumping is a necessity. Since constructing seven water tanks will be costly, combining the runoff from different sub-catchments and storing it in the same reservoir may be a better option keeping in consideration the areas to be irrigated. Many alternatives may be proposed, one option that will be discussed and assessed for the reliability is as shown in Figure 4.10. This option will be discussed to show that the system has the potential to operate and produce adequate results. The runoff of Sub-catchments 1, 2 and 7 can be combined in one tank and stored in Position 1 on the map, while the runoff from sub-catchments 3 and 4 can be combined into Position 2 and the runoff from Sub-catchments 5 and 6 can be stored in Position 3 as shown on the map.

Using this combination of reservoirs the areas to be irrigated will be Sub-catchments 1, 2, 6 and the top part of Sub-catchment 5 from the reservoir at Position 1, while the reservoir at Position 2 will be used to irrigate Sub-catchments 3, 4, 7 and the lower part of Sub-catchment 5, on the other hand, the reservoir at Position 3 will irrigate the tree fruits at the bottom of the campus, outlined in green in Figure 4.13 and presented in Table 4.2. The blue spots on the map stand for small plastic tanks that act as temporary storage before the water is used by the irrigation system.

Table 4.2. The reservoirs, the sub-catchments supplying their runoff and the corresponding irrigation areas.

Reservoir	Runoff from Sub-catchments	Sub-catchments to be irrigated
Reservoir 1	Sub-catchments 1, 2 and 7	Sub-catchments 1, 2, 6 and top part of 5
Reservoir 2	Sub-catchments 3, 4	Sub-catchments 3, 4, 7 and lower part of 5
Reservoir 3	Sub-catchments 5, 6	Fruit trees

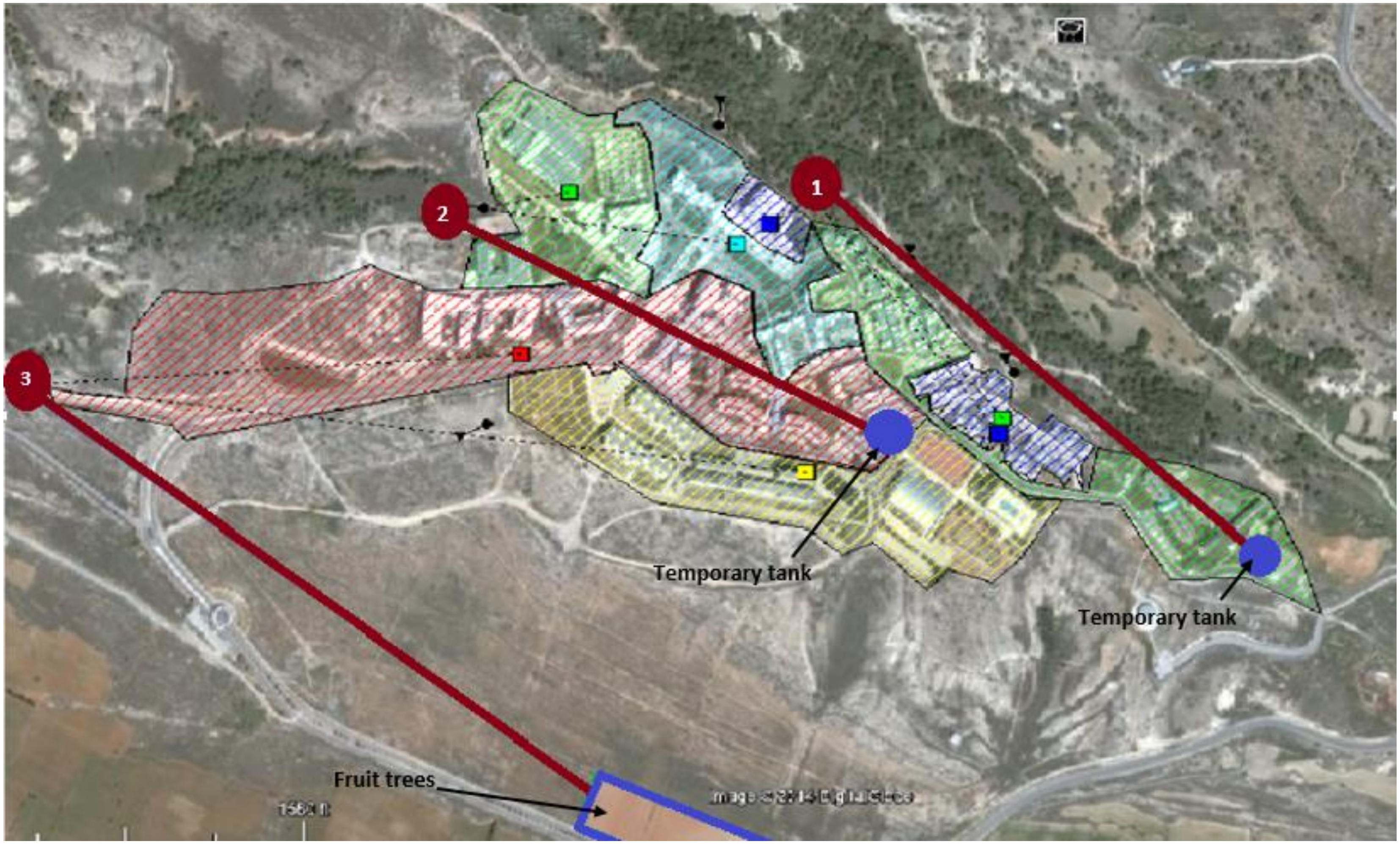


Figure 4.13. The map with reservoir locations and irrigation areas on campus.

Figure 4.14. The area that Reservoir 1 irrigates.

Figure 4.15. The area that Reservoir 2 irrigates.

4.6 Tank Size Calculation Method

Accordingly, the monthly water consumption for each sub-catchment can be computed and will be used to calculate the reservoir volumes. In order to perform such a task a water balance approach should be adopted, showing the water demand met from the excess precipitation. The water balance approach is similar to the Simple Tabular Method described in Chapter II (page 21). Two types of balances will be adopted the annual balance and the monthly balance. The annual balance will include the carryover of the excess stored water from one year to the next as well as from one month to the next. While the monthly balance will not have any carryover from the previous month or year. The monthly runoff is computed from the monthly simulations of SWMM. The tank volume will be computed using the method given in Nnaji and Mama (2014). In this method the Storage Capacity (SC), is calculated by subtracting the cumulative surplus at the end of the year from the maximum cumulative surplus. The Cumulative Surplus (CS) is computed using Equation 4.6, moreover, if the inflow and the water stored from the previous month is less than the demand then a deficit occurs and a value of zero is assigned (Nnaji and Mama, 2014). When calculating the volumes of the tanks in each year, water years will be considered not the regular year will be studied, for instance 1978-1979 will start at September 1978 and end at August 1979.

$$CS_i = \begin{cases} 0, \quad (if\ CS_{i-1} + R_i - D_i \leq 0)\ else \\ \qquad CS_{i-1} + R_i - D_i \end{cases} \tag{4.6}$$

where CS_i is the cumulative surplus of the current month; CS_{i-1} is the cumulative surplus of the previous month (m^3); R_i is the runoff of the current month (m^3); D_i is the demand of the current month (m^3).

Equation 4.7 illustrates how to compute the water in storage, if the inflow and the water in storage from the previous month is less than the demand then there will be no water to store. If the same expression is greater than or equal to the storage capacity then the value of the water in the storage is the storage capacity, which is the maximum value for the water in storage, otherwise the difference between the sum of the inflow and the water storage of the previous month and the demand is the water storage of the current month (Nnaji and Mama, 2014).

$$WS_i = \begin{cases} 0, & (if\ R_i + WS_{i-1} - D_i < 0)\ else \\ SC, & (if\ R_i + WS_{i-1} - D_i \geq SC)\ else \\ & R_i + WS_{i-1} - D_i \end{cases} \tag{4.7}$$

where WS_i is the water in storage of the current month; WS_{i-1} is the water in storage of the previous month; SC is the storage capacity.

In this study the aim is not to maximize the storage but to investigate if the water demand can be satisfied through the rainfall, therefore, excess water during a month may be spilled. Equation 4.8 shows how the spillage of the annual balance may be computed. There will be no spillage if the water in storage of the current month is less than the storage capacity else the spillage is the difference between the water storage of the current month and the storage capacity (Nnaji and Mama, 2014).

$$SP1_i = \begin{cases} 0, & (if\ R_i + WS_{i-1} - D_i < SC)\ else \\ & R_i + WS_{i-1} - D_i - SC \end{cases} \tag{4.8}$$

where $SP1_i$ is the water in storage of the current month in the annual balance.

To compute the demand met for each month in the annual balance Equation 4.9 is used. If the water in storage of the current month is greater than or equal to zero then the demand met is the demand of the current month otherwise the demand met is the sum of the inflow of the current month and the water in storage of the previous month (Nnaji and Mama, 2014).

$$DM1_i = \begin{cases} D_i, & (if\ R_i + WS_{i-1} - D_i \geq 0)\ else \\ & R_i + WS_{i-1} \end{cases} \tag{4.9}$$

where $DM1_i$ is the demand met of the current month in the annual balance.

Moreover, in turn the monthly rainfall was assessed to identify the sufficiency to satisfy the monthly demand without utilizing water from the previous month. If the difference between the inflow and demand in one month is greater than zero then the demand met is equal to the demand of that month, otherwise the demand met is the inflow of the current month. When the demand in a month is met, the remaining surplus is spilled, otherwise there will be no spill (Nnaji and Mama, 2014). Equation 4.10 and 4.11 show the demand met and spillage expressions respectively in the monthly balance approach.

$$DM2_i = \begin{cases} D_i, \ \ (if\ R_i - D_i > 0)\ else \\ \qquad\qquad R_i \end{cases} \tag{4.10}$$

where $DM2_i$ is the demand met of the current month in the monthly balance.

$$SP2_i = \begin{cases} R_i - DM_i, \ \ (if\ R_i - DM_i > 0)\ else \\ \qquad\qquad 0 \end{cases} \tag{4.11}$$

where $SP2_i$ is the spillage of the current month in the monthly balance.

CHAPTER V

CALCULATIONS, RESULTS AND DISCUSSION

5.1 Catchment Area

Using Figure 4.4 and Google Earth, the areas of each surface in the seven sub-catchments were determined as shown in Table 5.1. It can be inferred that the artificial compacted sand surface is only found in sub-catchments 3 and 6, and that the rubber surface is only present in sub-catchment 6 while sub-catchments 4 and 5 are the only sub-catchments that contain natural environment areas. Since gutters are not found in some areas of the campus, not all the area is covered by the rainwater drainage system. The total campus area that rainwater will be collected from is 346,971 m^2.

Table 5.1. Areas (m^2) of every surface in each sub-catchment

Sub-catchment	Interlocking Tiles and Concrete Area	Grass Area	Artificial sand Area	Rubber Area	Natural Environment Area	Total Area
1	10589	4299	0	20	0	14888
2	28834	15857	0	0	0	44691
3	21376	12604	589	0	0	34569
4	31646	9685	0	0	7029	48360
5	72100	20232	0	0	32130	124462
6	40397	25631	1311	5690	0	73029
7	5732	1239	0	0	0	6971
Total	210675	89547	1900	5690	39159	346971

5.2 Catchment Runoff

After the areas of the surfaces on campus are determined the parameters needed in the runoff calculation need to be computed. For the traditional SCS method parameters such as S_D, I_a and CN_N are required in the runoff calculation. On the other hand, in the SWMM model parameters such as the percent of impervious layer, percent slope and the width of overflow need to be determined before applying the model.

5.2.1 Traditional SCS Results

When applying this method the CN of each surface is determined from Table 2.2 according to soil group D. CN_N is determined from Equation 4.1, while S_D is computed from Equation 4.2 and I_a is computed from Equation 4.3. The data is placed into a table similar to Table 5.2, to calculate the monthly runoff produced by each sub-catchment.

Table 5.2. The data used in the spreadsheet SCS method.

Sub-Catchment / Surface Type	1	2	3	4	5	6	7
Interlocking Tiles and Concrete Area (m^2)	10589	28834	21376	31646	72100	40397	5732
CN	98	98	98	98	98	98	98
Grass Area (m^2)	4299	15857	12604	9685	20232	25631	1239
CN	82	82	82	82	82	82	82
Artificial sand Area (m^2)	0	0	589	0	0	1311	0
CN	88	88	88	88	88	88	88
Rubber Area (m^2)	0	0	0	0	0	5690	0
CN	98	98	98	98	98	98	98
Natural Environment Area (m^2)	0	0	0	7029	32130	0	0
CN	89	89	89	89	89	89	89
Total Area (m^2)	14888	44691	34569	48360	124462	73029	6971
CN_N	93.38	92.32	92.00	93.49	93.08	92.20	95.16
S_D (mm)	18.00	21.12	23.38	17.69	18.90	22.82	12.93
I_a (mm)	3.60	4.22	4.68	3.54	3.78	4.56	2.59

After the individual monthly precipitation values are plugged into the spreadsheet from 1978 to 2009, the monthly runoff volumes of each sub-catchment will be obtained by using Equation 4.4. The results showed that the 5th sub-catchment will obtain the largest runoff volume while the 7th sub-catchment will have the least runoff volume, this is mainly due to the difference in the areas of the sub-catchments, although the 7th sub-catchment has the highest percent of impervious layer. Table 5.3 shows the results of runoff in 1978 according to the traditional SCS method.

Table 5.3. Spreadsheet monthly runoff volume (m^3) from each sub-catchment.

1978	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	104.7	27.5	56.2	25.3	0.0	0.0	0.0	0.0	0.0	29.0	8.0	91.1
Sub-catchment 1	1277.6	202.9	583.4	176.5	0.0	0.0	0.0	0.0	0.0	221.3	12.9	1080.4
Sub-catchment 2	3710.4	545.4	1651.7	470.4	0.0	0.0	0.0	0.0	0.0	597.7	25.6	3123.2
Sub-catchment 3	2802.6	389.7	1225.1	334.1	0.0	0.0	0.0	0.0	0.0	428.7	14.3	2351.4
Sub-catchment 4	4163.9	666.6	1906.2	580.4	0.0	0.0	0.0	0.0	0.0	726.5	43.4	3522.6
Sub-catchment 5	10579.9	1643.3	4795.7	1426.2	0.0	0.0	0.0	0.0	0.0	1794.5	95.9	8934.7
Sub-catchment 6	5955.6	839.6	2615.2	720.9	0.0	0.0	0.0	0.0	0.0	922.8	32.8	5000.9
Sub-catchment 7	631.8	114.3	301.1	100.9	0.0	0.0	0.0	0.0	0.0	123.6	11.1	538.4

5.2.2 SWMM Model Results

In order to apply the SWMM software to compute the runoff the percent impervious layer, width of overflow and the percent slope are calculated and the results of these calculations are shown in Table 5.4. These parameters are placed in the input of the SWMM software in the sub-catchment characteristics. Since the SWMM model requires hourly rainfall, the daily rainfall data was converted to hourly rainfall using Figure 4.3. Some of the hourly rainfall are presented in Table 5.6 and are calculated from the daily rainfall in Table 5.5. Table 5.7 shows the SWMM monthly runoff in 1978.

Table 5.4. The input data in the SWMM model for all the sub-catchments.

Sub-Catchment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Total Area (ha)	1.4888	4.4691	3.4569	4.836	12.4462	7.3029	0.6971
CN_N	93.38	92.32	92.00	93.49	93.08	92.20	95.16
Interlocking Tiles and Concrete Area (ha)	1.0589	2.8834	2.1376	3.1646	7.2100	4.0397	0.5732
Percent of Impervious Layer (%)	71.12	64.52	63.54	65.44	57.93	64.90	82.22
Length from outlet to farthest point (m)	225.44	845.14	446.22	282.39	1340.32	847.90	139.31
Width of overflow(m)	66.04	52.88	77.47	171.25	92.86	86.13	50.04
Highest Elevation (m)	142.5	143.9	139.6	132	140.1	142	135.9
Lowest Elevation (m)	137.4	133.3	131.1	118.2	92	115.2	132.4
Distance between highest and lowest points (m)	248.7	775.1	518.3	219.2	1286.4	770.5	150
Percent slope (%)	2.05	1.37	1.64	6.30	3.74	3.48	2.33
Drying time (days)	8	8	8	8	8	8	8

Table 5.5. Daily rainfall data (mm) of days 1 to 10 in each month of 1978

Day	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	28.7	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	21.5
7	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.2
8	2.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
9	0.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	23.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6

Table 5.6. Hourly rainfall (mm) data for the first ten days of January 1978

Day **Time**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0:00-1:00	0	0.09	1.91	0.14	0	0	0	0.15	0.05	1.54
1:00-2:00	0	0.09	1.91	0.14	0	0	0	0.15	0.05	1.54
2:00-3:00	0	0.09	1.91	0.14	0	0	0	0.15	0.05	1.54
3:00-4:00	0	0.09	1.91	0.14	0	0	0	0.15	0.05	1.54
4:00-5:00	0	0.09	1.91	0.14	0	0	0	0.15	0.05	1.54
5:00-6:00	0	0.09	1.91	0.14	0	0	0	0.15	0.05	1.54
6:00-7:00	0	0.07	1.63	0.12	0	0	0	0.12	0.05	1.31
7:00-8:00	0	0.07	1.63	0.12	0	0	0	0.12	0.05	1.31
8:00-9:00	0	0.07	1.63	0.12	0	0	0	0.12	0.05	1.31
9:00-10:00	0	0.07	1.63	0.12	0	0	0	0.12	0.05	1.31
10:00-11:00	0	0.07	1.63	0.12	0	0	0	0.12	0.05	1.31
11:00-12:00	0	0.07	1.63	0.12	0	0	0	0.12	0.05	1.31
12:00-13:00	0	0.04	0.86	0.06	0	0	0	0.07	0.02	0.69
13:00-14:00	0	0.04	0.86	0.06	0	0	0	0.07	0.02	0.69
14:00-15:00	0	0.04	0.86	0.06	0	0	0	0.07	0.02	0.69
15:00-16:00	0	0.04	0.86	0.06	0	0	0	0.07	0.02	0.69
16:00-17:00	0	0.04	0.86	0.06	0	0	0	0.07	0.02	0.69
17:00-18:00	0	0.04	0.86	0.06	0	0	0	0.07	0.02	0.69
18:00-19:00	0	0.02	0.38	0.03	0	0	0	0.03	0.01	0.31
19:00-20:00	0	0.02	0.38	0.03	0	0	0	0.03	0.01	0.31
20:00-21:00	0	0.02	0.38	0.03	0	0	0	0.03	0.01	0.31
21:00-22:00	0	0.02	0.38	0.03	0	0	0	0.03	0.01	0.31
22:00-23:00	0	0.02	0.38	0.03	0	0	0	0.03	0.01	0.31
23:00-0:00	0	0.02	0.38	0.03	0	0	0	0.03	0.01	0.31
Total	0	1.30	28.70	2.10	0	0	0	2.20	0.80	23.10

In order to obtain monthly results from the SWMM software the dates of simulation should be manipulated from the Options tab. By clicking on the summary report, the runoff depth, infiltration depth and runoff volumes from each sub-catchment can be viewed in the form of a table. Similar to the traditional SCS results, the 5th sub-catchment showed the highest runoff volume while the 7th sub-catchment showed the least volume. But the values of the runoff volume are found to be different in both methods, this is due to the fact that the SWMM model uses the starting point as the traditional SCS method but then computes the infiltration differently since infiltration is changing during rainfall ("Hydrology comparison", 2009). On the other hand, in the traditional SCS method the infiltration is included in the initial abstraction which is considered to be constant for a sub-catchment.

