MODELLING OF RAINFALL-RUNOFF RELATIONSHIP FOR BUKIT KENAU STATION IN KUANTAN RIVER BASIN

NUR MIZA BINTI MOHAMAD

B.ENG (HONS.) CIVIL ENGINEERING
UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

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MODELLING OF RAINFALL-RUNOFF RELATIONSHIP FOR BUKIT KENAU STATION IN KUANTAN RIVER BASIN

NUR MIZA BINTI MOHAMAD

Report submitted in partial fulfilment of requirements
for the award of the degree of
B. Eng. (Hons) Civil Engineering

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UNIVERSITI MALAYSIA PAHANG

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SUPERVISOR'S DECLARATION

I hereby declared that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor (Hons.) of Civil Engineering.

Signature	:
Name of supervisor	: EN. NORASMAN BIN OTHMAN
Position	: LECTURER
Date	: JUNE 2016

Signature	:
Name of Co-supervisor	: PN. SHAIRUL ROHAZIAWATI BINTI SAMAT
Position	: LECTURER
Date	: JUNE 2016

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Name : NUR MIZA BINTI MOHAMAD
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DEDICATION

Praise be to ALLAH S.W.T the Lord of The World
Who says (interpretation of meaning)
"Give thanks to me and your parent. To me is final destination"
[Quran,Luqman 31:14]
This project is specially dedicated to my beloved parents,
En. Mohamad Bin Hanaffi, Pn. Asma Binti Ahmad
to my siblings,
Mursyid, Munzir, Mahfuzah, Maisarah
my supervisor,
En. Norasman Bin Othman
And friends.
For all their encouragement, patience
and unconditional support.

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ABSTRACT

Hydrological modeling is a commonly used tool to estimate the basin's hydrological response due to precipitation. This study presented a rainfall-runoff transformation model for Bukit Kenau station in Kuantan River Basin using HEC-HMS (Hydrologic Engineering Centre Hydrology Modeling System). The aim of this study is to calibrate and validate the rainfall-runoff transformation model for Bukit Kenau Station. As a result, it can forecast the river flow for future and helps in the flood mitigation works planning to reduce the impacts along with the cost use in the mitigation works. The modeling for Bukit Kenau station can also contributes to the future flood planning activities to prevent from upcoming flood event. The result obtained from this study can be as a guidelines for flood mitigation design in future and can be useful for the purpose of designing hydraulic structure in this study area. In this study, HEC-HMS model was used to simulate the rainfall-runoff relationship process and to compute the runoff volume, peak runoff rate, base flow, losses and transform. For losses rate, SCS Curve Number method was selected while for transfom method, Clark Unit Hydrograph and Snyder Unit Hydrograph method were used and analyzed. The value curve number (CN) for subbasin is 72 while the percentage of impervious area is 10% for all calibration and validation processes. From this study, it was found that the volume of runoff was depends on the rainfall intensity. After the comparison between Clark UH and Snyder UH method, it found that Snyder UH was the best method for Bukit Kenau station in Kuantan River Basin. The model calibration and validation for Snyder UH method was found to be satisfactory with highest values of percentage Efficiency Index 64.43% instead of that Clark is 56.56%.

ABSTRAK

Pemodelan hidrologi adalah alat yang biasa digunakan untuk menganggarkan sambutan hidrologi lembangan akibat hujan. Kajian ini membentangkan model transformasi hujan-air larian untuk stesen Bukit Kenau di Sungai Kuantan menggunakan HEC-HMS (Hydrologic Pusat Kejuruteraan Hidrologi Modeling System). Tujuan kajian ini adalah untuk mengubah suai dan mengesahkan model transformasi hujan-air larian untuk Stesen Bukit Kenau. Akibatnya, ia boleh meramal aliran sungai untuk masa depan dan membantu dalam kerja-kerja merancang kawalan banjir untuk mengurangkan kesan dengan penggunaan kos dalam kerja-kerja kawalan. Pemodelan untuk stesen Bukit Kenau juga boleh menyumbang kepada aktiviti perancangan banjir masa depan untuk mengelakkan dari peristiwa banjir akan datang. Keputusan yang diperolehi daripada kajian ini boleh menjadi garis panduan bagi reka bentuk tebatan banjir di masa depan dan boleh diguna untuk tujuan mereka bentuk struktur hidraulik di kawasan kajian ini. Dalam kajian ini, model HEC-HMS telah digunakan untuk mensimulasikan proses penurunan hujan-air larian dan untuk mengira jumlah air larian, kadar air larian puncak, aliran dasar, kerugian dan mengubah. Untuk kaedah kadar kerugian, SCS Curve Number dipilih manakala bagi kaedah mengubah, Clark Unit Hidrograf dan Snyder Unit Hidrograf telah digunakan dan menganalisis. Bilangan keluk (CN) untuk lembangan ialah 72 manakala peratusan kawasan tidak telap air adalah 10% untuk semua proses penentukuran dan pengesahan. Daripada kajian ini, didapati bahawa jumlah air larian adalah bergantung kepada keamatan hujan. Selepas perbandingan antara Clark UH dan kaedah Snyder UH, mendapati bahawa Snyder UH adalah kaedah terbaik untuk stesen Bukit Kenau di Sungai Kuantan. Penentukuran model dan pengesahan untuk kaedah Snyder UH didapati memuaskan dengan nilai tertinggi Indeks peratusan Kecekapan 64.43% dan Clark adalah 56.56%.

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LIST OF SYMBOLS

A	-	Watershed area
Am	-	Drainage area
C	-	Runoff coefficient
C_t	-	Basin coefficient
C_p	-	Peak coefficient
cfs	-	Cubic square foot
i	-	Rainfall intensity
km	-	Kilometer
km^2	-	Kilometer square
L	-	Length of stream
L_c	-	Distance in kilometers (miles) from the outlet to a point on the stream nearest the centroid
mm	-	Millimeter
m^3	-	Meter cube
m^3/s	-	Meter cube per second
N	-	Number of discharge data
Q	-	Flow rate of runoff
Q_p	-	Peak runoff
Q_i	-	Observed discharge at time,i
Q_{ag}	-	Mean of observed discharge
q_u	-	Unit peak discharge
R	-	Storage coefficient
S	-	Slope

SS	-	Sum of square
t_c	-	Time concentration
T_{lag}	-	Snyder's standard lag (hours)
$\sum$	-	Summation

LIST OF ABBREVATION

ARI	Average Recurrence Interval
CN	Curve Number
DID	Department of Irrigation and Drainage
EI	Efficiency Index
GUI	Graphical User Interface
HEC-HMS	Hydrologic Engineering Centre Hydrologic Modelling System
JPS	Jabatan Pengairan dan Saliran
RSWM	Regional Stormwater Management
SMA	Soil Moisture Accounting
SCS	Soil Conservation Service
SWMM	Storm Water Management Model (SWMM)
UH	Unit Hydrograph
USGS	United States Geological Survey

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Flood is a natural disaster where the situation water temporarily covers land that usually dry, then get filled with water. This natural disaster frequently happened in Malaysia during monsoon season that can affecting Malaysia from the perspective of their financial cost, frequency and most importantly the impacts on the population and the disruption to the socio-economic activities. There are few events that can causes a flooding which is rainfall, river overflow, dam breaking, ice snow melts and tsunami. Flood that cause by rainfall can occur when heavy rainfall for a short time or light rainfall for several days or weeks. The water will naturally flow from high areas to low lying area (Subramanya, 2013).

As a result, the low lying area will rapidly filled with water before it begins to get high area. In term of positive effect flood can enhance and restore biodiversity in floodplains particular, restoring nutrient-rich soil conditions where it is suitable for agriculture and natural vegetation, clear debris and sediment from flooded areas and recharges groundwater. Instead of that, negative effect flood can risk life threatening, disturbing social and economic activities and destroy property, cause inconvenience and cost recovery can be high for the government or individuals, and prevent new investment in flood prone areas.

In Malaysia, floods can be group into two types which are flash floods and monsoon floods. Flash flood occur when drainage at that area cannot cater the amount of rainfall that occurs quickly with high intensity. Normally this flood occurs in urban area that have rapid development where the paved area are larger than unpaved area. Besides that, there are two types of monsoon which is northeast and southwest. This is due to heavy and continuous rainfall where northeast occur in Kelantan, Pahang and Terengganu between early November until March where southwest occur in Sabah and Sarawak starting from late of May until September (DID, 2013). Figure 1.1 shows flood occured in Kuantan.

Figure 1.1: Flood occured in Kuantan

Source: Berita Harian (2014)

1.2 PROBLEM STATEMENT

Pahang is a state on the east coast, which involved the effects of the northeast monsoon, from November to March each year. Thus, Kuantan one of the town area identified as flood prone area in Pahang. It is due to the high intensity of rainfall exceeding 50mm /hr and 200-400mm /day which continuously and caused the river overflow to low-lying areas (DID, 2013). In December 2013, Kuantan recorded the highest number of evacuees were 30,307 persons from 1,561 families staying in 85 evacuation centers (Bernama, 2013). Figure 1.2 shows flood prone area in Peninsular Malaysia.

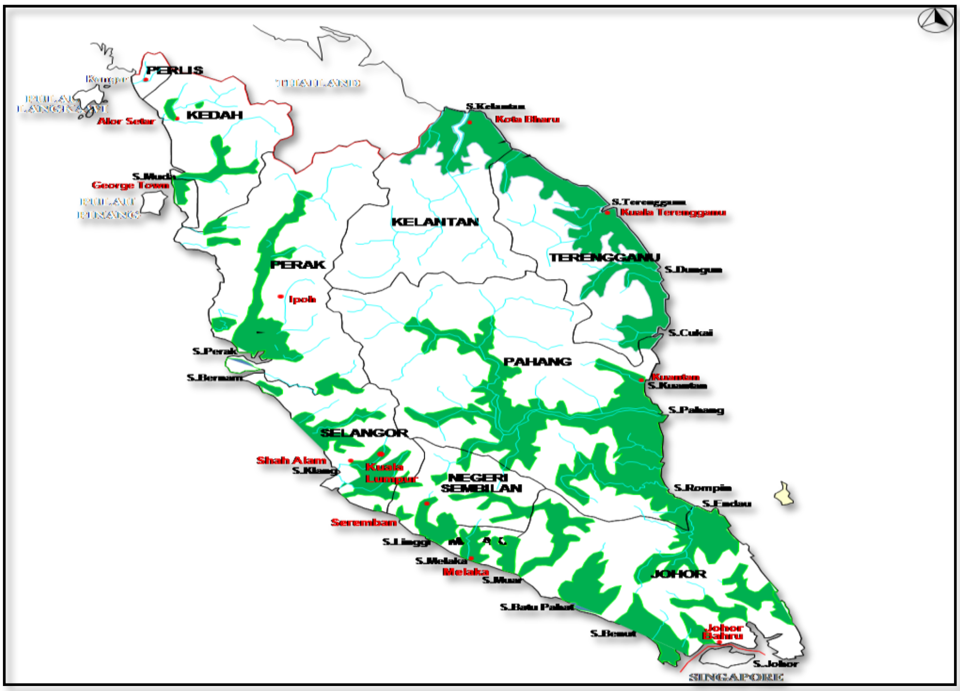


Figure 1.2: Flood prone area in Peninsular Malaysia

Source : DID (2013)

As a result, if the drainage and river basin is inadequate to cater the amount of runoff, it may occur a flood that impact on population in such as death, damages to property and inconvenience to resident of the city. In order to understand flood behavior, so the need of flood modeling study in this area is critical. This study should be carried out to calibrate and validate transformation model and determine the rainfall-runoff relationship for Bukit Kenau Station. This study will determine the best method of transformation in order to forecast the flood for future. The simulated hydrograph will show the amount of runoff volume based on various rainfall events for the several interval time for Bukit Kenau Station.

1.3 OBJECTIVES

The objectives of this study are :

i. To calibrate and validate the rainfall-runoff transformation model for Bukit Kenau Station.
ii. To determine and analyze the most suitable coefficients for Clark Unit Hydrograph and Snyder Unit Hydrograph for Bukit Kenau Station.
iii. To investigate the flow simulation from Clark UH parameters in Hydrologic Procedure No. 27 for Bukit Kenau Station in Kuantan River Basin.

1.4 SCOPE OF STUDY

The study area is Kuantan River Basin which covers an area about 1679 km square and length of the river is approximately 93.44 km. For analysis the study, only covers an area and length 582 km square and 36.2 km respectively. The upstream area of Kuantan river is started from forest reserved area in Mukim Ulu Kuantan through agricultural areas, Kuantan town and towards downstream Tanjung Lumpur which is South China Sea. The transform methods that will be used in this study are Clark UH and Snyder UH in HEC-HMS.

For this study, the river flow was simulated using HEC-HMS software by gathered data which is rainfall data and streamflow data from Department of Irrigation and Drainage (DID) from year 2002 until 2014 . In this study also, the river basin network was established using the Arc GIS software to delineation and the analysis was carried out using HEC-HMS model. The river simulation was carried out after all the data are insert and the networks are create. The river flow from upstream to downstream for Bukit Kenau sub-basin was marked in the model.

1.5 SIGNIFICANT OF STUDY

This study are very important since it can verify and calibrating the developed model to match the actual observed data. As a result, it can forecast the flood for future and helps in the flood mitigation works planning to reduce the impacts along with the cost use in the mitigation works especially in Kuantan River Basin. The modeling of rainfall-runoff for Bukit Kenau Station can also contributes to the future flood planning activities to prevent from flood event because this station is the only river flow station in Kuantan River Basin. The result obtained from this study can be a guidelines for design river system in future and can be useful for the purpose of designing hydraulic structure in this study area.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Malaysia have two types monsoon season in Peninsular which is Southwest Monsoon that affect west coast of peninsular Malaysia and Northeast monsoon that affected east coast of peninsular. Kuantan town, located in Pahang state was one of the developed towns in East coast of peninsular Malaysia and has been experiencing this phenomenon for a few decades. Every year, Malaysia have received 3500 mm of annual rainfall average which indirectly placed Malaysia as one of the riches country with water source.

In Malaysia, river play an important role since its usage approaching 98% compare to ground water, 2% in daily activities (DID, 2013). Most of areas in earth are receiving rainfall and runoff everywhere either in small or large amount. Rain that falls in long duration will produce a lot of runoff on surfaces especially for urban area where the capabilities of soil in absorbing the precipitation that falls is low. As the result, overflow of water will occur and floods will happen.

2.2 HYDROLOGIC CYCLE

Continuous movement of water from oceans to atmosphere and then release back to earth surface as precipitation is called hydrology cycle. Firstly, start with evaporation of water from water bodies such as oceans and lakes due to the heat energy by solar radiation. Then, the water vapor moves upwards and forms clouds. When the clouds through the condensation process, it will produce precipitation that falls to the ground. The precipitation can be transformed as rain, snow, hail, sleet and mist. Figure 2.1 shows the hydrologic cycle.

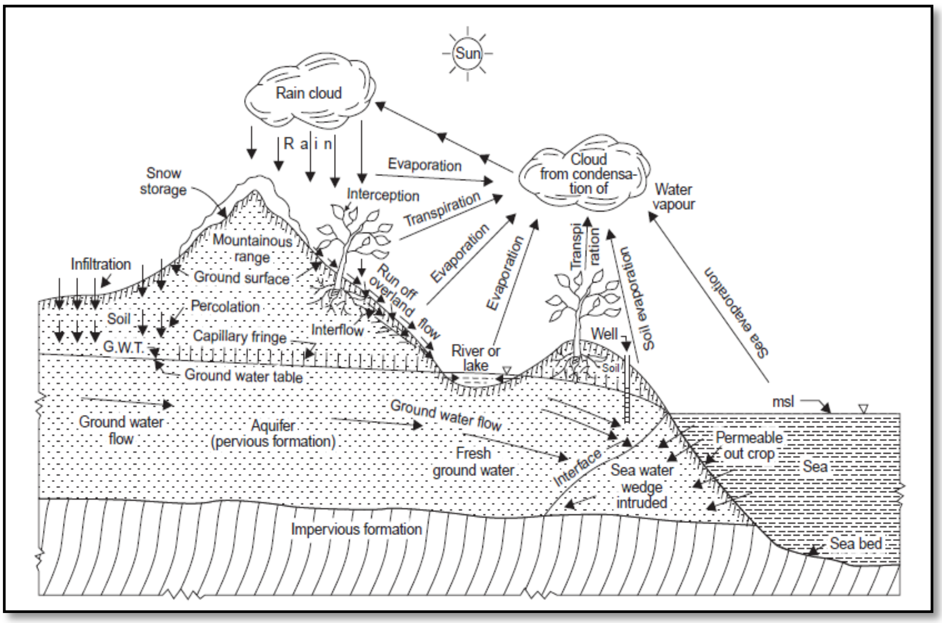


Figure 2.1: Hydrologic Cycle

Source: Raghunath (2006)

A portion of precipitation that reaches unpaved area will through the infiltration process with absorbed the water instead of, precipitation will be intercepted by vegetations and vaporized into the atmosphere. The water that penetrate in the ground called as ground water, and it will seep its way into the oceans, rivers or released back into the atmosphere through transpiration. If the water fall into the pavement area or the ground storage full with water it will flow on the ground surface. The balance of water that remains and flow on the earth surface is known as runoff, which filled into drainage, lakes, rivers and is carried back to the oceans, where the cycle begins again.

2.2.1 Evapotranspiration

Evapotranspiration is the way that water vapor re-enters the atmosphere. Generally, evapotranspiration is the sum of evaporation and transpiration. Also, defined as the water lost to the atmosphere from the ground surface, evaporation from the capillary fringe of the groundwater table, and the transpiration of groundwater by plants whose roots tap the capillary fringe of the groundwater table (Raghunath, 2006).

2.2.2 Condensation

Process of water changing from a vapor to a liquid. Water vapor in the air rises mostly by convection. This means that warm, humid air will rise, while cooler air will flow downward. As the warmer air rises, the water vapor will lose energy, causing its temperature to drop. The water vapor then has a change of state into liquid or ice.

2.2.3 Precipitation

Water being released from clouds as rain, sleet, snow or hail. Precipitation begins after water vapor which has condensed in the atmosphere, becomes too heavy to remain in atmospheric air currents and falls.

2.2.4 Infiltration

Process by which precipitation or water seeps into subsurface soils and moves into rocks through cracks and pore spaces. This is due to water that can be absorbed by the soil and may stay in the soil for long time until it gradually gets evaporated. If there is a lot of vegetation cover, the infiltrated water can also be absorbed by plant roots and later transpired. Normally, infiltration occurs at the upper layers of the ground but may also continue further downwards into the water table.

2.2.5 Percolation

Process of water that seeps into the ground called as precolation. where water travels downwards through the tiny spaces between rocks and soil particles. The water eventually saturates the underlying rock much like water fills the tiny holes of a sponge. This helps to replenish aquifers under the ground.

2.2.6 Runoff

Runoff is precipitation that reaches the surface of earth and did not infiltrated into the soil, or did not evaporate, therefore made its way from the ground surface into places that water collect. It will causes erosion, and also carry chemicals and substances on the ground surface along to the rivers where the water ends up.

2.2.7 Water Balance

Basic components of the hydrologic cycle include precipitation, evaporation, evapotranspiration, infiltration, overlandflow, streamflow and groundwater flow. The movement of water through various phases of the hydrologic cycle varies greatly in time and space, giving rise to extremes of floods or droughts. The magnitude and the frequency of occurrence of these extremes are of great interest to the engineering hydrologist from a design and operations standpoint.

In some cases, it is possible to perform a water budget calculation in order to predict changes in storage to be expected based on inputs and outputs from the system. For any hydrologic system, a water can be developed to account for various flow pathways and storage components. A small urban parking lot follows such as model and as rainfall accumulates on the surface, the surface detention or storage, it slowly increase and eventually become outflow from the system.

The evaporation for the period of input neglecting and assuming a long rainfall time period, all input rainfall eventually becomes outflow from the area but delayed in time. Also, same concept can be applied to small basins or large watersheds with added difficulty that all loss terms in the hydrologic budget may not be known.

2.3 WATERSHED

Watershed or basin area is an important physiographic property that determine the volume of runoff to be expected from a given rainfall event that falls over the area. The watershed areas vary in size from a few acres in an urban area to thousands of square miles for a major river basin. The watershed divide is loci of points ridge line that separates two adjacent watershed which then drain into two different outlets. The hydrologic response of rainfall at the outlet of an area called as hydrograph which plot of discharge channel versus time (Bedient, 2008).

The topographic divide for a basin is usually drawn on a USGS map or quadrangle sheet (1:24,000 scale) or other topographic map by identifying high points and contours of constant elevation to determine directions of surface runoff. The area encompassed by the divide is the watershed area. Runoff originates at higher elevation and moves toward lower elevations in a direction perpendicular to the contour lines. Generally, larger the watershed area, the greater the surface runoff rate, the greater the overland flow rate and the greater the stream flow rate.

2.4 RAINFALL-RUNOFF RELATIONSHIP

Rainfall runoff relationships shows where the quantity of runoff directly proportional increasingly more runoff . As the rain continues, water reaching the ground surface infiltrates into the soil until it reaches a stage where the rate of rainfall intensity exceeds the infiltration capacity of the soil. During a given rainfall, water is continually being abstracted to moisten the upper levels of the soil surface. However, this infiltration is only one of many continuous abstractions. Rainfall that intercepted by plant and roof surfaces will evaporated at the same time. Figure 2.2 shows the schematic diagram of rainfall-runoff relationship.

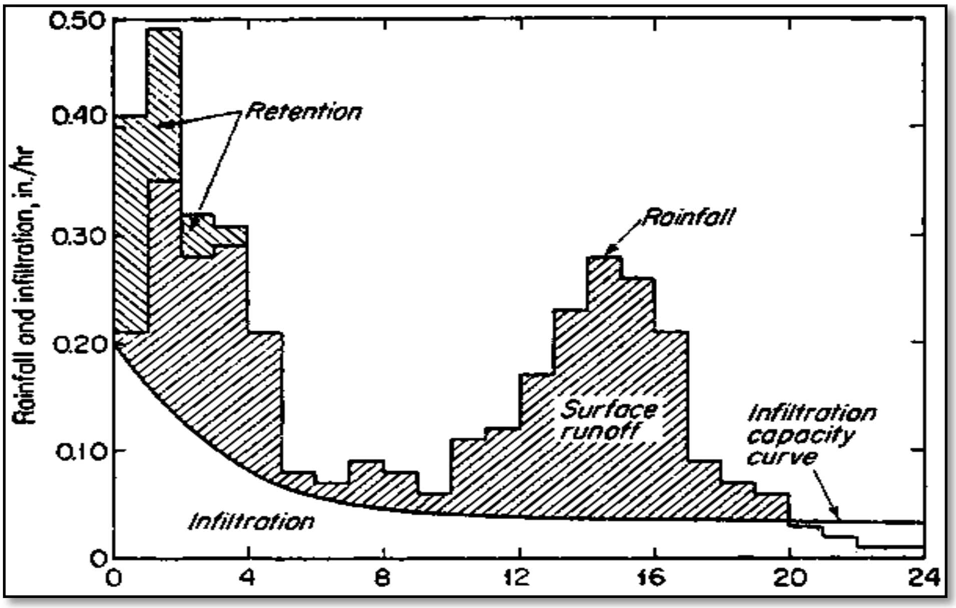


Figure 2.2: Schematic diagram of Rainfall-Runoff Relationship

Source: http://www.fao.org/docrep/u3160e/u3160e05.htm

Once, the rainfall exceeds the infiltration rate at the surface, excess water begins to accumulate as surface storage in small depressions governed by surface topography. As the depression storage begins to fill, overland flow or sheet flow may begin to occur in portions of a watershed, and the flow quickly concentrates into small rivulets or channels which can flow into larger streams. Contributions to a stream can also come from the shallow subsurface via interflow or base flow and contribute to the overall discharge hydrograph from rainfall event.

2.4.1 Hydrograph

Hydrograph is the result plot from variation of discharge with respect to time that is measured at a stream cross section. It is from combination of physiographic and meteorological conditions in watershed and represents the integrated effects of climate, hydrologic losses, surface runoff and base flow (Badient, 2008). Meteorological factors influence the hydrograph shape and volume of runoff include rainfall intensity and pattern, areal distribution of rainfall over the basin, and size and duration of the storm event. Figure 2.3 shows the hydrograph from storm event.

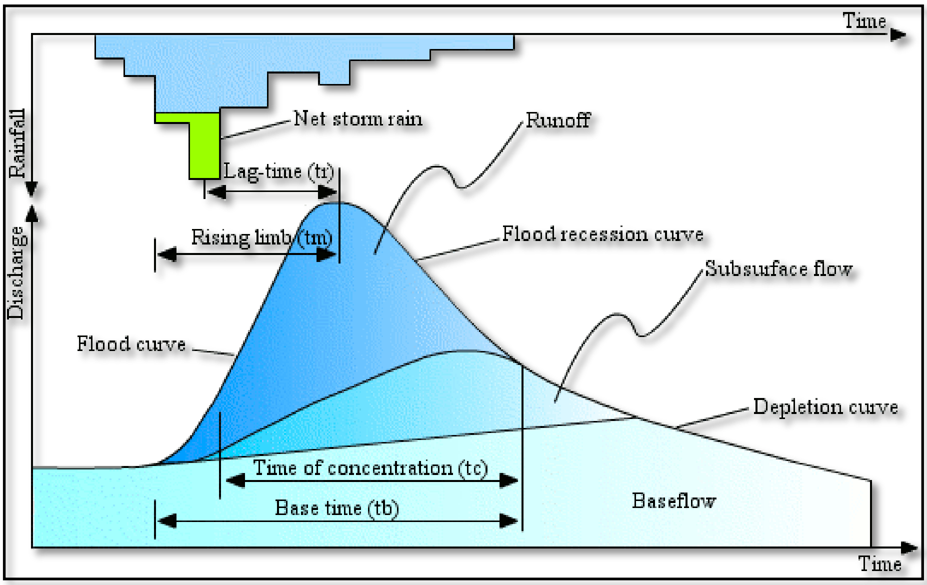


Figure 2.3: Hydrograph from storm event

Source : http://echo2.epfl.ch/VICAIRE/mod_1a/chapt_8/main.htm

Physiographic or watershed factors of importance include size and shape of the drainage area, slope of the land surface and the main channel, channel morphology and drainage type, soil type and distribution, and storage detention in the watershed. Human factors include the effects of land use and land cover. During a given rainfall, hydrologic losses such as infiltration, depression storage and detention storage should be satisfied prior to the onset surface runoff.

A typical hydrograph is characterized by a rising limb, a crest segment and depletion curve. The inflection point on the falling limb is often assumed to be the point where direct runoff ends. Rainfall excess is obtained by subtracting infiltration losses from total storm rainfall. The direct runoff represent the hydrograph response of the watershed to rainfall excess which defined as precipitation minus infiltration. As the depth of surface detention increases, overland flow will occur in portion of basin.

Water eventually moves into small rivulets , small channels and finally the main stream of watershed. The water that infiltrates the soil will move laterally through upper soil zone until it enters a stream channel (Bedient, 2008).. This portion of runoff is called as interflow or subsurface stream flow. After some time, direct runoff will begins to increase as a rising limb and levels off at the peak outflow. As a result, runoff from storage contributes to the overall response of watershed and hydrograph will recedes to a low value of base flow or returns to zero. Generally the time duration of rainfall is much shorter than the time base of hydrograph.

2.5 RAINFALL

Rainfall is a type of precipitation that occurs when water vapor in the clouds condenses into droplets since it can not longer be suspended in the air. The size of water drops is larger than 0.5 mm up to 6 mm. In case that, any water drops larger than this size it tends to break up into drops of smaller sizes during its fall from the clouds (Subramanya, 2013). It can be collected and measured the amount of intensity over a set period of time using rain gauges or also known as an udometer.

2.5.1 Characteristics of Rainfall

Rainfall characteristic includes intensity, duration and frequency. These characteristics of rainfall can provide important information for management and land use may also minimize the water erosion problems. This study will carried out to evaluate total amount water loss in erosion plots with different coverage, and the interference of natural rainfall characteristics on these processes.

2.5.1.1 Intensity

The intensity of rainfall can be measured in the height of the water covering the ground over period of time. Normally this value will be expressed in depth units per unit time, known as millimeters per hour (mm/hr). Rainfall intensity is most important for engineers, since they have to consider rainfall intensity in order to design highway and flood control structures.