Table 5.7. SWMM monthly runoff volume (m^3) from each sub-catchment.

1978	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	104.7	27.5	56.2	25.3	0.0	0.0	0.0	0.0	0.0	29.0	8.0	91.1
Sub-catchment 1	1402	330	716	330	0	0	0	0	0	362	95	1213
Sub-catchment 2	4023	916	2028	944	0	0	0	0	0	1002	265	3473
Sub-catchment 3	3031	682	1523	711	0	0	0	0	0	761	197	2615
Sub-catchment 4	4465	1021	2252	1045	0	0	0	0	0	1137	294	3853
Sub-catchment 5	11053	2426	5476	2570	0	0	0	0	0	2673	699	9515
Sub-catchment 6	6464	1463	3254	1518	0	0	0	0	0	1606	423	5581
Sub-catchment 7	696	172	363	165	0	0	0	0	0	185	50	604

5.2.3 Sensitivity Analysis

The difference between the two approaches is that the SWMM model uses CN to compute the infiltration as a starting point and then SWMM utilizes the runoff methodology to simulate the surface runoff hydrograph as stated by Lewis A. Rossman, the author of the SWMM user manual (Rossman, 2009). Some parameters included in the SWMM model but not in the spreadsheet SCS are the percent of impervious layer, depression storage, the pervious roughness coefficient and the soil drying time. The exact value of the soil drying time parameter can be determined through experimental analysis and the information regarding this parameter is not available, therefore a sensitivity analysis is performed to assess the effect of this parameter on the runoff. The range of this parameter on SWMM is between 2 days and 14 days.

The sensitivity analysis was performed on the two years with the highest annual precipitation which were 1988 and 1994 with 470.1 mm and 484.8 mm respectively. The monthly runoff was found for different values of the saturated soil drying time. The saturated soil drying time ranges from 2 days to 14 days with a median of 8 days. Figures 5.1 to 5.7 show the sensitivity of each sub-catchment to changing the saturated soil drying time. In Figures 5.1 to 5.7 the curves of April to October appear as one curve since during these months there is no or little rainfall so the change in the runoff due to the change in the saturated soil drying time is negligible. Moreover, the highest monthly rainfall through all the data such as 2003 February, 2010 January and 1986 November, with 159 mm, 154.7

mm and 131.2 mm respectively, were analyzed individually with respect to changing saturated soil drying time. In this analysis a major effect is indicated when the parameter was varied and the runoff change is greater than ± 5%, as shown in Figure 5.8. Both sensitivity tests illustrated the runoff is not sensitive to the change in soil saturated drying time. The main reason for the runoff not being sensitive to the change in the soil saturated drying time is that the sub-catchment areas are mainly consisting of impervious layers as seen from Table 5.4 the percent of impervious layer range from 57.9% to 71.1%, therefore, there is little effect on the runoff from the soil surface.

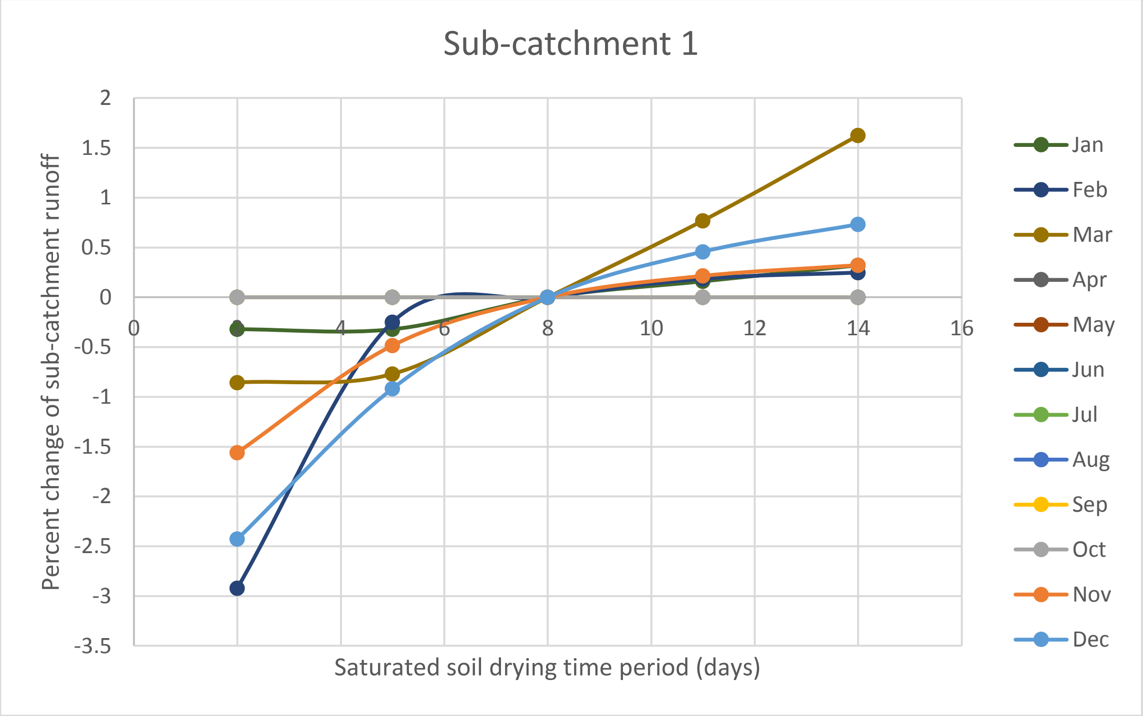


Figure 5.1. The effect of change in saturated soil drying time on runoff in sub-catchment 1.

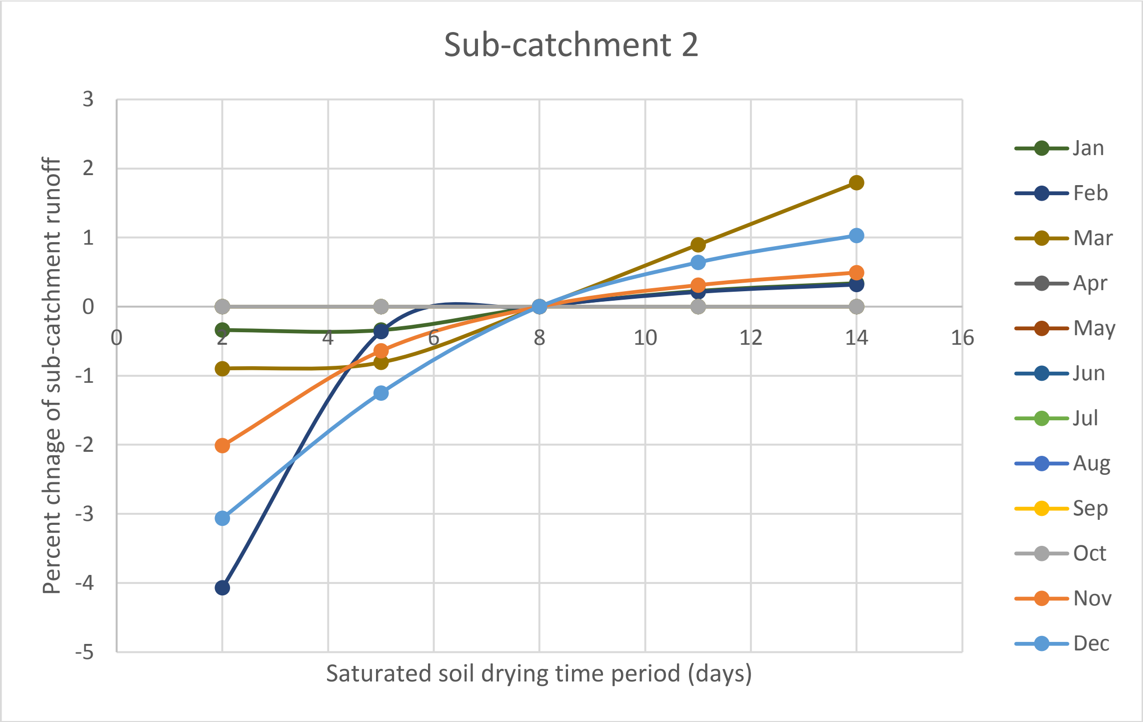


Figure 5.2. The effect of change in saturated soil drying time on runoff in sub-catchment 2.

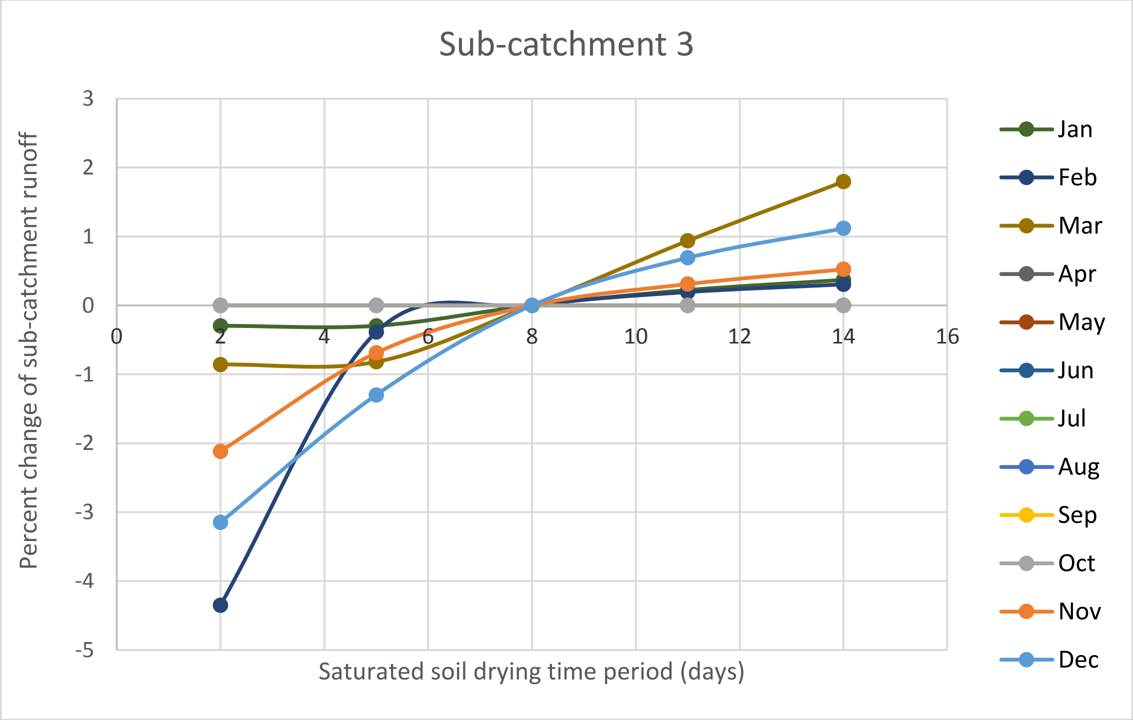


Figure 5.3. The effect of change in saturated soil drying time on runoff in sub-catchment 3.

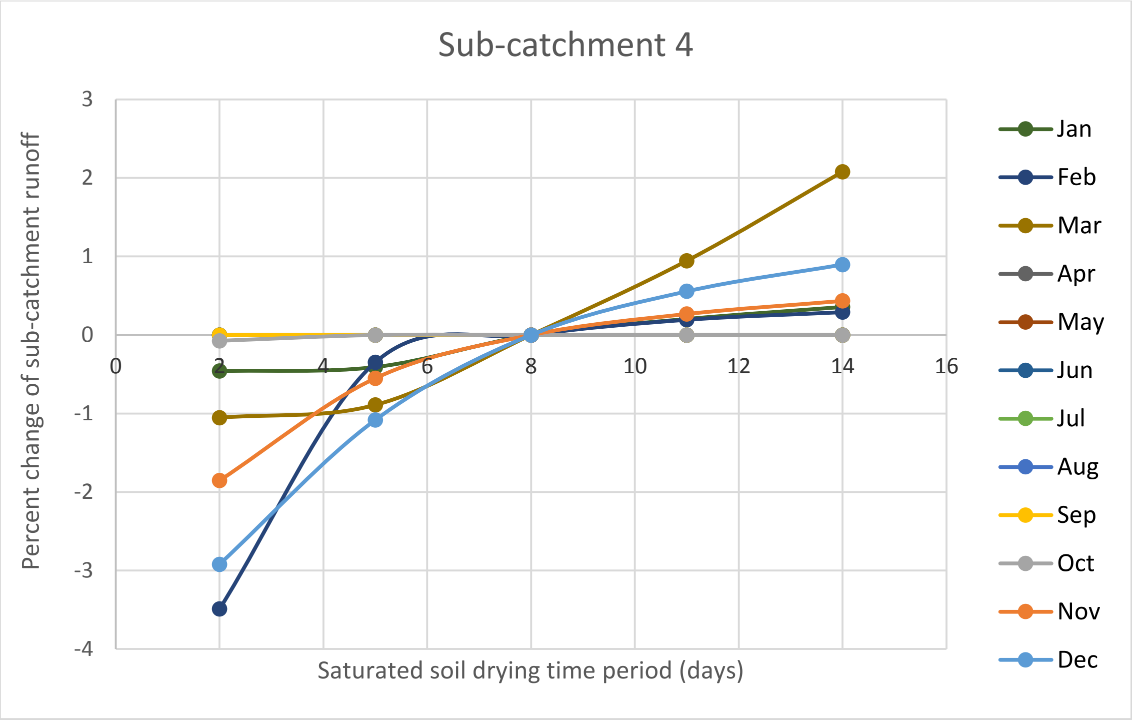


Figure 5.4. The effect of change in saturated soil drying time on runoff in sub-catchment 4.

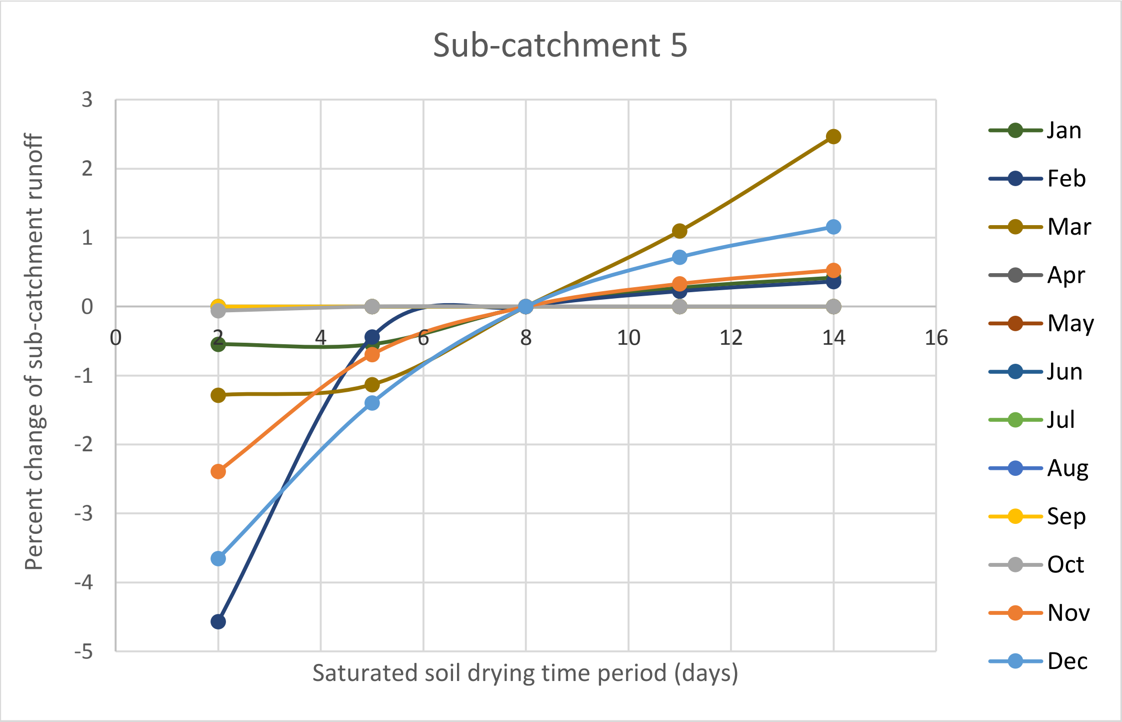


Figure 5.5. The effect of change in saturated soil drying time on runoff in sub-catchment 5.

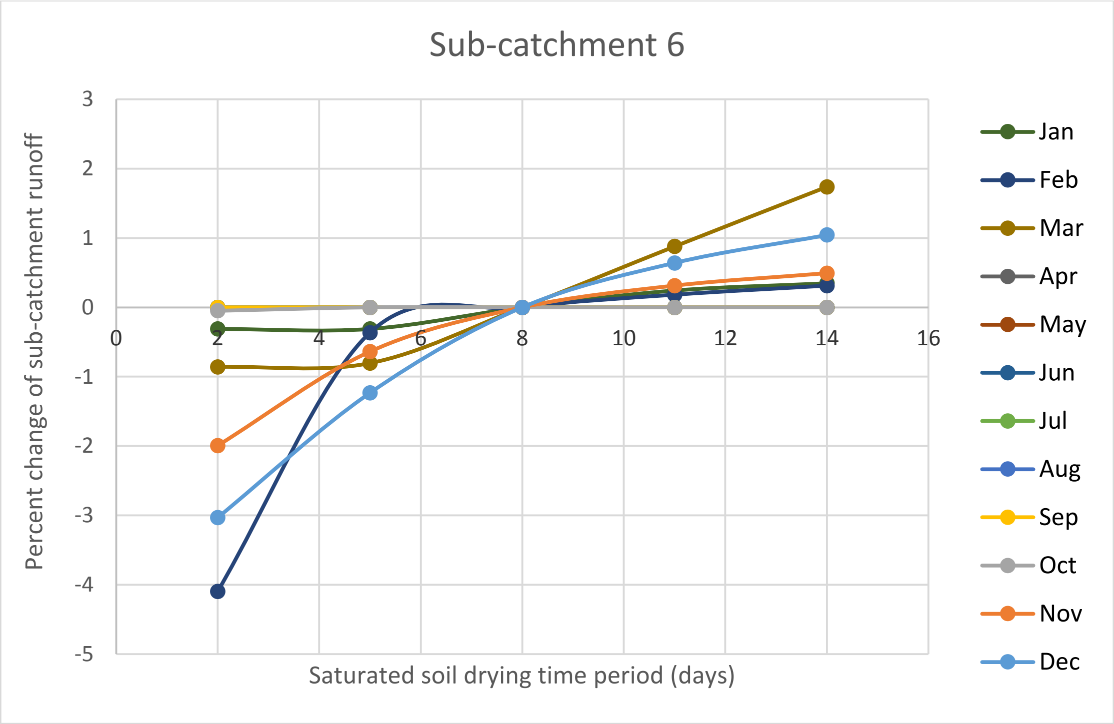


Figure 5.6. The effect of change in saturated soil drying time on runoff in sub-catchment 6.