High intensity rainfall normally produce larger size rain drops for a short duration that fall with more impact energy on the soil surface and generate more runoff instead of low intensity rainfall. As the result, the textured of soil aggregates break down rapidly into fine particles that seal the soil surface and can damage delicate vegetation and bare soil (Subramanya, 2013).

2.5.1.2 Duration

Rainfall duration is refers to the length of time or the amount of time that rainfall occur. Commonly, longer duration rainfall have lower average intensity that can influence infiltration, runoff, and soil erosion processes. Short duration generally associated with high intensity rainfall instead of low intensity which occur for long duration.

2.5.1.3 Frequency

Rainfall frequency is a measure of the probability or risk of occurrence. For a given rainfall duration, the probability that a rainfall event has of being equaled or exceeded in one year is known as its recurrence interval. The inverse of the recurrence interval is called the return period. A 100-year rainfall has a 1% chance recurrence interval of being equaled or exceeded in any given year.

Also note that a 100-year rainfall does not always produce a 100-year flood. The frequency, or more specifically the return period refers to how often rainfall occurs at a particular amount or intensity and duration (Hashmi, 2009). For example, rainfall return periods are referred to as 100 year-1 hour rainfall or 100 year-24 hours rainfall to define the probability that a given amount will fall within a given time of period.

2.6 RUNOFF

The total amount of water draining or flowing of precipitaion from a cachment area through a surface channel. As the rain continues, water reach the ground surface and infiltrates into the soil until it reaches when water storage in soil beyond the infiltration capacity of the soil. The textures, structure and moisture content of soil influence the infiltration capacity of the soil.

For dry soil infiltration capacity is high, since the rain continues it decreases until it reaches a final infiltration rate. The process of runoff generation continues as long as the rainfall intensity exceeds the actual infiltration capacity of the soil but it stops as soon as the rate of rainfall drops below the actual rate of infiltration. Runoff can be classified into two categories which is direct runoff and base flow.

2.6.1 Direct Runoff

Total sum of surfaces runoff and interflow. It is part of runoff which enters the stream immediately after the rainfall. Actually, it includes surface runoff, prompt interflow and rainfall on the surface of the stream. Direct runoff also known as in term such as storm runoff and direct storm runoff.

2.6.2 Base Flow

The flow that delay to reach stream essentially as groundwater flow is called base flow. It can be simply recognized as the slowly decreasing flow of the stream in rainless period. The portion of stream flow that is not runoff and results from seepage of water from the ground into a channel slowly over time.

2.6.3 Factors Affecting Runoff

There are few specific factors that can cause runoff which have a direct bearing on the occurrence and volume of runoff.

2.6.3.1 Soil Type

One of soil characteristic is permeability which is water can penetrate through the soil. Infiltration capacity depends on the porosity of a soil which considers water storage capacity and affects the resistance of water to flow into deeper layers. Normally, the highest infiltration capacities are observed in loose, sandy soils instead of heavy clay or loamy soils that have considerable smaller infiltration capacities (Arafin, 2009). Also, the infiltration capacity depends on the moisture content prevailing in a soil at the on set of a rainstorm.

The initial high capacity decreases with time provided the rain does not stop until it reaches a constant value as the soil profile becomes saturated. It is well known that high intensity rainfall when hitting the soil surface is considerable because it causes a breakdown of the soil aggregate as well as soil dispersion with driving fine soil particles into the upper soil pores. As a result, form clogging pores and formation of a thin but dense and compacted layer at the surface which highly reduces the infiltration capacity.

2.6.3.2 Vegetation

Vegetation also influent the absorption of rainfall. The amount of rain loss to interception storage on the foliage depends on the vegetation and its growth stage between 1 and 4 mm. In rural area, most of earth surface are covered by vegetation and hence it will increase permeability of rainfall into ground and only small amount of precipitation on the surface that called as runoff. As a result, dense vegetation covers shields the soil from the raindrop impact and it will reduces the crusting effect.

In addition, the root system as well as organic matter in the soil will increase soil porosity in order to allowing more water to infiltrate. It is also can retards the surface flow particularly on gentle slopes, so that the water has more time to infiltrate and to evaporate. Hence, the area that densely covered with vegetation, yields less runoff than bare ground.

2.6.3.3 Slope and Catchment Size

A slope profile prepared along the main stream is used to characterize the slope of the catchment. As a rule, at the beginning of the stream the catchment slope is the highest and gradually decreases as one move along the stream to the basin outlet. The increasing slope length will decreased the amount of runoff (Azhary, 2012). This is mainly due to the lower flow velocities and subsequently a longer time of concentration defined as the time needed to drop of water to reach the outlet of a catchment. Meaning that the water is exposed for a longer duration to evaporation and infiltration before it reaches the measuring point. The runoff efficiency which is volume of runoff per unit of area will increases with the decreasing size of the catchment.

2.6.4 Runoff Estimation

In order to estimate the amount of runoff, there are four methods that commonly used which is Rational Method, Graphical Peak Discharge Method, Tabular Method and Unit Hydrograph. Factors that influence to decide on a runoff estimation are size of drainage and output information required.

2.6.4.1 Rational Method

A rational approach is to obtain the yield of a catchment by assuming a suitable runoff coefficient. It is used to compute the peak runoff, Qp for each event. A proportionally factor C called as runoff coefficient was added in anattempt to account for infiltration into the ground and for evaporation (Raghunath, 2006).

$$Q_p = ACi \tag{2.1}$$

Where :

Qp = peak of runoff (cfs)
A = area of catchment (acres)
C = runoff coefficient
i = rainfall intensity (in/h)

The value of the runoff coefficient C varies depending upon the soil type and vegetation. In the rational method, the drainage area is divided into a number of sub-areas and with the known times of concentration for different subareas the runoff contribution from each area is determined. The choice of the value of the runoff coefficient C for the different sub-areas is an important factor in the runoff computation by this method.

2.6.4.2 Peak Discharge Method

In the Graphical Peak Discharge Method, runoff can be estimated by using this formula :

$$q_p = q_u A_m Q F_p \tag{2.2}$$

Where :

qp = peak discharge (cfs)
qu = unit peak discharge (cfs/mi²/in)
Am = drainage area (mi²/)
Q = runoff (in)
Fp = pond and swamp adjustment factor

2.6.4.3 Tabular Method

The Tabular Hydrograph Method is used to develop the composite hydrograph. First, this method extracts a specific unit hydrograph from a table based on a number of sub area and rainfall variables (Raghunath, 2006). The variables found to have significant influence on the shape of unit hydrograph are *Rainfall Type*, *Ia/P*, *Tc* and *Tt*. *Tc* is the time concentration within the subarea and *Tt* is the travel time from the subarea outlet to the watershed outlet.

2.6.4.4 Unit Hydrograph

The hydrograph of direct surface discharge measured at the outlet of drainage area, which produces a unit depth of direct runoff resulting from a unit storm of specified duration is called a unit hydrograph of that duration. Proposed by L.K. Sherman in 1932 and the theory of unit hydrograph is based on the following assumptions which is the net rainfall is of uniform intensity within its duration, the net rainfall uniformly occurs over the entire area of the drainage basin. For a given drainage basin, the base period of the hydrographs of direct runoff corresponding to net rains of different intensities but same unit duration is constant (Raghunath, 2006). Figure 2.4 shows the Unit Hydrograph for rainfall events.

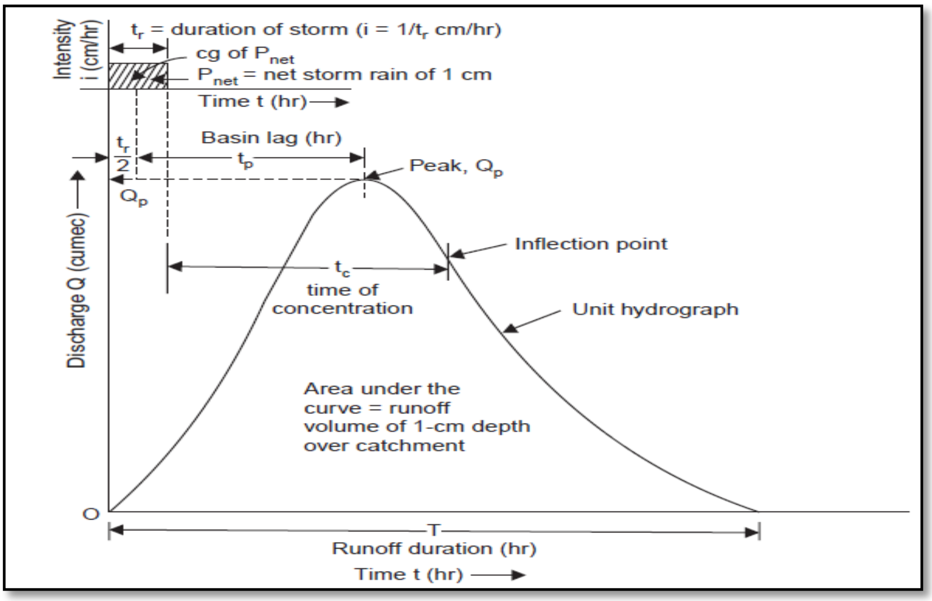


Figure 2.4: Unit Hydrograph

Source: Raghunath (2006)

The ordinates of direct runoff hydrographs due to net rains of different intensities but same unit duration are proportional. A unit hydrograph reflects all the physical characteristics of the basin. It is derived from an observed flood hydrograph for the drainage basin due to a known storm loss and net rain. Also, can be applied for any other storm of the same duration but producing different net rain occurring on the basin and the resulting flood hydrographs can be obtained.

2.7 HYDROLOGICAL SIMULATION MODELS

A hydrologic simulation models is composed of three basic elements which are equation that governed by the hydrologic processes, maps that define the study area and database tables that numerically describe the study area and model parameter. These software are problem analysis procedure by using computer software to improve the understanding and summarizing the problems into simpler approaches.

2.7.1 HEC-HMS

Program that designed to simulate the rainfall-runoff processes of stream or drainage basins system. Also, designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems such as large river basin water supply, flood hydrology, and small urban or natural watershed runoff. The model was developed and maintained by U.S. Army Corps Engineer and can be download for free. Hydrographs that generate by this program are used directly for studies of water availabilty, urban drainage, flood forecasting, future urbanization impact, reservoir spillway design, flood damage reduction and system operation. Based on researh Halwatura (2013) HEC-HMS reliably used to simulated Attanagalu Oya flows with calibration and validation.

In addition, this program can generalized modeling system capable of representing many different watersheds. A model of the watershed is constructed by separating the water cycle into manageable pieces and constructing boundaries around the watershed of interest. Any mass or energy flux in the cycle can then be represented with a mathematical model. In most cases, several model choices are available for representing each flux. Each mathematical model included in the program is suitable in different environments and under different conditions. In research study by Razi (2010) conclude that this program can be reliable tool to model river flows Johor River and used to generate missing data and estimate flood from rainfall data.

This model consists of Graphical User Interface (GUI), hydrologic analysis components, data storage, graphical management ability and report of the result. GUI provides the user s to manage their basin model, to identify or editing the model and also to show the results of the analysis. Hydrology elements that contain in this software including subbasin, routing, reach, junction, uncontrolled reservoir, diversion, source and sink. Watershed of selected area can be modelled by arranging the hydrology elements into one network. Based on Zorkeflee (2009) study, HEC-HMS can determined spatially distributed runoff and evaluate in the transformation of the rainfall for Kurau River Basin's area.

According to Hasrul (2009) for study in Muar River and Segamat River, this simulation software is able to estimate the peak discharge and almost same with the actual discharge that happened in real catchment areas. There are three parameters in this software that can use by user which is losses, transform and baseflow parameter. Each parameters have their on methods and can be selected depends on the study. Unit for the data input or output can be used as Metric units or U.S Customary units. Hence, this simulation model was selected in this study because it is very practical in order to determine the rainfall runoff relationship. In research James (2010), this program suitable for studied in Misai and Wan'an catchments due to powerful tool for flood forecasting.

2.7.2 Runoff Routing (RORB)

Runoff and stream flow routing program by Monash University in Australia used to calculate and produce flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce the hydrograph. It also can be used to design retarding basins and to route floods through channel networks. The program requires a data file to describe the particular features of the stream network being modelled and run interactively.

Other than that, it can be used both for the calculation of design hydrographs and for model calibration by fitting to rainfall and runoff data of recorded events. The model is a really distributed, nonlinear, and applicable to both urban and rural catchments. It makes provision for temporal and areal variation of rainfall and losses and can model flows at any number of gauging stations. In addition, to normal channel storage, specific modelling can be provided for retarding basins, storage reservoirs, lakes or large flood plain storages.

The new features include the provision to vary parameters over sub-catchments, additional features in the specification of design storms and special storages, the facility for multiple for a range of ARI or duration, extended interactive graphics capability, and simulation. In research article by Griffiths (1989) RORB model performance in predicting peak size, arrival time and the shape of four of eight measured basin outflow hydrographs given measured storm rainfall input was very good. Application of the calibrated model at the outlet station, under present climatic and physical condition gives the results consistent with regional flood frequency information.

2.7.3 MIKE SHE

Advanced integrated hydrological modeling system to simulates water flow in the entire land based phase of the hydrological cycle from rainfall to river flow, via various flow processes such as overland flow, infiltration into soils, evapotranspiration from vegetation, and groundwater flow. This program can been applied in a large number of studies world-wide focusing on conjunctive use of surface water and ground water for domestic and industrial consumption and irrigation, dynamics in wetlands, and water quality studies in connection with point and non-point pollution.

Also, it is used in regional studies covering entire river basins as well as in local studies focusing on specific problems on small scale. Integrated fully dynamic exchange of water between all major hydrological components is included, surface water, soil water and groundwater. Physically based for this program can solves basic equations governing the major flow processes within the study area. The spatial and temporal variation of meteorological, hydrological, geological and hydro geological data across the model area is described in gridded form for the input as well as the output from the model.

Based on article Zhiqiang Zhang (2008), it have been stated that this model could simulate the overland runoff generation mechanisms that occurred in the study watershed, but the model had large simulation errors for some individual storm events. Model performance for storm events was not as satisfactory as for the continuous daily stream flow simulation.

2.7.4 Regional Stormwater Model (RSWM)

RSWM is model software that widely used in Australia, Indonesia and Malaysia to study about runoff flow in urban, semi-urban, rural and semi-rural area. This model is selected to predict flood, designing flood control and studying urbanization effects on flood characteristics in catchment area. RSWM is also known as distributed model which is can distribute any catchment area into some sub-catchment and all data obtained in this software will be shown in hydrograph.

2.7.5 HYDRA

It is used for fully storm water analysis. The suitable methods that can be applied for urban catchment area in this model are Rational Method, SCS Santa Barbara Method and Hydrographic Simulation. These calculation methods are ideal for any projects held and peak flow rate also can be shown as the result for this software by using rainfall data and time curve. It is designed as flexible software, but if the estimation done is wrong, the design will be more expensive in cost and it is not sufficient.

To calibrate the data according to the actual data obtained, some of the data such as rainfall hyetograph, data radar and storm cell simulation data are used and will be inserted into HYDRA. This model simulation is very practical in modeling surface runoff and users are able to set the capacity of rainfall outlet by generally or individual.

2.8 HYDROLOGIC ELEMENTS

It is one of the fundamental needs to be taken in analyzing basin model. Hydrologic elements explain actual physical processes that took place on earth surface such as watershed area, channels, and river intersections and so on. Each element has its own role to describe the relationship between precipitations with the watershed area (Arafin, 2009). These elements are using mathematical models to interpret the physical processes that occur in actual situations. There are 7 different elements in hydrology that need to be understood, which are:

i. Subbasin

It is playing a role by using outflow concept only which there is no inflow happen in this element. The flow is calculated by three simple concepts which are reducing the losses from meteorological data obtained changing the precipitation exceeding and sum the baseflow values. There is no limit for any watershed size when using this hydrologic element.

ii. Reservoir

This element is using concept of one or more of inflow but it is limited to one outflow only by calculations. Usually inflow is taken from other element in watershed modeling. If there is more inflow, it needs to be sum for all of inflow before outflow value is calculated. Outflow can be determined by user-defined method and this element is applied for lakes, ponds or reservoirs.

iii. Reach

Reach is applied by using one or more inflow and only one outflow concept, and inflow are taken from other elements in basin model. Concept applied is more or less with reservoir if the inflow is more than one. The outflow of element is calculated as the open channel concept.

iv. Junction

This element is using one or more inflow and one outflow concept. To obtain the outflow value, all inflow values need to be sum by assuming the starting point at junction is zero.

v. Diversion

Concept used for this element is one or more inflow but there are two outflow are produced which are main outflow and directed outflow. Inflows are taken from other element in basin model and all inflows are summed if there are more inflows identified.

vi. Source

Source is an element without inflow but there outflow can be determined for this element. It is among two methods used to produce streams in watershed modeling.

vii. Sink

Sink is an element with one or more inflows but there is no outflow produced from this element. All inflows directed to sink are calculated to obtain the amount of inflows. Sink is used to estimate the lowest level in watershed model outflow area.

2.8.1 Losses Method

This method defines the equations used in the HMS simulation to separate precipitation volumes from runoff excess. In this software, there are seven methods provided in losses method such as Deficit and Constant, Green Ampt, Gridded SCS Curve Number, Gridded Soil Moisture Accounting (SMA), Initial and Constant, SCS Curve Number and Soil Moisture Accounting. Each of the following methods require one or more input parameters to be defined.

2.8.1.1 SCS Curve Number

This is the simplest, predictable and stable method among others method because it is just relies for only one parameter. It is also well established, widely accepted and predicted values not in accordance with classical unsaturated flow theory. This method does not considered rainfall intensity and infiltration rate will approach zero during a storm of long duration. The curve number will taken from standard curve number tables and the curve number value range is from 30 to 100.

2.8.1.2 Deficit and Constant

A total losses volume of precipitation and an initial losses volume are used to determine an initial value. The parameters that need to specify in this method is initial deficit, constant loss rate, maximum deficit and percentage of drainage basin that is impervious.

2.8.1.3 Green Ampt

The method that combines unsaturated flow from Darcy’s law with requirements of mass conservation. Initial loss is included to model interception and depression storage. The parameters for this method is initial loss, volumetric, moisture deficit, wetting front suction and hydraulic conductivity.

2.8.1.4 Gridded SCS Curve Number

The gridded SCS curve number method a grid that defining the CN value. An initial abstraction ratio must also be defined as well as the potential retention scale factor. The default initial abstraction ratio as originally suggested by the SCS is 0.2, but later research has shown that for many watersheds this value could be as small as 0.05. This method should only be used with the ModClark unit hydrograph transform method.

2.8.1.5 Gridded Soil Moisture Accounting (SMA)

The gridded soil moisture accounting method can be used to specify a SMA unit for each gridded cell. The gridded SMA method uses the same parameters as the SMA, except that they are defined on a gridded basis rather than by sub-basin. This method should only be used with the ModClark unit hydrograph transform method.

2.8.1.6 Initial and Constant

This method use an initial value and uniform value in order to define infiltration losses. The maximum potential rate of precipitation loss is constant throughout an event and can be viewed as the ultimate infiltration capacity of the soils. The parameters that have to identified is initial precipitation loss, uniform precipitation loss which is used after the starting loss has been satisfied and percentage of drainage basin that is impervious.

2.8.1.7 Soil Moisture Accounting

Method that use five layers model which includes evapotranspiration calculations. The five layers include canopy storage layer, surface depression, storage layer, soil profile layer, shallow groundwater, deep percolation groundwater. In order to define this method, should define the capacity of each layer as well as the initial storage as a percent of that capacity. In addition, infiltration rates for the soil and groundwater layers have to be defined depends on types of soil and the tension zone capacity for the soil profile layer and storage coefficients for the groundwater layer must also be defined.

2.8.2 Transform Method

Precipitation of rainfall which did not undergo a process of infiltration, evaporation or water loss will be flushing and flow into low areas where the flow is known as the flow of surface runoff. Surface runoff can be analyzed using six methods of transformation. These methods include the Kinematic Wave, Mod Clark, Clark UH, Snyder UH, SCS UH and User-Specified Hydrograph.

2.8.2.1 Clark UH

Models translation and attenuation of excess precipitation which is translation is the movement of excess from origin to outlet based on synthetic time area curve and time of concentration. Attenuation is reduction of discharge as excess is stored in watershed modeled with linear reservoir (Subramanya, 2013). The parameters that need to be identified is time concentration (Tc) and storage coefficient (R). Reduction modeled by linear and parameter storage required is the time of concentration and coefficient storage. Both these coefficient is in units of hours.

Based on study for small tropical catchment in Nigeria by Ogunlela (2012), stated that this method is very useful, effective in situations with minimal data and suitable in development storm for rivers in small watershed. Also, in study Magdalena (2011) for Gabinka River cathment, found that this method parameter value used was successful in simualtion of flood discharges. In Malaysia, it have a study by Kamarul (2005) for Benus River which stated that this method produce reliable flood estimation. Table 2.1 shows the value of Clark parameters based on study area.

Table 2.1: Parameters for Clark

Study Area	Tc (hours)	Area of Watershed (km²)
Small Tropical Catchment in Nigeria	1.98	0.18
Grabinka River	34	218.68
Benus River	0.26	0.55

2.8.2.2 Snyder UH

The concept of synthetic unit hydrograph was introduced by Snyder (1938) based on a study watersheds in Appalachian Highlands. Normally, this method for basins area in ranging 10 to 10,000 mi². It was originally developed to compute the peak flow as a unit precipitation. There are two parameters that need to be defined in this method which is lag time in hours (*tp*) and peak disharge of unit hydrograph (*Qp*). The unit hydrograph technique is used in the runoff component of a rain event to transform rainfall excess to out flow and as direct runoff at the outlet of a basin resulting from one unit of precipitation excess over the basin.

Also, in this method empirical method have been developed in order to estimate the time base of hydrograph and the width at 50% of the peak flow. According to Kamarul (2005) study for Benus River, he found that this method produce reliable flood estimation once the model had been calibrated and validated. Other than that, based on Magdalena (2011) for Gabrinka River this parameters which is *tp* and *Cp* fits well towards observed hydrographs. Also, regarding to Halwatura (2013) for study area in Attanagalu Oya catchment, this method more reliable for simulates flows in this catchment. Table 2.2 shows the parameters for Snyder based on the study area.

Table 2.2: Parameters for Snyder

Study Area	**Area, km²**	***tp, (hour)***	***Cp***
Benus River	0.227	0.11	0.65
	0.324	0.72	0.10
Gabrinka River	218.68	30	0.8
Attanagalu Oya	337.06	41.1	0.2

2.8.2.3 SCS UH

The soil conservation service presently known as the Natural Resources Conservation Service building parameter unit of a hydrograph. It is also synthetic UH which the discharge is expressed by the ratio of discharge, Q, to peak discharge, Qp and the time by the ratio of time, t, to time to peak of the UH, tp. Estimating parameters for generating a unit hydrograph using the SCS dimensionless method include lag time in hours and peak discharge can be estimated from synthetic dimensionless hydrograph for the given basin. Based on study in Johor River by Razi (2010), found that the parameter for this model $Tlag$= 2980 minutes cover an area 272 km² and satisfied because reliable tool to model river flow. Besides that, for Balijore Nala watershed study by Kishor (2014), $Tlag$=17.9 minutes for area 15.5172 km² and it suitable for small and agricultural watersheds.

2.8.2.4 Kinematic Wave

This method uses the relationship between continuous equation and momentum equation to analyze the surface flow. Distributed outflow from a basin may be obtained by utilizing combinations of three conceptual elements which are overland flow planes, collector channels and a main channel. These elements can be defined if the kinematic wave option is specified. For this method overland flow length, representative slope, manning roughness coefficient and percentage of sub-basin area are the parameters that should be specified.

2.8.2.5 Mod Clark

For this method, watershed of study area is divided into uniform grids cells and each cell represents a small sub watershed. Each grid cells and scaled to overall watershed time of concentration is calculated for travel time. The lagged runoff from each grid cell is routed through the linear reservoir. The outputs from each linear reservoir are combined to form outflow hydrograph. The required parameters for this method are gridded representation of watershed, gridded cell file, time of concentration and storage coefficient.

2.8.2.6 User Specified Hydrograph

Application of User-specified UH in practice, direct runoff computation with a specified-UH is uncommon. The data are seldom available and it is quite difficult to apply. The user specified unit hydrograph option allows users to define the exact unit hydrograph for the basin in the time series editor. Estimating the model parameters by collect data for an appropriate observed storm runoff hydrograph and the causal precipitation, losses and subtract precipitation, baseflow and separate from the runoff , total volume of direct runoff and convert to equivalent uniform depth over the watershed and divide the direct runoff ordinates by the equivalent uniform depth.

2.8.3 Baseflow Method

Precipitation that fall into earth has infiltrated into the soil through the unsaturated zone before entering the zone of ground water. The basic flow for each sub-basin can be modeled using three different methods, namely Monthly Constant, Linear Reservoir and Recession. Constant Monthly and Recession are suitable for sub-basin but Linear Reservoir is suitable for sub-basins using gridded Soil Moisture Accounting (SMA) or Soil Moisture Accounting. For this study, it will considered that there is no base flow or the base flow is to be zero.

2.8.3.1 Monthly Constant

The constant monthly method uses a constant base flow in for all simulation time steps that fall within a given month. It is intended for use in long term simulations and requires a separate value for each month that is part of the overall simulation time.This method uses a uniform basic flow during the simulation period surface flow calculated using the method of variation then added it to the base of the total outlay. The value of the base flow required for all months in the period simulation.

2.8.3.2 Linear Reservoir

Method that computes base flow from groundwater storage and only can be used in conjunction with the soil moisture accounting loss method. Available water from each groundwater layer is converted to base flow through a specified number of linear reservoirs. The storage coefficient and number of linear reservoirs is required for each of the two layers. This method of calculating the basic flow of water storage.

2.8.3.3 Recession

Generally more applicable to shorter duration periods for watersheds where the volume and timing of the base flow is strongly influenced by the precipitation event. The input parameters for the recession base flow method are initial flow at the start of the storm, recession constant describing the rate of base flow decay. The constant represents the ratio of base flow at the present time to the flow one day earlier and consequently ranges between 0 and 1. Also, threshold flow below which base flow recession occurs in accordance with the recession constant and corresponds to the point on the hydrograph where base flow replaces overland or runoff flow as the source from the sub-basin. This can be specified as an absolute value or as a ratio of the peak flow.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

There are various method can be applied in order to determined the rainfall runoff relationship either by observation to the site selected, modeling simulations or mathematical calculations by using certain equations or formulas. Even though there are various techniques and method that can implemented, but the aims is the same in order to determine the rainfall runoff relationship. The hydrologic model used in this study is HEC-HMS model.

The model was developed and maintained by U.S. Army Corps Engineer and can be download for free. In this model there are various methods for transformation of effective rainfall such a SCS UH, Snyder UH, Clark UH, Kinematic Wave, Mod. Clark UH and user specified S-Graph. The Clark UH and Snyder UH methods will be selected in this study to transform effective rainfall to the outlet. Prior to that, observed rainfall and stream flow data will be used in order to calibrate the parameters of Clark UH and Snyder UH.

Figure 3.1 shows the flow chart for overall processed involved in this study analysis from start until finish.

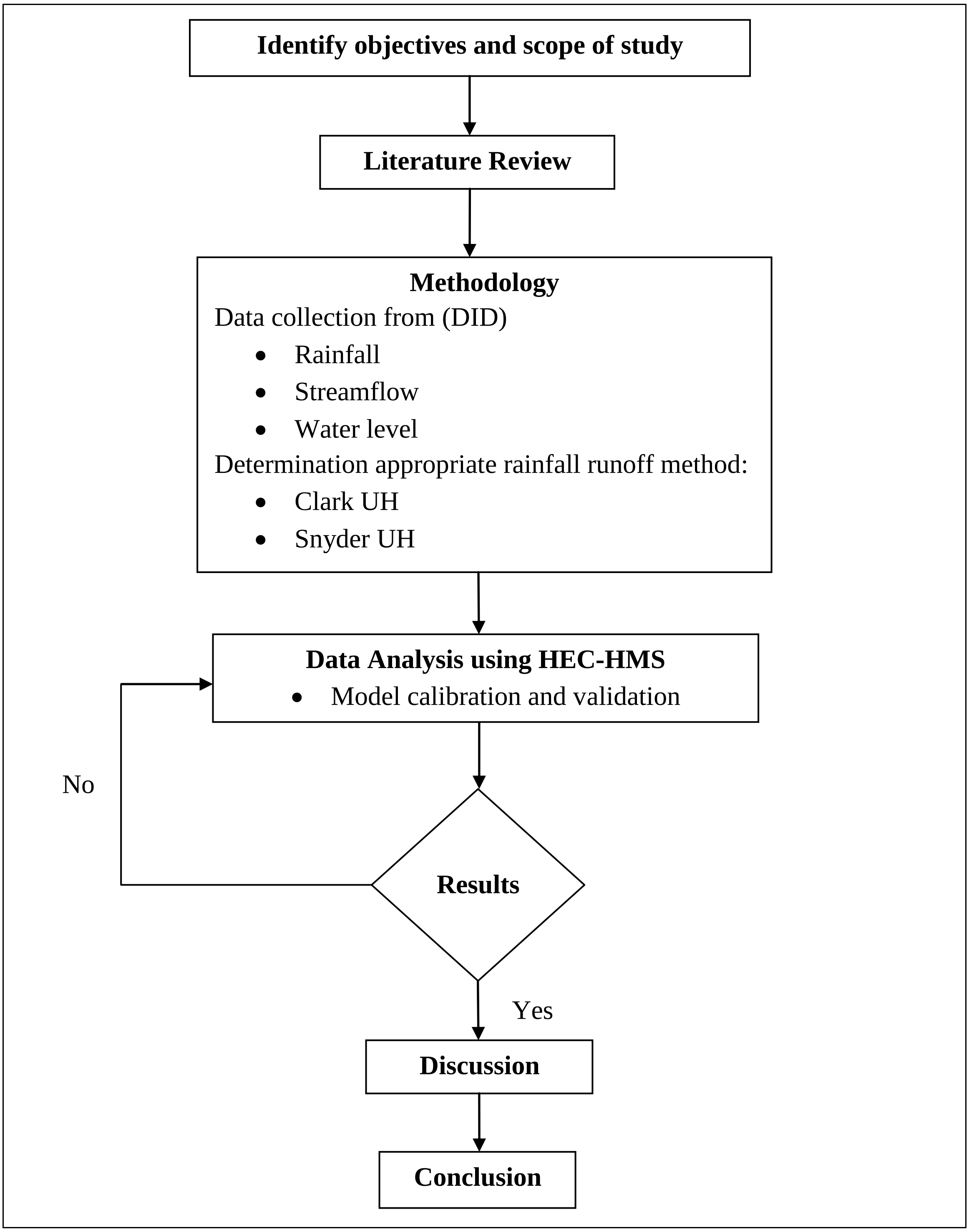


Figure 3.1: Flow Chart

3.2 STUDY AREA

The study area only included the top part sub-basins from Bukit Kenau Station. The sub-basin covers an area 582 km square and length 36.2 km. The location start from upstream Mukim Ulu Kuantan to downstream in Bukit Kenau streamflow station. Figure 3.2 shows the plan of study area.

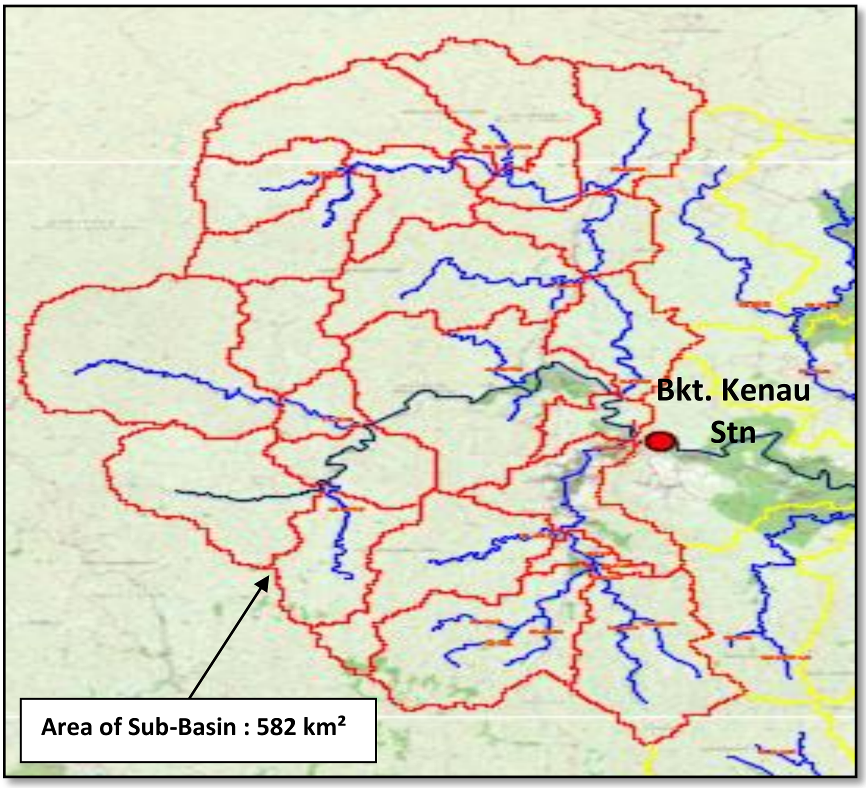


Figure 3.2: Study Area

3.3 DATA COLLECTION

In this study, the data required are rainfall data, stream flow data, water level data for every 15 minutes and watershed properties can be obtained from Department of Irrigation and Drainage (DID) Headquarters in Ampang Selangor. The rainfall data for each station and stream flow data in Kuantan watershed were very important to be collected because the analysis and design work only can be done by using these data.

The data was collected from year 2002 until 2014. Table 3.1 shows rainfall and streamflow station in Kuantan River Basin.

Table 3.1: Rainfall and Streamflow station in Kuantan River Basin

Station ID	Station Name	Function
3631001	Kg. Pulau Manis	Rainfall
3731018	JKR Gambang	Rainfall
3732020	Paya Besar	Rainfall
3732021	Kg. Sg. Soi	Rainfall
3831001	Pasir Kemudi	Rainfall
3832015	Rancangan Pam Paya Pinang	Rainfall
3833002	Pejabat JPS Negeri Pahang	Rainfall
3930012	Sg. Lembing P.C.C.L Mill	Rainfall
3930013	Bukit Kenau	Rainfall and Streamflow
3931013	Ladang Nada	Rainfall
3931014	Ladang Kuala Reman	Rainfall
3432001	Sri Damai	Rainfall
-	Jabatan Meterologi Kuantan	Rainfall

Source: DID (2015)

3.4 HEC-HMS Modeling Application

The rainfall data and daily streamflow will computed using HEC-HMS 3.5 model and the prepared data maps will be used in the model. After the volumes precipitation and stream flow data screening process done to select the appropriate data for certain date and time, the catchment area for selected sub-basins need to be measured in order to determine the actual size of sub-basins areas by using topographic maps of Kuantan river basin. There are steps taken in implementing simulation modeling for Kuantan River case study.

i. Basin Modeling

It is created in the form of a background map file imported to HEC-HMS from the data derived through HEC-GeoHMS for model simulation. Actually, it is an interface that shows the actual condition that created with significant components of hydrology that represents the actual watershed area on earth.

ii. Meteorologic Modeling

The actual precipitation and discharge data were used to create meteorological model by inserting the description of the selected watershed such as precipitation method to be used, basin model that involved in this study, evapotranspiration methods if there is condition that mentioned is happened in watershed.

iii. Control Specifications

Information that related to the case study data such as to determine the time patern for the simulation which is start date, start time, end date, end time and computation time step. The data are need to be inserted into the specifications to ensure the time taken for the study area is gauged.

iv. Time Series Data

Hydrologic often require time-series precipitation data for estimating basin average rainfall. A time series of flow data, often called observed flow or observed discharge which helpful in calibrating a model and required for optimization. Time Series Data are store in project as a gage. The program separates different types of data with different gage types. Gage data only has to be entered one time. The gages are part of the project and can be shared by multiple basin or meteorological models.

3.5 MODEL SIMULATION

Simulation of hydrograph is produced after the simulation run button in HEC-HMS version 3.5 is pressed. The simulation hydrograph is appeared in two types of graph which are observed hydrograph and simulated hydrograph. Observed hydrograph is generated by the actual data of rainfall and discharged that have been inserted. Otherwise, simulated hydrograph is created after base flow, transform and losses parameter values are inserted for the area of study.

i. Model Calibration

Calibration is the process to reduce the difference between observed hydrograph and simulated hydrograph. The parameters will adjusted until the observed and simulated hydrograph are almost fitted well. The parameters depends on the transform method that have been selected. For this study, Snyder UH and Clark UH transform method will be used in order to determine the appropriate parameter.

ii. Model Validation

Validation is the process that carried out the test for robustness of the calibrated model. In order to validated, statistical tests of error function should be carried on. Each calibrated model should be validated before it is recommended for use. The model parameter obtained will used to validated by using different sets of events. The simulation hydrograph is compared with the observed hydrograph. If the results for values of error functions is small, the model is validated.

3.6 SUB-BASIN MODELING METHOD

Sub-basin represents the whole characteristics of studied watershed. It is involving the level of processes which are losses, transforms and base flow. Losses process can be determined as a summary for water infiltration process into ground. Infiltration occurs by precipitation that falls into pervious surface of earth such as loose sand. Transform process can be summarized as runoff surface process by exceeding precipitation that cannot be infiltration by impervious surfaces such as concrete and road pavement. Baseflow process covers the infiltration of runoff as groundwater and its movement below the ground surface. But all these processes can be concluded into three main processes to ease the modeling analysis.

3.6.1 Losses Parameter

Losses can defined as the amount of precipitation that loss from its watershed. Runoff that supposed to be in its area of watershed, were infiltrated into ground and this process is called losses. For this program there are seven methods for losses which is Initial and Constant, SCS Curve Number, Gridded SCS CN, Green and Ampt, Deficit and Constant, Gridded Soil Moisture Accounting (SMA) and Soil Moisture Accounting. In this study case, will be focused on SCS Curve Number method for losses rate.

3.6.1.1 SCS CN

The SCS CN method is implements the curve number methodology for incremental losses. The methodology was intended to calculate total infiltration during a storm by computes incremental precipitation in recalculating the infiltration volume at the end of each time interval. This method requires percentage imperviousness land use pattern of the catchment and sub-catchments, total length of the stream and elevation of the catchment area. Percentage imperviousness represents the fraction of that area that is impervious such as buildings, roads, pavements.

Weighted curve number will calculated and used in the calibration model. The curve number will taken from standard curve number tables and the curve number value range is from 30 to 100. If the value of curve number is 30 it represent that the land is very permeable. Instead of that, if the value of curve number is 100 it represent that the surface of land is impervious cover. Figure 3.3 shows the SCS Curve Number editor in HEC-HMS.

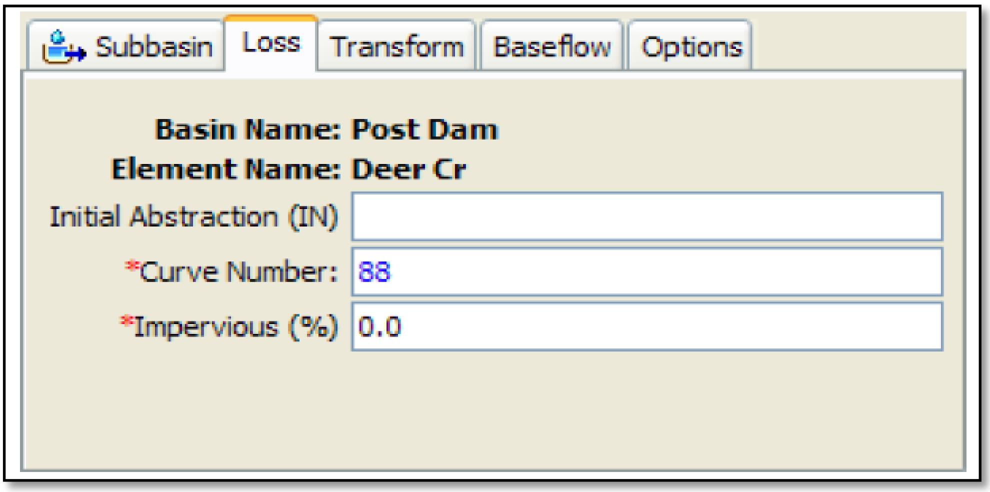


Figure 3.3: SCS Curve Number editor

Source: User Manual HEC-HMS 3.5

3.6.2 Transform Parameter

A sub-basin elements represents infiltration, surface runoff and subsurface process that interact together with the actual surface runoff. The surface runoff can be generated by using calculation in transform method. In this study case, Clark UH and Snyder UH have been selected to be used in order to calibrate the model.

3.6.2.1 Clark UH

A watershed is modeled as a linear channel in series with a linear reservoir to account for translation and attenuation as it flows across the catchment to the outlet. In term of translation, it is based on the synthetic time-area and the time concentration. Time of concentration (Tc) which can be measured in a gages basin as the time from the end of a burst of rainfall to its inflection point on the receding limb, normally measured in hours. Storage coefficient (R), usually expressed in hours and can be estimated by taking the flow at the inflection point of the receding limb of the hydrograph and dividing it by the slope of the recession at the same flow. Figure 3.4 shows the Clark UH editor in HEC-HMS.

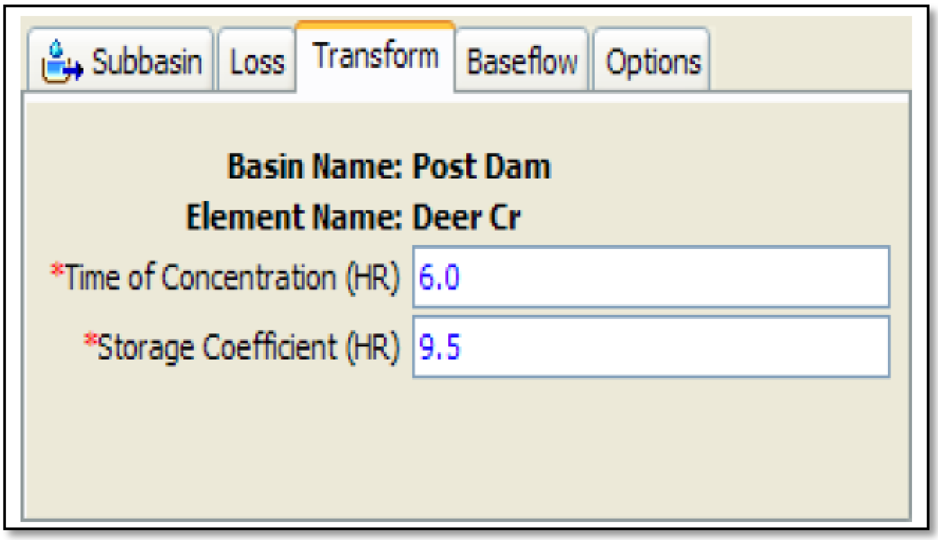


Figure 3.4: Clark UH editor

Source: User Manual HEC-HMS 3.5

In order to determine the value of parameter for this method which is time concentration and storage coefficient, the equation by Hydrological Procedure No.27 (JPS, 2010) will be used for estimation of design using Clark UH method and have shown below.

$$T_c = 2.32A^{-0.1188}L^{0.9573}S^{-0.5074} \tag{3.1}$$

$$R = 2.976A^{-0.1943}L^{0.9995}S^{-0.4588} \tag{3.2}$$

Where :

T_c = Time concentration (hr)
A = Area of catchment (km)
L = Main stream length (km)
S = Weighted slope of main stream (m/km)
R = Storage coefficient (hr)

3.6.2.2 Snyder UH

Snyder was the first to develop a synthetic UH based on a study of watershed in the Appalachian Highlands (Badient, 2008). It is a relationship for estimating Unit Hydrograph parameters from watershed characteristics. Figure 3.5 shows the Snyder UH editor in HEC-HMS.

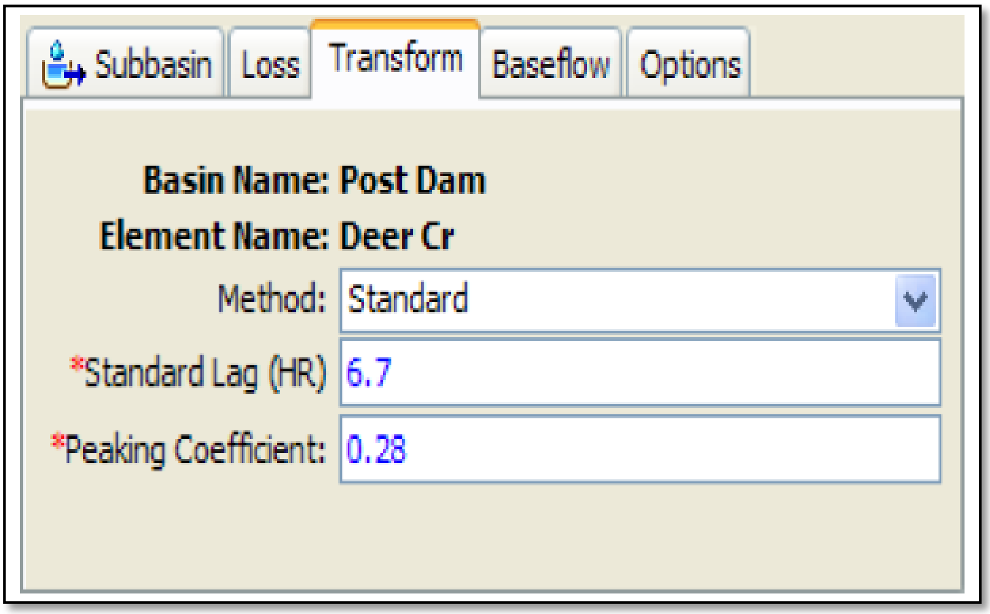


Figure 3.5: Snyder UH Editor

Source: User Manual HEC-HMS 3.5

In this method, there are two parameters which is lag time and peak flow. Lag time is defined as the time of the peak. Snyder use the following relationship to compute the lag time:

$$tp = Ct(LLc)^{0.3} \quad (3.3)$$

Where :

tp = Basin lag in (hr)

L = Length of the main stream from basin outlet to upstream watershed boundary (km)

Lc = Length along the main stream from outlet to a point nearest the watershed centroid (km),

Ct = Basin Coefficient usually ranging from 0.2 to 2.2

$$Cp = \frac{Qptp}{2.78A} \quad (3.4)$$

Where :

Qp = Peak discharge of unit hydrpgraph (m^3/s)

A = Catchment area in (km^2)

Cp = Peak flow coefficient ranging from 0.3 to 0.93 where larger values of are associated with smaller values of Ct

CHAPTER 4

DISCUSSION AND ANALYSIS

4.1 INTRODUCTION

In this chapter, the data collected were analyzed in order to study the rainfall runoff relationship for Bukit Kenau Station in Kuantan River Basin and to compare the rainfall runoff relationship using Clark UH and Snyder UH method. Also, to verify the Clark UH parameters from Hydrologic Procedure No. 27 for Bukit Kenau Station in Kuantan River Basin. Among the rainfall data collection from July 2002 until December 2014, there were six events of rainfall that have been selected.

The data was then been analyzed with HEC-HMS by using Clark UH and Snyder UH method. In case of study, parameter methods used for modeling and analysis was SCS Curve Number for losses, Clark UH and Snyder UH for transform, and Constant Monthly for base flow. These methods are selected for reason of large size of watershed area since the catchment area for Kuantan River Basin is 582 km^2, this method is reasonable. All methods selected are also common and well known in studying rainfall runoff relationship.

4.2 BASIN MODEL CONSTRUCTION

Model of basin is the first step taken in visualizing the actual of catchment area, after rainfall and discharge data are taken from Department of Irrigation and Drainage. The data are used for observed data in HEC-HMS version 3.5 model simulation software for the analysis sub-basin.

In this study, sub-basin and outlet model has been constructed and shown in Figure 4.1. Sub-basin with area of watershed 582 km^2 and length 32 km. The model is designed according to the manual catchment calculations obtained from topographic maps.

4.3 RAINFALL-RUNOFF RELATIONSHIP ANALYSIS

Runoff was generated by rainstorm and occur depends on the characteristics of rainfall event. In this analysis, six events of rainfall were selected to analyze the rainfall runoff relationship. All the data of events was taken 15 minutes. Table 4.1 shows the maximum flowrate and rainfall depth for all events that were selected. For this study, 15 minutes interval of events were used for calibrated and validated model.

Table 4.1: Events data for analysis

Date	Time Duration	Observed Peak Flow (m^3/s)	Rainfall Depth (mm)
04/09/2010-06/09/2010	06:45 pm - 2.30 pm	60.6	20.8
19/03/2011-20/03/2011	5:15 pm - 11:45 am	64.9	14
20/03/2011-21/03/2011	7:00 pm - 9:30 am	82.1	9.5
12/11/2011-13/11/2011	1:15 pm - 03:00 pm	93.1	28.3
13/11/2011-14/11/2011	3:15 pm - 3:30 pm	60	10.9
12/10/2013-13/10/2013	7:30 pm - 9:15 am	99.8	35.5

On 04th September 2010, the rainfall event start from 06:45 pm until 06 September 2010 at 2.30 pm with total precipitation 20.8 mm. For this event the maximum flow rate is 60.6 m³/s. Hydrograph for this event was shown in Figure 4.1.

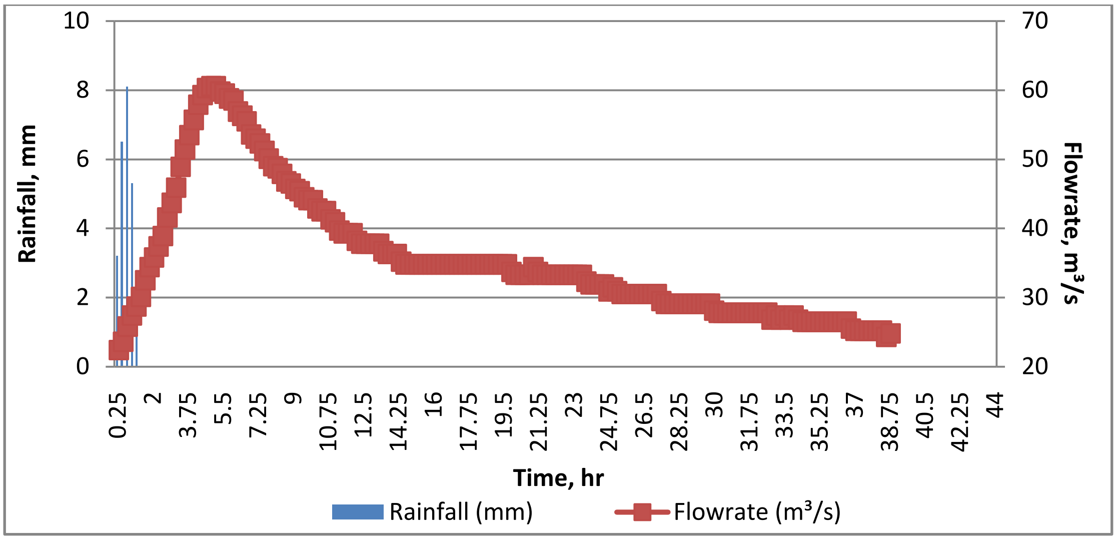


Figure 4.1: Unit Hydrograph on 04th September 2010

On 19th March 2011, the rainfall event start from 05:15 pm until 20th March 2011 at 11.45 am with total precipitation 14 mm. For this event the maximum flowrate is 64.9 m³/s. Hydrograph for this event was shown in Figure 4.2.

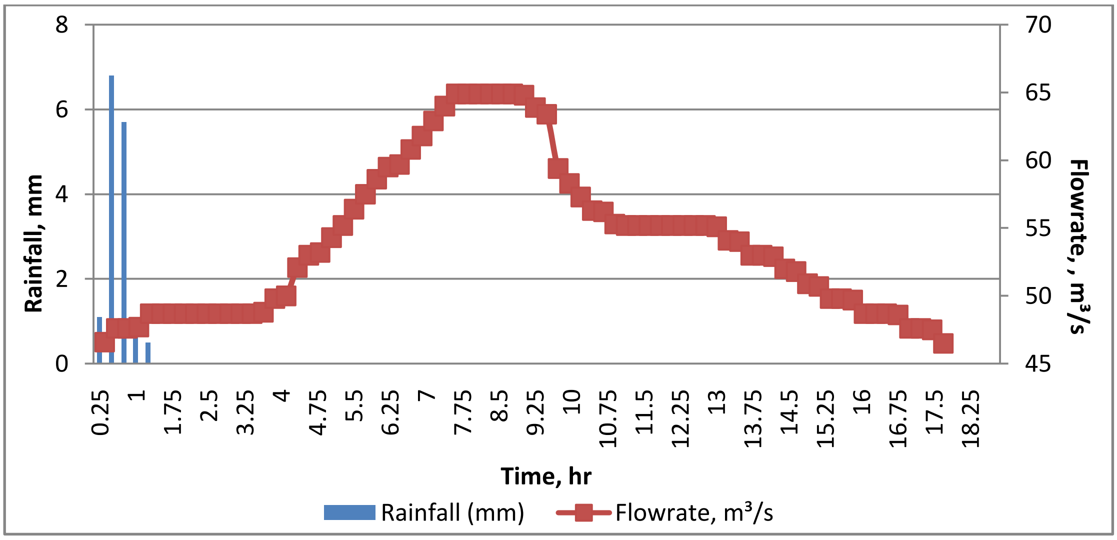


Figure 4.2: Unit Hydrograph on 19th March 2011

On 20th March 2011, the rainfall event start from 07:00 pm until 21th March 2011 at 9.30 am with total precipitation 9.5 mm. For this event the maximum flowrate is 82.1 m³/s. Hydrograph for this event was shown in Figure 4.3.

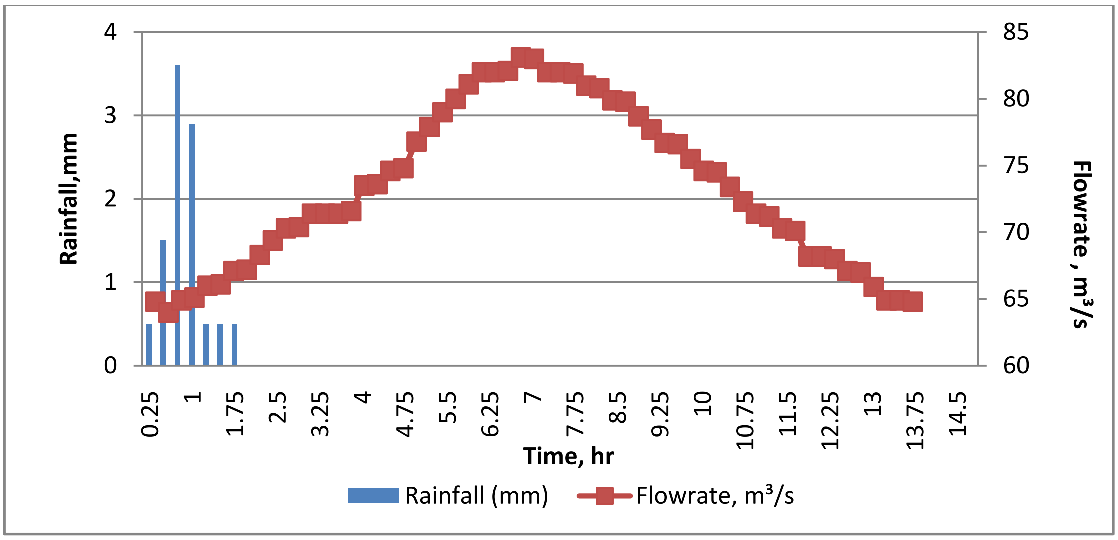


Figure 4.3: Unit Hydrograph on 20th March 2011

On 12th November 2011, the rainfall event start from 01:15 pm until 13th November 2011 at 3.00 pm with total precipitation 28.3 mm. For this event the maximum flowrate is 93.1 m³/s. Hydrograph for this event was shown in Figure 4.4.