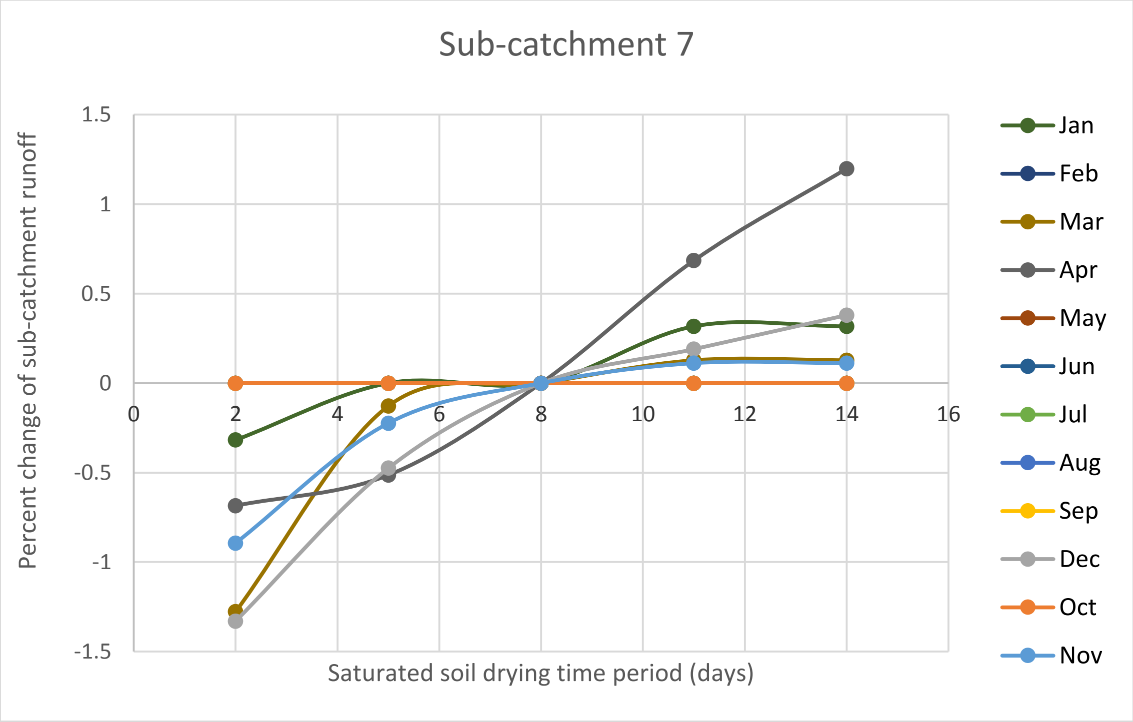


Figure 5.7. The effect of change in saturated soil drying time on runoff in sub-catchment 7.

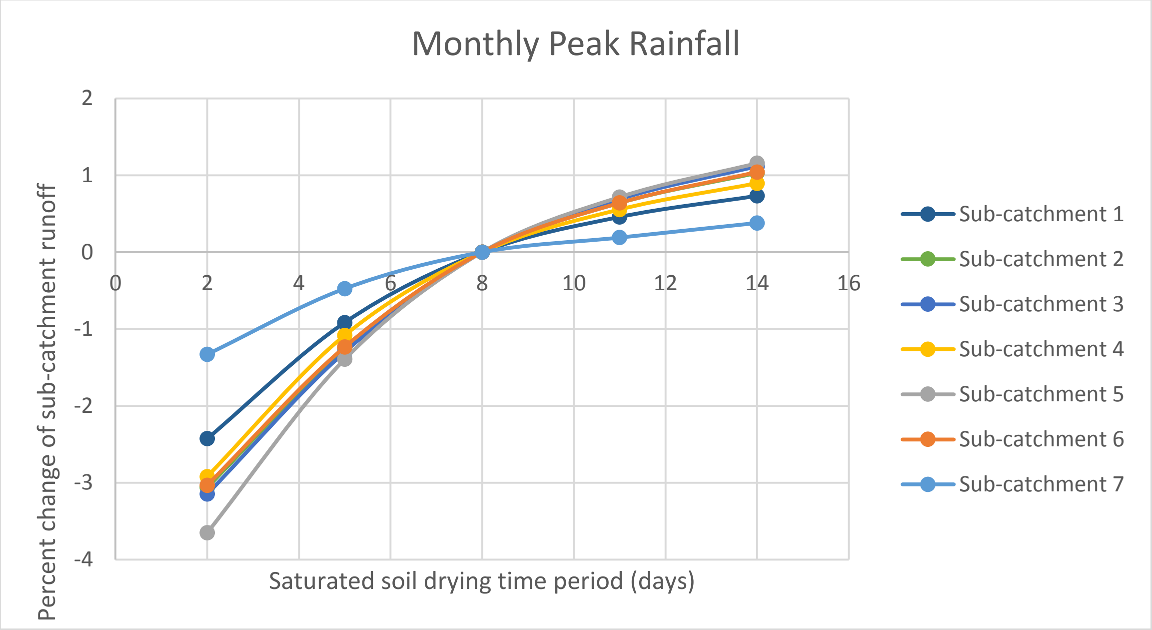


Figure 5.8. The effect of change in saturated soil drying time on runoff in all sub-catchments during the peak monthly rainfall.

5.3 Irrigation Requirements

The monthly irrigation requirements of each sub-catchment are calculated by multiplying the monthly water demand of each vegetation type shown in Table 4.2 by the corresponding areas of the vegetation in each sub-catchment from Table 5.9. Moreover, Table 5.8 shows that Sub-catchments 1 and 2 do not contain any lawn areas. Due to that reason, the monthly water consumption of Sub-catchments 1 and 2 are the same throughout all the months of the year as presented in Table 5.9. Consequently, the monthly demand of each reservoir should be summed, this is shown in Table 5.10.

Table 5.8. The areas occupied of each crop type in the seven sub-catchments.

Sub- catchment	**Ground cover (m^2)**	**Trees and bushes**		**Lawn area (m^2)**
		m^2	**Number of trees and bushes**	
Sub-catchment 1	2324	1976	1149	0
Sub- catchment 2	6938	8919	5185	0
Sub- catchment 3	2779	6286	3653	3540
Sub- catchment 4	4714	1876	1091	3095
Sub- catchment 5	5211	1922	1117	13099
Sub- catchment 6	15263	9286	5399	1082
Sub- catchment 7	162	480	279	1259
Total Area	37390	30745	17873	22074

Table 5.9. The monthly water consumption (m^3) of each sub-catchment.

Sub-catchment **Month**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Jan	174	762	1230	802	2810	1065	291
Feb	174	762	1230	802	2810	1065	291
Mar	174	762	1230	802	2810	1065	291
Apr	174	762	1230	802	2810	1065	291
May	174	762	1542	1074	3963	1161	402
Jun	174	762	1542	1074	3963	1161	402
Jul	174	762	1542	1074	3963	1161	402
Aug	174	762	1542	1074	3963	1161	402
Sep	174	762	1542	1074	3963	1161	402
Oct	174	762	1542	1074	3963	1161	402
Nov	174	762	1230	802	2810	1065	291
Dec	174	762	1230	802	2810	1065	291

Table 5.10. The monthly water consumption (m^3) of the three irrigation areas.

Month	Reservoir 1	Reservoir 2	Reservoir 3
Jan	3406	3728	0
Feb	3406	3728	0
Mar	3406	3728	369
Apr	3406	3728	369
May	4078	4999	369
Jun	4078	4999	369
Jul	4078	4999	369
Aug	4078	4999	369
Sep	4078	4999	369
Oct	4078	4999	369
Nov	3406	3728	0
Dec	3406	3728	0
Annual Consumption	44906	52365	2950
Total Annual Consumption of campus	100221		

5.4 Rainwater Tank Sizing Results

Before calculating the reservoir volumes, the runoff from one of two methods used should be chosen to be utilized in the reservoir sizing calculations. The traditional SCS method has some drawbacks when compared to the SWMM model. The traditional SCS is considered to be a combined loss method since the initial abstraction includes infiltration, interception and depression storage, the losses caused by these processes are calculated simultaneously. Moreover, in the traditional SCS method the infiltration in the initial abstraction does not vary with changing rainfall events on a sub-catchment, on the contrary it would stay the same before and during the rainfall event. On the other hand, in the SWMM model, the infiltration changes with changing rainfall events and therefore the SWMM model simulates infiltration better than the traditional SCS. Therefore, the runoff results from the SWMM model were chosen to be utilized in the tank sizing calculations. After applying Equations 4.6 to 4.11, the annual reservoir volume is computed such as in Table 5.12. The volumes of the three water reservoirs were taken as the average of all the years without the years that showed zero as the volume of the water tanks. Since rainwater will not be collected in those years, they will not be included in the reservoir sizing calculations. Furthermore, Reservoir 1 was computed to be 2305 m^3, Reservoir 2 was calculated as 3490 m^3 while Reservoir 3 was computed to be 1071 m^3. The percentage of demand met according to Reservoir 1 is 37.8% in the annual balance and 32.4% in the monthly balance. Reservoir 2 shows 41.3% and 34.1% for the percentage of demand met in the annual balance and monthly balance respectively, while Reservoir 3 shows 90.5% and 66.8% for the percentage of demand met in the annual balance and monthly balance respectively, as shown in Table 5.11. In other words, the annual balance approach (with carryover) shows better results in meeting the demand and therefore such an approach should be selected. Figures 5.9, 5.10 and 5.11 show the annual reservoir volume and the average reservoir volume throughout the 31 years on rainfall data.

Table 5.11. Reservoir volumes and corresponding percent demand met.

Reservoir	**Volume (m^3)**	**Annual balance demand met (carryover) (%)**	**Monthly balance demand met (no carryover) (%)**
Reservoir 1	2305	37.8	32.4
Reservoir 2	3490	41.3	34.1
Reservoir 3	1071	90.5	66.8

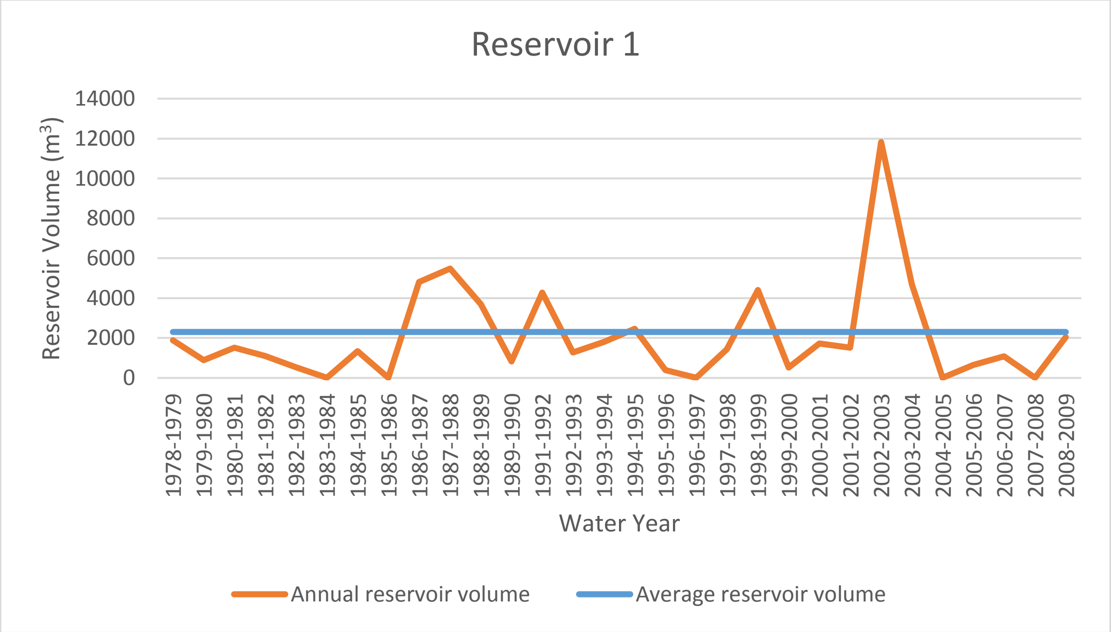


Figure 5.9. The annual and average water tank volume of Reservoir 1.

Table 5.12. The water balance during 1986-1987 to find the volume of Reservoir 1.

1986-1987	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Rainfall (mm)	0.2	11.6	131.1	26.8	57.8	17.0	89.3	2.4	2.8	1.6	0.0	0.0
Runoff (m^3)	6	562	8219	1456	3192	870	5311	101	131	72	0	0
Demand (m^3)	4078	4078	3406.4	3406.4	3406.4	3406.4	3406.4	3406.4	4078	4078	4078	4078
CS (m^3)	0	0	4812.6	2862.2	2647.7	111.3	2015.9	0	0	0	0	0
WS (m^3)	0	0	4812.6	2862.2	2647.7	111.3	2015.9	0	0	0	0	0
SP1 (m^3)	0	0	0	0	0	0	0	0	0	0	0	0
DM1 (m^3)	6	562	3406.4	3406.4	3406.4	3406.4	3406.4	2116.9	131	72	0	0
DM2 (m^3)	6	562	3406.4	1456	3192	870	3406.4	101	131	72	0	0
SP2 (m^3)	0	0	4812.6	0	0	0	1904.6	0	0	0	0	0
%DM1	0.15	13.8	100	100	100	100	100	62.1	3.2	1.8	0	0
%DM2	0.15	13.8	100	42.7	93.7	25.5	100	3.0	3.2	1.8	0	0
SC (m^3)	4812.58											

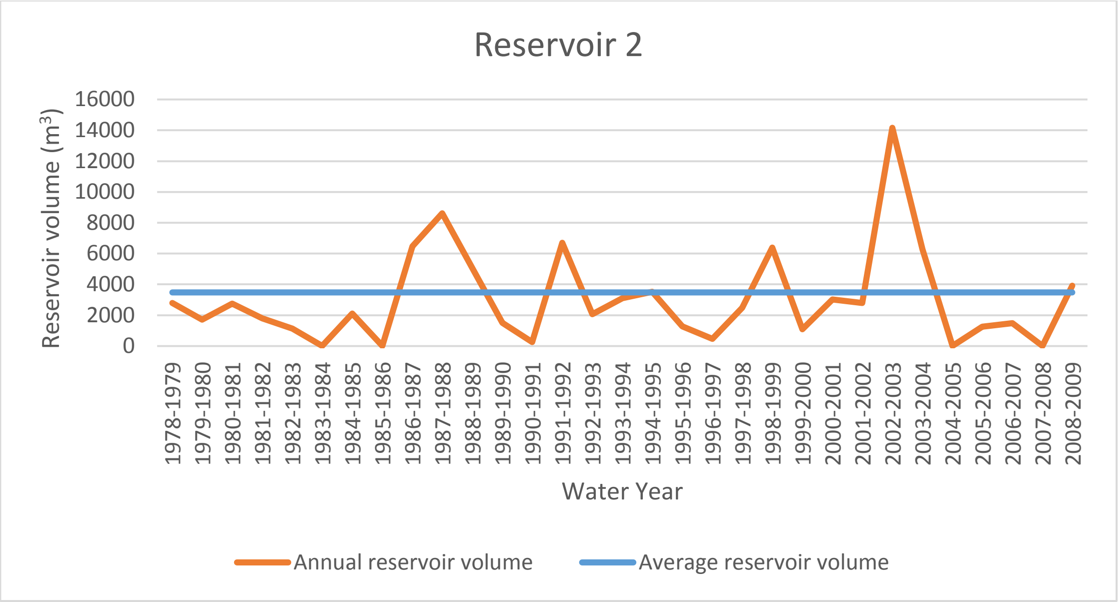


Figure 5.10. The annual and average water tank volume of Reservoir 2.

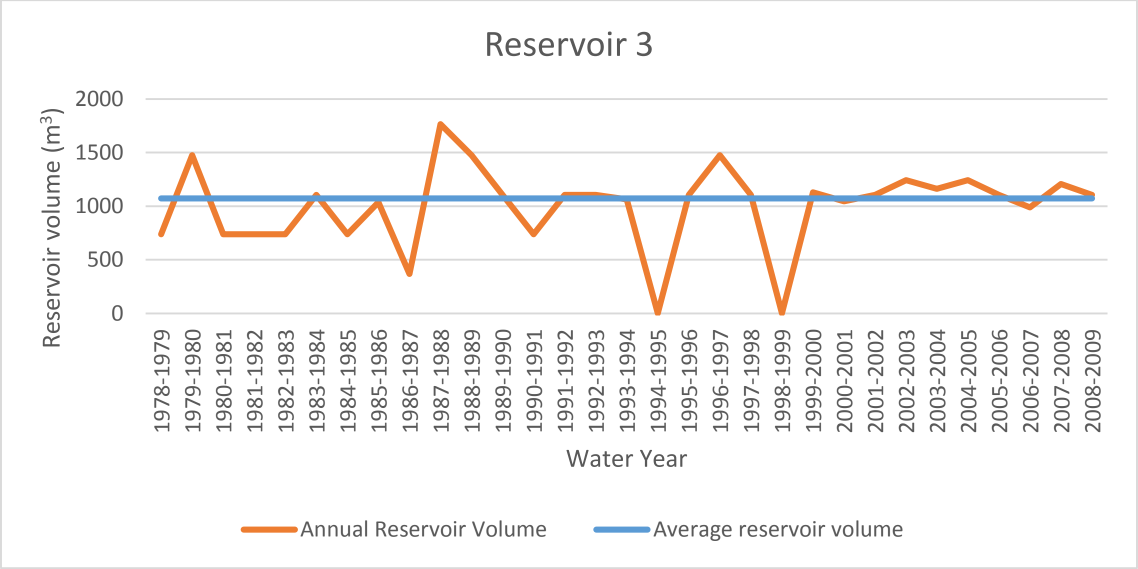


Figure 5.11. The annual and average water tank volume of reservoir 3.

Table 5.13. Annual water demand and annual saving.

Reservoir	Annual Water Demand (m^3)	Percent of Water Demand Met (%)	Annual Water Demand met (m^3)
Reservoir 1	44,906	37.8	16,974
Reservoir 2	52,365	41.3	21,627
Reservoir 3	2,950	90.5	2,670
Total	100,221	41.2	41,271

As shown in Table 5.13 the annual water supplied by the proposed system is 41,271 m^3, which is 41.2% of the total annual irrigation demand of the campus. The proposed system can be integrated with the present irrigation system by pumping the water to a temporary tank located at the blue spots which are at higher elevations in order to for the water to move by gravity. The temporary tanks are of small volumes, when they are full the pumps at the storage tanks will switch off and the system is functional. When there is insufficient rainfall and not enough water is pumped to the small tanks then the system will not be functional and the water from the main tank will be used. By that, the rainwater harvesting system will be working in parallel with the existing system supplying rainwater for irrigation when it is available.

As shown in Figure 5.12, the first flush will remove the first 0.2 – 2 mm that is not of good quality to be used. The first flush tank operates with a trap door that closes once a certain volume of water is attained and allowing the following runoff to proceed to the sedimentation tank. The sedimentation tank will serve the purpose of removing the solid particles such as soil, sand and other particles that are large enough to sediment. In order to reduce the cleaning process of the storage tank and to protect the pump located in the tank. Moreover, screens can be used at the inlet of the system to reduce the debris from entering to the system. The system does not need heavy labor operation during operation, labor is needed mainly in the cleaning process of the system. In addition, the water tank is preferably reinforced concrete to withstand the hydrostatic pressure and underground in order to support the structure and keep the scenery clean from any large structure. Furthermore, this will ensure a good quality water that if necessary treatment processes were to be applied may be used for other purposes such as household water.