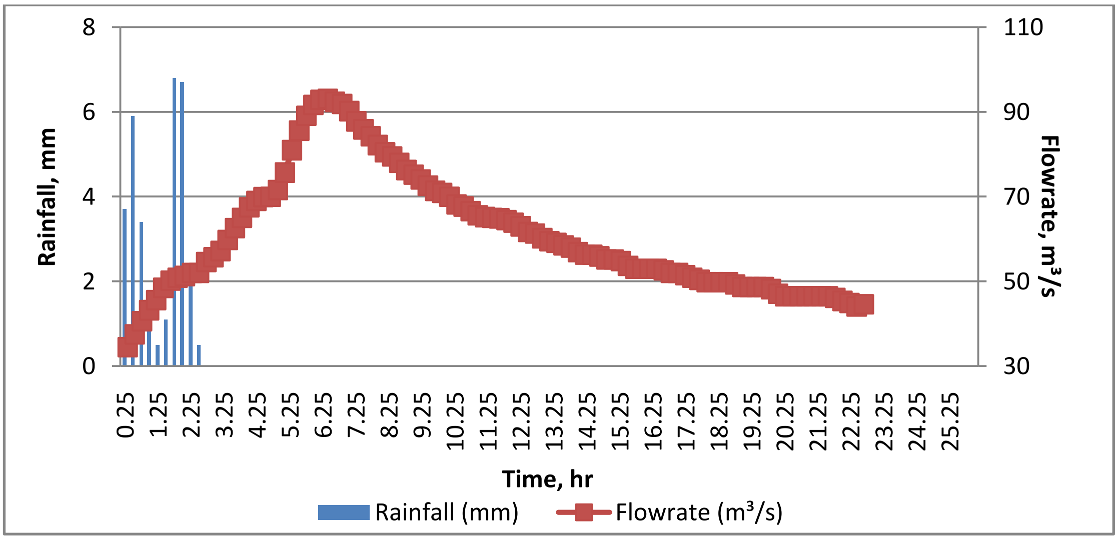


Figure 4.4: Unit Hydrograph on 12th November 2011

On 13th November 2011, the rainfall event start from 3:15 pm until 14th November 2011 at 3.30 am with total precipitation 10.9 mm. For this event the maximum flowrate is 60 m³/s. Hydrograph for this event was shown in Figure 4.5.

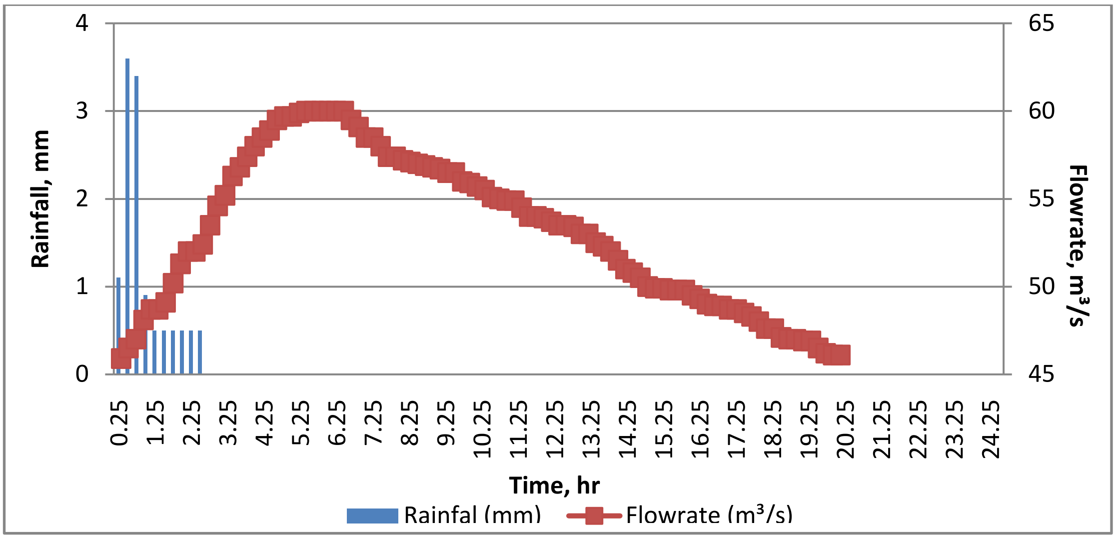


Figure 4.5: Unit Hydrograph on 13th November 2011

On 12 October 2013, the rainfall event start from 07:30 pm until 13 October 2013 at 9.15 am with total precipitation 35.5 mm. For this event the maximum flowrate is 99.8 m³/s. Hydrograph for this event was shown in Figure 4.6.

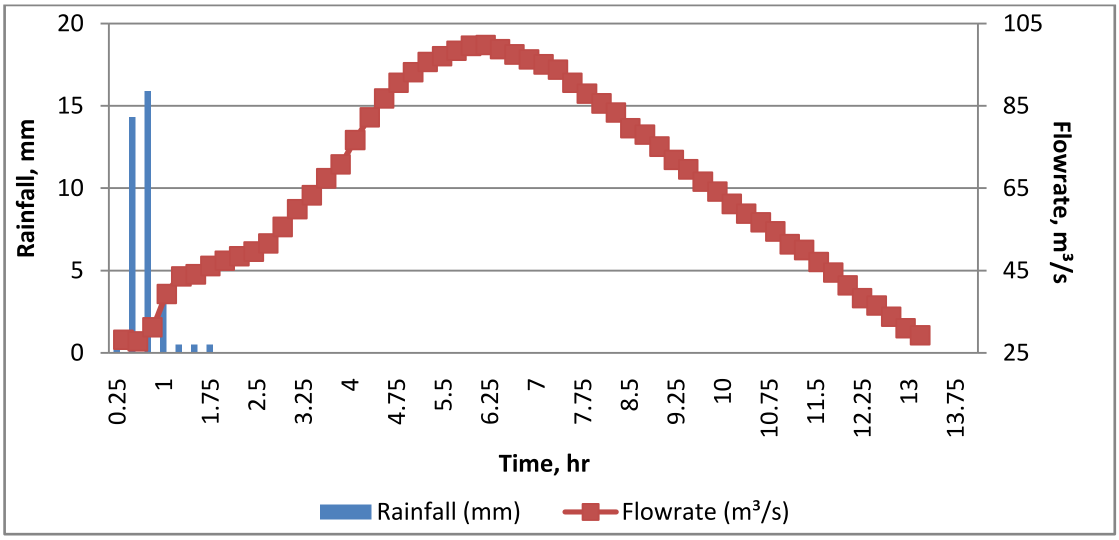


Figure 4.6: Unit Hydrograph on 12October 2013

4.4 ANALYSIS AND SIMULATION

This process was carried out according to the parameter and data was computed in the HEC-HMS. In this analysis, different parameter were used based on the method selected. The graphical result and summary can be obtained after analyzed and simulated the data. The simulation hydrograph was appeared in two types of graph which were observed hydrograph and simulated hydrograph. Observed hydrograph was generated by the actual data of rainfall and discharged that have been inserted. Otherwise, simulated hydrograph was created after base flow, transform and losses parameter values were inserted for the area of study.

4.4.1 Model Parameters

In this study analysis, different parameters were required in order to compute in HEC-HMS program. This is due to the two methods were used in this analysis which is Clark UH and Snyder UH method.

4.4.1.1 Loss Rate

Initial loss is the value to account for interception and depression storage. For this study, SCS CN method was used and required two parameters which is curve number and percentage of imperviousness. The curve number value is from 30 until 100 which based on the type of soil of study area. For this area study, the value of curve number and percentage of impervious were used for all events based on study case by Mamat (2015) was shown in Table 4.2.

Table 4.2: Loss rate parameter

Curve Number	72
Imperviousness (%)	10

4.4.1.2 Transform

There are two parameters were used for each transform method. For Clark UH required time concentration and storage coefficient while in Snyder UH required time peak and peak coefficient in order to compute in HEC-HMS. The values of parameters were used based on Hydrologic Procedure 27 for Clark UH was shown in Table 4.3. Instead of that, Table 4.4 and Table 4.5 shows the parameters that have been used for this study area which based on season either dry season or wet season.

Table 4.3: HP No. 27 Transform parameter for Clark

Time of Concentration (hr)	8.6
Storage of Coefficient (hr)	5.9

Table 4.4: Transform parameter for Clark

Months	Time of Concentration (hr)	Storage of Coefficient (hr)
Dry season (March)	8.5	6
Wet Season (September, October, November)	6	5.5

Table 4.5: Transform Parameter for Snyder

Months	Time of Peak (hr)	Peak Coefficient
Dry season (March)	7.5	0.7
Wet Season (September, October, November)	5.5	0.5

4.5 CALIBRATION

Calibration process where the model was calibrated for identified parameters to achieve fit between simulated hydrograph and observed hydrograph by adjusting parameters value required. The value of transform parameters were depends on month of rainfall whether it is dry season or wet season.

4.5.1 Clark UH

The rainfall event start on 04 September 2010 from 06:45 pm until 06 September 2010 at 2.30 pm with total precipitation 20.8 mm. From the computed result event on 04 September 2010 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.7. The peak discharge for simulated hydrograph was 59.9 m³/s and 60.6 m³/s from the observed hydrograph was shown in Figure 4.8.

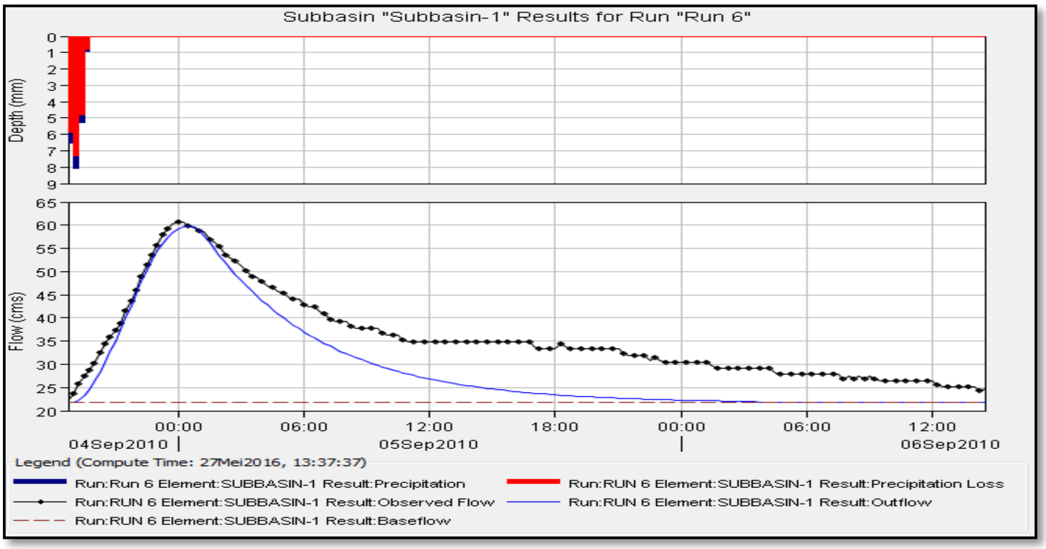


Figure 4.7: Calibration hydrograph on 04 September 2010 using wet parameter for Clark

Project: 04092010
Simulation Run: Run 6 Subbasin: Subbasin-1

Start of Run:	04Sep2010, 18:45	Basin Model:	Basin 1
End of Run:	06Sep2010, 14:30	Meteorologic Model:	Met 1
Compute Time:	27Mei2016, 13:37:37	Control Specifications:	Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	59.9 (M3/S)	Date/Time of Peak Discharge :	05Sep2010, 00:30
Total Precipitation :	20.80 (MM)	Total Direct Runoff :	2.09 (MM)
Total Loss :	18.71 (MM)	Total Baseflow :	5.87 (MM)
Total Excess :	2.09 (MM)	Discharge :	7.96 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	60.60 (M3/S)	Date/Time of Peak Discharge :	05Sep2010, 00:00
Avg Abs Residual :	6.16 (M3/S)		
Total Residual :	-1.67 (MM)	Total Obs Q :	9.64 (MM)

Figure 4.8: Calibration result summary on 04 September 2010 using wet parameter for Clark

The rainfall event start on 19 March 2011 from 05:15 pm until 20 March 2011 at 11.45 am with total precipitation 14 mm. From the computed result event on 19 March 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.9. The peak discharge is 67 m³/s from simulated hydrograph and 64.9 m³/s from the observed hydrograph was shown in Figure 4.10.

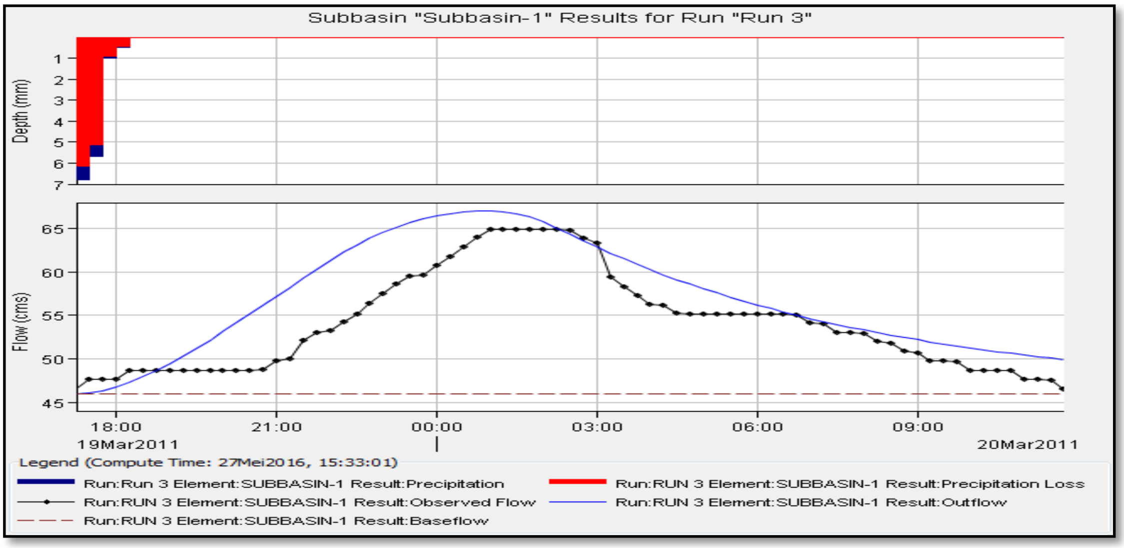
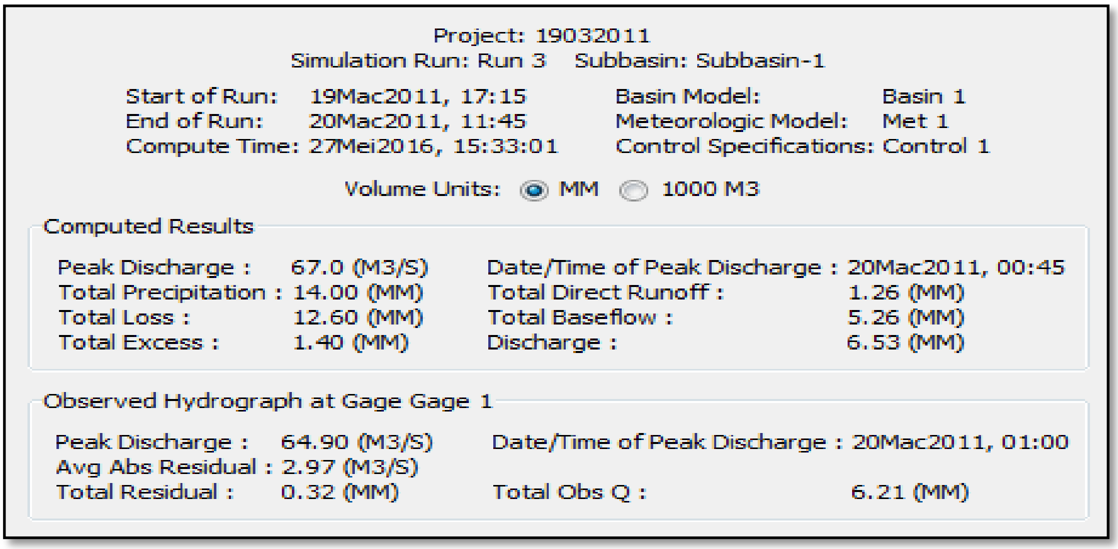


Figure 4.9: Calibration hydrograph on 19 March 2011 using dry parameter for Clark



Project: 19032011
Simulation Run: Run 3 Subbasin: Subbasin-1

Start of Run:	19Mac2011, 17:15	Basin Model:	Basin 1
End of Run:	20Mac2011, 11:45	Meteorologic Model:	Met 1
Compute Time:	27Mei2016, 15:33:01	Control Specifications:	Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	67.0 (M3/S)	Date/Time of Peak Discharge :	20Mac2011, 00:45
Total Precipitation :	14.00 (MM)	Total Direct Runoff :	1.26 (MM)
Total Loss :	12.60 (MM)	Total Baseflow :	5.26 (MM)
Total Excess :	1.40 (MM)	Discharge :	6.53 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	64.90 (M3/S)	Date/Time of Peak Discharge :	20Mac2011, 01:00
Avg Abs Residual :	2.97 (M3/S)		
Total Residual :	0.32 (MM)	Total Obs Q :	6.21 (MM)

Figure 4.10: Calibration result summary on 19 March 2011 using dry parameter for Clark

4.5.2 Snyder UH

The rainfall event start on 04 September 2010 from 06:45 pm until 06 September 2010 at 2.30 pm with total precipitation 20.8 mm. From the computed result event on 04 September 2010 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.11. The peak discharge is 52.8 m³/s from simulated hydrograph and 60.6 m³/s from the observed hydrograph was shown in Figure 4.12.

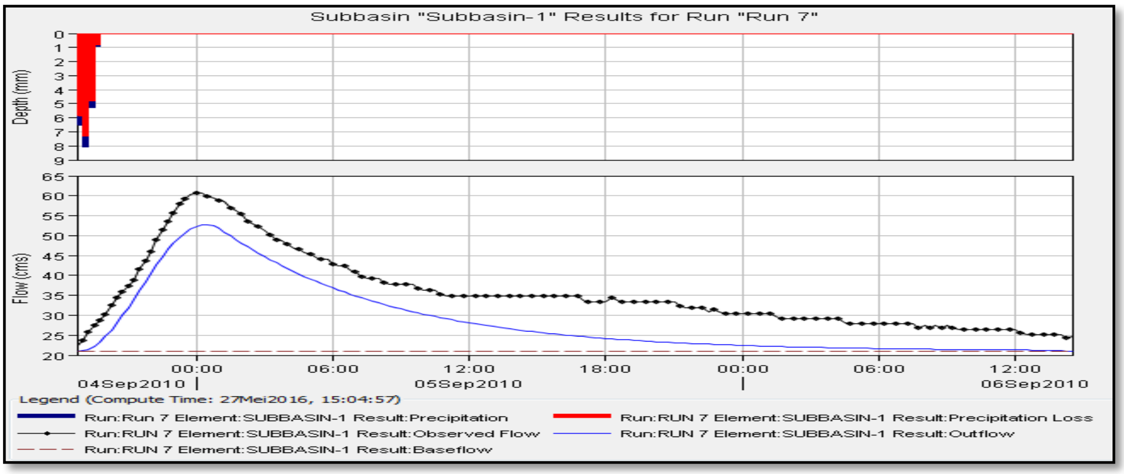
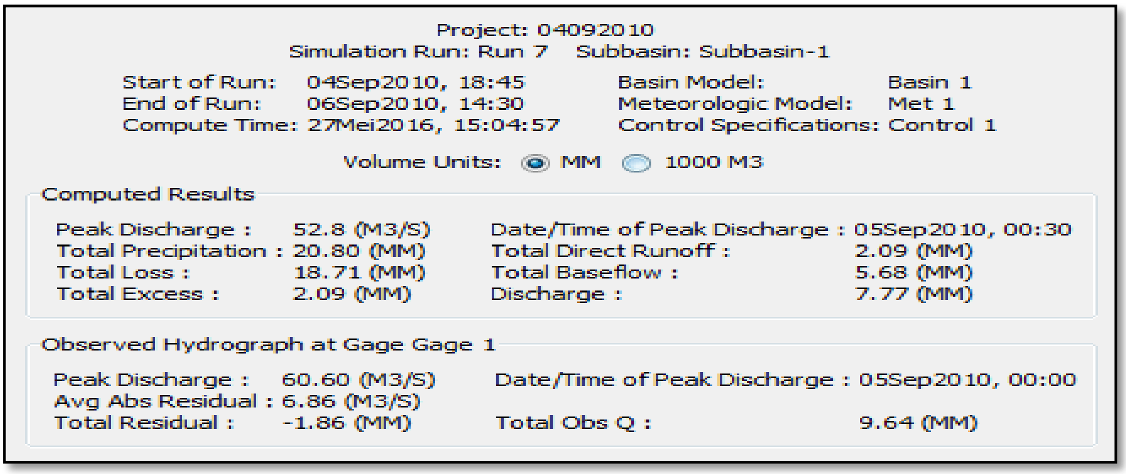


Figure 4.11: Calibration hydrograph on 04 September 2010 using wet parameter for Snyder


Project: 04092010
Simulation Run: Run 7 Subbasin: Subbasin-1

Start of Run: 04Sep2010, 18:45 Basin Model: Basin 1
End of Run: 06Sep2010, 14:30 Meteorologic Model: Met 1
Compute Time: 27Mei2016, 15:04:57 Control Specifications: Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	52.8 (M3/S)	Date/Time of Peak Discharge :	05Sep2010, 00:30
Total Precipitation :	20.80 (MM)	Total Direct Runoff :	2.09 (MM)
Total Loss :	18.71 (MM)	Total Baseflow :	5.68 (MM)
Total Excess :	2.09 (MM)	Discharge :	7.77 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	60.60 (M3/S)	Date/Time of Peak Discharge :	05Sep2010, 00:00
Avg Abs Residual :	6.86 (M3/S)		
Total Residual :	-1.86 (MM)	Total Obs Q :	9.64 (MM)

Figure 4.12: Calibration result summary on 04 September 2010 using wet parameter for Snyder

The rainfall event start on 19 March 2011 from 05:15 pm until 20 March 2011 at 11.45 am with total precipitation 14 mm. From the computed result event on 19 March 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.13. The peak discharge is 67.9 m³/s from the simulated hydrograph and 64.9 m³/s from the observed hydrograph was shown in Figure 4.14.

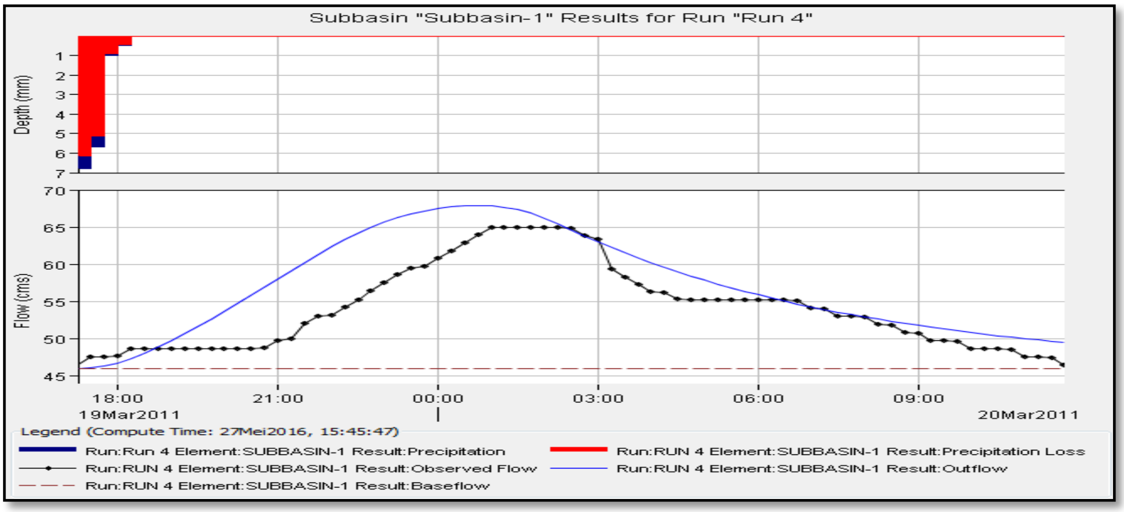
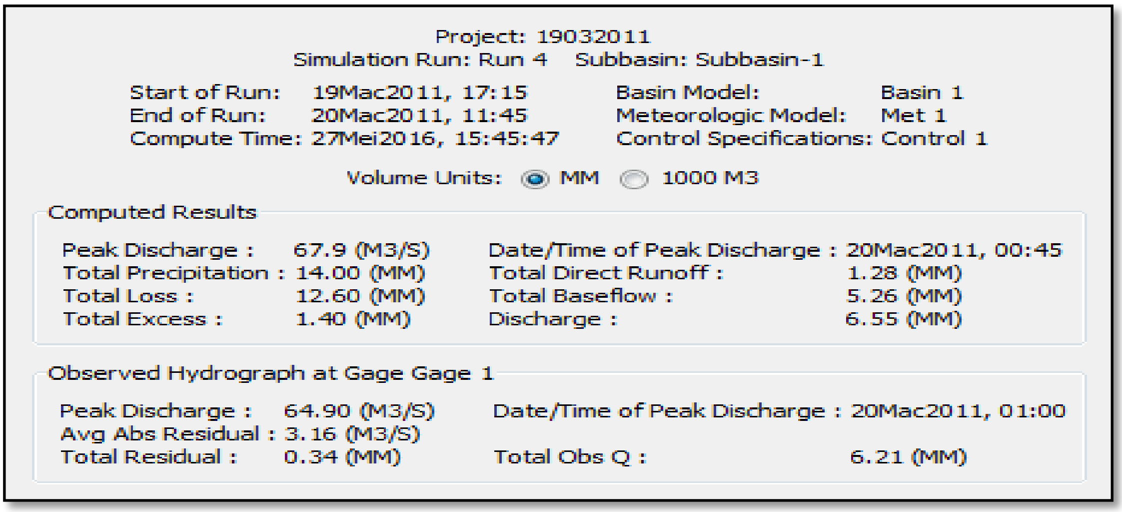


Figure 4.13: Calibration hydrograph on 19 March 2011 using dry parameter for Snyder



Project: 19032011
Simulation Run: Run 4 Subbasin: Subbasin-1

Start of Run:	19Mac2011, 17:15	Basin Model:	Basin 1
End of Run:	20Mac2011, 11:45	Meteorologic Model:	Met 1
Compute Time:	27Mei2016, 15:45:47	Control Specifications:	Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	67.9 (M3/S)	Date/Time of Peak Discharge :	20Mac2011, 00:45
Total Precipitation :	14.00 (MM)	Total Direct Runoff :	1.28 (MM)
Total Loss :	12.60 (MM)	Total Baseflow :	5.26 (MM)
Total Excess :	1.40 (MM)	Discharge :	6.55 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	64.90 (M3/S)	Date/Time of Peak Discharge :	20Mac2011, 01:00
Avg Abs Residual :	3.16 (M3/S)		
Total Residual :	0.34 (MM)	Total Obs Q :	6.21 (MM)

Figure 4.14: Calibration result summary on 19 March 2011 using dry parameter for Snyder

4.6 VALIDATION

Validation is a process where calibrated model parameters for Clark and Snyder were use in others events of rainfall in order to verify that the value parameters that have been used were suitable. Also, tested the calibrated parameters on the events which based on the dry season and wet season. If the results shows that, the observed hydrograph and simulated hydrograph were not fitted well the calibration process should repeated.

4.6.1 Clark UH

The rainfall event start on 12 October 2013 from 07:30 pm until 13 October 2013 at 09.15 am with total precipitation 35.5 mm. From the computed result event on 12 October 2013 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.15 by using wet season parameter . The peak discharge is 127.3 m³/s from the simulated hydrograph and 99.8 m³/s from the observed hydrograph was shown in Figure 4.16.

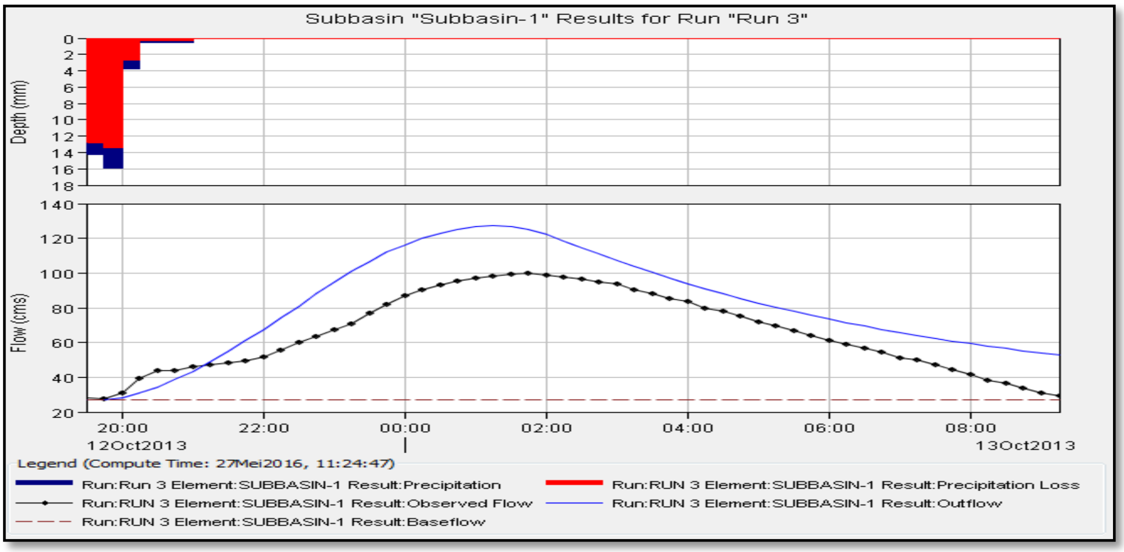


Figure 4.15: Validation hydrograph on 12 October 2013 using wet parameter for Clark

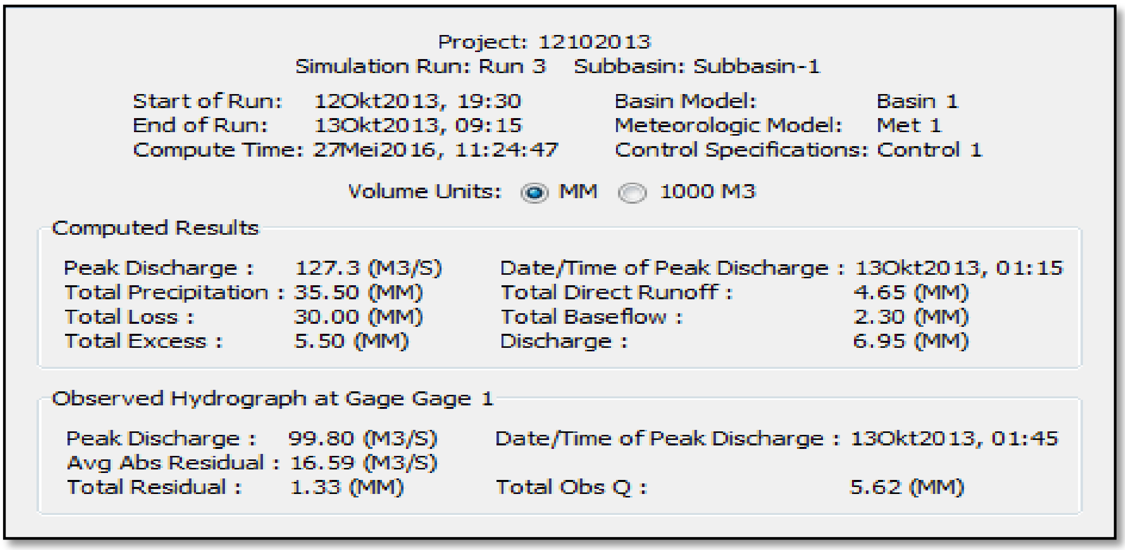


Figure 4.16: Validation result summary 12 October 2013 using wet parameter for Clark

The rainfall event start on 12 November 2011 from 01:15 pm until 13 November 2011 at 03.00 pm with total precipitation 28.3 mm. From the computed result event on 12 November 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.17 by using wet season parameter . The peak discharge is 95.3 m³/s from the simulated hydrograph and 93.1 m³/s from the observed hydrograph was shown in Figure 4.18.

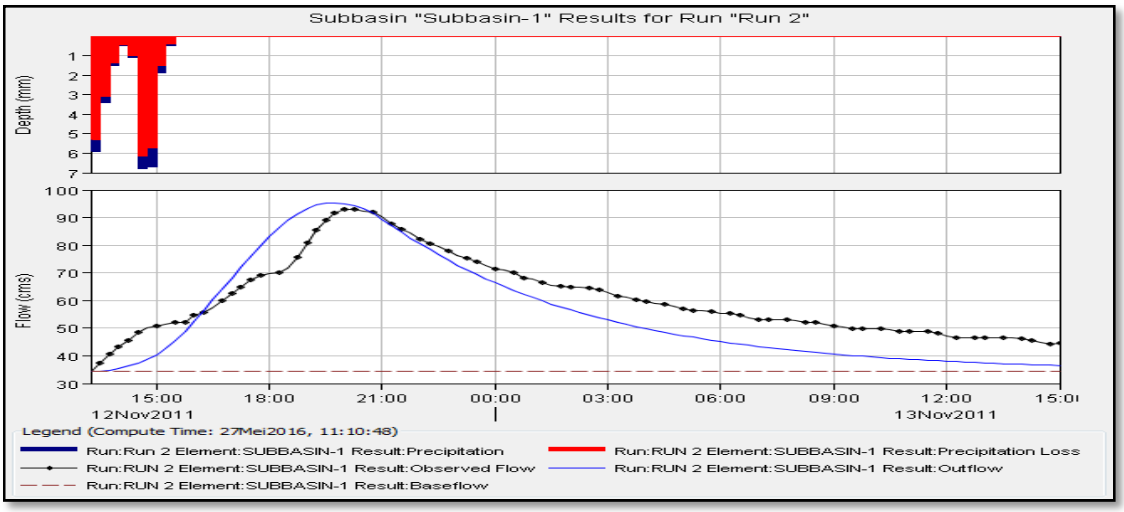


Figure 4.17: Validation hydrograph on 12 November 2011 using wet parameter for Clark

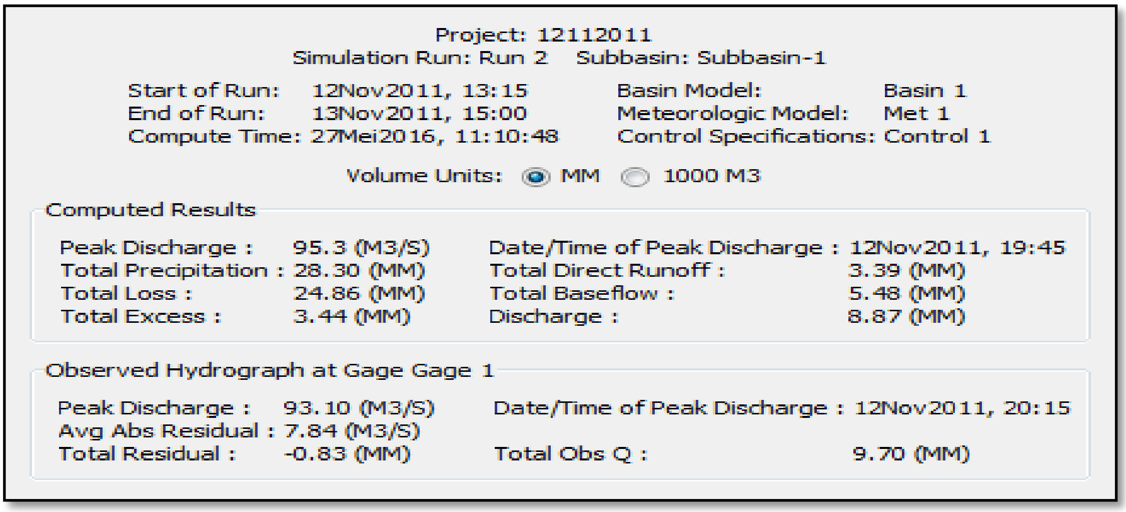


Figure 4.18: Validation result summary 12 November 2011 using wet parameter for Clark

The rainfall event start on 13 November 2011 from 03:15 pm until 14 November 2011 at 03.30 pm with total precipitation 10.9 mm. From the computed result event on 13 November 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.19 by using wet season parameter . The peak discharge is 64.5 m³/s from the simulated hydrograph and 60 m³/s from the observed hydrograph was shown in Figure 4.20.

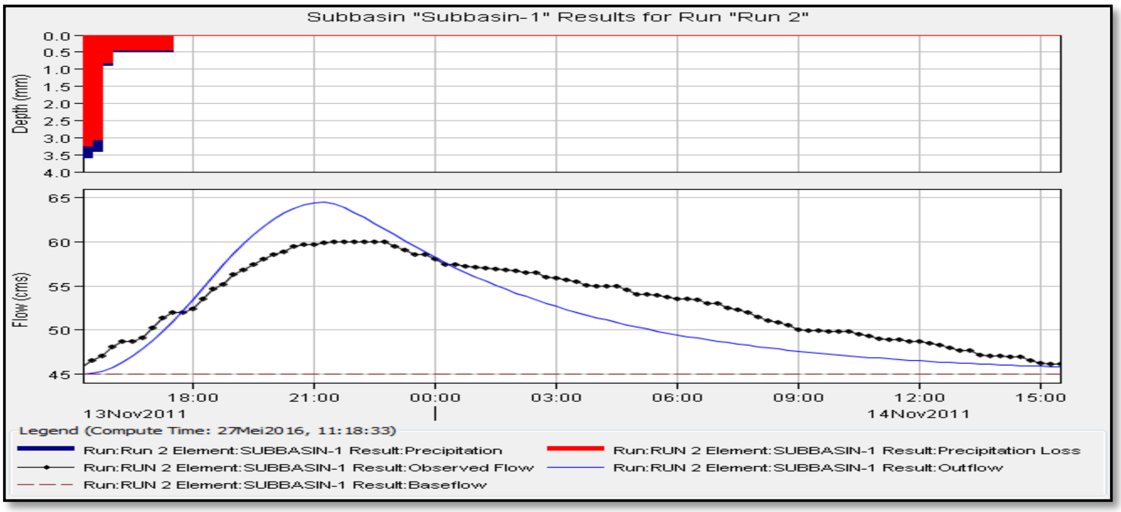


Figure 4.19: Validation hydrograph on 13 November 2011 using wet parameter for Clark

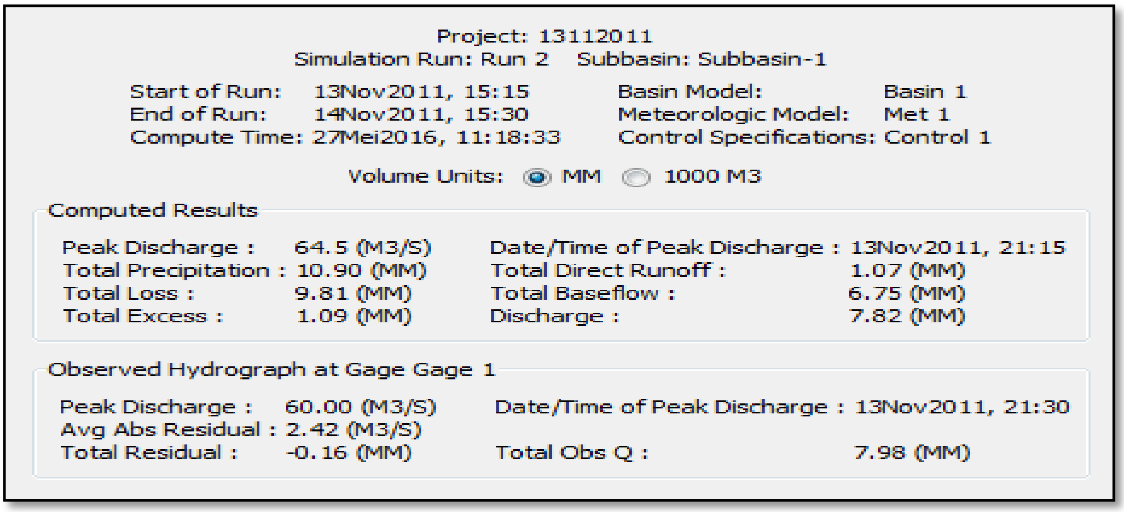


Figure 4.20: Validation result summary 13 November 2011 using wet parameter for Clark

The rainfall event start on 20 March 2011 from 07:00 pm until 21 March 2011 at 09.30 am with total precipitation 9.5 mm. From the computed result event on 20 March 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.21 by using dry season parameter . The peak discharge is 78.7 m³/s from the simulated hydrograph and 82.1 m³/s from the observed hydrograph was shown in Figure 4.22.

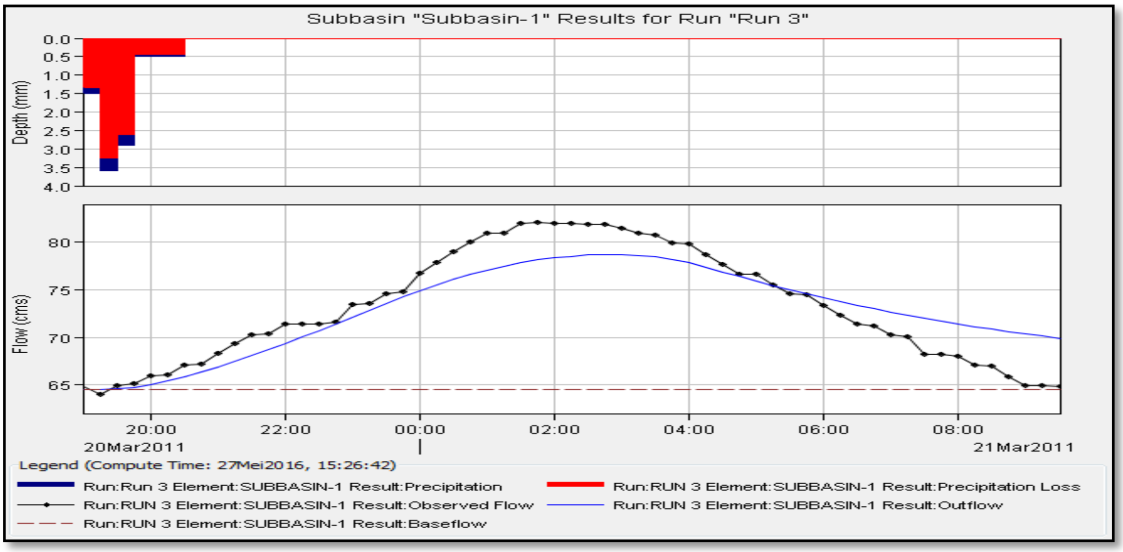
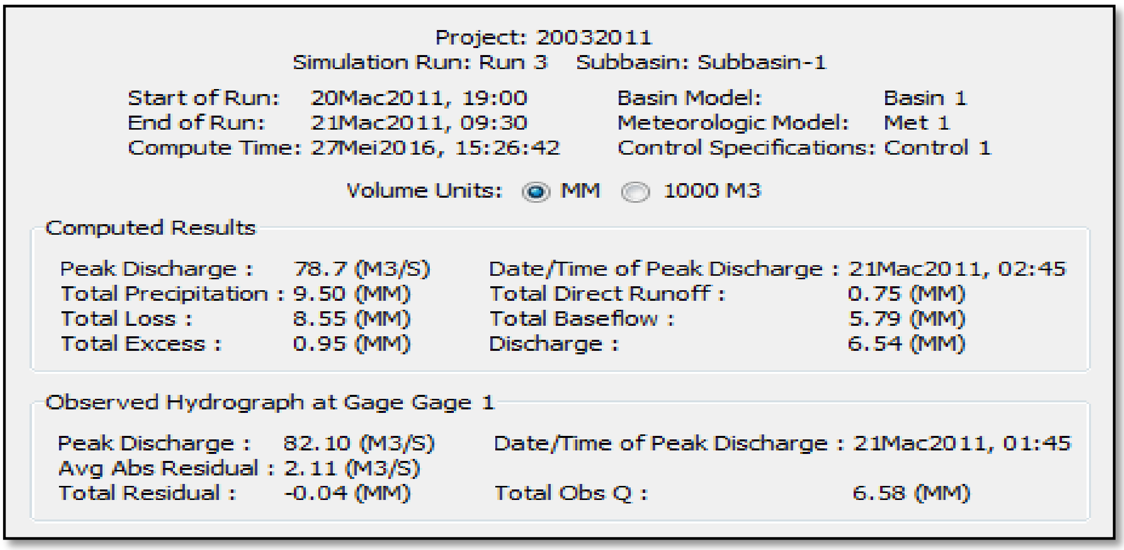


Figure 4.21: Validation hydrograph on 20 March 2011 using dry parameter for Clark


Project: 20032011
Simulation Run: Run 3 Subbasin: Subbasin-1

Start of Run: 20Mac2011, 19:00 Basin Model: Basin 1
End of Run: 21Mac2011, 09:30 Meteorologic Model: Met 1
Compute Time: 27Mei2016, 15:26:42 Control Specifications: Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge : 78.7 (M3/S) Date/Time of Peak Discharge : 21Mac2011, 02:45
Total Precipitation : 9.50 (MM) Total Direct Runoff : 0.75 (MM)
Total Loss : 8.55 (MM) Total Baseflow : 5.79 (MM)
Total Excess : 0.95 (MM) Discharge : 6.54 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge : 82.10 (M3/S) Date/Time of Peak Discharge : 21Mac2011, 01:45
Avg Abs Residual : 2.11 (M3/S)
Total Residual : -0.04 (MM) Total Obs Q : 6.58 (MM)

Figure 4.22: Validation result summary 20 March 2011 using dry parameter for Clark

4.6.2 Snyder UH

The rainfall event start on 12 October 2013 from 07:30 pm until 13 October 2013 at 09.15 am with total precipitation 35 mm. From the computed result event on 12 October 2013 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.23 by using wet season parameter . The peak discharge is 110.5 m³/s from the simulated hydrograph and 99.8 m³/s from the observed hydrograph was shown in Figure 4.24.

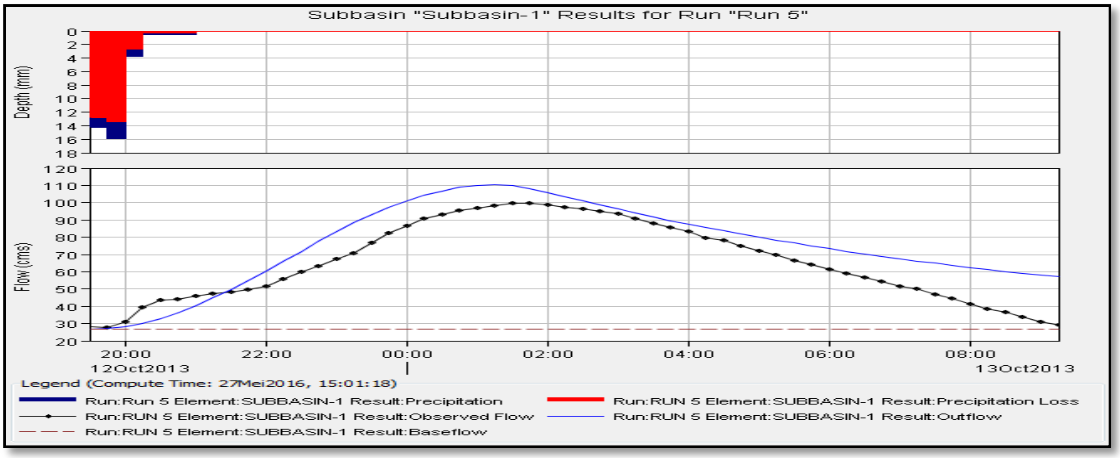


Figure 4.23: Validation hydrograph on 12 October 2013 using wet parameter for Snyder

Project: 12102013
Simulation Run: Run 5   Subbasin: Subbasin-1

Start of Run:	12Okt2013, 19:30	Basin Model:	Basin 1
End of Run:	13Okt2013, 09:15	Meteorologic Model:	Met 1
Compute Time:	27Mei2016, 15:01:18	Control Specifications:	Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	110.5 (M3/S)	Date/Time of Peak Discharge :	13Okt2013, 01:15
Total Precipitation :	35.50 (MM)	Total Direct Runoff :	4.14 (MM)
Total Loss :	30.00 (MM)	Total Baseflow :	2.30 (MM)
Total Excess :	5.50 (MM)	Discharge :	6.43 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	99.80 (M3/S)	Date/Time of Peak Discharge :	13Okt2013, 01:45
Avg Abs Residual :	11.09 (M3/S)		
Total Residual :	0.81 (MM)	Total Obs Q :	5.62 (MM)

Figure 4.24: Validation result summary 12 October 2013 using wet parameter for Snyder

The rainfall event start on 12 November 2011 from 01:15 pm until 13 November 2011 at 03.00 pm with total precipitation 28.3 mm. From the computed result event on 12 November 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.25 by using wet season parameter . The peak discharge is 84.7 m³/s from the simulated hydrograph and 93.1 m³/s from the observed hydrograph was shown in Figure 4.26.

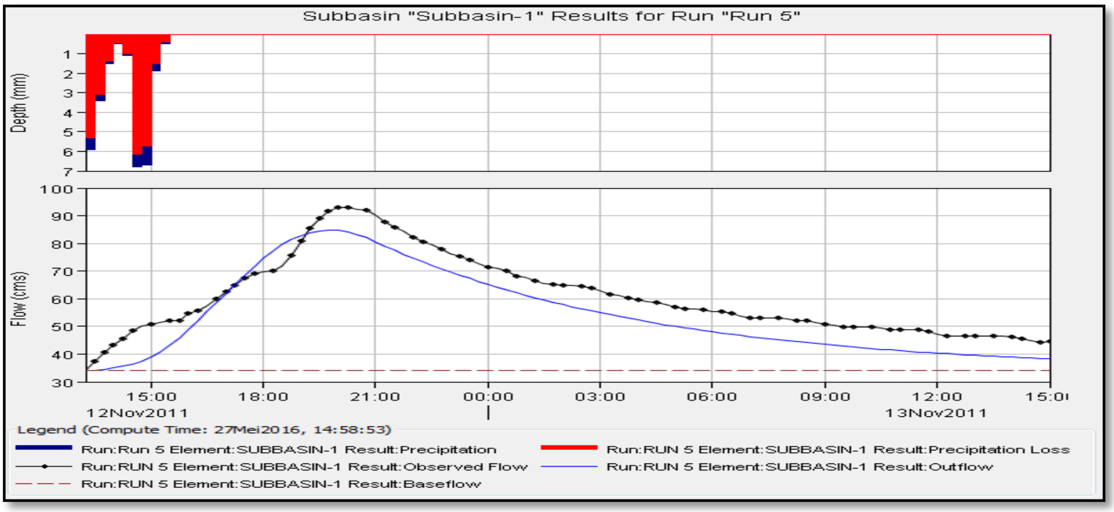


Figure 4.25: Validation hydrograph on 12 November 2011 using wet parameter for Snyder

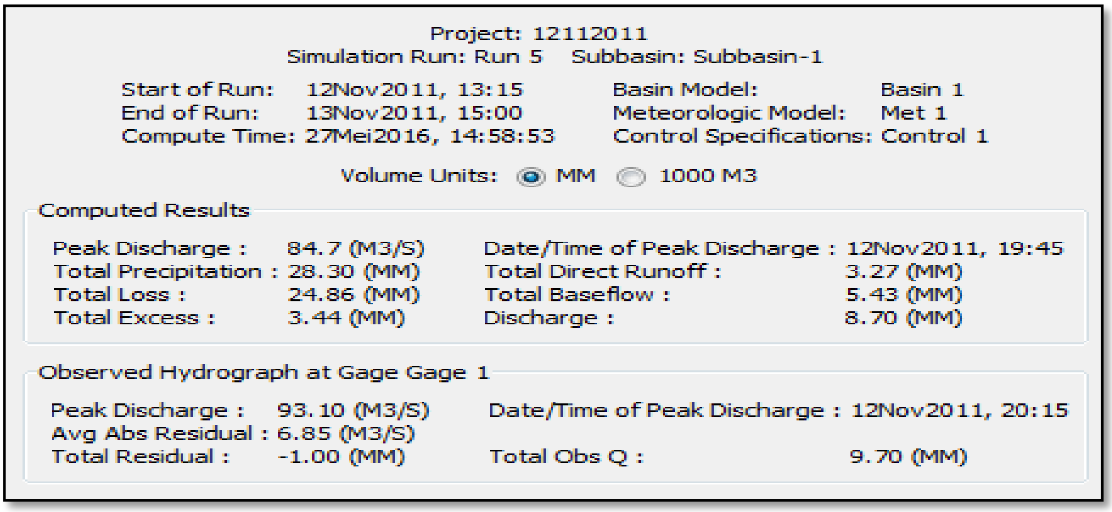


Figure 4.26: Validation result summary 12 November 2011 using wet parameter for Snyder

The rainfall event start on 13 November 2011 from 03:15 pm until 14 November 2011 at 03.30 pm with total precipitation 10.9 mm. From the computed result event on 13 November 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.27 by using wet season parameter . The peak discharge is 62.2 m³/s from the simulated hydrograph and 60 m³/s from the observed hydrograph was shown in Figure 4.28.

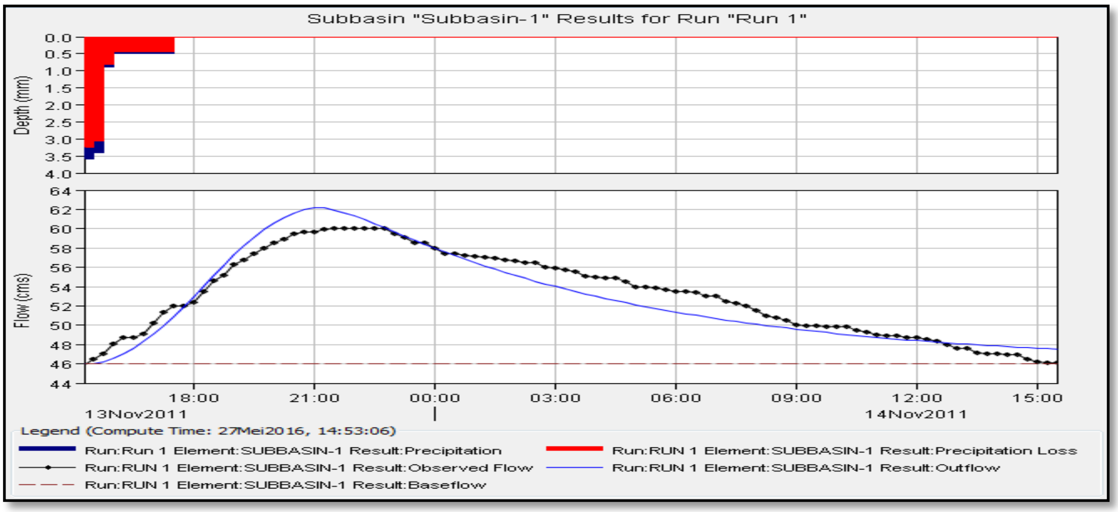
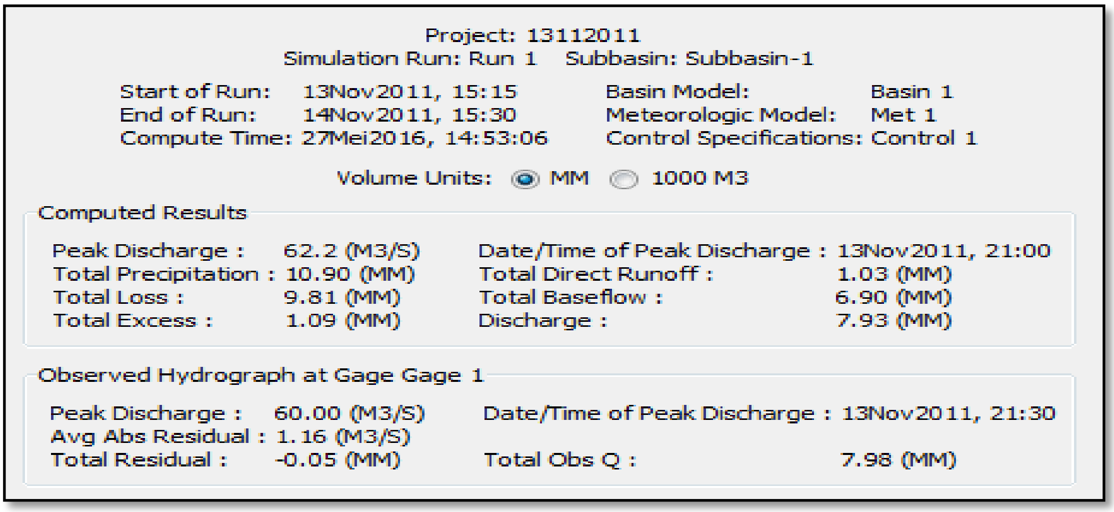


Figure 4.27: Validation hydrograph on 13 November 2011 using wet parameter for Snyder


Project: 13112011
Simulation Run: Run 1 Subbasin: Subbasin-1

Start of Run: 13Nov2011, 15:15 Basin Model: Basin 1
End of Run: 14Nov2011, 15:30 Meteorologic Model: Met 1
Compute Time: 27Mei2016, 14:53:06 Control Specifications: Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	62.2 (M3/S)	Date/Time of Peak Discharge :	13Nov2011, 21:00
Total Precipitation :	10.90 (MM)	Total Direct Runoff :	1.03 (MM)
Total Loss :	9.81 (MM)	Total Baseflow :	6.90 (MM)
Total Excess :	1.09 (MM)	Discharge :	7.93 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	60.00 (M3/S)	Date/Time of Peak Discharge :	13Nov2011, 21:30
Avg Abs Residual :	1.16 (M3/S)		
Total Residual :	-0.05 (MM)	Total Obs Q :	7.98 (MM)

Figure 4.28: Validation result summary 13 November 2011 using wet parameter for Snyder

The rainfall event start on 20 March 2011 from 07:00 pm until 21 March 2011 at 09.30 am with total precipitation 9.5 mm. From the computed result event on 20 March 2011 from HEC-HMS was shown the simulated and observed hydrograph in Figure 4.29 by using dry season parameter . The peak discharge is 78.8 m³/s from the simulated hydrograph and 82.1 m³/s from the observed hydrograph was shown in Figure 4.30.