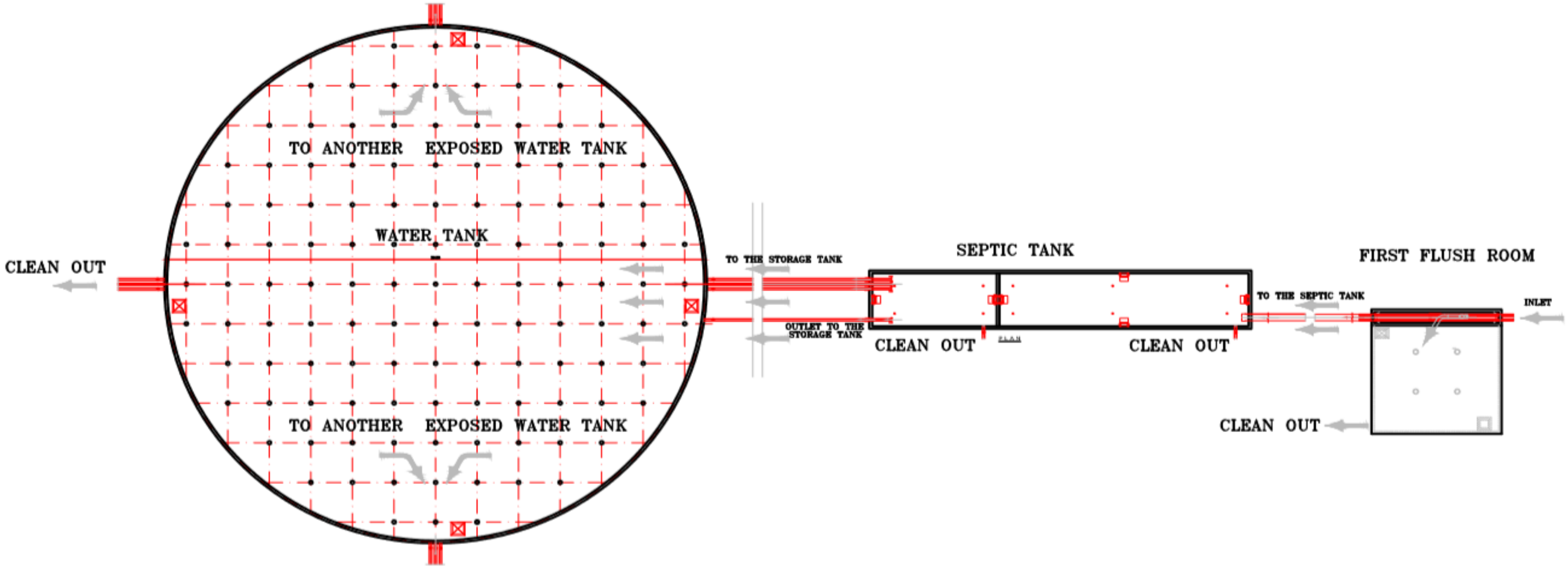


Figure 5.12. The storage system with a first flush tank and a sedimentation tank

On the other hand, another option for the storage tank is the Modular tank system. The Modular tank system is sub-surface tank might be less costly than the concrete tank. There are eleven steps to install the Modular tank system (Atlantis, 2005):

1. Excavation of the location site to place the storage system. The Modular system is best employed under flat ground.
2. Placing the base material. The base material should be compactible such as sand or stone.
3. Placing the impermeable plastic lining to cover the base and the walls of the excavated area.
4. Laying the Geotextile over the plastic lining to cover the tanks.
5. Installing the Modular tanks over the Geotextile layer.
6. Installing the inspection or maintenance ports. Those ports are usually PVC pipes that offer access to the system from the ground.
7. Wrapping the tanks with the Geotextile and plastic linings to cover them completely, only keeping the inspection ports protruding.
8. Connect the inlet and outlet pipes.
9. Backfill the sides and compact it to ensure maximum stability of the system.
10. Backfill the top and compact it.
11. Placing the Geogrid to ensure the system can withstand loads.

The Modular tanks are assembled on site so their transport is easy. This method is becoming widely used. It is a cost-effective and efficient technique to store rainwater.

Some advantages of using this system include (Fibromat, 2014):

- High compressive strength which allows the system to be used under urban areas (parking lots and roads).
- The Modular tanks link vertically and horizontally for maximum.
- Cost-effective versus concrete and metal storage systems.
- Low transportation cost.
- Can be modified for different volume needs.
- Easily assembled on site.

Therefore the Modular storage system can be an option to replace the concrete tank. Figure 5.13 illustrates a Modular tank system.

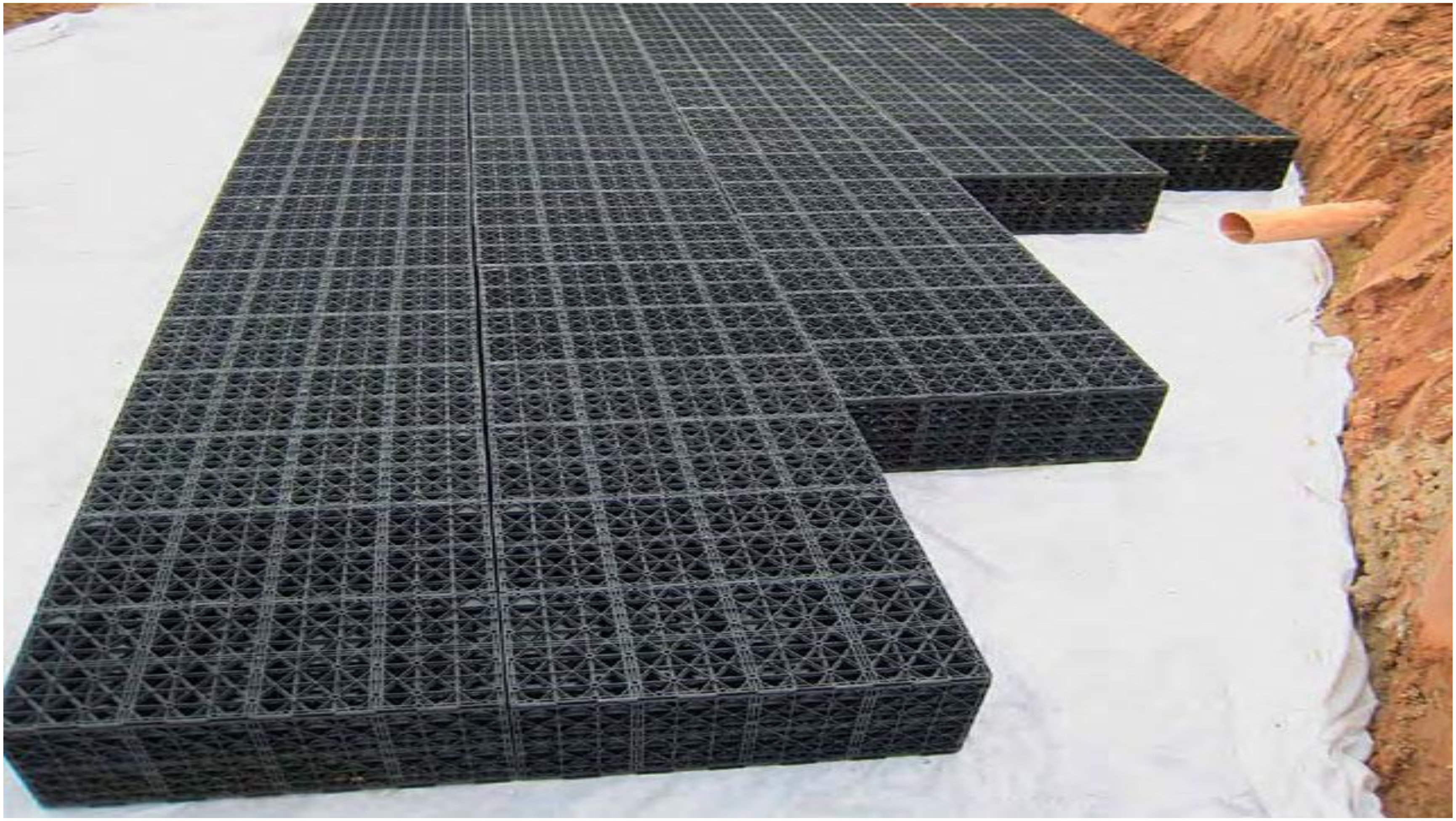


Figure 5.13. Modular Tank System (Fibromat, 2014

CHAPTER VI
CONCLUSION

Rainwater harvesting system, where rainfall runoff collected and utilized, is a prominent solution to address the issue of water scarcity by conserving the available water resources and the energy needed to deliver water to the water supply system. The impact of climate change on water resources can also be reduced by rainwater harvesting. Rainwater harvesting is becoming an important part of the sustainable water management around the world. The Eastern Mediterranean countries with semi-arid climate obtain low precipitation and high temperature, therefore, applying rainwater harvesting systems will be very beneficial in these areas at least to provide non-potable uses such as irrigation and household use. This study investigated the potential of rainwater harvesting in METU-NCC. Two approaches for runoff calculation were adopted, the traditional SCS method and the SWMM model. Daily rainfall data from 1978 to 2009 was used to obtain the monthly and hourly rainfall. Moreover, in order to demonstrate its potential a rainwater harvesting system was proposed. The reservoir locations were chosen with their relative irrigation areas and the reservoir volumes were calculated after finding the irrigation consumption of the campus. The study was not aimed at optimizing the system, rather the system serves the purpose to show if there is a potential in rainwater harvesting on the campus. The system showed that 41.2% of the campus irrigation demand was met. The reservoir volumes were found to be about 2300 m^3, 3500 m^3 and 1100 m^3 with efficiencies of 37.8%, 41.3% and 90.5% respectively. Finally, this illustrates that there is potential for collecting rainwater as in the proposed system for irrigation purposes of the campus.

This study is preliminary to assess the potential of constructing a rainwater harvesting system, therefore there is much work that can be conducted to evaluate different aspects of the project. A cost-benefit analysis is required to implement this project as well as calibration of the models in this paper should be done in order to examine how these models are related to the actual runoff, this can be done by installing a flow meter in the rainwater pipes to measure the runoff attained. Once the models that were generated using the past data are calibrated using the present data then forecasting can be performed to estimate the future expected runoff. Furthermore, a study on the cost of different rainwater harvesting systems and the location of the reservoirs using the Analytical Hierarchy Process (AHP) can be conducted in order to obtain a system that can lead to better saving at lower cost of construction and maintenance. Other studies that might be conducted are studies to implement this technique in other location in North Cyprus as well as awareness campaigns that can help the people of the island conserve the current water resources as well as support the dry environment by collecting rainfall to serve irrigation and household purposes.

Concerning the drainage system, investigations on the efficiency of the drainage system including modifying the system to drain more water from depression areas can be performed. In addition, ensuring that the drainage system is collecting water from parts of the campus that do not contain any gutters and studying the effect this would have on the rainwater harvesting system.

Regarding the proposed system in the previous section, further studies can be conducted to optimize the tank volumes and the efficiency of the system, in other words the percentage of demand met. Moreover, modifications to the irrigation system can be conducted to reduce water consumption, for instance, studying the effects of a dropper system on the water consumption and on the rainwater harvesting system. On the other hand, studies regarding changing crop type and introducing local crops and reducing grass areas can be examined to evaluate its effects on the water consumption. In addition, testing the quality of the water collected and perform studies on the capability of increasing the quality of water at a feasible cost for different uses of the water may be conducted.

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APPENDIX A

SWMM Model Runoff Results

Tables A.1, A.2, and A.3 show the SWMM model runoff results for each reservoir discussed in Chapter V pages 56-59.

Table A.1. Reservoir 1 SWMM model runoff.

Reservoir 1	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1978-1979	0	1550	409	5290	2008	942	1426	332	317	472	0	0
1979-1980	0	1361	3394	2979	2900	4303	2546	600	0	0	0	0
1980-1981	0	1463	193	2176	4647	3675	1940	590	848	346	0	0
1981-1982	0	69	2136	1750	1801	2519	4507	560	6	3570	0	0
1982-1983	0	70	1306	1182	1392	3946	2075	765	1194	956	0	0
1983-1984	0	940	1583	2107	1846	706	1654	2774	0	0	0	0
1984-1985	0	87	2694	2328	4740	2281	1846	149	168	0	0	0
1985-1986	0	1295	782	1045	1401	2533	615	565	1531	249	0	0
1986-1987	6	562	8219	1456	3192	870	5311	101	131	72	0	0
1987-1988	0	2487	1202	4229	2703	7084	5098	379	44	0	494	0
1988-1989	0	1873	2601	7108	2889	490	848	0	30	0	0	0
1989-1990	0	976	1352	908	690	4235	1401	22	0	123	0	0
1990-1991	0	630	168	1001	3256	1869	1625	489	163	0	0	0
1991-1992	0	697	2003	7689	837	5959	1892	285	419	168	0	0
1992-1993	0	33	3046	4680	2110	2854	2578	168	580	0	0	0
1993-1994	0	288	1920	729	4953	3665	2016	2003	148	0	0	0
1994-1995	2469	3569	5871	2738	1054	677	636	1609	549	0	17	0
1995-1996	14	327	2016	764	3310	3797	1885	1783	6	0	0	2117
1996-1997	0	1079	260	3414	408	1526	1499	1476	481	0	0	0
1997-1998	747	1141	4846	3230	1601	693	2361	242	372	0	0	0
1998-1999	0	44	1643	4977	6236	1673	1711	2294	0	0	0	0
1999-2000	61	44	958	1811	1985	3923	1463	1300	194	0	0	0
2000-2001	316	437	4128	5766	1171	3341	437	1082	213	0	0	5437
2001-2002	0	583	1199	4832	3501	2191	2998	1537	130	0	0	0
2002-2003	436	6332	3904	5854	2989	9829	4024	557	3	156	0	0
2003-2004	0	1444	2146	2146	8102	3046	0	409	150	17	0	0
2004-2005	0	1877	2577	2865	1953	2427	1665	1598	44	44	0	0
2005-2006	0	958	2525	529	4059	1677	1276	1852	174	0	0	0
2006-2007	16	2543	736	171	1839	4224	1517	382	5168	44	0	0
2007-2008	0	0	1936	2191	807	1708	331	68	168	0	0	0
2008-2009	212	699	30	3376	4431	4430	2113	788	332	0	0	0

Table A.2. Reservoir 2 SWMM model runoff.

Reservoir 2	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1978-1979	0	1913	496	6512	2454	1152	1737	400	383	569	0	0
1979-1980	0	1660	4192	3639	3525	5278	3106	726	0	0	0	0
1980-1981	0	1810	237	2658	5709	4506	2372	718	1030	419	0	0
1981-1982	0	82	2612	2127	2206	3094	5526	679	7	4417	0	0
1982-1983	0	83	1596	1449	1692	4853	2533	923	1460	1170	0	0
1983-1984	0	1151	1934	2561	2242	858	2029	3402	0	0	0	0
1984-1985	0	104	3294	2847	5826	2775	2262	178	202	0	0	0
1985-1986	0	1579	948	1271	1692	3104	744	682	1873	300	0	0
1986-1987	7	682	10193	1779	3909	1053	6545	123	157	86	0	0
1987-1988	0	3060	1462	5190	3311	8767	6266	459	53	0	602	0
1988-1989	0	2304	3180	8792	3552	595	1026	0	36	0	0	0
1989-1990	0	1176	1646	1095	833	5232	1715	26	0	147	0	0
1990-1991	0	763	202	1209	3989	2276	1976	593	195	0	0	0
1991-1992	0	844	2464	9519	1016	7357	2304	343	505	202	0	0
1992-1993	0	39	3758	5765	2582	3492	3161	201	697	0	0	0
1993-1994	0	350	2353	882	6091	4481	2472	2477	176	0	0	0
1994-1995	3047	4397	7258	3342	1274	821	767	1959	667	0	20	0
1995-1996	18	392	2461	922	4065	4673	2290	2187	7	0	0	2611
1996-1997	0	1307	314	4185	494	1866	1820	1805	584	0	0	0
1997-1998	912	1382	5973	3959	1939	840	2893	290	446	0	0	0
1998-1999	0	52	1999	6139	7710	2046	2091	2824	0	0	0	0
1999-2000	72	52	1165	2214	2410	4814	1773	1576	233	0	0	0
2000-2001	382	524	5112	7103	1418	4094	529	1311	255	0	0	6744
2001-2002	0	710	1451	5949	4299	2696	3688	1874	154	0	0	0
2002-2003	529	767	4810	7208	3665	12192	4938	673	4	187	0	0
2003-2004	0	1767	2636	2636	10023	3727	0	496	179	20	0	0
2004-2005	0	2312	3153	3511	2385	2993	2048	1964	52	52	0	0
2005-2006	0	1166	3086	637	4993	2059	1548	2275	208	0	0	0
2006-2007	20	3148	889	204	2242	5203	1859	459	6396	52	0	0
2007-2008	0	0	2381	2677	982	2092	399	81	202	0	0	0
2008-2009	256	846	36	4166	5467	5461	2572	951	399	0	0	0

Table A.3. Reservoir 3 SWMM model runoff.

Reservoir 3	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1978-1979	0	4314	1132	15190	5664	2664	3997	908	870	1291	0	0
1979-1980	0	3823	9777	8398	8071	12194	7155	1655	0	0	0	0
1980-1981	0	4054	502	6121	13226	10404	5480	1647	2357	954	0	0
1981-1982	0	183	6030	4867	5034	7001	12824	1550	15	10366	0	0
1982-1983	0	185	3685	3273	3877	11291	5840	2098	3375	2703	0	0
1983-1984	0	2653	4453	5869	5133	1970	4713	7889	0	0	0	0
1984-1985	0	232	7614	6579	13474	6368	5231	399	449	0	0	0
1985-1986	0	3634	2115	2914	3821	7185	1678	1549	4329	681	0	0
1986-1987	15	1527	24074	4098	9046	2396	15286	262	352	193	0	0
1987-1988	0	7021	3356	12066	7655	20583	14587	1000	117	0	1362	0
1988-1989	0	5362	7341	20669	8273	1362	2342	0	80	0	0	0
1989-1990	0	2658	3770	2484	1889	12269	3962	59	0	331	0	0
1990-1991	0	1737	455	2753	9154	5226	4528	1353	434	0	0	0
1991-1992	0	1907	5634	22286	2272	17244	5296	774	1147	455	0	0
1992-1993	0	87	8788	13456	5959	8080	7335	452	1575	0	0	0
1993-1994	0	781	5435	2011	14035	10334	5738	5599	395	0	0	0
1994-1995	7105	10262	17023	7625	2903	1878	1739	4501	1526	0	44	0
1995-1996	35	879	5679	2094	9456	10898	5247	5079	16	0	0	6094
1996-1997	0	2979	699	9691	1106	4312	4164	4177	1337	0	0	0
1997-1998	2095	3155	13968	9171	4415	1905	6700	649	1004	0	0	0
1998-1999	0	116	4554	14237	18114	4728	4804	6577	0	0	0	0
1999-2000	161	116	2672	5113	5468	11137	4051	3602	524	0	0	0
2000-2001	863	1181	11972	16527	3234	9476	1205	2982	572	0	0	15904
2001-2002	0	1623	3283	13891	9989	6284	8499	4316	345	0	0	0
2002-2003	1209	1757	11168	16792	8502	28782	11468	1528	8	421	0	0
2003-2004	0	4078	6128	6128	23440	8623	0	1131	404	44	0	0
2004-2005	0	5389	7281	8135	5453	7008	4776	4572	116	116	0	0
2005-2006	0	2658	7123	1439	11629	4789	3539	5284	468	0	0	0
2006-2007	43	7163	2022	456	5137	11989	4308	1035	15055	116	0	0
2007-2008	0	0	5548	6182	2245	4839	886	181	455	0	0	0
2008-2009	565	1915	80	9700	12688	12746	5903	2164	901	0	0	0

APPENDIX B

TANK VOLUME CALCULATION TABLES

Tables B.1 to B.31 show the tank volume calculations for Reservoir 1 previously discussed in Chapter V, pages 66-67.

Table B.1.