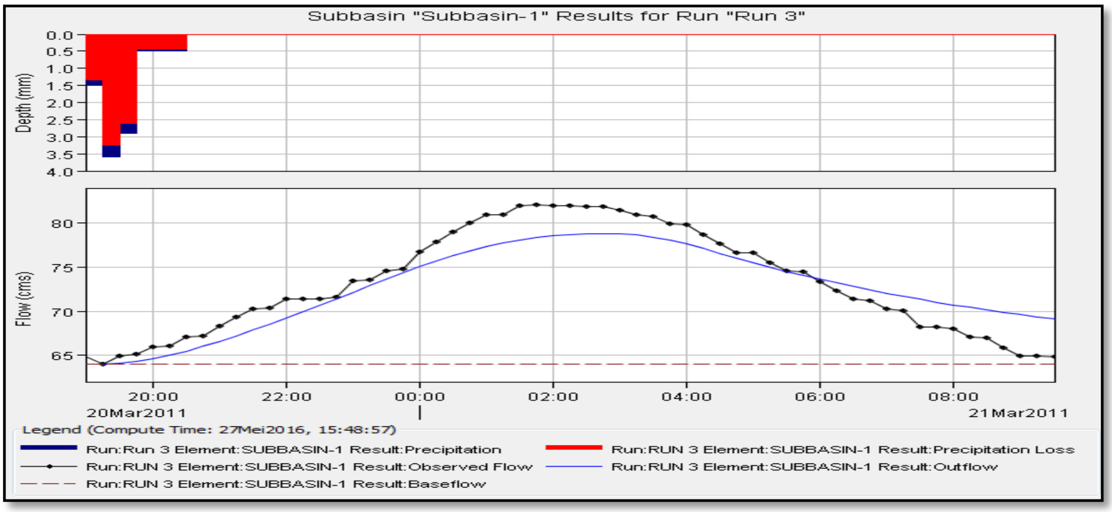


Figure 4.29 Validation hydrograph on 20 March 2011 using dry parameter for Snyder

Project: 20032011
Simulation Run: Run 3 Subbasin: Subbasin-1

Start of Run:	20Mac2011, 19:00	Basin Model:	Basin 1
End of Run:	21Mac2011, 09:30	Meteorologic Model:	Met 1
Compute Time:	27Mei2016, 15:48:57	Control Specifications:	Control 1

Volume Units: MM 1000 M3

Computed Results

Peak Discharge :	78.8 (M3/S)	Date/Time of Peak Discharge :	21Mac2011, 02:45
Total Precipitation :	9.50 (MM)	Total Direct Runoff :	0.78 (MM)
Total Loss :	8.55 (MM)	Total Baseflow :	5.74 (MM)
Total Excess :	0.95 (MM)	Discharge :	6.52 (MM)

Observed Hydrograph at Gage Gage 1

Peak Discharge :	82.10 (M3/S)	Date/Time of Peak Discharge :	21Mac2011, 01:45
Avg Abs Residual :	1.99 (M3/S)		
Total Residual :	-0.06 (MM)	Total Obs Q :	6.58 (MM)

Figure 4.30 Validation result summary 20 March 2011 using dry parameter for Snyder

4.7 RESULT ANALYSIS

From the calibration and validation results, the observed and simulated peak flow have been analyzed. Table 4.6 and Table 4.7 shows comparison between the observed and simulated peak flow for Clark and Snyder method respectively. The percentage difference peak flow was estimated in order to determine the percentage error between the observed and simulated peak flow. The parameter value is good if the percentage difference peak flow equal to 0%.

Table 4.6: Comparison of peak and predicted flows for calibration and validation result for Clark

Events	Observed Peak Flow (m^3/s)	HEC-HMS Peak Flow (m^3/s)	Difference Peak Flow (m^3/s)	Percentage Difference Peak Flow (%)
19/03/2011	64.9	67	2.1	3.24
20/03/2011	82.1	78.7	3.4	4.14
04/09/2010	60.6	59.9	0.7	1.16
12/10/2013	99.8	127.3	27.5	27.56
12/11/2011	93.1	95.3	2.2	2.36
13/11/2011	60	64.5	4.5	7.5

Table 4.7: Comparison of peak and predicted flows for calibration and validation result for Snyder

Events	Observed Peak Flow (m^3/s)	HEC-HMS Peak Flow (m^3/s)	Difference Peak Flow (m^3/s)	Percentage Difference Peak Flow (%)
19/03/2011	64.9	67.9	3	4.62
20/03/2011	82.1	78.8	3.3	4.02
04/09/2010	60.6	52.8	7.8	12.87
12/10/2013	99.8	110.5	10.7	10.72
12/11/2011	93.1	84.7	8.4	9.03
13/11/2011	60	62.2	2.2	3.67

Regarding Hydrology Procedure No. 27 (DID, 2010), it have been stated that the value of Clark parameter for Kuantan River Basin were *Tc=8.6* hours and *R=5.9* hours. These value were tested on the six of selected events for this study in order to verify the parameter value. Table 4.8 shows comparison between the observed peak flow and simulated peak flow for each events using HP No. 27 parameters.

Table 4.8: Comparison of peak and predicted flows result using HP No. 27 parameters

Events	**Observed Peak Flow (m^3/s)**	**HEC-HMS Peak Flow (HP No. 27) (m^3/s)**	**Difference Peak Flow (m^3/s)**	**Percentage Difference Peak Flow (%)**
19/03/2011	64.9	53.2	11.7	18.03
20/03/2011	82.1	109.7	27.6	33.62
04/09/2010	60.6	85.5	24.9	12.87
12/10/2013	99.8	61.2	38.6	41.09
12/11/2011	93.1	67.1	26	27.93
13/11/2011	60	78.8	18.8	31.33

Based on the percentage difference of peak flow using HP No. 27 parameters, the value of percentage for each events were higher than the percentage difference peak flow using Clark parameter. Hence, the HP No. 27 parameters were not suitable to be used in this study area since the rainfall events which used by DID were not the latest data. DID used the events on December 1981, January 1984, February 1996, November 1997 and December 1998 to validate that parameters.

4.8 EFFICIENCY INDEX

The accuracy of results computed by HEC-HMS was determined by using one of the statistics methods which is the Efficiency Index. Efficiency Index can be defined as below:

$$\text{Efficiency Index} = \frac{\text{SSTotal} - \text{SSError}}{\text{SSTotal}} \qquad (4.1)$$

SSTotal, the total sum of squared error is the sum of squared error when predicting using the mean; the sum of the squared products of all the actual values minus the mean. The formula of SSTotal is as follows:

$$\text{SSTotal} = \Sigma\,(Qi-Qag)^2 \qquad (4.2)$$

SSError, the sum of squared error is the sum of squared error when using the prediction model, the sum of squared products of all the actual values minus their predicted values. The formula of SSError is as below:

$$\text{SSError} = \Sigma(Qi-Fi)^2 \qquad (4.3)$$

Where:

Qi = Observed Discharge at Time i
Qag = Mean of Observed Discharge, Qag=$\Sigma Qi/N$
N = Number of Discharge Data
Fi = Simulated Discharge at Time i

4.8.1 Efficiency Index of Calibration Process for Clark

The EI of calibration for Clark method have been calculated for calibrated events which can be refer on appendix D. The same procedure and formula was also used for event 04 September 2010.

Calculation of Efficiency Index for 19th March 2011:

Mean of Observed discharge, Qag = $\Sigma \frac{Qi}{N}$

$$= \frac{4060.7}{75}$$

$$=54.143 m^3/s$$

Efficiency Index = $\frac{SSTotal - SSError}{SSTotal}$

$$= \frac{2390.54 - 1099.3}{2390.54} \times 100\%$$

$$=54.01\%$$

4.8.2 Efficiency Index of Calibration Process for Snyder

The EI of calibration for Snyder method have been calculated for calibrated events which can be refer on appendix E. The same procedure and formula was also used for event 04 September 2010.

Calculation of Efficiency Index for 19th March 2011:

Mean of Observed discharge, Qag = $\Sigma \frac{Qi}{N}$

$$= \frac{4060.7}{75}$$

$$=54.143 m^3/s$$

Efficiency Index = $\frac{\text{SSTotal} - \text{SSError}}{\text{SSTotal}}$

$= \frac{2390.54-1353.3}{2390.54}$ x 100%

=43.39%

4.8.3 Efficiency Index of Validation Process for Clark

The EI of validation process for Clark method for all events can be refer on appendix D. The same procedure and formula were also used on 12th October 2013, 12th November 2011 and 13th November 2011.

Calculation of Efficiency Index for 20th March 2011:

Mean of Observed discharge, Qag = $\Sigma \frac{\text{Qi}}{\text{N}}$

$= \frac{4318.5}{75}$

=73.195m^3/s

Efficiency Index = $\frac{\text{SSTotal} - \text{SSError}}{\text{SSTotal}}$

$= \frac{2036.05-387.58}{2036.05}$ x 100%

=80.96%

4.8.4 Efficiency Index of Validation Process for Snyder

The EI of validation process for Snyder method for validated events can be refer on appendix E. The same procedure and formula were also used on 12th November 2011, 13th November 2011 and 12th October 2013.

Calculation of Efficiency Index for 20th March 2011:

Mean of Observed discharge, Qag = $\Sigma \frac{\mathrm{Qi}}{\mathrm{N}}$

$$= \frac{4318.5}{75}$$

$$=73.195 m^3/s$$

Efficiency Index = $\frac{\mathrm{SSTotal} \ - \mathrm{SSError}}{\mathrm{SSTotal}}$

$$= \frac{2036.05 - 320.81}{2036.05} \text{ x } 100\%$$

$$=84.24\%$$

4.8.5 Summary of Efficiency Index

Summary of Efficiency Index for six rainfall events were shown in Table 4.9 for both Clark UH and Snyder UH method. From the Table 4.9 the average Eficciency Index for Clark and Snyder were 56.56% and 64.43% respectively. By using HEC-HMS analysis for calibration and validation, it shows that the Snyder UH method is the most appropriate method for this study area. This is due to Snyder UH method have highest Efficiency Index which is 64.43% compare to Clark UH method.

Table 4.9: Summary of Efficiency Index for Clark and Snyder method

Events	**Date**	**Method**	
		Clark (%)	**Snyder (%)**
1	04/09/2010	47.07	43.2
2	12/10/2013	33.1	67.63
3	12/11/2011	63.32	58.06
4	13/11/2011	60.91	90.08
5	19/03/2011	54.01	43.39
6	20/03/2011	80.96	84.24
AVERAGE		56.56	64.43

CHAPTER 5

CONCLUSIONS

5.1 INTRODUCTION

The most appropriate method that suitable for Bukit Kenau station in Kuantan River Basin can be determine after simulation and calibration of the rainfall and runoff by using HEC-HMS. The result from Efficiency Index was important to be determined because it can shows that eiher Clark UH or Snyder UH method is the most appropriate method to be used for this study area.

5.2 CONCLUSION

As a conclusion, the three objectives of this study were achieved in order to calibrate and validate the rainfall-runoff transformation model for Bukit Kenau station, to determine and analyze the most suitable coefficients for Clark UH and Snyder UH for Bukit Kenau Station and to investigate the flow simulation from Clark UH parameters in Hydrologic Procedure No. 27 for Bukit Kenau Station in Kuantan River Basin. By using Efficiency Index result, the average value of EI for both method Clark and Snyder were 56.56% and 64.43% respectively. Based on the EI results, it can be conclude that the Snyder UH method is the most appropriate method for Bukit Kenau station in Kuantan River Basin. This is due to Snyder have the higher in average percentage of EI value which is 64.43% compare to Clark UH method is 56.56%.

According to result of percentage difference of peak flow using HP No. 27 parameters, obviously shows that the HP No. 27 parameters were not suitable to be used in this study area since the percentage difference of peak flow was larger. It were found that the maximum percentage difference of peak flow was 41.09%, the minimum percentage difference of peak flow was 12.87% and the average percentage difference of peak flow was 27.48%. Hence, the parameters from calibrated for Clark method were more accurate to be used in this study area since the percentage difference of peak flow was smaller than percentage difference of peak flow using HP No. 27 parameters.

From this software, hydrologic parameters such as losses, transform and baseflow will be obtained and the result can be used as references for further research and study to any catchment area that have the same characteristics with the studied area. However, there some of the data that needs to be inserted cautiously, such as the impervious percentage, initial loss and constant rate loss. These data need to be monitored and well calculated because those data affecting the hydrograph that will be produced at the end of simulation process.

5.3 RECOMMENDATION

Based on the results and conclusions of the study that has been made, HEC-HMS software was able to predict the accuracy of the actual parameter for Bukit Kenau station in Kuantan River Basin. However, there are still needs to improve to get better result by using this software. For upcoming research, use other HEC-HMS model method for the basin model such as SCS UH method in order to determine the accuracy parameters for this study area. There are some suggestions that can be made in this research to ensure the best result to be produced in the future. Information for the selected area of study need to be observed as much as possible and must be realistic and accurate.

The information can be obtained by observation in the actual site of study and data collecting from authorized party such as Department of Irrigation and Drainage (DID) to ensure that the result is accurate and reliable. Parameter that has been used can be applied for further research related to the rainfall runoff and many more processes that can be done in hydrology discipline. Also, DID should provide more streamflow station and raingage station in order to have various flowrate data and rainfall data and use good equipments to measure rainfall data and streamflow data in order to prevent from error data. Besides that, DID should recheck the Clark parameters by HP No. 27 for Bukit Kenau station in Kuantan River Basin.

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Appendix A: Rainfall Data

Appendix A: Rainfall Data

Event 1		
Date	Time	Rainfall (mm)
04/09/2010	6:45 PM	3.2
04/09/2010	7:00 PM	6.5
04/09/2010	7:15 PM	8.1
04/09/2010	7:30 PM	5.3
04/09/2010	7:45 PM	0.9
Event 2		
Date	Time	Rainfall (mm)
19/03/2011	5:15 PM	1.1
19/03/2011	5:30 PM	6.8
19/03/2011	5:45 PM	5.7
19/03/2011	6:00 PM	1
19/03/2011	6:15 PM	0.5
Event 3		
Date	Time	Rainfall (mm)
20/03/2011	7:00 PM	0.5
20/03/2011	7:15 PM	1.5
20/03/2011	7:30 PM	3.6
20/03/2011	7:45 PM	2.9
20/03/2011	8:00 PM	0.5
20/03/2011	8:15 PM	0.5
20/03/2011	8:30 PM	0.5
Event 4		
Date	Time	Rainfall (mm)
12/11/2011	1:15 PM	3.7
12/11/2011	1:30 PM	5.9
12/11/2011	1:45 PM	3.4
12/11/2011	2:00 PM	1.5
12/11/2011	2:15 PM	0.5
12/11/2011	2:30 PM	1.1
12/11/2011	2:45 PM	6.8
12/11/2011	3:00 PM	6.7
12/11/2011	3:15 PM	1.9
12/11/2011	3:30 PM	0.5

Event 5		
Date	Time	Rainfall (mm)
12/10/2013	7:30 PM	0.5
12/10/2013	7:45 PM	14.3
12/10/2013	8:00 PM	15.9
12/10/2013	8:15 PM	3.8
12/10/2013	8:30 PM	0.5
12/10/2013	8:45 PM	0.5
12/10/2013	9:00 PM	0.5
Event 6		
Date	Time	Rainfall (mm)
13/11/2011	3:15 PM	1.1
13/11/2011	3:30 PM	3.6
13/11/2011	3:45 PM	3.4
13/11/2011	4:00 PM	0.9
13/11/2011	4:15 PM	0.5
13/11/2011	4:30 PM	0.5
13/11/2011	4:45 PM	0.5
13/11/2011	5:00 PM	0.5
13/11/2011	5:15 PM	0.5
13/11/2011	5:30 PM	0.5

Appendix B: Flow Rate Data

Appendix B: Flow Rate Data

Event 1		
Date	Time	Flowrate (m³/s)
04/09/2010	6:45 PM	22.4
04/09/2010	7:00 PM	23.6
04/09/2010	7:15 PM	25.8
04/09/2010	7:30 PM	27.4
04/09/2010	7:45 PM	28.7
04/09/2010	8:00 PM	30.1
04/09/2010	8:15 PM	32.5
04/09/2010	8:30 PM	34.4
04/09/2010	8:45 PM	35.8
04/09/2010	9:00 PM	37.4
04/09/2010	9:15 PM	38.9
04/09/2010	9:30 PM	41.6
04/09/2010	9:45 PM	43.7
04/09/2010	10:00 PM	45.9
04/09/2010	10:15 PM	48.9
04/09/2010	10:30 PM	51.4
04/09/2010	10:45 PM	53.5
04/09/2010	11:00 PM	55.7
04/09/2010	11:15 PM	57.9
04/09/2010	11:30 PM	59.3
04/09/2010	11:45 PM	60.3
04/09/2010	12:00 AM	60.6
05/09/2010	12:15 AM	60.6
05/09/2010	12:30 AM	59.8
05/09/2010	12:45 AM	59.5
05/09/2010	1:00 AM	58.8
05/09/2010	1:15 AM	58.5
05/09/2010	1:30 AM	56.9
05/09/2010	1:45 AM	56.3
05/09/2010	2:00 AM	55.5
05/09/2010	2:15 AM	53.6
05/09/2010	2:30 AM	53
05/09/2010	2:45 AM	52.3
05/09/2010	3:00 AM	51.2
05/09/2010	3:15 AM	50.1
05/09/2010	3:30 AM	49
05/09/2010	3:45 AM	48.7
05/09/2010	4:00 AM	47.9
05/09/2010	4:15 AM	46.8
05/09/2010	4:30 AM	46.5
05/09/2010	4:45 AM	45.7
05/09/2010	5:00 AM	45.4
05/09/2010	5:15 AM	44.5
05/09/2010	5:30 AM	44.1
05/09/2010	5:45 AM	44.1
05/09/2010	6:00 AM	42.9
05/09/2010	6:15 AM	42.5
05/09/2010	6:30 AM	42.5
05/09/2010	6:45 AM	41.3
05/09/2010	7:00 AM	40.9
05/09/2010	7:15 AM	39.7
05/09/2010	7:30 AM	39.3
05/09/2010	7:45 AM	39.3
05/09/2010	8:00 AM	39.3
05/09/2010	8:15 AM	38.2
05/09/2010	8:30 AM	37.8
05/09/2010	8:45 AM	37.8
05/09/2010	9:00 AM	37.8
05/09/2010	9:15 AM	37.8
05/09/2010	9:30 AM	37.8
05/09/2010	9:45 AM	36.7
05/09/2010	10:00 AM	36.3
05/09/2010	10:15 AM	36.3
05/09/2010	10:30 AM	36.3
05/09/2010	10:45 AM	35.2
05/09/2010	11:00 AM	34.8
05/09/2010	11:15 AM	34.8
05/09/2010	11:30 AM	34.8
05/09/2010	11:45 AM	34.8
05/09/2010	12:00 PM	34.8
05/09/2010	12:15 PM	34.8
05/09/2010	12:30 PM	34.8
05/09/2010	12:45 PM	34.8
05/09/2010	1:00 PM	34.8
05/09/2010	1:15 PM	34.8
05/09/2010	1:30 PM	34.8
05/09/2010	1:45 PM	34.8
05/09/2010	2:00 PM	34.8
05/09/2010	2:15 PM	34.8
05/09/2010	2:30 PM	34.8

05/09/2010	2:45 PM	34.8
05/09/2010	3:00 PM	34.8
05/09/2010	3:15 PM	34.8
05/09/2010	3:30 PM	34.8
05/09/2010	3:45 PM	34.8
05/09/2010	4:00 PM	34.8
05/09/2010	4:15 PM	34.8
05/09/2010	4:30 PM	34.8
05/09/2010	4:45 PM	34.8
05/09/2010	5:00 PM	33.7
05/09/2010	5:15 PM	33.3
05/09/2010	5:30 PM	33.3
05/09/2010	5:45 PM	33.3
05/09/2010	6:00 PM	33.3
05/09/2010	6:15 PM	34.4
05/09/2010	6:30 PM	33.7
05/09/2010	6:45 PM	33.3
05/09/2010	7:00 PM	33.3
05/09/2010	7:15 PM	33.3
05/09/2010	7:30 PM	33.3
05/09/2010	7:45 PM	33.3
05/09/2010	8:00 PM	33.3
05/09/2010	8:15 PM	33.3
05/09/2010	8:30 PM	33.3
05/09/2010	8:45 PM	33.3
05/09/2010	9:00 PM	33.3
05/09/2010	9:15 PM	32.3
05/09/2010	9:30 PM	31.9
05/09/2010	9:45 PM	31.9
05/09/2010	10:00 PM	31.9
05/09/2010	10:15 PM	31.9
05/09/2010	10:30 PM	30.9
05/09/2010	10:45 PM	31.5
05/09/2010	11:00 PM	30.9
05/09/2010	11:15 PM	30.5
05/09/2010	11:30 PM	30.5
05/09/2010	11:45 PM	30.5
05/09/2010	12:00 AM	30.5
06/09/2010	12:15 AM	30.5
06/09/2010	12:30 AM	30.5
06/09/2010	12:45 AM	30.5
06/09/2010	1:00 AM	30.5
06/09/2010	1:15 AM	30.5
06/09/2010	1:30 AM	29.5

06/09/2010	1:45 AM	29.1
06/09/2010	2:00 AM	29.1
06/09/2010	2:15 AM	29.1
06/09/2010	2:30 AM	29.1
06/09/2010	2:45 AM	29.1
06/09/2010	3:00 AM	29.1
06/09/2010	3:15 AM	29.1
06/09/2010	3:30 AM	29.1
06/09/2010	3:45 AM	29.1
06/09/2010	4:00 AM	29.1
06/09/2010	4:15 AM	29.1
06/09/2010	4:30 AM	28.1
06/09/2010	4:45 AM	27.8
06/09/2010	5:00 AM	27.8
06/09/2010	5:15 AM	27.8
06/09/2010	5:30 AM	27.8
06/09/2010	5:45 AM	27.8
06/09/2010	6:00 AM	27.8
06/09/2010	6:15 AM	27.8
06/09/2010	6:30 AM	27.8
06/09/2010	6:45 AM	27.8
06/09/2010	7:00 AM	27.8
06/09/2010	7:15 AM	27.8
06/09/2010	7:30 AM	27.8
06/09/2010	7:45 AM	26.8
06/09/2010	8:00 AM	27.4
06/09/2010	8:15 AM	26.8
06/09/2010	8:30 AM	27.4
06/09/2010	8:45 AM	26.8
06/09/2010	9:00 AM	27.4
06/09/2010	9:15 AM	26.8
06/09/2010	9:30 AM	26.5
06/09/2010	9:45 AM	26.5
06/09/2010	10:00 AM	26.5
06/09/2010	10:15 AM	26.5
06/09/2010	10:30 AM	26.5
06/09/2010	10:45 AM	26.5
06/09/2010	11:00 AM	26.5
06/09/2010	11:15 AM	26.5
06/09/2010	11:30 AM	26.5
06/09/2010	11:45 AM	26.5
06/09/2010	12:00 PM	26.5
06/09/2010	12:15 PM	25.5
06/09/2010	12:30 PM	25.2

06/09/2010	12:45 PM	25.2
06/09/2010	1:00 PM	25.2
06/09/2010	1:15 PM	25.2
06/09/2010	1:30 PM	25.2
06/09/2010	1:45 PM	25.2
06/09/2010	2:00 PM	25.2
06/09/2010	2:15 PM	24.3
06/09/2010	2:30 PM	24.8

Event 2		
Date	Time	Flowrate (m³/s)
19/03/2011	5:15 PM	46.6
19/03/2011	5:30 PM	47.6
19/03/2011	5:45 PM	47.6
19/03/2011	6:00 PM	47.7
19/03/2011	6:15 PM	48.7
19/03/2011	6:30 PM	48.7
19/03/2011	6:45 PM	48.7
19/03/2011	7:00 PM	48.7
19/03/2011	7:15 PM	48.7
19/03/2011	7:30 PM	48.7
19/03/2011	7:45 PM	48.7
19/03/2011	8:00 PM	48.7
19/03/2011	8:15 PM	48.7
19/03/2011	8:30 PM	48.7
19/03/2011	8:45 PM	48.8
19/03/2011	9:00 PM	49.8
19/03/2011	9:15 PM	50
19/03/2011	9:30 PM	52.1
19/03/2011	9:45 PM	53
19/03/2011	10:00 PM	53.2
19/03/2011	10:15 PM	54.3
19/03/2011	10:30 PM	55.2
19/03/2011	10:45 PM	56.4
19/03/2011	11:00 PM	57.5
19/03/2011	11:15 PM	58.6
19/03/2011	11:30 PM	59.5
19/03/2011	11:45 PM	59.7
19/03/2011	12:00 AM	60.8
20/03/2011	12:15 AM	61.8
20/03/2011	12:30 AM	62.9
20/03/2011	12:45 AM	64
20/03/2011	1:00 AM	64.9
20/03/2011	1:15 AM	64.9
20/03/2011	1:30 AM	64.9
20/03/2011	1:45 AM	64.9
20/03/2011	2:00 AM	64.9
20/03/2011	2:15 AM	64.9
20/03/2011	2:30 AM	64.8
20/03/2011	2:45 AM	63.9
20/03/2011	3:00 AM	63.4
20/03/2011	3:15 AM	59.4
20/03/2011	3:30 AM	58.3
20/03/2011	3:45 AM	57.3
20/03/2011	4:00 AM	56.3
20/03/2011	4:15 AM	56.2
20/03/2011	4:30 AM	55.3
20/03/2011	4:45 AM	55.2
20/03/2011	5:00 AM	55.2
20/03/2011	5:15 AM	55.2
20/03/2011	5:30 AM	55.2
20/03/2011	5:45 AM	55.2
20/03/2011	6:00 AM	55.2
20/03/2011	6:15 AM	55.2
20/03/2011	6:30 AM	55.2
20/03/2011	6:45 AM	55.1
20/03/2011	7:00 AM	54.1
20/03/2011	7:15 AM	54
20/03/2011	7:30 AM	53
20/03/2011	7:45 AM	53
20/03/2011	8:00 AM	52.9
20/03/2011	8:15 AM	52
20/03/2011	8:30 AM	51.8
20/03/2011	8:45 AM	50.9
20/03/2011	9:00 AM	50.7
20/03/2011	9:15 AM	49.8
20/03/2011	9:30 AM	49.8
20/03/2011	9:45 AM	49.7
20/03/2011	10:00 AM	48.7
20/03/2011	10:15 AM	48.7
20/03/2011	10:30 AM	48.7
20/03/2011	10:45 AM	48.6
20/03/2011	11:00 AM	47.6
20/03/2011	11:15 AM	47.6
20/03/2011	11:30 AM	47.5
20/03/2011	11:45 AM	46.5

Event 3		
Date	Time	Flowrate (m³/s)
20/03/2011	7:00 PM	64.8
20/03/2011	7:15 PM	64
20/03/2011	7:30 PM	64.9
20/03/2011	7:45 PM	65.1
20/03/2011	8:00 PM	66
20/03/2011	8:15 PM	66.1
20/03/2011	8:30 PM	67.1
20/03/2011	8:45 PM	67.2
20/03/2011	9:00 PM	68.3
20/03/2011	9:15 PM	69.4
20/03/2011	9:30 PM	70.3
20/03/2011	9:45 PM	70.4
20/03/2011	10:00 PM	71.4
20/03/2011	10:15 PM	71.4
20/03/2011	10:30 PM	71.4
20/03/2011	10:45 PM	71.6
20/03/2011	11:00 PM	73.5
20/03/2011	11:15 PM	73.6
20/03/2011	11:30 PM	74.6
20/03/2011	11:45 PM	74.8
20/03/2011	12:00 AM	76.8
21/03/2011	12:15 AM	77.9
21/03/2011	12:30 AM	79
21/03/2011	12:45 AM	80
21/03/2011	1:00 AM	81
21/03/2011	1:15 AM	81
21/03/2011	1:30 AM	82
21/03/2011	1:45 AM	82.1
21/03/2011	2:00 AM	82
21/03/2011	2:15 AM	82
21/03/2011	2:30 AM	81.9
21/03/2011	2:45 AM	81.9
21/03/2011	3:00 AM	81.5
21/03/2011	3:15 AM	81
21/03/2011	3:30 AM	80.8
21/03/2011	3:45 AM	79.9
21/03/2011	4:00 AM	79.8
21/03/2011	4:15 AM	78.7
21/03/2011	4:30 AM	77.7
21/03/2011	4:45 AM	76.7
21/03/2011	5:00 AM	76.6
21/03/2011	5:15 AM	75.5
21/03/2011	5:30 AM	74.6
21/03/2011	5:45 AM	74.5
21/03/2011	6:00 AM	73.4
21/03/2011	6:15 AM	72.3
21/03/2011	6:30 AM	71.4
21/03/2011	6:45 AM	71.2
21/03/2011	7:00 AM	70.3
21/03/2011	7:15 AM	70.1
21/03/2011	7:30 AM	68.2
21/03/2011	7:45 AM	68.2
21/03/2011	8:00 AM	68
21/03/2011	8:15 AM	67.1
21/03/2011	8:30 AM	67
21/03/2011	8:45 AM	65.9
21/03/2011	9:00 AM	64.9
21/03/2011	9:15 AM	64.9
21/03/2011	9:30 AM	64.8

Event 4		
Date	Time	Flowrate (m³/s)
12/11/2011	1:15 PM	34.5
12/11/2011	1:30 PM	37.5
12/11/2011	1:45 PM	40.6
12/11/2011	2:00 PM	43.2
12/11/2011	2:15 PM	45.6
12/11/2011	2:30 PM	48.5
12/11/2011	2:45 PM	50.2
12/11/2011	3:00 PM	50.9
12/11/2011	3:15 PM	51.3
12/11/2011	3:30 PM	52
12/11/2011	3:45 PM	52
12/11/2011	4:00 PM	54.6
12/11/2011	4:15 PM	55.7
12/11/2011	4:30 PM	57.2
12/11/2011	4:45 PM	59.8
12/11/2011	5:00 PM	62.6
12/11/2011	5:15 PM	65
12/11/2011	5:30 PM	67.5
12/11/2011	5:45 PM	69
12/11/2011	6:00 PM	69.9
12/11/2011	6:15 PM	70
12/11/2011	6:30 PM	71.6
12/11/2011	6:45 PM	75.7
12/11/2011	7:00 PM	81
12/11/2011	7:15 PM	85.6
12/11/2011	7:30 PM	89.1
12/11/2011	7:45 PM	91.7
12/11/2011	8:00 PM	92.9
12/11/2011	8:15 PM	93.1
12/11/2011	8:30 PM	92.4
12/11/2011	8:45 PM	91.9
12/11/2011	9:00 PM	90.2
12/11/2011	9:15 PM	87.8
12/11/2011	9:30 PM	85.9
12/11/2011	9:45 PM	84.3
12/11/2011	10:00 PM	82.2
12/11/2011	10:15 PM	80.5
12/11/2011	10:30 PM	79.5
12/11/2011	10:45 PM	78
12/11/2011	11:00 PM	76.3
12/11/2011	11:15 PM	75.2
12/11/2011	11:30 PM	74.1
12/11/2011	11:45 PM	72.6
12/11/2011	12:00 AM	71.4
13/11/2011	12:15 AM	70.9
13/11/2011	12:30 AM	70
13/11/2011	12:45 AM	68.2
13/11/2011	1:00 AM	67.7
13/11/2011	1:15 AM	66.6
13/11/2011	1:30 AM	65.6
13/11/2011	1:45 AM	65.2
13/11/2011	2:00 AM	65
13/11/2011	2:15 AM	64.9
13/11/2011	2:30 AM	64.5
13/11/2011	2:45 AM	63.9
13/11/2011	3:00 AM	63
13/11/2011	3:15 AM	61.7
13/11/2011	3:30 AM	61.3
13/11/2011	3:45 AM	60.2
13/11/2011	4:00 AM	59.5
13/11/2011	4:15 AM	59.1
13/11/2011	4:30 AM	58.5
13/11/2011	4:45 AM	58
13/11/2011	5:00 AM	56.9
13/11/2011	5:15 AM	56.3
13/11/2011	5:30 AM	56.3
13/11/2011	5:45 AM	55.9
13/11/2011	6:00 AM	55.2
13/11/2011	6:15 AM	55.2
13/11/2011	6:30 AM	54.8
13/11/2011	6:45 AM	53.7
13/11/2011	7:00 AM	53
13/11/2011	7:15 AM	53
13/11/2011	7:30 AM	53
13/11/2011	7:45 AM	53
13/11/2011	8:00 AM	52.6
13/11/2011	8:15 AM	52
13/11/2011	8:30 AM	52
13/11/2011	8:45 AM	51.5
13/11/2011	9:00 AM	50.9
13/11/2011	9:15 AM	50.4
13/11/2011	9:30 AM	49.8
13/11/2011	9:45 AM	49.8
13/11/2011	10:00 AM	49.8
13/11/2011	10:15 AM	49.8
13/11/2011	10:30 AM	49.3

13/11/2011	10:45 AM	48.7
13/11/2011	11:00 AM	48.7
13/11/2011	11:15 AM	48.7
13/11/2011	11:30 AM	48.7
13/11/2011	11:45 AM	48.2
13/11/2011	12:00 PM	47.1
13/11/2011	12:15 PM	46.5
13/11/2011	12:30 PM	46.5
13/11/2011	12:45 PM	46.5
13/11/2011	1:00 PM	46.5
13/11/2011	1:15 PM	46.5
13/11/2011	1:30 PM	46.5
13/11/2011	1:45 PM	46.5
13/11/2011	2:00 PM	46.1
13/11/2011	2:15 PM	45.4
13/11/2011	2:30 PM	44.9
13/11/2011	2:45 PM	44.1
13/11/2011	3:00 PM	44.6

Event 5		
Date	Time	Flowrate (m³/s)
13/11/2011	3:15 PM	45.9
13/11/2011	3:30 PM	46.5
13/11/2011	3:45 PM	47
13/11/2011	4:00 PM	48.1
13/11/2011	4:15 PM	48.7
13/11/2011	4:30 PM	48.7
13/11/2011	4:45 PM	49.1
13/11/2011	5:00 PM	50.2
13/11/2011	5:15 PM	51.3
13/11/2011	5:30 PM	52
13/11/2011	5:45 PM	52
13/11/2011	6:00 PM	52.4
13/11/2011	6:15 PM	53.5
13/11/2011	6:30 PM	54.6
13/11/2011	6:45 PM	55.2
13/11/2011	7:00 PM	56.3
13/11/2011	7:15 PM	56.8
13/11/2011	7:30 PM	57.4
13/11/2011	7:45 PM	58
13/11/2011	8:00 PM	58.5
13/11/2011	8:15 PM	58.9
13/11/2011	8:30 PM	59.5
13/11/2011	8:45 PM	59.7
13/11/2011	9:00 PM	59.7
13/11/2011	9:15 PM	59.9
13/11/2011	9:30 PM	60
13/11/2011	9:45 PM	60
13/11/2011	10:00 PM	60
13/11/2011	10:15 PM	60
13/11/2011	10:30 PM	60
13/11/2011	10:45 PM	60
13/11/2011	11:00 PM	59.5
13/11/2011	11:15 PM	59.1
13/11/2011	11:30 PM	58.5
13/11/2011	11:45 PM	58.5
13/11/2011	12:00 AM	58
14/11/2011	12:15 AM	57.4
14/11/2011	12:30 AM	57.4
14/11/2011	12:45 AM	57.2
14/11/2011	1:00 AM	57.1
14/11/2011	1:15 AM	57
14/11/2011	1:30 AM	56.9
14/11/2011	1:45 AM	56.8
14/11/2011	2:00 AM	56.7
14/11/2011	2:15 AM	56.5
14/11/2011	2:30 AM	56.5
14/11/2011	2:45 AM	56
14/11/2011	3:00 AM	55.9
14/11/2011	3:15 AM	55.7
14/11/2011	3:30 AM	55.5
14/11/2011	3:45 AM	55.1
14/11/2011	4:00 AM	55
14/11/2011	4:15 AM	54.9
14/11/2011	4:30 AM	54.9
14/11/2011	4:45 AM	54.5
14/11/2011	5:00 AM	54
14/11/2011	5:15 AM	54
14/11/2011	5:30 AM	53.9
14/11/2011	5:45 AM	53.7
14/11/2011	6:00 AM	53.5
14/11/2011	6:15 AM	53.5
14/11/2011	6:30 AM	53.4
14/11/2011	6:45 AM	53
14/11/2011	7:00 AM	53
14/11/2011	7:15 AM	52.5
14/11/2011	7:30 AM	52.3
14/11/2011	7:45 AM	52
14/11/2011	8:00 AM	51.5
14/11/2011	8:15 AM	51
14/11/2011	8:30 AM	50.8
14/11/2011	8:45 AM	50.5
14/11/2011	9:00 AM	50
14/11/2011	9:15 AM	49.9
14/11/2011	9:30 AM	49.9
14/11/2011	9:45 AM	49.8
14/11/2011	10:00 AM	49.8
14/11/2011	10:15 AM	49.8
14/11/2011	10:30 AM	49.5
14/11/2011	10:45 AM	49.3
14/11/2011	11:00 AM	49
14/11/2011	11:15 AM	48.9
14/11/2011	11:30 AM	48.9
14/11/2011	11:45 AM	48.7
14/11/2011	12:00 PM	48.7
14/11/2011	12:15 PM	48.5
14/11/2011	12:30 PM	48.3

14/11/2011	12:45 PM	48
14/11/2011	1:00 PM	47.6
14/11/2011	1:15 PM	47.6
14/11/2011	1:30 PM	47.1
14/11/2011	1:45 PM	47
14/11/2011	2:00 PM	47
14/11/2011	2:15 PM	46.9
14/11/2011	2:30 PM	46.9
14/11/2011	2:45 PM	46.5
14/11/2011	3:00 PM	46.2
14/11/2011	3:15 PM	46.1
14/11/2011	3:30 PM	46.1

Event 6		
Date	Time	Flowrate (m³/s)
12/10/2013	7:30 PM	28.2
12/10/2013	7:45 PM	27.8
12/10/2013	8:00 PM	31.2
12/10/2013	8:15 PM	39.3
12/10/2013	8:30 PM	43.6
12/10/2013	8:45 PM	44.1
12/10/2013	9:00 PM	46.1
12/10/2013	9:15 PM	47.4
12/10/2013	9:30 PM	48.5
12/10/2013	9:45 PM	49.6
12/10/2013	10:00 PM	51.6
12/10/2013	10:15 PM	55.6
12/10/2013	10:30 PM	59.9
12/10/2013	10:45 PM	63.3
12/10/2013	11:00 PM	67.4
12/10/2013	11:15 PM	70.8
12/10/2013	11:30 PM	76.7
12/10/2013	11:45 PM	82.2
12/10/2013	12:00 AM	86.8
13/10/2013	12:15 AM	90.6
13/10/2013	12:30 AM	93.2
13/10/2013	12:45 AM	95.7
13/10/2013	1:00 AM	97.1
13/10/2013	1:15 AM	98.4
13/10/2013	1:30 AM	99.6
13/10/2013	1:45 AM	99.8
13/10/2013	2:00 AM	98.8
13/10/2013	2:15 AM	97.5
13/10/2013	2:30 AM	96.3
13/10/2013	2:45 AM	95.1
13/10/2013	3:00 AM	93.8
13/10/2013	3:15 AM	90.6
13/10/2013	3:30 AM	88
13/10/2013	3:45 AM	85.6
13/10/2013	4:00 AM	83.4
13/10/2013	4:15 AM	79.6
13/10/2013	4:30 AM	78
13/10/2013	4:45 AM	75.1
13/10/2013	5:00 AM	71.9
13/10/2013	5:15 AM	69.6
13/10/2013	5:30 AM	66.6
13/10/2013	5:45 AM	64.2
13/10/2013	6:00 AM	61.2
13/10/2013	6:15 AM	58.8
13/10/2013	6:30 AM	56.7
13/10/2013	6:45 AM	54.5
13/10/2013	7:00 AM	51.4
13/10/2013	7:15 AM	50
13/10/2013	7:30 AM	47.1
13/10/2013	7:45 AM	44.5
13/10/2013	8:00 AM	41.4
13/10/2013	8:15 AM	38.3
13/10/2013	8:30 AM	36.5
13/10/2013	8:45 AM	33.8
13/10/2013	9:00 AM	31
13/10/2013	9:15 AM	29.3

Appendix C: Water Level Data

Appendix C: Water Level Data

Event 1		
Date	Time	Water Level (mm)
04/09/2010	6:45 PM	16.87
04/09/2010	7:00 PM	16.88
04/09/2010	7:15 PM	16.89
04/09/2010	7:30 PM	16.9
04/09/2010	7:45 PM	16.92
04/09/2010	8:00 PM	16.93
04/09/2010	8:15 PM	16.94
04/09/2010	8:30 PM	16.95
04/09/2010	8:45 PM	16.97
04/09/2010	9:00 PM	16.98
04/09/2010	9:15 PM	16.99
04/09/2010	9:30 PM	17
04/09/2010	9:45 PM	17.01
04/09/2010	10:00 PM	17.03
04/09/2010	10:15 PM	17.04
04/09/2010	10:30 PM	17.07
04/09/2010	10:45 PM	17.09
04/09/2010	11:00 PM	17.11
04/09/2010	11:15 PM	17.13
04/09/2010	11:30 PM	17.15
04/09/2010	11:45 PM	17.17
04/09/2010	12:00 AM	17.18
05/09/2010	12:15 AM	17.18
05/09/2010	12:30 AM	17.18
05/09/2010	12:45 AM	17.17
05/09/2010	1:00 AM	17.17
05/09/2010	1:15 AM	17.16
05/09/2010	1:30 AM	17.16
05/09/2010	1:45 AM	17.15
05/09/2010	2:00 AM	17.14
05/09/2010	2:15 AM	17.13
05/09/2010	2:30 AM	17.12
05/09/2010	2:45 AM	17.11
05/09/2010	3:00 AM	17.1
05/09/2010	3:15 AM	17.09
05/09/2010	3:30 AM	17.08
05/09/2010	3:45 AM	17.07
05/09/2010	4:00 AM	17.07
05/09/2010	4:15 AM	17.06
05/09/2010	4:30 AM	17.05
05/09/2010	4:45 AM	17.05
05/09/2010	5:00 AM	17.04
05/09/2010	5:15 AM	17.04
05/09/2010	5:30 AM	17.03
05/09/2010	5:45 AM	17.03
05/09/2010	6:00 AM	17.03
05/09/2010	6:15 AM	17.02
05/09/2010	6:30 AM	17.02
05/09/2010	6:45 AM	17.02
05/09/2010	7:00 AM	17.01
05/09/2010	7:15 AM	17.01
05/09/2010	7:30 AM	17
05/09/2010	7:45 AM	17
05/09/2010	8:00 AM	17
05/09/2010	8:15 AM	17
05/09/2010	8:30 AM	16.99
05/09/2010	8:45 AM	16.99
05/09/2010	9:00 AM	16.99
05/09/2010	9:15 AM	16.99
05/09/2010	9:30 AM	16.99
05/09/2010	9:45 AM	16.99
05/09/2010	10:00 AM	16.98
05/09/2010	10:15 AM	16.98
05/09/2010	10:30 AM	16.98
05/09/2010	10:45 AM	16.98
05/09/2010	11:00 AM	16.97
05/09/2010	11:15 AM	16.97
05/09/2010	11:30 AM	16.97
05/09/2010	11:45 AM	16.97
05/09/2010	12:00 PM	16.97
05/09/2010	12:15 PM	16.97
05/09/2010	12:30 PM	16.97
05/09/2010	12:45 PM	16.97
05/09/2010	1:00 PM	16.97
05/09/2010	1:15 PM	16.97
05/09/2010	1:30 PM	16.97
05/09/2010	1:45 PM	16.97
05/09/2010	2:00 PM	16.97
05/09/2010	2:15 PM	16.97
05/09/2010	2:30 PM	16.97

05/09/2010	2:45 PM	16.97
05/09/2010	3:00 PM	16.97
05/09/2010	3:15 PM	16.97
05/09/2010	3:30 PM	16.97
05/09/2010	3:45 PM	16.97
05/09/2010	4:00 PM	16.97
05/09/2010	4:15 PM	16.97
05/09/2010	4:30 PM	16.97
05/09/2010	4:45 PM	16.97
05/09/2010	5:00 PM	16.97
05/09/2010	5:15 PM	16.96
05/09/2010	5:30 PM	16.96
05/09/2010	5:45 PM	16.96
05/09/2010	6:00 PM	16.96
05/09/2010	6:15 PM	16.96
05/09/2010	6:30 PM	16.97
05/09/2010	6:45 PM	16.96
05/09/2010	7:00 PM	16.96
05/09/2010	7:15 PM	16.96
05/09/2010	7:30 PM	16.96
05/09/2010	7:45 PM	16.96
05/09/2010	8:00 PM	16.96
05/09/2010	8:15 PM	16.96
05/09/2010	8:30 PM	16.96
05/09/2010	8:45 PM	16.96
05/09/2010	9:00 PM	16.96
05/09/2010	9:15 PM	16.96
05/09/2010	9:30 PM	16.95
05/09/2010	9:45 PM	16.95
05/09/2010	10:00 PM	16.95
05/09/2010	10:15 PM	16.95
05/09/2010	10:30 PM	16.95
05/09/2010	10:45 PM	16.94
05/09/2010	11:00 PM	16.95
05/09/2010	11:15 PM	16.94
05/09/2010	11:30 PM	16.94
05/09/2010	11:45 PM	16.94
05/09/2010	12:00 AM	16.94
06/09/2010	12:15 AM	16.94
06/09/2010	12:30 AM	16.94
06/09/2010	12:45 AM	16.94
06/09/2010	1:00 AM	16.94
06/09/2010	1:15 AM	16.94
06/09/2010	1:30 AM	16.94

06/09/2010	1:45 AM	16.93
06/09/2010	2:00 AM	16.93
06/09/2010	2:15 AM	16.93
06/09/2010	2:30 AM	16.93
06/09/2010	2:45 AM	16.93
06/09/2010	3:00 AM	16.93
06/09/2010	3:15 AM	16.93
06/09/2010	3:30 AM	16.93
06/09/2010	3:45 AM	16.93
06/09/2010	4:00 AM	16.93
06/09/2010	4:15 AM	16.93
06/09/2010	4:30 AM	16.93
06/09/2010	4:45 AM	16.92
06/09/2010	5:00 AM	16.92
06/09/2010	5:15 AM	16.92
06/09/2010	5:30 AM	16.92
06/09/2010	5:45 AM	16.92
06/09/2010	6:00 AM	16.92
06/09/2010	6:15 AM	16.92
06/09/2010	6:30 AM	16.92
06/09/2010	6:45 AM	16.92
06/09/2010	7:00 AM	16.92
06/09/2010	7:15 AM	16.92
06/09/2010	7:30 AM	16.92
06/09/2010	7:45 AM	16.92
06/09/2010	8:00 AM	16.91
06/09/2010	8:15 AM	16.92
06/09/2010	8:30 AM	16.91
06/09/2010	8:45 AM	16.92
06/09/2010	9:00 AM	16.91
06/09/2010	9:15 AM	16.92
06/09/2010	9:30 AM	16.91
06/09/2010	9:45 AM	16.91
06/09/2010	10:00 AM	16.91
06/09/2010	10:15 AM	16.91
06/09/2010	10:30 AM	16.91
06/09/2010	10:45 AM	16.91
06/09/2010	11:00 AM	16.91
06/09/2010	11:15 AM	16.91
06/09/2010	11:30 AM	16.91
06/09/2010	11:45 AM	16.91
06/09/2010	12:00 PM	16.91
06/09/2010	12:15 PM	16.91
06/09/2010	12:30 PM	16.9

06/09/2010	12:45 PM	16.9
06/09/2010	1:00 PM	16.9
06/09/2010	1:15 PM	16.9
06/09/2010	1:30 PM	16.9
06/09/2010	1:45 PM	16.9
06/09/2010	2:00 PM	16.9
06/09/2010	2:15 PM	16.9
06/09/2010	2:30 PM	16.89

Event 2		
Date	Time	Water Level (mm)
19/03/2011	5:15 PM	17.05
19/03/2011	5:30 PM	17.06
19/03/2011	5:45 PM	17.06
19/03/2011	6:00 PM	17.06
19/03/2011	6:15 PM	17.07
19/03/2011	6:30 PM	17.07
19/03/2011	6:45 PM	17.07
19/03/2011	7:00 PM	17.07
19/03/2011	7:15 PM	17.07
19/03/2011	7:30 PM	17.07
19/03/2011	7:45 PM	17.07
19/03/2011	8:00 PM	17.07
19/03/2011	8:15 PM	17.07
19/03/2011	8:30 PM	17.07
19/03/2011	8:45 PM	17.07
19/03/2011	9:00 PM	17.08
19/03/2011	9:15 PM	17.08
19/03/2011	9:30 PM	17.1
19/03/2011	9:45 PM	17.11
19/03/2011	10:00 PM	17.11
19/03/2011	10:15 PM	17.12
19/03/2011	10:30 PM	17.13
19/03/2011	10:45 PM	17.13
19/03/2011	11:00 PM	17.13
19/03/2011	11:15 PM	17.13
19/03/2011	11:30 PM	17.13
19/03/2011	11:45 PM	17.13
19/03/2011	12:00 AM	17.13
20/03/2011	12:15 AM	17.13
20/03/2011	12:30 AM	17.13
20/03/2011	12:45 AM	17.14
20/03/2011	1:00 AM	17.15
20/03/2011	1:15 AM	17.16
20/03/2011	1:30 AM	17.17
20/03/2011	1:45 AM	17.17
20/03/2011	2:00 AM	17.18
20/03/2011	2:15 AM	17.19
20/03/2011	2:30 AM	17.2
20/03/2011	2:45 AM	17.21
20/03/2011	3:00 AM	17.22
20/03/2011	3:15 AM	17.22
20/03/2011	3:30 AM	17.22
20/03/2011	3:45 AM	17.22
20/03/2011	4:00 AM	17.22
20/03/2011	4:15 AM	17.22
20/03/2011	4:30 AM	17.22
20/03/2011	4:45 AM	17.21
20/03/2011	5:00 AM	17.21
20/03/2011	5:15 AM	17.17
20/03/2011	5:30 AM	17.16
20/03/2011	5:45 AM	17.15
20/03/2011	6:00 AM	17.14
20/03/2011	6:15 AM	17.14
20/03/2011	6:30 AM	17.13
20/03/2011	6:45 AM	17.13
20/03/2011	7:00 AM	17.12
20/03/2011	7:15 AM	17.12
20/03/2011	7:30 AM	17.11
20/03/2011	7:45 AM	17.11
20/03/2011	8:00 AM	17.11
20/03/2011	8:15 AM	17.1
20/03/2011	8:30 AM	17.1
20/03/2011	8:45 AM	17.09
20/03/2011	9:00 AM	17.09
20/03/2011	9:15 AM	17.08
20/03/2011	9:30 AM	17.08
20/03/2011	9:45 AM	17.08
20/03/2011	10:00 AM	17.07
20/03/2011	10:15 AM	17.07
20/03/2011	10:30 AM	17.07
20/03/2011	10:45 AM	17.07
20/03/2011	11:00 AM	17.06
20/03/2011	11:15 AM	17.06
20/03/2011	11:30 AM	17.06
20/03/2011	11:45 AM	17.05

Event 3		
Date	Time	Water Level (mm)
20/03/2011	7:00 PM	17.22
20/03/2011	7:15 PM	17.21
20/03/2011	7:30 PM	17.22
20/03/2011	7:45 PM	17.22
20/03/2011	8:00 PM	17.23
20/03/2011	8:15 PM	17.23
20/03/2011	8:30 PM	17.24
20/03/2011	8:45 PM	17.24
20/03/2011	9:00 PM	17.25
20/03/2011	9:15 PM	17.26
20/03/2011	9:30 PM	17.27
20/03/2011	9:45 PM	17.27
20/03/2011	10:00 PM	17.28
20/03/2011	10:15 PM	17.28
20/03/2011	10:30 PM	17.28
20/03/2011	10:45 PM	17.28
20/03/2011	11:00 PM	17.3
20/03/2011	11:15 PM	17.3
20/03/2011	11:30 PM	17.31
20/03/2011	11:45 PM	17.31
20/03/2011	12:00 AM	17.33
21/03/2011	12:15 AM	17.34
21/03/2011	12:30 AM	17.35
21/03/2011	12:45 AM	17.36
21/03/2011	1:00 AM	17.37
21/03/2011	1:15 AM	17.38
21/03/2011	1:30 AM	17.38
21/03/2011	1:45 AM	17.38
21/03/2011	2:00 AM	17.39
21/03/2011	2:15 AM	17.39
21/03/2011	2:30 AM	17.38
21/03/2011	2:45 AM	17.38
21/03/2011	3:00 AM	17.38
21/03/2011	3:15 AM	17.37
21/03/2011	3:30 AM	17.37
21/03/2011	3:45 AM	17.36
21/03/2011	4:00 AM	17.36
21/03/2011	4:15 AM	17.35
21/03/2011	4:30 AM	17.34
21/03/2011	4:45 AM	17.33
21/03/2011	5:00 AM	17.33
21/03/2011	5:15 AM	17.32
21/03/2011	5:30 AM	17.31
21/03/2011	5:45 AM	17.31
21/03/2011	6:00 AM	17.3
21/03/2011	6:15 AM	17.29
21/03/2011	6:30 AM	17.28
21/03/2011	6:45 AM	17.28
21/03/2011	7:00 AM	17.27
21/03/2011	7:15 AM	17.27
21/03/2011	7:30 AM	17.25
21/03/2011	7:45 AM	17.25
21/03/2011	8:00 AM	17.25
21/03/2011	8:15 AM	17.24
21/03/2011	8:30 AM	17.24
21/03/2011	8:45 AM	17.23
21/03/2011	9:00 AM	17.22
21/03/2011	9:15 AM	17.22
21/03/2011	9:30 AM	17.22