1978-1979	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	29.0	8.0	91.1	36.6	23.0	26.6	6.7	6.3	9.6	0.0	0.0
Runoff	0	1550	409	5290	2008	942	1426	332	317	472	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	1883.58	485.16	0	0	0	0	0	0	0
WS	0	0	0	1883.58	485.16	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1550	409	3406.42	3406.42	1427.16	1426	332	317	472	0	0
DM2	0	1550	409	3406.42	2008	942	1426	332	317	472	0	0
SP2	0	0	0	1883.58	0	0	0	0	0	0	0	0
%DM1	0	38.00911	12.00674	100	100	41.89618	41.86213	9.746303	7.773476	11.57439	0	0
%DM2	0	38.00911	12.00674	100	58.94752	27.65367	41.86213	9.746303	7.773476	11.57439	0	0
SC	1883.58											

Table B.2.

1979-1980	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	25.3	57.4	54.7	55.3	76.6	47.4	11.8	0.9	0.0	0.0	0.0
Runoff	0	1361	3394	2979	2900	4303	2546	600	0	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	896.58	36.16	0	0	0	0	0
WS	0	0	0	0	0	896.58	36.16	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1361	3394	2979	2900	3406.42	3406.42	636.16	0	0	0	0
DM2	0	1361	3394	2979	2900	3406.42	2546	600	0	0	0	0
SP2	0	0	0	0	0	896.58	0	0	0	0	0	0
%DM1	0	33.37445	99.63539	87.45252	85.13337	100	100	18.67532	0	0	0	0
%DM2	0	33.37445	99.63539	87.45252	85.13337	100	74.74122	17.6138	0	0	0	0
SC	896.58											

Table B.3.

1980-1981	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	27.6	4.3	40.1	82.7	66.3	35.4	11.3	16.3	6.9	0.0	0.0
Runoff	0	1463	193	2176	4647	3675	1940	590	848	346	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	1240.58	1509.16	42.74	0	0	0	0	0
WS	0	0	0	0	1240.58	1509.16	42.74	0	0	0	0	0
SP1	0	0	0	0	0	268.58	0	0	0	0	0	0
DM1	0	1463	193	2176	3406.42	3406.42	3406.42	632.74	848	346	0	0
DM2	0	1463	193	2176	3406.42	3406.42	1940	590	848	346	0	0
SP2	0	0	0	0	1240.58	268.58	0	0	0	0	0	0
%DM1	0	35.87569	5.665772	63.87938	100	100	100	18.57493	20.79466	8.484614	0	0
%DM2	0	35.87569	5.665772	63.87938	100	100	56.95129	17.32024	20.79466	8.484614	0	0
SC	1509.16											

Table B.4.

1981-1982	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.5	38.8	33.4	33.6	47.7	80.2	10.9	0.2	58.8	0.01	0.0
Runoff	0	69	2136	1750	1801	2519	4507	560	6	3570	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	0	1100.58	0	0	0	0	0
WS	0	0	0	0	0	0	1100.58	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	69	2136	1750	1801	2519	3406.42	1660.58	6	3570	0	0
DM2	0	69	2136	1750	1801	2519	3406.42	560	6	3570	0	0
SP2	0	0	0	0	0	0	1100.58	0	0	0	0	0
%DM1	0	1.692018	62.70513	51.37358	52.87076	73.9486	100	48.74854	0.147132	87.54356	0	0
%DM2	0	1.692018	62.70513	51.37358	52.87076	73.9486	100	16.43955	0.147132	87.54356	0	0
SC	1100.58											

Table B.5.

1982-1983	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.5	23.9	22.6	26.6	69.0	38.4	15.4	21.7	17.4	0.0	0.0
Runoff	0	70	1306	1182	1392	3946	2075	765	1194	956	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	539.58	0	0	0	0	0	0
WS	0	0	0	0	0	539.58	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	70	1306	1182	1392	3406.42	2614.58	765	1194	956	0	0
DM2	0	70	1306	1182	1392	3406.42	2075	765	1194	956	0	0
SP2	0	0	0	0	0	539.58	0	0	0	0	0	0
%DM1	0	1.71654	38.33937	34.69919	40.86402	100	76.75448	22.45759	29.27927	23.44304	0	0
%DM2	0	1.71654	38.33937	34.69919	40.86402	100	60.91439	22.45759	29.27927	23.44304	0	0
SC	539.58											

Table B.6.

1983-1984	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	17.3	29.1	40.1	35.6	13.4	29.3	49.5	0.0	0.0	0.0	0.0
Runoff	0	940	1583	2107	1846	706	1654	2774	0	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	940	1583	2107	1846	706	1654	2774	0	0	0	0
DM2	0	940	1583	2107	1846	706	1654	2774	0	0	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	23.05068	46.47108	61.85379	54.19179	20.72557	48.55537	81.43447	0	0	0	0
%DM2	0	23.05068	46.47108	61.85379	54.19179	20.72557	48.55537	81.43447	0	0	0	0
SC	0											

Table B.7.

1984-1985	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.9	49.2	42.4	84.2	43.3	33.1	3.4	3.6	0.0	0.0	0.0
Runoff	0	87	2694	2328	4740	2281	1846	149	168	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	1333.58	208.16	0	0	0	0	0	0
WS	0	0	0	0	1333.58	208.16	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	87	2694	2328	3406.42	3406.42	2054.16	149	168	0	0	0
DM2	0	87	2694	2328	3406.42	2281	1846	149	168	0	0	0
SP2	0	0	0	0	1333.58	0	0	0	0	0	0	0
%DM1	0	2.133414	79.08596	68.34154	100	100	60.30261	4.374094	4.119697	0	0	0
%DM2	0	2.133414	79.08596	68.34154	100	66.9618	54.19179	4.374094	4.119697	0	0	0
SC	1333.58											

Table B.8.

1985-1986	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	24.1	15.8	19.9	28.2	45.6	12.3	11.3	27.7	5.1	0.0	0.0
Runoff	0	1295	782	1045	1401	2533	615	565	1531	249	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1295	782	1045	1401	2533	615	565	1531	249	0	0
DM2	0	1295	782	1045	1401	2533	615	565	1531	249	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	31.756	22.95665	30.67737	41.12822	74.35959	18.05414	16.58633	37.54319	6.105979	0	0
%DM2	0	31.756	22.95665	30.67737	41.12822	74.35959	18.05414	16.58633	37.54319	6.105979	0	0
SC	0											

Table B.9.

1986-1987	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.2	11.6	131.1	26.8	57.8	17.0	89.3	2.4	2.8	1.6	0.0	0.0
Runoff	6	562	8219	1456	3192	870	5311	101	131	72	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	4812.58	2862.16	2647.74	111.32	2015.9	0	0	0	0	0
WS	0	0	4812.58	2862.16	2647.74	111.32	2015.9	0	0	0	0	0
SP1	0	0	0	0	0	0	1904.58	0	0	0	0	0
DM1	6	562	3406.42	3406.42	3406.42	3406.42	3406.42	2116.9	131	72	0	0
DM2	6	562	3406.42	1456	3192	870	3406.42	101	131	72	0	0
SP2	0	0	4812.58	0	0	0	1904.58	0	0	0	0	0
%DM1	0.147132	13.78137	100	100	100	100	100	62.14442	3.212383	1.765584	0	0
%DM2	0.147132	13.78137	100	42.74282	93.70542	25.54001	100	2.96499	3.212383	1.765584	0	0
SC	4812.58											

Table B.10.

1987-1988	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	45.1	23.1	74.5	49.0	116.3	89.1	8.3	1.1	0.0	9.6	0.0
Runoff	0	2487	1202	4229	2703	7084	5098	379	44	0	494	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	822.58	119.16	3796.74	5488.32	2460.9	0	0	0	0
WS	0	0	0	822.58	119.16	3796.74	5488.32	2460.9	0	0	0	0
SP1	0	0	0	0	0	3677.58	1691.58	0	0	0	0	0
DM1	0	2487	1202	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	0	494	0
DM2	0	2487	1202	3406.42	2703	3406.42	3406.42	379	44	0	494	0
SP2	0	0	0	822.58	0	3677.58	1691.58	0	0	0	0	0
%DM1	0	60.98623	35.28631	100	100	100	100	100	100	0	12.11387	0
%DM2	0	60.98623	35.28631	100	79.35017	100	100	11.12605	1.078968	0	12.11387	0
SC	5488.32											

Table B.11.

1988-1989	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	32.6	47.6	116.5	50.3	9.5	16.7	0.0	0.7	0.0	0.0	0.0
Runoff	0	1873	2601	7108	2889	490	848	0	30	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	3701.58	3184.16	267.74	0	0	0	0	0	0
WS	0	0	0	3701.58	3184.16	267.74	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1873	2601	3406.42	3406.42	3406.42	3406.42	0	30	0	0	0
DM2	0	1873	2601	3406.42	2889	490	848	0	30	0	0	0
SP2	0	0	0	3701.58	0	0	0	0	0	0	0	0
%DM1	0	45.92972	76.35582	100	100	100	100	0	0.73566	0	0	0
%DM2	0	45.92972	76.35582	100	84.81045	14.3846	24.89417	0	0.73566	0	0	0
SC	3701.58											

Table B.12.

1989-1990	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	20.0	25.5	18.3	13.6	70.5	25.4	0.5	0.0	4.0	0.0	0.0
Runoff	0	976	1352	908	690	4235	1401	22	0	123	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	828.58	0	0	0	0	0	0
WS	0	0	0	0	0	828.58	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	976	1352	908	690	3406.42	2229.58	22	0	123	0	0
DM2	0	976	1352	908	690	3406.42	1401	22	0	123	0	0
SP2	0	0	0	0	0	828.58	0	0	0	0	0	0
%DM1	0	23.93348	39.68976	26.65555	20.25587	100	65.45229	0.645839	0	3.016207	0	0
%DM2	0	23.93348	39.68976	26.65555	20.25587	100	41.12822	0.645839	0	3.016207	0	0
SC	828.58											

Table B.13.

1990-1991	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	12.5	3.5	19.9	60.0	34.8	31.0	9.6	3.5	0.0	0.0	0.0
Runoff	0	630	168	1001	3256	1869	1625	489	163	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	630	168	1001	3256	1869	1625	489	163	0	0	0
DM2	0	630	168	1001	3256	1869	1625	489	163	0	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	15.44886	4.931864	29.38569	95.58422	54.86699	47.70404	14.35525	3.997087	0	0	0
%DM2	0	15.44886	4.931864	29.38569	95.58422	54.86699	47.70404	14.35525	3.997087	0	0	0
SC	0											

Table B.14.

1991-1992	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	14.0	36.6	128.3	17.2	99.8	35.5	5.9	8.4	3.5	0.0	0.0
Runoff	0	697	2003	7689	837	5959	1892	285	419	168	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	4282.58	1713.16	4265.74	2751.32	0	0	0	0	0
WS	0	0	0	4282.58	1713.16	4265.74	2751.32	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	697	2003	3406.42	3406.42	3406.42	3406.42	3036.32	419	168	0	0
DM2	0	697	2003	3406.42	837	3406.42	1892	285	419	168	0	0
SP2	0	0	0	4282.58	0	2552.58	0	0	0	0	0	0
%DM1	0	17.09184	58.80074	100	100	100	100	89.13522	10.27472	4.119697	0	0
%DM2	0	17.09184	58.80074	100	24.57125	100	55.54218	8.366555	10.27472	4.119697	0	0
SC	4282.58											

Table B.15.

1992-1993	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	0.8	51.4	80.3	38.6	51.8	45.9	3.6	12.0	0.0	0.0	0.0
Runoff	0	33	3046	4680	2110	2854	2578	168	580	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	1273.58	0	0	0	0	0	0	0	0
WS	0	0	0	1273.58	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	33	3046	3406.42	3383.58	2854	2578	168	580	0	0	0
DM2	0	33	3046	3406.42	2110	2854	2578	168	580	0	0	0
SP2	0	0	0	1273.58	0	0	0	0	0	0	0	0
%DM1	0	0.809226	89.41939	100	99.3295	83.78297	75.68063	4.931864	14.22276	0	0	0
%DM2	0	0.809226	89.41939	100	61.94186	83.78297	75.68063	4.931864	14.22276	0	0	0
SC	1273.58											

Table B.16.

1993-1994	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	5.9	34.6	14.4	88.6	67.1	35.8	37.1	3.2	0.0	0.0	0.0
Runoff	0	288	1920	729	4953	3665	2016	2003	148	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	1546.58	1805.16	414.74	0	0	0	0	0
WS	0	0	0	0	1546.58	1805.16	414.74	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	288	1920	729	3406.42	3406.42	3406.42	2417.74	1953.16	0	0	0
DM2	0	288	1920	729	3406.42	3406.42	2016	2003	148	0	0	0
SP2	0	0	0	0	1546.58	258.58	0	0	0	0	0	0
%DM1	0	7.062337	56.36416	21.40077	100	100	100	70.97598	3.629257	0	0	0
%DM2	0	7.062337	56.36416	21.40077	100	100	59.18237	58.80074	3.629257	0	0	0
SC	1805.16											

Table B.17.

1994-1995	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	42.0	61.2	99.3	50.5	20.8	13.1	13.0	30.4	10.5	0.0	0.4	0.0
Runoff	2469	3569	5871	2738	1054	677	636	1609	549	0	17	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	2464.58	1796.16	0	0	0	0	0	0	0	0
WS	0	0	2464.58	1796.16	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	2469	3569	3406.42	3406.42	2850.16	677	636	1609	549	0	17	0
DM2	2469	3569	3406.42	2738	1054	677	636	1609	549	0	17	0
SP2	0	0	2464.58	0	0	0	0	0	0	0	0	0
%DM1	60.54483	87.51904	100	100	83.67025	19.87424	18.67063	47.23434	13.46258	0	0.416874	0
%DM2	60.54483	87.51904	100	80.37764	30.94158	19.87424	18.67063	47.23434	13.46258	0	0.416874	0
SC	2464.58											

Table B.18.

1995-1996	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.4	6.9	37.0	15.4	57.9	65.4	36.1	31.7	0.2	0.0	0.0	36.0
Runoff	14	327	2016	764	3310	3797	1885	1783	6	0	0	2117
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	390.58	0	0	0	0	0	0
WS	0	0	0	0	0	390.58	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	14	327	2016	764	3310	3406.42	2275.58	1783	6	0	0	2117
DM2	14	327	2016	764	3310	3406.42	1885	1783	6	0	0	2117
SP2	0	0	0	0	0	390.58	0	0	0	0	0	0
%DM1	0.343308	8.018696	59.18237	22.42824	97.16946	100	66.80268	52.34234	0.147132	0	0	51.91308
%DM2	0.343308	8.018696	59.18237	22.42824	97.16946	100	55.33669	52.34234	0.147132	0	0	51.91308
SC	390.58											

Table B.19.

1996-1997	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	21.3	5.3	61.3	8.3	27.8	29.1	26.8	9.4	0.0	0.0	0.0
Runoff	0	1079	260	3414	408	1526	1499	1476	481	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	7.58	0	0	0	0	0	0	0	0
WS	0	0	0	7.58	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1079	260	3406.42	415.58	1526	1499	1476	481	0	0	0
DM2	0	1079	260	3406.42	408	1526	1499	1476	481	0	0	0
SP2	0	0	0	7.58	0	0	0	0	0	0	0	0
%DM1	0	26.45924	7.632647	100	12.1999	44.79776	44.00514	43.32995	11.79508	0	0	0
%DM2	0	26.45924	7.632647	100	11.97738	44.79776	44.00514	43.32995	11.79508	0	0	0
SC	7.58											

Table B.20.

1997-1998	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	14.0	22.3	82.5	57.9	31.5	13.9	42.2	5.2	7.9	0.0	0.0	0.0
Runoff	747	1141	4846	3230	1601	693	2361	242	372	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	1439.58	1263.16	0	0	0	0	0	0	0	0
WS	0	0	1439.58	1263.16	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	747	1141	3406.42	3406.42	2864.16	693	2361	242	372	0	0	0
DM2	747	1141	3406.42	3230	1601	693	2361	242	372	0	0	0
SP2	0	0	1439.58	0	0	0	0	0	0	0	0	0
%DM1	18.31794	27.97961	100	100	84.08123	20.34394	69.3103	7.104233	9.122186	0	0	0
%DM2	18.31794	27.97961	100	94.82096	46.99949	20.34394	69.3103	7.104233	9.122186	0	0	0
SC	1439.58											

Table B.21.

1998-1999	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	1.0	31.7	86.4	102.9	30.7	31.8	39.6	0.0	0.0	0.0	0.0
Runoff	0	44	1643	4977	6236	1673	1711	2294	0	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	1570.58	4400.16	2666.74	971.32	0	0	0	0	0
WS	0	0	0	1570.58	4400.16	2666.74	971.32	0	0	0	0	0
SP1	0	0	0	0	2829.58	0	0	0	0	0	0	0
DM1	0	44	1643	3406.42	3406.42	3406.42	3406.42	3265.32	0	0	0	0
DM2	0	44	1643	3406.42	3406.42	1673	1711	2294	0	0	0	0
SP2	0	0	0	1570.58	2829.58	0	0	0	0	0	0	0
%DM1	0	1.078968	48.23246	100	100	100	100	95.86782	0	0	0	0
%DM2	0	1.078968	48.23246	100	100	49.11315	50.22869	67.34343	0	0	0	0
SC	4400.16											

Table B.22.

1999-2000	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	1.4	1.0	18.2	33.1	39.0	70.1	28.6	25.3	4.1	0.0	0.0	0.0
Runoff	61	44	958	1811	1985	3923	1463	1300	194	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	516.58	0	0	0	0	0	0
WS	0	0	0	0	0	516.58	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	61	44	958	1811	1985	3406.42	1979.58	1300	194	0	0	0
DM2	61	44	958	1811	1985	3406.42	1463	1300	194	0	0	0
SP2	0	0	0	0	0	516.58	0	0	0	0	0	0
%DM1	1.495842	1.078968	28.12337	53.16432	58.27232	100	58.11321	38.16323	4.757269	0	0	0
%DM2	1.495842	1.078968	28.12337	53.16432	58.27232	100	42.94832	38.16323	4.757269	0	0	0
SC	516.58											

Table B.23.

2000-2001	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	6.4	9.1	68.2	99.8	22.9	60.3	8.5	21.2	4.5	0.0	0.0	87.0
Runoff	316	437	4128	5766	1171	3341	437	1082	213	0	0	5437
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	721.58	3081.16	845.74	780.32	0	0	0	0	0	1359.03
WS	0	0	721.58	1722.13	0	0	0	0	0	0	0	1722.13
SP1	0	0	0	2359.58	0	0	0	0	0	0	0	0
DM1	316	437	3406.42	3406.42	2893.13	3341	437	1082	213	0	0	4077.97
DM2	316	437	3406.42	3406.42	1171	3341	437	1082	213	0	0	4077.97
SP2	0	0	721.58	2359.58	0	0	0	0	0	0	0	1359.03
%DM1	7.748954	10.71612	100	100	84.93169	98.07951	12.82872	31.76355	5.223187	0	0	100
%DM2	7.748954	10.71612	100	100	34.37627	98.07951	12.82872	31.76355	5.223187	0	0	100
SC	1722.13											

Table B.24.

2001-2002	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	11.1	24.2	83.2	61.5	37.9	53.4	28.8	2.8	0.0	0.0	0.0
Runoff	0	583	1199	4832	3501	2191	2998	1537	130	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	1425.58	1520.16	304.74	0	0	0	0	0	0
WS	0	0	0	1425.58	1520.16	304.74	0	0	0	0	0	0
SP1	0	0	0	0	94.58	0	0	0	0	0	0	0
DM1	1359.03	583	1199	3406.42	3406.42	3406.42	3302.74	1537	130	0	0	0
DM2	0	583	1199	3406.42	3406.42	2191	2998	1537	130	0	0	0
SP2	0	0	0	1425.58	94.58	0	0	0	0	0	0	0
%DM1	33.32614	14.29633	35.19824	100	100	100	96.95634	45.12068	3.187861	0	0	0
%DM2	0	14.29633	35.19824	100	100	64.31973	88.01029	45.12068	3.187861	0	0	0
SC	1520.16											

Table B.25.

2002-2003	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	8.5	12.2	67.9	107.1	53.2	159.0	71.4	11.1	0.1	3.3	0.0	0.0
Runoff	436	6332	3904	5854	2989	9829	4024	557	3	156	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	2254.03	2751.61	5199.19	4781.77	11204.35	11821.9	8972.51	4897.54	975.57	0	0
WS	0	2254.03	2751.61	5199.19	4781.77	11204.35	11821.9	8972.51	4897.54	975.57	0	0
SP1	0	0	497.58	2447.58	0	6422.58	617.58	0	0	0	0	0
DM1	436	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	975.57	0
DM2	436	4077.97	3406.42	3406.42	2989	3406.42	3406.42	557	3	156	0	0
SP2	0	2254.03	497.58	2447.58	0	6422.58	617.58	0	0	0	0	0
%DM1	10.69159	100	100	100	100	100	100	100	100	100	23.92293	0
%DM2	10.69159	100	100	100	87.74608	100	100	16.35148	0.073566	3.825433	0	0
SC	11821.9											

Table B.26.

2003-2004	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	26.2	37.8	37.1	135.3	55.2	0.01	8.1	3.2	0.4	0.0	0.0
Runoff	0	1444	2146	2146	8102	3046	0	409	150	17	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	4695.58	4335.16	928.74	0	0	0	0	0
WS	0	0	0	0	4695.58	4335.16	928.74	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1444	2146	2146	3406.42	3406.42	3406.42	1337.74	150	17	0	0
DM2	0	1444	2146	2146	3406.42	3046	0	409	150	17	0	0
SP2	0	0	0	0	4695.58	0	0	0	0	0	0	0
%DM1	0	35.40977	62.99869	62.99869	100	100	100	39.27114	3.678301	0.416874	0	0
%DM2	0	35.40977	62.99869	62.99869	100	89.41939	0	12.00674	3.678301	0.416874	0	0
SC	4695.58											

Table B.27.

2004-2005	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	32.2	46.9	51.6	36.8	40.8	28.8	27.9	1.1	1.0	0.0	0.0
Runoff	0	1877	2577	2865	1953	2427	1665	1598	44	44	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1877	2577	2865	1953	2427	1665	1598	44	44	0	0
DM2	0	1877	2577	2865	1953	2427	1665	1598	44	44	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	46.0278	75.65127	84.10589	57.33292	71.24782	48.87829	46.91142	1.078968	1.078968	0	0
%DM2	0	46.0278	75.65127	84.10589	57.33292	71.24782	48.87829	46.91142	1.078968	1.078968	0	0
SC	0											

Table B.28.

2005-2006	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	18.5	46.3	10.7	70.6	29.4	24.6	32.6	3.7	0.0	0.01	0.0
Runoff	0	958	2525	529	4059	1677	1276	1852	174	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	652.58	0	0	0	0	0	0	0
WS	0	0	0	0	652.58	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	958	2525	529	3406.42	2329.58	1276	1852	174	0	0	0
DM2	0	958	2525	529	3406.42	1677	1276	1852	174	0	0	0
SP2	0	0	0	0	652.58	0	0	0	0	0	0	0
%DM1	0	23.49208	74.12474	15.5295	100	68.38793	37.45868	54.36793	4.266829	0	0	0
%DM2	0	23.49208	74.12474	15.5295	100	49.23057	37.45868	54.36793	4.266829	0	0	0
SC	652.58											

Table B.29.

2006-2007	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.4	45.8	14.6	3.7	34.7	75.1	27.1	7.8	84.1	1.0	0.0	0.0
Runoff	16	2543	736	171	1839	4224	1517	382	5168	44	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	817.58	0	0	1090.03	0	0	0
WS	0	0	0	0	0	817.58	0	0	1090.03	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	16	2543	736	171	1839	3406.42	2334.58	382	4077.97	1134.03	0	0
DM2	16	2543	736	171	1839	3406.42	1517	382	4077.97	44	0	0
SP2	0	0	0	0	0	817.58	0	0	1090.03	0	0	0
%DM1	0.392352	62.35946	21.60626	5.019933	53.9863	100	68.53471	11.21412	100	27.80869	0	0
%DM2	0.392352	62.35946	21.60626	5.019933	53.9863	100	44.53356	11.21412	100	1.078968	0	0
SC	1090.03											

Table B.30.

2007-2008	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	0.0	33.5	40.1	15.4	31.0	7.1	1.5	3.5	0.0	0.0	0.0
Runoff	0	0	1936	2191	807	1708	331	68	168	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	0	1936	2191	807	1708	331	68	168	0	0	0
DM2	0	0	1936	2191	807	1708	331	68	168	0	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	0	56.83386	64.31973	23.69056	50.14062	9.716946	1.996231	4.119697	0	0	0
%DM2	0	0	56.83386	64.31973	23.69056	50.14062	9.716946	1.996231	4.119697	0	0	0
SC	0											

Table B.31.

2008-2009	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	4.5	13.9	0.7	57.7	76.4	75.6	39.7	14.9	6.9	0.0	0.0	0.0
Runoff	212	699	30	3376	4431	4430	2113	788	332	0	0	0
Demand	4077.97	4077.97	3406.42	3406.42	3406.42	3406.42	3406.42	3406.42	4077.97	4077.97	4077.97	4077.97
CS	0	0	0	0	1024.58	2048.16	754.74	0	0	0	0	0
WS	0	0	0	0	1024.58	2048.16	754.74	0	0	0	0	0
SP1	0	0	0	0	0	1023.58	0	0	0	0	0	0
DM1	212	699	30	3376	3406.42	3406.42	3406.42	1542.74	332	0	0	0
DM2	212	699	30	3376	3406.42	3406.42	2113	788	332	0	0	0
SP2	0	0	0	0	1024.58	1023.58	0	0	0	0	0	0
%DM1	5.198665	17.14088	0.88069	99.10698	100	100	100	45.28919	8.141306	0	0	0
%DM2	5.198665	17.14088	0.88069	99.10698	100	100	62.02993	23.13279	8.141306	0	0	0
SC	2048.16											

Tables B.32 to B.63 show the tank volume calculations for Reservoir 2 previously discussed in Chapter V, pages 66-67.

Table B.32.

1978-1979	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	29.0	8.0	91.1	36.6	23.0	26.6	6.7	6.3	9.6	0.0	0.0
Runoff	0	1913	496	6512	2454	1152	1737	400	383	569	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	2783.74	1509.48	0	0	0	0	0	0	0
WS	0	0	0	2783.74	1509.48	0	0	0	0	0	0	0
SP1	0	0	0	2783.74	1509.48	0	0	0	0	0	0	0
DM1	0	1913	496	3728.26	3728.26	2661.48	1737	400	383	569	0	0
DM2	0	1913	496	3728.26	2454	1152	1737	400	383	569	0	0
SP2	0	0	0	2783.74	0	0	0	0	0	0	0	0
%DM1	0	38.265816	13.303793	100	100	71.386652	46.590098	10.728865	7.6611645	11.38173	0	0
%DM2	0	38.265816	13.303793	100	65.82159	30.899133	46.590098	10.728865	7.6611645	11.38173	0	0
SC	2783.74											

Table B.33.

1979-1980	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	25.3	57.4	54.7	55.3	76.6	47.4	11.8	0.9	0.0	0.0	0.0
Runoff	0	1660	4192	3639	3525	5278	3106	726	0	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	463.74	374.48	171.22	1720.96	1098.7	0	0	0	0	0
WS	0	0	463.74	374.48	171.22	1720.96	1098.7	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1660	3728.26	3728.26	3728.26	3728.26	3728.26	1824.7	0	0	0	0
DM2	0	1660	3728.26	3639	3525	3728.26	3106	726	0	0	0	0
SP2	0	0	463.74	0	0	1549.74	0	0	0	0	0	0
%DM1	0	33.205047	100	100	100	100	100	48.942402	0	0	0	0
%DM2	0	33.205047	100	97.605854	94.548127	100	83.30964	19.472891	0	0	0	0
SC	1720.96											

Table B.34.

1980-1981	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	27.6	4.3	40.1	82.7	66.3	35.4	11.3	16.3	6.9	0.0	0.0
Runoff	0	1810	237	2658	5709	4506	2372	718	1030	419	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	1980.74	2758.48	1402.22	0	0	0	0	0
WS	0	0	0	0	1980.74	2758.48	1402.22	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1810	237	2658	3728.26	3728.26	3728.26	2120.22	1030	419	0	0
DM2	0	1810	237	2658	3728.26	3728.26	2372	718	1030	419	0	0
SP2	0	0	0	0	1980.74	777.74	0	0	0	0	0	0
%DM1	0	36.205503	6.3568528	71.293311	100	100	100	56.868888	20.603132	8.381274	0	0
%DM2	0	36.205503	6.3568528	71.293311	100	100	63.622172	19.258314	20.603132	8.381274	0	0
SC	2758.48											

Table B.35.

1981-1982	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.5	38.8	33.4	33.6	47.7	80.2	10.9	0.2	58.8	0.01	0.0
Runoff	0	82	2612	2127	2206	3094	5526	679	7	4417	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	0	1797.74	0	0	0	0	0
WS	0	0	0	0	0	0	1797.74	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	82	2612	2127	2206	3094	3728.26	2476.74	7	4417	0	0
DM2	0	82	2612	2127	2206	3094	3728.26	679	7	4417	0	0
SP2	0	0	0	0	0	0	1797.74	0	0	0	0	0
%DM1	0	1.6402493	70.059492	57.050742	59.169693	82.987774	100	66.431526	0.1400213	88.35343	0	0
%DM2	0	1.6402493	70.059492	57.050742	59.169693	82.987774	100	18.212249	0.1400213	88.35343	0	0
SC	1797.74											

Table B.36.

1982-1983	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.5	23.9	22.6	26.6	69.0	38.4	15.4	21.7	17.4	0.0	0.0
Runoff	0	83	1596	1449	1692	4853	2533	923	1460	1170	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	1124.74	0	0	0	0	0	0
WS	0	0	0	0	0	1124.74	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	83	1596	1449	1692	3728.26	3657.74	923	1460	1170	0	0
DM2	0	83	1596	1449	1692	3728.26	2533	923	1460	1170	0	0
SP2	0	0	0	0	0	1124.74	0	0	0	0	0	0
%DM1	0	1.6602524	42.808173	38.865315	45.383101	100	98.108501	24.756857	29.204439	23.403557	0	0
%DM2	0	1.6602524	42.808173	38.865315	45.383101	100	67.940541	24.756857	29.204439	23.403557	0	0
SC	1124.74											

Table B.37.

1983-1984	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	17.3	29.1	40.1	35.6	13.4	29.3	49.5	0.0	0.0	0.0	0.0
Runoff	0	1151	1934	2561	2242	858	2029	3402	0	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1151	1934	2561	2242	858	2029	3402	0	0	0	0
DM2	0	1151	1934	2561	2242	858	2029	3402	0	0	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	23.0235	51.874065	68.691561	60.135291	23.013416	54.42217	91.249001	0	0	0	0
%DM2	0	23.0235	51.874065	68.691561	60.135291	23.013416	54.42217	91.249001	0	0	0	0
SC	0											

Table B.38.

1984-1985	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.9	49.2	42.4	84.2	43.3	33.1	3.4	3.6	0.0	0.0	0.0
Runoff	0	104	3294	2847	5826	2775	2262	178	202	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	2097.74	1144.48	0	0	0	0	0	0
WS	0	0	0	0	2097.74	1144.48	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	104	3294	2847	3728.26	3728.26	3406.48	178	202	0	0	0
DM2	0	104	3294	2847	3728.26	2775	2262	178	202	0	0	0
SP2	0	0	0	0	2097.74	0	0	0	0	0	0	0
%DM1	0	2.0803162	88.352207	76.3627	100	100	91.369164	4.7743451	4.0406142	0	0	0
%DM2	0	2.0803162	88.352207	76.3627	100	74.431504	60.671734	4.7743451	4.0406142	0	0	0
SC	2097.74											

Table B.39.

1985-1986	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	24.1	15.8	19.9	28.2	45.6	12.3	11.3	27.7	5.1	0.0	0.0
Runoff	0	1579	948	1271	1692	3104	744	682	1873	300	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1579	948	1271	1692	3104	744	682	1873	300	0	0
DM2	0	1579	948	1271	1692	3104	744	682	1873	300	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	31.584801	25.427411	34.09097	45.383101	83.255996	19.95569	18.292716	37.465695	6.0009121	0	0
%DM2	0	31.584801	25.427411	34.09097	45.383101	83.255996	19.95569	18.292716	37.465695	6.0009121	0	0
SC	0											

Table B.40.

1986-1987	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.2	11.6	131.1	26.8	57.8	17.0	89.3	2.4	2.8	1.6	0.0	0.0
Runoff	7	682	10193	1779	3909	1053	6545	123	157	86	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	6464.74	4515.48	4696.22	2020.96	4837.7	1232.44	0	0	0	0
WS	0	0	6464.74	4515.48	4696.22	2020.96	4837.7	1232.44	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	7	682	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	1389.44	86	0	0
DM2	7	682	3728.26	1779	3728.26	1053	3728.26	123	157	86	0	0
SP2	0	0	6464.74	0	180.74	0	2816.74	0	0	0	0	0
%DM1	0.1400213	13.642074	100	100	100	100	100	100	27.793025	1.7202615	0	0
%DM2	0.1400213	13.642074	100	47.716629	100	28.243738	100	3.2991261	3.1404774	1.7202615	0	0
SC	6464.74											

Table B.41.

1987-1988	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	45.1	23.1	74.5	49.0	116.3	89.1	8.3	1.1	0.0	9.6	0.0
Runoff	0	3060	1462	5190	3311	8767	6266	459	53	0	602	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	1461.74	1044.48	6083.22	8620.96	5351.7	405.46	0	0	0
WS	0	0	0	1461.74	1044.48	6083.22	8620.96	5351.7	405.46	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	3060	1462	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	405.46	602	0
DM2	0	3060	1462	3728.26	3311	3728.26	3728.26	459	53	0	602	0
SP2	0	0	0	1461.74	0	5038.74	2537.74	0	0	0	0	0
%DM1	0	61.209304	39.214003	100	100	100	100	100	100	8.1104328	12.04183	0
%DM2	0	61.209304	39.214003	100	88.808184	100	100	12.311373	1.0601611	0	12.04183	0
SC	8620.96											

Table B.42.

1988-1989	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	32.6	47.6	116.5	50.3	9.5	16.7	0.0	0.7	0.0	0.0	0.0
Runoff	0	2304	3180	8792	3552	595	1026	0	36	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	5063.74	4887.48	1754.22	0	0	0	0	0	0
WS	0	0	0	5063.74	4887.48	1754.22	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	2304	3180	3728.26	3728.26	3728.26	2780.22	0	36	0	0	0
DM2	0	2304	3180	3728.26	3552	595	1026	0	36	0	0	0
SP2	0	0	0	5063.74	0	0	0	0	0	0	0	0
%DM1	0	46.087005	85.294481	100	100	100	74.571516	0	0.7201095	0	0	0
%DM2	0	46.087005	85.294481	100	95.272325	15.959187	27.51954	0	0.7201095	0	0	0
SC	5063.74											

Table B.43.

1989-1990	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	20.0	25.5	18.3	13.6	70.5	25.4	0.5	0.0	4.0	0.0	0.0
Runoff	0	1176	1646	1095	833	5232	1715	26	0	147	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	1503.74	0	0	0	0	0	0
WS	0	0	0	0	0	1503.74	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1176	1646	1095	833	3728.26	3218.74	26	0	147	0	0
DM2	0	1176	1646	1095	833	3728.26	1715	26	0	147	0	0
SP2	0	0	0	0	0	1503.74	0	0	0	0	0	0
%DM1	0	23.523576	44.149281	29.370269	22.342862	100	86.333571	0.6973763	0	2.9404469	0	0
%DM2	0	23.523576	44.149281	29.370269	22.342862	100	46.000011	0.6973763	0	2.9404469	0	0
SC	1503.74											

Table B.44.

1990-1991	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	12.5	3.5	19.9	60.0	34.8	31.0	9.6	3.5	0.0	0.0	0.0
Runoff	0	763	202	1209	3989	2276	1976	593	195	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	260.74	0	0	0	0	0	0	0
WS	0	0	0	0	260.74	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	763	202	1209	3728.26	2536.74	1976	593	195	0	0	0
DM2	0	763	202	1209	3728.26	2276	1976	593	195	0	0	0
SP2	0	0	0	0	260.74	0	0	0	0	0	0	0
%DM1	0	15.26232	5.4180771	32.427996	100	68.040856	53.000595	15.905543	3.9005929	0	0	0
%DM2	0	15.26232	5.4180771	32.427996	100	61.047245	53.000595	15.905543	3.9005929	0	0	0
SC	260.74											

Table B.45.

1991-1992	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	14.0	36.6	128.3	17.2	99.8	35.5	5.9	8.4	3.5	0.0	0.0
Runoff	0	844	2464	9519	1016	7357	2304	343	505	202	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	5790.74	3078.48	6707.22	5282.96	1897.7	0	0	0	0
WS	0	0	0	5790.74	3078.48	6707.22	5282.96	1897.7	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	844	2464	3728.26	3728.26	3728.26	3728.26	3728.26	2402.7	202	0	0
DM2	0	844	2464	3728.26	1016	3728.26	2304	343	505	202	0	0
SP2	0	0	0	5790.74	0	3628.74	0	0	0	0	0	0
%DM1	0	16.882566	66.089811	100	100	100	100	100	48.061305	4.0406142	0	0
%DM2	0	16.882566	66.089811	100	27.251318	100	61.798265	9.2000021	10.101535	4.0406142	0	0
SC	6707.22											

Table B.46.

1992-1993	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	0.8	51.4	80.3	38.6	51.8	45.9	3.6	12.0	0.0	0.0	0.0
Runoff	0	39	3758	5765	2582	3492	3161	201	697	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	29.74	2066.48	920.22	683.96	116.7	0	0	0	0	0
WS	0	0	29.74	2066.48	920.22	683.96	116.7	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	39	3728.26	3728.26	3728.26	3728.26	3728.26	317.7	697	0	0	0
DM2	0	39	3728.26	3728.26	2582	3492	3161	201	697	0	0	0
SP2	0	0	29.74	2036.74	0	0	0	0	0	0	0	0
%DM1	0	0.7801186	100	100	100	100	100	8.5214014	13.942119	0	0	0
%DM2	0	0.7801186	100	100	69.254827	93.662996	84.784859	5.3912549	13.942119	0	0	0
SC	2066.48											

Table B.47.

1993-1994	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	5.9	34.6	14.4	88.6	67.1	35.8	37.1	3.2	0.0	0.0	0.0
Runoff	0	350	2353	882	6091	4481	2472	2477	176	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	2362.74	3115.48	1859.22	607.96	0	0	0	0
WS	0	0	0	0	2362.74	3115.48	1859.22	607.96	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	350	2353	882	3728.26	3728.26	3728.26	3728.26	783.96	0	0	0
DM2	0	350	2353	882	3728.26	3728.26	2472	2477	176	0	0	0
SP2	0	0	0	0	2362.74	752.74	0	0	0	0	0	0
%DM1	0	7.0010642	63.112551	23.657148	100	100	100	100	15.681584	0	0	0
%DM2	0	7.0010642	63.112551	23.657148	100	100	66.304389	66.438499	3.5205351	0	0	0
SC	3115.48											

Table B.48.

1994-1995	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	42.0	61.2	99.3	50.5	20.8	13.1	13.0	30.4	10.5	0.0	0.4	0.0
Runoff	3047	4397	7258	3342	1274	821	767	1959	667	0	20	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	3529.74	3143.48	689.22	0	0	0	0	0	0	0
WS	0	0	3529.74	3143.48	689.22	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	3047	4397	3728.26	3728.26	3728.26	1510.22	767	1959	667	0	20	0
DM2	3047	4397	3728.26	3342	1274	821	767	1959	667	0	20	0
SP2	0	0	3529.74	0	0	0	0	0	0	0	0	0
%DM1	60.949264	87.953369	100	100	100	40.507368	20.5726	52.544619	13.342028	0	0.4000608	0
%DM2	60.949264	87.953369	100	89.639671	34.171437	22.020996	20.5726	52.544619	13.342028	0	0.4000608	0
SC	3529.74											

Table B.49.

1995-1996	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.4	6.9	37.0	15.4	57.9	65.4	36.1	31.7	0.2	0.0	0.0	36.0
Runoff	18	392	2461	922	4065	4673	2290	2187	7	0	0	2611
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	336.74	1281.48	0	0	0	0	0	0
WS	0	0	0	0	336.74	1281.48	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	18	392	2461	922	3728.26	3728.26	3571.48	2187	7	0	0	2611
DM2	18	392	2461	922	3728.26	3728.26	2290	2187	7	0	0	2611
SP2	0	0	0	0	336.74	944.74	0	0	0	0	0	0
%DM1	0.3600547	7.8411919	66.009345	24.730035	100	100	95.794821	58.660072	0.1400213	0	0	52.227939
%DM2	0.3600547	7.8411919	66.009345	24.730035	100	100	61.422755	58.660072	0.1400213	0	0	52.227939
SC	1281.48											

Table B.50.

1996-1997	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	21.3	5.3	61.3	8.3	27.8	29.1	26.8	9.4	0.0	0.0	0.0
Runoff	0	1307	314	4185	494	1866	1820	1805	584	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	456.74	0	0	0	0	0	0	0	0
WS	0	0	0	456.74	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1307	314	3728.26	950.74	1866	1820	1805	584	0	0	0
DM2	0	1307	314	3728.26	494	1866	1820	1805	584	0	0	0
SP2	0	0	0	456.74	0	0	0	0	0	0	0	0
%DM1	0	26.143974	8.4221594	100	25.500904	50.050157	48.816338	48.414005	11.681776	0	0	0
%DM2	0	26.143974	8.4221594	100	13.250149	50.050157	48.816338	48.414005	11.681776	0	0	0
SC	456.74											

Table B.51.

1997-1998	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	14.0	22.3	82.5	57.9	31.5	13.9	42.2	5.2	7.9	0.0	0.0	0.0
Runoff	912	1382	5973	3959	1939	840	2893	290	446	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	2244.74	2475.48	686.22	0	0	0	0	0	0	0
WS	0	0	2244.74	2475.48	686.22	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	912	1382	3728.26	3728.26	3728.26	1526.22	2893	290	446	0	0	0
DM2	912	1382	3728.26	3728.26	1939	840	2893	290	446	0	0	0
SP2	0	0	2244.74	230.74	0	0	0	0	0	0	0	0
%DM1	18.242773	27.644202	100	100	100	40.936523	77.59652	7.7784275	8.921356	0	0	0
%DM2	18.242773	27.644202	100	100	52.008175	22.530617	77.59652	7.7784275	8.921356	0	0	0
SC	2475.48											

Table B.52.

1998-1999	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.0	31.7	86.4	102.9	30.7	31.8	39.6	0.0	0.0	0.0	0.0
Runoff	0	52	1999	6139	7710	2046	2091	2824	0	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	2410.74	6392.48	4710.22	3072.96	2168.7	0	0	0	0
WS	0	0	0	2410.74	6392.48	4710.22	3072.96	2168.7	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	52	1999	3728.26	3728.26	3728.26	3728.26	3728.26	2168.7	0	0	0
DM2	0	52	1999	3728.26	3728.26	2046	2091	2824	0	0	0	0
SP2	0	0	0	2410.74	3981.74	0	0	0	0	0	0	0
%DM1	0	1.0401581	53.617505	100	100	100	100	100	43.380594	0	0	0
%DM2	0	1.0401581	53.617505	100	100	54.878147	56.085144	75.74579	0	0	0	0
SC	6392.48											

Table B.53.

1999-2000	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	1.4	1.0	18.2	33.1	39.0	70.1	28.6	25.3	4.1	0.0	0.0	0.0
Runoff	72	52	1165	2214	2410	4814	1773	1576	233	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	1085.74	0	0	0	0	0	0
WS	0	0	0	0	0	1085.74	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	72	52	1165	2214	2410	3728.26	2858.74	1576	233	0	0	0
DM2	72	52	1165	2214	2410	3728.26	1773	1576	233	0	0	0
SP2	0	0	0	0	0	1085.74	0	0	0	0	0	0
%DM1	1.4402189	1.0401581	31.247821	59.38427	64.641414	100	76.677592	42.27173	4.6607084	0	0	0
%DM2	1.4402189	1.0401581	31.247821	59.38427	64.641414	100	47.555696	42.27173	4.6607084	0	0	0
SC	1085.74											

Table B.54.

2000-2001	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	6.4	9.1	68.2	99.8	22.9	60.3	8.5	21.2	4.5	0.0	0.0	87.0
Runoff	382	524	5112	7103	1418	4094	529	1311	255	0	0	6744
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	1383.74	4758.48	2448.22	2813.96	0	0	0	0	0	1744.76
WS	0	0	1383.74	4758.48	2448.22	2813.96	0	0	0	0	0	1744.76
SP1	0	0	0	1744.76	0	0	0	0	0	0	0	0
DM1	382	524	3728.26	3728.26	3728.26	3728.26	3342.96	1311	255	0	0	4999.24
DM2	382	524	3728.26	3728.26	1418	3728.26	529	1311	255	0	0	4999.24
SP2	0	0	1383.74	3374.74	0	365.74	0	0	0	0	0	1744.76
%DM1	7.6411615	10.481593	100	100	100	100	89.66542	35.163857	5.1007753	0	0	100
%DM2	7.6411615	10.481593	100	100	38.033828	100	14.188925	35.163857	5.1007753	0	0	100
SC	3013.72											

Table B.55.

2001-2002	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	11.1	24.2	83.2	61.5	37.9	53.4	28.8	2.8	0.0	0.0	0.0
Runoff	0	710	1451	5949	4299	2696	3688	1874	154	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	2220.74	2791.48	1759.22	1718.96	0	0	0	0	0
WS	0	0	0	2220.74	2791.48	1759.22	1718.96	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	1744.76	710	1451	3728.26	3728.26	3728.26	3728.26	3592.96	154	0	0	0
DM2	0	710	1451	3728.26	3728.26	2696	3688	1874	154	0	0	0
SP2	0	0	0	2220.74	570.74	0	0	0	0	0	0	0
%DM1	34.900505	14.202159	38.91896	100	100	100	100	96.370961	3.0804682	0	0	0
%DM2	0	14.202159	38.91896	100	100	72.312553	98.92014	50.264735	3.0804682	0	0	0
SC	2791.48											

Table B.56.

2002-2003	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	8.5	12.2	67.9	107.1	53.2	159.0	71.4	11.1	0.1	3.3	0.0	0.0
Runoff	529	767	4810	7208	3665	12192	4938	673	4	187	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	1081.74	4561.48	4498.22	12961.96	14171.7	11116.44	6121.2	1308.96	0	0
WS	0	0	1081.74	4561.48	4498.22	12961.96	14171.7	11116.44	6121.2	1308.96	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	529	767	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	1308.96	0
DM2	529	767	3728.26	3728.26	3665	3728.26	3728.26	673	4	187	0	0
SP2	0	0	1081.74	3479.74	0	8463.74	1209.74	0	0	0	0	0
%DM1	10.581608	15.342332	100	100	100	100	100	100	100	100	26.18318	0
%DM2	10.581608	15.342332	100	100	98.30323	100	100	18.051316	0.0800122	3.7405686	0	0
SC	14171.7											

Table B.57.

2003-2004	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	26.2	37.8	37.1	135.3	55.2	0.01	8.1	3.2	0.4	0.0	0.0
Runoff	0	1767	2636	2636	10023	3727	0	496	179	20	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	6294.74	6293.48	2565.22	0	0	0	0	0
WS	0	0	0	0	6294.74	6293.48	2565.22	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1767	2636	2636	3728.26	3728.26	3728.26	3061.22	179	20	0	0
DM2	0	1767	2636	2636	3728.26	3727	0	496	179	20	0	0
SP2	0	0	0	0	6294.74	0	0	0	0	0	0	0
%DM1	0	35.345372	70.703223	70.703223	100	100	100	82.108544	3.5805442	0.4000608	0	0
%DM2	0	35.345372	70.703223	70.703223	100	99.966204	0	13.303793	3.5805442	0.4000608	0	0
SC	6294.74											

Table B.58.

2004-2005	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	32.2	46.9	51.6	36.8	40.8	28.8	27.9	1.1	1.0	0.0	0.0
Runoff	0	2312	3153	3511	2385	2993	2048	1964	52	52	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	2312	3153	3511	2385	2993	2048	1964	52	52	0	0
DM2	0	2312	3153	3511	2385	2993	2048	1964	52	52	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	46.24703	84.570282	94.172617	63.97086	80.278736	54.931791	52.678729	1.0401581	1.0401581	0	0
%DM2	0	46.24703	84.570282	94.172617	63.97086	80.278736	54.931791	52.678729	1.0401581	1.0401581	0	0
SC	0											

Table B.59.

2005-2006	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	18.5	46.3	10.7	70.6	29.4	24.6	32.6	3.7	0.0	0.01	0.0
Runoff	0	1166	3086	637	4993	2059	1548	2275	208	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	1264.74	0	0	0	0	0	0	0
WS	0	0	0	0	1264.74	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	1166	3086	637	3728.26	3323.74	1548	2275	208	0	0	0
DM2	0	1166	3086	637	3728.26	2059	1548	2275	208	0	0	0
SP2	0	0	0	0	1264.74	0	0	0	0	0	0	0
%DM1	0	23.323545	82.773197	17.085718	100	89.149898	41.520709	61.020422	4.1606324	0	0	0
%DM2	0	23.323545	82.773197	17.085718	100	55.226835	41.520709	61.020422	4.1606324	0	0	0
SC	1264.74											

Table B.60.

2006-2007	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.4	45.8	14.6	3.7	34.7	75.1	27.1	7.8	84.1	1.0	0.0	0.0
Runoff	20	3148	889	204	2242	5203	1859	459	6396	52	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	1474.74	0	0	1396.76	0	0	0
WS	0	0	0	0	0	1474.74	0	0	1396.76	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	20	3148	889	204	2242	3728.26	3333.74	459	4999.24	1448.76	0	0
DM2	20	3148	889	204	2242	3728.26	1859	459	4999.24	52	0	0
SP2	0	0	0	0	0	1474.74	0	0	1396.76	0	0	0
%DM1	0.4000608	62.969571	23.844904	5.4717214	60.135291	100	89.41812	12.311373	100	28.979605	0	0
%DM2	0.4000608	62.969571	23.844904	5.4717214	60.135291	100	49.862402	12.311373	100	1.0401581	0	0
SC	1474.74											

Table B.61.

2007-2008	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	0.0	33.5	40.1	15.4	31.0	7.1	1.5	3.5	0.0	0.0	0.0
Runoff	0	0	2381	2677	982	2092	399	81	202	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	0	0	0	0	0	0	0	0	0
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	0	0	2381	2677	982	2092	399	81	202	0	0	0
DM2	0	0	2381	2677	982	2092	399	81	202	0	0	0
SP2	0	0	0	0	0	0	0	0	0	0	0	0
%DM1	0	0	63.863572	71.802932	26.339365	56.111966	10.702043	2.1725953	4.0406142	0	0	0
%DM2	0	0	63.863572	71.802932	26.339365	56.111966	10.702043	2.1725953	4.0406142	0	0	0
SC	0											

Table B.62.

2008-2009	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	4.5	13.9	0.7	57.7	76.4	75.6	39.7	14.9	6.9	0.0	0.0	0.0
Runoff	256	846	36	4166	5467	5461	2572	951	399	0	0	0
Demand	4999.24	4999.24	3728.26	3728.26	3728.26	3728.26	3728.26	3728.26	4999.24	4999.24	4999.24	4999.24
CS	0	0	0	437.74	2176.48	3909.22	2752.96	0	0	0	0	0
WS	0	0	0	437.74	2176.48	3909.22	2752.96	0	0	0	0	0
SP1	0	0	0	0	0	0	0	0	0	0	0	0
DM1	256	846	36	3728.26	3728.26	3728.26	3728.26	3703.96	399	0	0	0
DM2	256	846	36	3728.26	3728.26	3728.26	2572	951	399	0	0	0
SP2	0	0	0	437.74	1738.74	1732.74	0	0	0	0	0	0
%DM1	5.1207784	16.922572	0.9655979	100	100	100	100	99.348221	7.9812131	0	0	0
%DM2	5.1207784	16.922572	0.9655979	100	100	100	68.986605	25.507878	7.9812131	0	0	0
SC	3909.22											

Tables B.63 to B.93 show the tank volume calculations for Reservoir 3 previously discussed in Chapter V, pages 66-67.

Table B.63.

1978-1979	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	29.0	8.0	91.1	36.6	23.0	26.6	6.7	6.3	9.6	0.0	0.0
Runoff	0	4314	1132	15190	5664	2664	3997	908	870	1291	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	0	3945.2	5077.2	20267.2	25931.2	28595.2	32223.4	32762.6	33263.8	34186	33817.2	33448.4
WS	0	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	368.8	5.798E-12
SP1	0	3945.2	1869.6	15927.6	6401.6	3401.6	4365.8	1276.8	1238.8	1659.8	368.8	5.798E-12
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	0	0
SP2	0	3945.2	1132	15190	5664	2664	3628.2	539.2	501.2	922.2	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	100	0	0
SC	737.6											

Table B.64.

1979-1980	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	25.3	57.4	54.7	55.3	76.6	47.4	11.8	0.9	0.0	0.0	0.0
Runoff	0	3823	9777	8398	8071	12194	7155	1655	0	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	33079.6	36533.8	46310.8	54708.8	62779.8	74973.8	81760	83046.2	82677.4	82308.6	81939.8	81571
WS	0	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2	1106.4	737.6	368.8	1.171E-11
SP1	0	1979	9777	8398	8071	12194	6786.2	1286.2	0	0	0	0
DM1	5.798E-12	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	0	0	0	0
SP2	0	3454.2	9777	8398	8071	12194	6786.2	1286.2	0	0	0	0
%DM1	1.572E-12	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	0	0	0	0
SC	1475.2											

Table B.65.

1980-1981	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	27.6	4.3	40.1	82.7	66.3	35.4	11.3	16.3	6.9	0.0	0.0
Runoff	0	4054	502	6121	13226	10404	5480	1647	2357	954	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	81202.2	84887.4	85389.4	91510.4	104736.4	115140.4	120251.6	121529.8	123518	124103.2	123734.4	123365.6
WS	0	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	368.8	5.798E-12
SP1	0	2947.6	502	6121	13226	10404	5111.2	1278.2	1988.2	585.2	0	0
DM1	1.171E-11	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	0	0
SP2	0	3685.2	502	6121	13226	10404	5111.2	1278.2	1988.2	585.2	0	0
%DM1	3.175E-12	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	100	0	0
SC	737.6											

Table B.66.

1981-1982	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.5	38.8	33.4	33.6	47.7	80.2	10.9	0.2	58.8	0.01	0.0
Runoff	0	183	6030	4867	5034	7001	12824	1550	15	10366	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	122996.8	122811	128841	133708	138742	145743	158198.2	159379.4	159025.6	169022.8	168654	168285.2
WS	0	0	737.6	737.6	737.6	737.6	737.6	737.6	383.8	737.6	368.8	0
SP1	0	0	5292.4	4867	5034	7001	12455.2	1181.2	0	9643.4	0	0
DM1	5.798E-12	183	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	183	0	0	0	0	368.8	368.8	15	368.8	0	0
SP2	0	0	6030	4867	5034	7001	12455.2	1181.2	0	9997.2	0	0
%DM1	1.572E-12	49.62039	100	100	100	100	100	100	100	100	100	100
%DM2	0	49.62039	100	100	100	100	100	100	4.0672451	100	0	0
SC	737.6											

Table B.67.

1982-1983	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.5	23.9	22.6	26.6	69.0	38.4	15.4	21.7	17.4	0.0	0.0
Runoff	0	185	3685	3273	3877	11291	5840	2098	3375	2703	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	167916.4	167732.6	171417.6	174690.6	178567.6	189858.6	195329.8	197059	200065.2	202399.4	202030.6	201661.8
WS	0	0	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	368.8	0
SP1	0	0	2947.4	3273	3877	11291	5471.2	1729.2	3006.2	2334.2	0	0
DM1	0	185	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	185	0	0	0	0	368.8	368.8	368.8	368.8	0	0
SP2	0	0	3685	3273	3877	11291	5471.2	1729.2	3006.2	2334.2	0	0
%DM1	0	50.16269	100	100	100	100	100	100	100	100	100	100
%DM2	0	50.16269	100	100	100	100	100	100	100	100	0	0
SC	737.6											

Table B.68.

1983-1984	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	17.3	29.1	40.1	35.6	13.4	29.3	49.5	0.0	0.0	0.0	0.0
Runoff	0	2653	4453	5869	5133	1970	4713	7889	0	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	201293	203577.2	208030.2	213899.2	219032.2	221002.2	225346.4	232866.6	232497.8	232129	231760.2	231391.4
WS	0	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2	1106.4	737.6	368.8	0
SP1	0	809	4453	5869	5133	1970	4344.2	7520.2	0	0	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	0	0	0	0
SP2	0	2284.2	4453	5869	5133	1970	4344.2	7520.2	0	0	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	0	0	0	0
SC	1475.2											

Table B.69.

1984-1985	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	1.9	49.2	42.4	84.2	43.3	33.1	3.4	3.6	0.0	0.0	0.0
Runoff	0	232	7614	6579	13474	6368	5231	399	449	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	231022.6	230885.8	238499.8	245078.8	258552.8	264920.8	269783	269813.2	269893.4	269524.6	269155.8	268787
WS	0	0	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	0
SP1	0	0	6507.6	6579	13474	6368	4862.2	30.2	80.2	0	0	0
DM1	0	232	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	232	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	0	7614	6579	13474	6368	4862.2	30.2	80.2	0	0	0
%DM1	0	62.906725	100	100	100	100	100	100	100	100	100	100
%DM2	0	62.906725	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.70.

1985-1986	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	24.1	15.8	19.9	28.2	45.6	12.3	11.3	27.7	5.1	0.0	0.0
Runoff	0	3634	2115	2914	3821	7185	1678	1549	4329	681	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	268418.2	271683.4	273798.4	276712.4	280533.4	287718.4	289027.6	290207.8	294168	294480.2	294111.4	293742.6
WS	0	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	368.8	0
SP1	0	2527.6	2115	2914	3821	7185	1309.2	1180.2	3960.2	312.2	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	0	0
SP2	0	3265.2	2115	2914	3821	7185	1309.2	1180.2	3960.2	312.2	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	100	0	0
SC	737.6											

Table B.71.

1986-1987	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.2	11.6	131.1	26.8	57.8	17.0	89.3	2.4	2.8	1.6	0.0	0.0
Runoff	15	1527	24074	4098	9046	2396	15286	262	352	193	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	293388.8	294547	318621	322719	331765	334161	349078.2	348971.4	348954.6	348778.8	348410	348041.2
WS	0	1037	1037	1037	1037	1037	1037	930.2	913.4	737.6	368.8	0
SP1	0	121.2	24074	4098	9046	2396	14917.2	0	0	0	0	0
DM1	15	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	15	368.8	0	0	0	0	368.8	262	352	193	0	0
SP2	0	1158.2	24074	4098	9046	2396	14917.2	0	0	0	0	0
%DM1	4.0672451	100	100	100	100	100	100	100	100	100	100	100
%DM2	4.0672451	100	100	100	100	100	100	71.041215	95.444685	52.331887	0	0
SC	1037											

Table B.72.

1987-1988	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	45.1	23.1	74.5	49.0	116.3	89.1	8.3	1.1	0.0	9.6	0.0
Runoff	0	7021	3356	12066	7655	20583	14587	1000	117	0	1362	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	347672.4	354324.6	357680.6	369746.6	377401.6	397984.6	412202.8	412834	412582.2	412213.4	413206.6	412837.8
WS	0	368.8	368.8	368.8	368.8	368.8	368.8	368.8	117	0	368.8	0
SP1	0	6283.4	3356	12066	7655	20583	14218.2	631.2	0	0	624.4	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	117	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	117	0	368.8	0
SP2	0	6652.2	3356	12066	7655	20583	14218.2	631.2	0	0	993.2	0
%DM1	0	100	100	100	100	100	100	100	100	31.724512	100	100
%DM2	0	100	100	100	100	100	100	100	31.724512	0	100	0
SC	368.8											

Table B.73.

1988-1989	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	32.6	47.6	116.5	50.3	9.5	16.7	0.0	0.7	0.0	0.0	0.0
Runoff	0	5362	7341	20669	8273	1362	2342	0	80	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	412469	417462.2	424803.2	445472.2	453745.2	455107.2	457080.4	456711.6	456422.8	456054	455685.2	455316.4
WS	0	1764	1764	1764	1764	1764	1764	1395.2	1106.4	737.6	368.8	0
SP1	0	3229.2	7341	20669	8273	1362	1973.2	0	0	0	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	0	80	0	0	0
SP2	0	4993.2	7341	20669	8273	1362	1973.2	0	0	0	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	0	21.691974	0	0	0
SC	1764											

Table B.74.

1989-1990	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	20.0	25.5	18.3	13.6	70.5	25.4	0.5	0.0	4.0	0.0	0.0
Runoff	0	2658	3770	2484	1889	12269	3962	59	0	331	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	454947.6	457236.8	461006.8	463490.8	465379.8	477648.8	481242	480932.2	480563.4	480525.6	480156.8	479788
WS	0	1454	1454	1454	1454	1454	1454	1144.2	775.4	737.6	368.8	0
SP1	0	835.2	3770	2484	1889	12269	3593.2	0	0	0	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	59	0	331	0	0
SP2	0	2289.2	3770	2484	1889	12269	3593.2	0	0	0	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	15.997831	0	89.750542	0	0
SC	1454											

Table B.75.

1990-1991	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	12.5	3.5	19.9	60.0	34.8	31.0	9.6	3.5	0.0	0.0	0.0
Runoff	0	1737	455	2753	9154	5226	4528	1353	434	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	479419.2	480787.4	481242.4	483995.4	493149.4	498375.4	502534.6	503518.8	503584	503215.2	502846.4	502477.6
WS	0	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	0
SP1	0	261.8	455	2753	9154	5226	4159.2	984.2	65.2	0	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	1368.2	455	2753	9154	5226	4159.2	984.2	65.2	0	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.76.

1991-1992	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	14.0	36.6	128.3	17.2	99.8	35.5	5.9	8.4	3.5	0.0	0.0
Runoff	0	1907	5634	22286	2272	17244	5296	774	1147	455	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	502108.8	503647	509281	531567	533839	551083	556010.2	556415.4	557193.6	557279.8	556911	556542.2
WS	0	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	737.6	368.8	9.311E-11
SP1	0	800.6	5634	22286	2272	17244	4927.2	405.2	778.2	86.2	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	0	0
SP2	0	1538.2	5634	22286	2272	17244	4927.2	405.2	778.2	86.2	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	100	0	0
SC	737.6											

Table B.77.

1992-1993	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	0.8	51.4	80.3	38.6	51.8	45.9	3.6	12.0	0.0	0.0	0.0
Runoff	0	87	8788	13456	5959	8080	7335	452	1575	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	556173.4	555891.6	564679.6	578135.6	584094.6	592174.6	599140.8	599224	600430.2	600061.4	599692.6	599323.8
WS	0	0	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	0	0	7681.6	13456	5959	8080	6966.2	83.2	1206.2	0	0	0
DM1	9.311E-11	87	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	87	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	0	8788	13456	5959	8080	6966.2	83.2	1206.2	0	0	0
%DM1	2.525E-11	23.590022	100	100	100	100	100	100	100	100	100	100
%DM2	0	23.590022	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.78.

1993-1994	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	5.9	34.6	14.4	88.6	67.1	35.8	37.1	3.2	0.0	0.0	0.0
Runoff	0	781	5435	2011	14035	10334	5738	5599	395	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	598955	599367.2	604802.2	606813.2	620848.2	631182.2	636551.4	641781.6	641807.8	641439	641070.2	640701.4
WS	0	412.2	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	0	0	4740.8	2011	14035	10334	5369.2	5230.2	26.2	0	0	0
DM1	1.397E-10	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	412.2	5435	2011	14035	10334	5369.2	5230.2	26.2	0	0	0
%DM1	3.789E-11	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.79.

1994-1995	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	42.0	61.2	99.3	50.5	20.8	13.1	13.0	30.4	10.5	0.0	0.4	0.0
Runoff	7105	10262	17023	7625	2903	1878	1739	4501	1526	0	44	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	647437.6	657330.8	674353.8	681978.8	684881.8	686759.8	688130	692262.2	693419.4	693050.6	692725.8	692357
WS	1062.4	1062.4	1062.4	1062.4	1062.4	1062.4	1062.4	1062.4	1062.4	693.6	368.8	1.397E-10
SP1	5673.8	9893.2	17023	7625	2903	1878	1370.2	4132.2	1157.2	0	0	0
DM1	368.8	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	368.8	368.8	0	0	0	0	368.8	368.8	368.8	0	44	0
SP2	6736.2	9893.2	17023	7625	2903	1878	1370.2	4132.2	1157.2	0	0	0
%DM1	100	100	100	100	100	100	100	100	100	100	100	100
%DM2	100	100	100	100	100	100	100	100	100	0	11.930586	0
SC	1062.4											

Table B.80.

1995-1996	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.4	6.9	37.0	15.4	57.9	65.4	36.1	31.7	0.2	0.0	0.0	36.0
Runoff	35	879	5679	2094	9456	10898	5247	5079	16	0	0	6094
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	692023.2	692533.4	698212.4	700306.4	709762.4	720660.4	725538.6	730248.8	729896	729527.2	729158.4	734883.6
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	0	510.2	5679	2094	9456	10898	4878.2	4710.2	0	0	0	5725.2
DM1	35	368.8	0	0	0	0	368.8	368.8	16	0	0	368.8
DM2	35	368.8	0	0	0	0	368.8	368.8	16	0	0	368.8
SP2	0	510.2	5679	2094	9456	10898	4878.2	4710.2	0	0	0	5725.2
%DM1	9.4902386	100	100	100	100	100	100	100	4.3383948	0	0	100
%DM2	9.4902386	100	100	100	100	100	100	100	4.3383948	0	0	100
SC	0											

Table B.81.

1996-1997	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	21.3	5.3	61.3	8.3	27.8	29.1	26.8	9.4	0.0	0.0	0.0
Runoff	0	2979	699	9691	1106	4312	4164	4177	1337	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	734514.8	737125	737824	747515	748621	752933	756728.2	760536.4	761504.6	761135.8	760767	760398.2
WS	0	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	0	1503.8	699	9691	1106	4312	3795.2	3808.2	968.2	0	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	2610.2	699	9691	1106	4312	3795.2	3808.2	968.2	0	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.82.

1997-1998	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	14.0	22.3	82.5	57.9	31.5	13.9	42.2	5.2	7.9	0.0	0.0	0.0
Runoff	2095	3155	13968	9171	4415	1905	6700	649	1004	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	762124.4	764910.6	778878.6	788049.6	792464.6	794369.6	800700.8	800981	801616.2	801247.4	800878.6	800509.8
WS	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	619.8	2786.2	13968	9171	4415	1905	6331.2	280.2	635.2	0	0	0
DM1	368.8	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	368.8	368.8	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	1726.2	2786.2	13968	9171	4415	1905	6331.2	280.2	635.2	0	0	0
%DM1	100	100	100	100	100	100	100	100	100	100	100	100
%DM2	100	100	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.83.

1998-1999	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	1.0	31.7	86.4	102.9	30.7	31.8	39.6	0.0	0.0	0.0	0.0
Runoff	0	116	4554	14237	18114	4728	4804	6577	0	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	800141	799888.2	804442.2	818679.2	836793.2	841521.2	845956.4	852164.6	851795.8	851427	851058.2	850689.4
WS	0	0	1475.2	1475.2	1475.2	1475.2	1475.2	1475.2	1106.4	737.6	368.8	1.863E-10
SP1	0	0	3078.8	14237	18114	4728	4435.2	6208.2	0	0	0	0
DM1	1.397E-10	116	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	116	0	0	0	0	368.8	368.8	0	0	0	0
SP2	0	0	4554	14237	18114	4728	4435.2	6208.2	0	0	0	0
%DM1	3.789E-11	31.453362	100	100	100	100	100	100	100	100	100	100
%DM2	0	31.453362	100	100	100	100	100	100	0	0	0	0
SC	1475.2											

Table B.84.

1999-2000	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	1.4	1.0	18.2	33.1	39.0	70.1	28.6	25.3	4.1	0.0	0.0	0.0
Runoff	161	116	2672	5113	5468	11137	4051	3602	524	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	850481.6	850228.8	852900.8	858013.8	863481.8	874618.8	878301	881534.2	881689.4	881320.6	880951.8	880583
WS	0	0	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	0	0	1565.6	5113	5468	11137	3682.2	3233.2	155.2	0	0	0
DM1	161	116	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	161	116	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	0	2672	5113	5468	11137	3682.2	3233.2	155.2	0	0	0
%DM1	43.655098	31.453362	100	100	100	100	100	100	100	100	100	100
%DM2	43.655098	31.453362	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.85.

2000-2001	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	6.4	9.1	68.2	99.8	22.9	60.3	8.5	21.2	4.5	0.0	0.0	87.0
Runoff	863	1181	11972	16527	3234	9476	1205	2982	572	0	0	15904
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	881077.2	881889.4	893861.4	910388.4	913622.4	923098.4	923934.6	926547.8	926751	926382.2	926013.4	941548.6
WS	0	0	0	0	0	0	0	0	0	0	0	0
SP1	494.2	812.2	11972	16527	3234	9476	836.2	2613.2	203.2	0	0	15535.2
DM1	368.8	368.8	0	0	0	0	368.8	368.8	368.8	0	0	368.8
DM2	368.8	368.8	0	0	0	0	368.8	368.8	368.8	0	0	368.8
SP2	494.2	812.2	11972	16527	3234	9476	836.2	2613.2	203.2	0	0	15535.2
%DM1	100	100	100	100	100	100	100	100	100	0	0	100
%DM2	100	100	100	100	100	100	100	100	100	0	0	100
SC	0											

Table B.86.

2001-2002	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	11.1	24.2	83.2	61.5	37.9	53.4	28.8	2.8	0.0	0.0	0.0
Runoff	0	1623	3283	13891	9989	6284	8499	4316	345	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	941179.8	942434	945717	959608	969597	975881	984011.2	987958.4	987934.6	987565.8	987197	986828.2
WS	0	1130.2	1130.2	1130.2	1130.2	1130.2	1130.2	1130.2	1106.4	737.6	368.8	1.863E-10
SP1	0	124	3283	13891	9989	6284	8130.2	3947.2	0	0	0	0
DM1	0	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	345	0	0	0
SP2	0	1254.2	3283	13891	9989	6284	8130.2	3947.2	0	0	0	0
%DM1	0	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	93.546638	0	0	0
SC	1130.2											

Table B.87.

2002-2003	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	8.5	12.2	67.9	107.1	53.2	159.0	71.4	11.1	0.1	3.3	0.0	0.0
Runoff	1209	1757	11168	16792	8502	28782	11468	1528	8	421	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	987668.4	989056.6	1000224.6	1017016.6	1025518.6	1054300.6	1065399.8	1066559	1066198.2	1066250.4	1065881.6	1065512.8
WS	840.2	1046.2	1046.2	1046.2	1046.2	1046.2	1046.2	1046.2	685.4	737.6	368.8	1.863E-10
SP1	0	1182.2	11168	16792	8502	28782	11099.2	1159.2	0	0	0	0
DM1	368.8	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	368.8	368.8	0	0	0	0	368.8	368.8	8	368.8	0	0
SP2	840.2	1388.2	11168	16792	8502	28782	11099.2	1159.2	0	52.2	0	0
%DM1	100	100	100	100	100	100	100	100	100	100	100	100
%DM2	100	100	100	100	100	100	100	100	2.1691974	100	0	0
SC	1046.2											

Table B.88.

2003-2004	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	26.2	37.8	37.1	135.3	55.2	0.01	8.1	3.2	0.4	0.0	0.0
Runoff	0	4078	6128	6128	23440	8623	0	1131	404	44	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	1065144	1068853.2	1074981.2	1081109.2	1104549.2	1113172.2	1112803.4	1113565.6	1113600.8	1113276	1112907.2	1112538.4
WS	0	1062.4	1062.4	1062.4	1062.4	1062.4	693.6	1062.4	1062.4	737.6	368.8	1.397E-10
SP1	0	2646.8	6128	6128	23440	8623	0	393.4	35.2	0	0	0
DM1	1.863E-10	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	0	368.8	368.8	44	0	0
SP2	0	3709.2	6128	6128	23440	8623	0	762.2	35.2	0	0	0
%DM1	5.052E-11	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	0	100	100	11.930586	0	0
SC	1062.4											

Table B.89.

2004-2005	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	32.2	46.9	51.6	36.8	40.8	28.8	27.9	1.1	1.0	0.0	0.0
Runoff	0	5389	7281	8135	5453	7008	4776	4572	116	116	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	1112169.6	1117189.8	1124470.8	1132605.8	1138058.8	1145066.8	1149474	1153677.2	1153424.4	1153171.6	1152802.8	1152434
WS	0	1243.2	1243.2	1243.2	1243.2	1243.2	1243.2	1243.2	990.4	737.6	368.8	1.863E-10
SP1	0	3777	7281	8135	5453	7008	4407.2	4203.2	0	0	0	0
DM1	1.397E-10	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	116	116	0	0
SP2	0	5020.2	7281	8135	5453	7008	4407.2	4203.2	0	0	0	0
%DM1	3.789E-11	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	31.453362	31.453362	0	0
SC	1243.2											

Table B.90.

2005-2006	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	0.0	18.5	46.3	10.7	70.6	29.4	24.6	32.6	3.7	0.0	0.01	0.0
Runoff	0	2658	7123	1439	11629	4789	3539	5284	468	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	1152065.2	1154354.4	1161477.4	1162916.4	1174545.4	1179334.4	1182504.6	1187419.8	1187519	1187150.2	1186781.4	1186412.6
WS	0	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	0	1182.8	7123	1439	11629	4789	3170.2	4915.2	99.2	0	0	0
DM1	1.863E-10	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	368.8	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	0	2289.2	7123	1439	11629	4789	3170.2	4915.2	99.2	0	0	0
%DM1	5.052E-11	100	100	100	100	100	100	100	100	100	100	100
%DM2	0	100	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

Table B.91.

2006-2007	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.4	45.8	14.6	3.7	34.7	75.1	27.1	7.8	84.1	1.0	0.0	0.0
Runoff	43	7163	2022	456	5137	11989	4308	1035	15055	116	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	1186086.8	1192881	1194903	1195359	1200496	1212485	1216424.2	1217090.4	1231776.6	1231523.8	1231155	1230786.2
WS	0	990.4	990.4	990.4	990.4	990.4	990.4	990.4	990.4	737.6	368.8	1.397E-10
SP1	0	5803.8	2022	456	5137	11989	3939.2	666.2	14686.2	0	0	0
DM1	43	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	43	368.8	0	0	0	0	368.8	368.8	368.8	116	0	0
SP2	0	6794.2	2022	456	5137	11989	3939.2	666.2	14686.2	0	0	0
%DM1	11.659436	100	100	100	100	100	100	100	100	100	100	100
%DM2	11.659436	100	100	100	100	100	100	100	100	31.453362	0	0
SC	990.4											

Table B.92.

2007-2008	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Rainfall	0.0	0.0	33.5	40.1	15.4	31.0	7.1	1.5	3.5	0.0	0.0	0.0
Runoff	0	0	5548	6182	2245	4839	886	181	455	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	1230417.4	1230048.6	1235596.6	1241778.6	1244023.6	1248862.6	1249379.8	1249192	1249278.2	1248909.4	1248540.6	1248171.8
WS	0	0	1208	1208	1208	1208	1208	1020.2	1106.4	737.6	368.8	2.329E-10
SP1	0	0	4340	6182	2245	4839	517.2	0	0	0	0	0
DM1	1.397E-10	0	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	0	0	0	0	0	0	368.8	181	368.8	0	0	0
SP2	0	0	5548	6182	2245	4839	517.2	0	86.2	0	0	0
%DM1	3.789E-11	0	100	100	100	100	100	100	100	100	100	100
%DM2	0	0	100	100	100	100	100	49.078091	100	0	0	0
SC	1208											

Table B.93.

2008-2009	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**
Rainfall	4.5	13.9	0.7	57.7	76.4	75.6	39.7	14.9	6.9	0.0	0.0	0.0
Runoff	565	1915	80	9700	12688	12746	5903	2164	901	0	0	0
Demand	368.8	368.8	0.0	0.0	0.0	0.0	368.8	368.8	368.8	368.8	368.8	368.8
CS	1248368	1249914.2	1249994.2	1259694.2	1272382.2	1285128.2	1290662.4	1292457.6	1292989.8	1292621	1292252.2	1291883.4
WS	196.2	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	1106.4	737.6	368.8	1.397E-10
SP1	0	636	80	9700	12688	12746	5534.2	1795.2	532.2	0	0	0
DM1	368.8	368.8	0	0	0	0	368.8	368.8	368.8	368.8	368.8	368.8
DM2	368.8	368.8	0	0	0	0	368.8	368.8	368.8	0	0	0
SP2	196.2	1546.2	80	9700	12688	12746	5534.2	1795.2	532.2	0	0	0
%DM1	100	100	100	100	100	100	100	100	100	100	100	100
%DM2	100	100	100	100	100	100	100	100	100	0	0	0
SC	1106.4											

APPENDIX C

MAPS OF METU-NCC

Figure C.1 and Figure C.2 are enlarged from Figure 3.4, in Chapter III, page 29 and Figure 4.4 from Chapter IV, page 37 respectively.

Figure C.1.


Sub-catchment 1 🟨
Sub-catchment 2 🟩
Sub-catchment 3 🟦
Sub-catchment 4 🟥
Sub-catchment 5 🟪
Sub-catchment 6 🟧
Sub-catchment 7 🟪

Figure C.2.