Event 4		
Date	Time	Water Level (mm)
12/11/2011	1:15 PM	16.97
12/11/2011	1:30 PM	16.99
12/11/2011	1:45 PM	17.01
12/11/2011	2:00 PM	17.02
12/11/2011	2:15 PM	17.04
12/11/2011	2:30 PM	17.07
12/11/2011	2:45 PM	17.08
12/11/2011	3:00 PM	17.09
12/11/2011	3:15 PM	17.09
12/11/2011	3:30 PM	17.1
12/11/2011	3:45 PM	17.1
12/11/2011	4:00 PM	17.1
12/11/2011	4:15 PM	17.09
12/11/2011	4:30 PM	17.09
12/11/2011	4:45 PM	17.1
12/11/2011	5:00 PM	17.1
12/11/2011	5:15 PM	17.11
12/11/2011	5:30 PM	17.12
12/11/2011	5:45 PM	17.13
12/11/2011	6:00 PM	17.15
12/11/2011	6:15 PM	17.17
12/11/2011	6:30 PM	17.2
12/11/2011	6:45 PM	17.22
12/11/2011	7:00 PM	17.25
12/11/2011	7:15 PM	17.28
12/11/2011	7:30 PM	17.32
12/11/2011	7:45 PM	17.37
12/11/2011	8:00 PM	17.41
12/11/2011	8:15 PM	17.44
12/11/2011	8:30 PM	17.46
12/11/2011	8:45 PM	17.47
12/11/2011	9:00 PM	17.48
12/11/2011	9:15 PM	17.47
12/11/2011	9:30 PM	17.47
12/11/2011	9:45 PM	17.45
12/11/2011	10:00 PM	17.43
12/11/2011	10:15 PM	17.42
12/11/2011	10:30 PM	17.4
12/11/2011	10:45 PM	17.38
12/11/2011	11:00 PM	17.37
12/11/2011	11:15 PM	17.36
12/11/2011	11:30 PM	17.34
12/11/2011	11:45 PM	17.33
12/11/2011	12:00 AM	17.32
13/11/2011	12:15 AM	17.31
13/11/2011	12:30 AM	17.29
13/11/2011	12:45 AM	17.28
13/11/2011	1:00 AM	17.28
13/11/2011	1:15 AM	17.26
13/11/2011	1:30 AM	17.25
13/11/2011	1:45 AM	17.25
13/11/2011	2:00 AM	17.24
13/11/2011	2:15 AM	17.23
13/11/2011	2:30 AM	17.22
13/11/2011	2:45 AM	17.21
13/11/2011	3:00 AM	17.2
13/11/2011	3:15 AM	17.19
13/11/2011	3:30 AM	17.19
13/11/2011	3:45 AM	17.18
13/11/2011	4:00 AM	17.17
13/11/2011	4:15 AM	17.17
13/11/2011	4:30 AM	17.16
13/11/2011	4:45 AM	17.16
13/11/2011	5:00 AM	17.15
13/11/2011	5:15 AM	17.14
13/11/2011	5:30 AM	17.14
13/11/2011	5:45 AM	17.14
13/11/2011	6:00 AM	17.13
13/11/2011	6:15 AM	17.13
13/11/2011	6:30 AM	17.13
13/11/2011	6:45 AM	17.12
13/11/2011	7:00 AM	17.11
13/11/2011	7:15 AM	17.11
13/11/2011	7:30 AM	17.11
13/11/2011	7:45 AM	17.11
13/11/2011	8:00 AM	17.11
13/11/2011	8:15 AM	17.1
13/11/2011	8:30 AM	17.1
13/11/2011	8:45 AM	17.1
13/11/2011	9:00 AM	17.09
13/11/2011	9:15 AM	17.09
13/11/2011	9:30 AM	17.08
13/11/2011	9:45 AM	17.08
13/11/2011	10:00 AM	17.08
13/11/2011	10:15 AM	17.08
13/11/2011	10:30 AM	17.08

13/11/2011	10:45 AM	17.07
13/11/2011	11:00 AM	17.07
13/11/2011	11:15 AM	17.07
13/11/2011	11:30 AM	17.07
13/11/2011	11:45 AM	17.07
13/11/2011	12:00 PM	17.06
13/11/2011	12:15 PM	17.05
13/11/2011	12:30 PM	17.05
13/11/2011	12:45 PM	17.05
13/11/2011	1:00 PM	17.05
13/11/2011	1:15 PM	17.05
13/11/2011	1:30 PM	17.05
13/11/2011	1:45 PM	17.05
13/11/2011	2:00 PM	17.05
13/11/2011	2:15 PM	17.04
13/11/2011	2:30 PM	17.04
13/11/2011	2:45 PM	17.03
13/11/2011	3:00 PM	17.03

Event 5		
Date	Time	Water Level (mm)
13/11/2011	3:15 PM	17.04
13/11/2011	3:30 PM	17.05
13/11/2011	3:45 PM	17.05
13/11/2011	4:00 PM	17.06
13/11/2011	4:15 PM	17.07
13/11/2011	4:30 PM	17.07
13/11/2011	4:45 PM	17.07
13/11/2011	5:00 PM	17.08
13/11/2011	5:15 PM	17.09
13/11/2011	5:30 PM	17.1
13/11/2011	5:45 PM	17.1
13/11/2011	6:00 PM	17.1
13/11/2011	6:15 PM	17.11
13/11/2011	6:30 PM	17.11
13/11/2011	6:45 PM	17.11
13/11/2011	7:00 PM	17.11
13/11/2011	7:15 PM	17.11
13/11/2011	7:30 PM	17.12
13/11/2011	7:45 PM	17.13
13/11/2011	8:00 PM	17.13
13/11/2011	8:15 PM	17.13
13/11/2011	8:30 PM	17.13
13/11/2011	8:45 PM	17.13
13/11/2011	9:00 PM	17.14
13/11/2011	9:15 PM	17.14
13/11/2011	9:30 PM	17.14
13/11/2011	9:45 PM	17.14
13/11/2011	10:00 PM	17.14
13/11/2011	10:15 PM	17.14
13/11/2011	10:30 PM	17.14
13/11/2011	10:45 PM	17.14
13/11/2011	11:00 PM	17.14
13/11/2011	11:15 PM	17.14
13/11/2011	11:30 PM	17.14
13/11/2011	11:45 PM	17.14
13/11/2011	12:00 AM	17.14
14/11/2011	12:15 AM	17.14
14/11/2011	12:30 AM	17.14
14/11/2011	12:45 AM	17.15
14/11/2011	1:00 AM	17.15
14/11/2011	1:15 AM	17.15
14/11/2011	1:30 AM	17.15
14/11/2011	1:45 AM	17.16
14/11/2011	2:00 AM	17.16
14/11/2011	2:15 AM	17.16
14/11/2011	2:30 AM	17.16
14/11/2011	2:45 AM	17.17
14/11/2011	3:00 AM	17.17
14/11/2011	3:15 AM	17.17
14/11/2011	3:30 AM	17.17
14/11/2011	3:45 AM	17.17
14/11/2011	4:00 AM	17.17
14/11/2011	4:15 AM	17.17
14/11/2011	4:30 AM	17.17
14/11/2011	4:45 AM	17.16
14/11/2011	5:00 AM	17.16
14/11/2011	5:15 AM	17.16
14/11/2011	5:30 AM	17.16
14/11/2011	5:45 AM	17.16
14/11/2011	6:00 AM	17.15
14/11/2011	6:15 AM	17.14
14/11/2011	6:30 AM	17.14
14/11/2011	6:45 AM	17.14
14/11/2011	7:00 AM	17.14
14/11/2011	7:15 AM	17.13
14/11/2011	7:30 AM	17.13
14/11/2011	7:45 AM	17.13
14/11/2011	8:00 AM	17.13
14/11/2011	8:15 AM	17.12
14/11/2011	8:30 AM	17.11
14/11/2011	8:45 AM	17.11
14/11/2011	9:00 AM	17.11
14/11/2011	9:15 AM	17.11
14/11/2011	9:30 AM	17.11
14/11/2011	9:45 AM	17.1
14/11/2011	10:00 AM	17.1
14/11/2011	10:15 AM	17.1
14/11/2011	10:30 AM	17.1
14/11/2011	10:45 AM	17.1
14/11/2011	11:00 AM	17.09
14/11/2011	11:15 AM	17.08
14/11/2011	11:30 AM	17.08
14/11/2011	11:45 AM	17.08
14/11/2011	12:00 PM	17.08
14/11/2011	12:15 PM	17.08
14/11/2011	12:30 PM	17.08

14/11/2011	12:45 PM	17.08
14/11/2011	1:00 PM	17.07
14/11/2011	1:15 PM	17.07
14/11/2011	1:30 PM	17.07
14/11/2011	1:45 PM	17.07
14/11/2011	2:00 PM	17.07
14/11/2011	2:15 PM	17.07
14/11/2011	2:30 PM	17.07
14/11/2011	2:45 PM	17.06
14/11/2011	3:00 PM	17.06
14/11/2011	3:15 PM	17.06
14/11/2011	3:30 PM	17.05

Event 6		
Date	Time	Water Level (mm)
12/10/2013	7:30 PM	16.92
12/10/2013	7:45 PM	16.92
12/10/2013	8:00 PM	16.94
12/10/2013	8:15 PM	17
12/10/2013	8:30 PM	17.03
12/10/2013	8:45 PM	17.03
12/10/2013	9:00 PM	17.05
12/10/2013	9:15 PM	17.06
12/10/2013	9:30 PM	17.07
12/10/2013	9:45 PM	17.08
12/10/2013	10:00 PM	17.1
12/10/2013	10:15 PM	17.13
12/10/2013	10:30 PM	17.17
12/10/2013	10:45 PM	17.2
12/10/2013	11:00 PM	17.24
12/10/2013	11:15 PM	17.27
12/10/2013	11:30 PM	17.33
12/10/2013	11:45 PM	17.38
12/10/2013	12:00 AM	17.42
13/10/2013	12:15 AM	17.45
13/10/2013	12:30 AM	17.48
13/10/2013	12:45 AM	17.5
13/10/2013	1:00 AM	17.51
13/10/2013	1:15 AM	17.52
13/10/2013	1:30 AM	17.53
13/10/2013	1:45 AM	17.53
13/10/2013	2:00 AM	17.52
13/10/2013	2:15 AM	17.51
13/10/2013	2:30 AM	17.5
13/10/2013	2:45 AM	17.49
13/10/2013	3:00 AM	17.48
13/10/2013	3:15 AM	17.46
13/10/2013	3:30 AM	17.43
13/10/2013	3:45 AM	17.41
13/10/2013	4:00 AM	17.39
13/10/2013	4:15 AM	17.36
13/10/2013	4:30 AM	17.34
13/10/2013	4:45 AM	17.32
13/10/2013	5:00 AM	17.29
13/10/2013	5:15 AM	17.26
13/10/2013	5:30 AM	17.24
13/10/2013	5:45 AM	17.21
13/10/2013	6:00 AM	17.19
13/10/2013	6:15 AM	17.16
13/10/2013	6:30 AM	17.14
13/10/2013	6:45 AM	17.12
13/10/2013	7:00 AM	17.1
13/10/2013	7:15 AM	17.08
13/10/2013	7:30 AM	17.06
13/10/2013	7:45 AM	17.03
13/10/2013	8:00 AM	17.01
13/10/2013	8:15 AM	16.99
13/10/2013	8:30 AM	16.98
13/10/2013	8:45 AM	16.96
13/10/2013	9:00 AM	16.94
13/10/2013	9:15 AM	16.93

Appendix D:

Efficiency Index Data

(Clark UH Method)

Appendix D: Efficiency Index Data (Clark UH Method)

04/09/2010							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
6:45 PM	22.4	21.7	0.7	0.49	35.536	-13.136	172.5545
7:00 PM	23.6	21.8	1.8	3.24	35.536	-11.936	142.4681
7:15 PM	25.8	22.3	3.5	12.25	35.536	-9.736	94.7897
7:30 PM	27.4	23.2	4.2	17.64	35.536	-8.136	66.1945
7:45 PM	28.7	24.6	4.1	16.81	35.536	-6.836	46.7309
8:00 PM	30.1	26.3	3.8	14.44	35.536	-5.436	29.5501
8:15 PM	32.5	28.2	4.3	18.49	35.536	-3.036	9.217296
8:30 PM	34.4	30.4	4	16	35.536	-1.136	1.290496
8:45 PM	35.8	32.6	3.2	10.24	35.536	0.264	0.069696
9:00 PM	37.4	35	2.4	5.76	35.536	1.864	3.474496
9:15 PM	38.9	37.5	1.4	1.96	35.536	3.364	11.3165
9:30 PM	41.6	40	1.6	2.56	35.536	6.064	36.7721
9:45 PM	43.7	42.7	1	1	35.536	8.164	66.6509
10:00 PM	45.9	45.3	0.6	0.36	35.536	10.364	107.4125
10:15 PM	48.9	47.9	1	1	35.536	13.364	178.5965
10:30 PM	51.4	50.3	1.1	1.21	35.536	15.864	251.6665
10:45 PM	53.5	52.5	1	1	35.536	17.964	322.7053
11:00 PM	55.7	54.4	1.3	1.69	35.536	20.164	406.5869
11:15 PM	57.9	56	1.9	3.61	35.536	22.364	500.1485
11:30 PM	59.3	57.4	1.9	3.61	35.536	23.764	564.7277
11:45 PM	60.3	58.4	1.9	3.61	35.536	24.764	613.2557
12:00 AM	60.6	59.2	1.4	1.96	35.536	25.064	628.2041
12:15 AM	60.6	59.7	0.9	0.81	35.536	25.064	628.2041
12:30 AM	59.8	59.9	-0.1	0.01	35.536	24.264	588.7417
12:45 AM	59.5	59.7	-0.2	0.04	35.536	23.964	574.2733
1:00 AM	58.8	59	-0.2	0.04	35.536	23.264	541.2137
1:15 AM	58.5	57.8	0.7	0.49	35.536	22.964	527.3453
1:30 AM	56.9	56.4	0.5	0.25	35.536	21.364	456.4205
1:45 AM	56.3	54.8	1.5	2.25	35.536	20.764	431.1437
2:00 AM	55.5	53.4	2.1	4.41	35.536	19.964	398.5613
2:15 AM	53.6	52	1.6	2.56	35.536	18.064	326.3081
2:30 AM	53	50.6	2.4	5.76	35.536	17.464	304.9913
2:45 AM	52.3	49.3	3	9	35.536	16.764	281.0317
3:00 AM	51.2	48.1	3.1	9.61	35.536	15.664	245.3609
3:15 AM	50.1	46.9	3.2	10.24	35.536	14.564	212.1101
3:30 AM	49	45.8	3.2	10.24	35.536	13.464	181.2793
3:45 AM	48.7	44.7	4	16	35.536	13.164	173.2909
4:00 AM	47.9	43.7	4.2	17.64	35.536	12.364	152.8685
4:15 AM	46.8	42.7	4.1	16.81	35.536	11.264	126.8777

4:30 AM	46.5	41.8	4.7	22.09	35.536	10.964	120.2093
4:45 AM	45.7	40.9	4.8	23.04	35.536	10.164	103.3069
5:00 AM	45.4	40	5.4	29.16	35.536	9.864	97.2985
5:15 AM	44.5	39.2	5.3	28.09	35.536	8.964	80.3533
5:30 AM	44.1	38.5	5.6	31.36	35.536	8.564	73.3421
5:45 AM	44.1	37.7	6.4	40.96	35.536	8.564	73.3421
6:00 AM	42.9	37	5.9	34.81	35.536	7.364	54.2285
6:15 AM	42.5	36.3	6.2	38.44	35.536	6.964	48.4973
6:30 AM	42.5	35.7	6.8	46.24	35.536	6.964	48.4973
6:45 AM	41.3	35	6.3	39.69	35.536	5.764	33.2237
7:00 AM	40.9	34.5	6.4	40.96	35.536	5.364	28.7725
7:15 AM	39.7	33.9	5.8	33.64	35.536	4.164	17.3389
7:30 AM	39.3	33.3	6	36	35.536	3.764	14.1677
7:45 AM	39.3	32.8	6.5	42.25	35.536	3.764	14.1677
8:00 AM	39.3	32.3	7	49	35.536	3.764	14.1677
8:15 AM	38.2	31.9	6.3	39.69	35.536	2.664	7.096896
8:30 AM	37.8	31.4	6.4	40.96	35.536	2.264	5.125696
8:45 AM	37.8	31	6.8	46.24	35.536	2.264	5.125696
9:00 AM	37.8	30.6	7.2	51.84	35.536	2.264	5.125696
9:15 AM	37.8	30.2	7.6	57.76	35.536	2.264	5.125696
9:30 AM	37.8	29.8	8	64	35.536	2.264	5.125696
9:45 AM	36.7	29.4	7.3	53.29	35.536	1.164	1.354896
10:00 AM	36.3	29.1	7.2	51.84	35.536	0.764	0.583696
10:15 AM	36.3	28.8	7.5	56.25	35.536	0.764	0.583696
10:30 AM	36.3	28.4	7.9	62.41	35.536	0.764	0.583696
10:45 AM	35.2	28.1	7.1	50.41	35.536	-0.336	0.112896
11:00 AM	34.8	27.9	6.9	47.61	35.536	-0.736	0.541696
11:15 AM	34.8	27.6	7.2	51.84	35.536	-0.736	0.541696
11:30 AM	34.8	27.3	7.5	56.25	35.536	-0.736	0.541696
11:45 AM	34.8	27.1	7.7	59.29	35.536	-0.736	0.541696
12:00 PM	34.8	26.8	8	64	35.536	-0.736	0.541696
12:15 PM	34.8	26.6	8.2	67.24	35.536	-0.736	0.541696
12:30 PM	34.8	26.4	8.4	70.56	35.536	-0.736	0.541696
12:45 PM	34.8	26.2	8.6	73.96	35.536	-0.736	0.541696
1:00 PM	34.8	26	8.8	77.44	35.536	-0.736	0.541696
1:15 PM	34.8	25.8	9	81	35.536	-0.736	0.541696
1:30 PM	34.8	25.6	9.2	84.64	35.536	-0.736	0.541696
1:45 PM	34.8	25.4	9.4	88.36	35.536	-0.736	0.541696
2:00 PM	34.8	25.3	9.5	90.25	35.536	-0.736	0.541696
2:15 PM	34.8	25.1	9.7	94.09	35.536	-0.736	0.541696
2:30 PM	34.8	25	9.8	96.04	35.536	-0.736	0.541696
2:45 PM	34.8	24.8	10	100	35.536	-0.736	0.541696
3:00 PM	34.8	24.7	10.1	102.01	35.536	-0.736	0.541696
3:15 PM	34.8	24.5	10.3	106.09	35.536	-0.736	0.541696

3:30 PM	34.8	24.4	10.4	108.16	35.536	-0.736	0.541696
3:45 PM	34.8	24.3	10.5	110.25	35.536	-0.736	0.541696
4:00 PM	34.8	24.2	10.6	112.36	35.536	-0.736	0.541696
4:15 PM	34.8	24.1	10.7	114.49	35.536	-0.736	0.541696
4:30 PM	34.8	24	10.8	116.64	35.536	-0.736	0.541696
4:45 PM	34.8	23.9	10.9	118.81	35.536	-0.736	0.541696
5:00 PM	33.7	23.8	9.9	98.01	35.536	-1.836	3.370896
5:15 PM	33.3	23.7	9.6	92.16	35.536	-2.236	4.999696
5:30 PM	33.3	23.6	9.7	94.09	35.536	-2.236	4.999696
5:45 PM	33.3	23.5	9.8	96.04	35.536	-2.236	4.999696
6:00 PM	33.3	23.4	9.9	98.01	35.536	-2.236	4.999696
6:15 PM	34.4	23.3	11.1	123.21	35.536	-1.136	1.290496
6:30 PM	33.7	23.3	10.4	108.16	35.536	-1.836	3.370896
6:45 PM	33.3	23.2	10.1	102.01	35.536	-2.236	4.999696
7:00 PM	33.3	23.1	10.2	104.04	35.536	-2.236	4.999696
7:15 PM	33.3	23.1	10.2	104.04	35.536	-2.236	4.999696
7:30 PM	33.3	23	10.3	106.09	35.536	-2.236	4.999696
7:45 PM	33.3	23	10.3	106.09	35.536	-2.236	4.999696
8:00 PM	33.3	22.9	10.4	108.16	35.536	-2.236	4.999696
8:15 PM	33.3	22.8	10.5	110.25	35.536	-2.236	4.999696
8:30 PM	33.3	22.8	10.5	110.25	35.536	-2.236	4.999696
8:45 PM	33.3	22.7	10.6	112.36	35.536	-2.236	4.999696
9:00 PM	33.3	22.7	10.6	112.36	35.536	-2.236	4.999696
9:15 PM	32.3	22.7	9.6	92.16	35.536	-3.236	10.4717
9:30 PM	31.9	22.6	9.3	86.49	35.536	-3.636	13.2205
9:45 PM	31.9	22.6	9.3	86.49	35.536	-3.636	13.2205
10:00 PM	31.9	22.5	9.4	88.36	35.536	-3.636	13.2205
10:15 PM	31.9	22.5	9.4	88.36	35.536	-3.636	13.2205
10:30 PM	30.9	22.5	8.4	70.56	35.536	-4.636	21.4925
10:45 PM	31.5	22.4	9.1	82.81	35.536	-4.036	16.2893
11:00 PM	30.9	22.4	8.5	72.25	35.536	-4.636	21.4925
11:15 PM	30.5	22.4	8.1	65.61	35.536	-5.036	25.3613
11:30 PM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
11:45 PM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
12:00 AM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
12:15 AM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
12:30 AM	30.5	22.2	8.3	68.89	35.536	-5.036	25.3613
12:45 AM	30.5	22.2	8.3	68.89	35.536	-5.036	25.3613
1:00 AM	30.5	22.2	8.3	68.89	35.536	-5.036	25.3613
1:15 AM	30.5	22.2	8.3	68.89	35.536	-5.036	25.3613
1:30 AM	29.5	22.1	7.4	54.76	35.536	-6.036	36.4333
1:45 AM	29.1	22.1	7	49	35.536	-6.436	41.4221
2:00 AM	29.1	22.1	7	49	35.536	-6.436	41.4221
2:15 AM	29.1	22.1	7	49	35.536	-6.436	41.4221

2:30 AM	29.1	22.1	7	49	35.536	-6.436	41.4221
2:45 AM	29.1	22.1	7	49	35.536	-6.436	41.4221
3:00 AM	29.1	22	7.1	50.41	35.536	-6.436	41.4221
3:15 AM	29.1	22	7.1	50.41	35.536	-6.436	41.4221
3:30 AM	29.1	21.9	7.2	51.84	35.536	-6.436	41.4221
3:45 AM	29.1	21.8	7.3	53.29	35.536	-6.436	41.4221
4:00 AM	29.1	21.7	7.4	54.76	35.536	-6.436	41.4221
4:15 AM	29.1	21.7	7.4	54.76	35.536	-6.436	41.4221
4:30 AM	28.1	21.7	6.4	40.96	35.536	-7.436	55.2941
4:45 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:00 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:15 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:30 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:45 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
6:00 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
6:15 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
6:30 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
6:45 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
7:00 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
7:15 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
7:30 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
7:45 AM	26.8	21.7	5.1	26.01	35.536	-8.736	76.3177
8:00 AM	27.4	21.7	5.7	32.49	35.536	-8.136	66.1945
8:15 AM	26.8	21.7	5.1	26.01	35.536	-8.736	76.3177
8:30 AM	27.4	21.7	5.7	32.49	35.536	-8.136	66.1945
8:45 AM	26.8	21.7	5.1	26.01	35.536	-8.736	76.3177
9:00 AM	27.4	21.7	5.7	32.49	35.536	-8.136	66.1945
9:15 AM	26.8	21.7	5.1	26.01	35.536	-8.736	76.3177
9:30 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
9:45 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
10:00 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
10:15 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
10:30 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
10:45 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
11:00 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
11:15 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
11:30 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
11:45 AM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
12:00 PM	26.5	21.7	4.8	23.04	35.536	-9.036	81.6493
12:15 PM	25.5	21.7	3.8	14.44	35.536	-10.036	100.7213
12:30 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329
12:45 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329
1:00 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329
1:15 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329

1:30 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329
1:45 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329
2:00 PM	25.2	21.7	3.5	12.25	35.536	-10.336	106.8329
2:15 PM	24.3	21.7	2.6	6.76	35.536	-11.236	126.2477
2:30 PM	24.8	21.7	3.1	9.61	35.536	-10.736	115.2617
$\sum Qi=$	6254.4	$\Sigma(Qi - Fi)^2 =$		8184.05	$\sum(Qi\text{-}Qag)^2=$		15460.75

19/03/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
5:15 PM	46.6	46	0.6	0.36	54.143	-7.543	56.89685
5:30 PM	47.6	46.1	1.5	2.25	54.143	-6.543	42.81085
5:45 PM	47.6	46.3	1.3	1.69	54.143	-6.543	42.81085
6:00 PM	47.7	46.7	1	1	54.143	-6.443	41.51225
6:15 PM	48.7	47.3	1.4	1.96	54.143	-5.443	29.62625
6:30 PM	48.7	47.9	0.8	0.64	54.143	-5.443	29.62625
6:45 PM	48.7	48.7	0	0	54.143	-5.443	29.62625
7:00 PM	48.7	49.5	-0.8	0.64	54.143	-5.443	29.62625
7:15 PM	48.7	50.3	-1.6	2.56	54.143	-5.443	29.62625
7:30 PM	48.7	51.2	-2.5	6.25	54.143	-5.443	29.62625
7:45 PM	48.7	52.2	-3.5	12.25	54.143	-5.443	29.62625
8:00 PM	48.7	53.1	-4.4	19.36	54.143	-5.443	29.62625
8:15 PM	48.7	54.1	-5.4	29.16	54.143	-5.443	29.62625
8:30 PM	48.7	55.1	-6.4	40.96	54.143	-5.443	29.62625
8:45 PM	48.8	56.1	-7.3	53.29	54.143	-5.343	28.54765
9:00 PM	49.8	57.2	-7.4	54.76	54.143	-4.343	18.86165
9:15 PM	50	58.2	-8.2	67.24	54.143	-4.143	17.16445
9:30 PM	52.1	59.3	-7.2	51.84	54.143	-2.043	4.173849
9:45 PM	53	60.3	-7.3	53.29	54.143	-1.143	1.306449
10:00 PM	53.2	61.4	-8.2	67.24	54.143	-0.943	0.889249
10:15 PM	54.3	62.3	-8	64	54.143	0.157	0.024649
10:30 PM	55.2	63.1	-7.9	62.41	54.143	1.057	1.117249
10:45 PM	56.4	63.9	-7.5	56.25	54.143	2.257	5.094049
11:00 PM	57.5	64.6	-7.1	50.41	54.143	3.357	11.26945
11:15 PM	58.6	65.2	-6.6	43.56	54.143	4.457	19.86485
11:30 PM	59.5	65.7	-6.2	38.44	54.143	5.357	28.69745
11:45 PM	59.7	66.1	-6.4	40.96	54.143	5.557	30.88025
12:00 AM	60.8	66.5	-5.7	32.49	54.143	6.657	44.31565
12:15 AM	61.8	66.7	-4.9	24.01	54.143	7.657	58.62965
12:30 AM	62.9	66.9	-4	16	54.143	8.757	76.68505
12:45 AM	64	67	-3	9	54.143	9.857	97.16045
1:00 AM	64.9	67	-2.1	4.41	54.143	10.757	115.713
1:15 AM	64.9	66.9	-2	4	54.143	10.757	115.713
1:30 AM	64.9	66.7	-1.8	3.24	54.143	10.757	115.713
1:45 AM	64.9	66.3	-1.4	1.96	54.143	10.757	115.713
2:00 AM	64.9	65.8	-0.9	0.81	54.143	10.757	115.713
2:15 AM	64.9	65.1	-0.2	0.04	54.143	10.757	115.713
2:30 AM	64.8	64.3	0.5	0.25	54.143	10.657	113.5716
2:45 AM	63.9	63.6	0.3	0.09	54.143	9.757	95.19905
3:00 AM	63.4	62.9	0.5	0.25	54.143	9.257	85.69205
3:15 AM	59.4	62.2	-2.8	7.84	54.143	5.257	27.63605
3:30 AM	58.3	61.5	-3.2	10.24	54.143	4.157	17.28065

3:45 AM	57.3	60.9	-3.6	12.96	54.143	3.157	9.966649
4:00 AM	56.3	60.3	-4	16	54.143	2.157	4.652649
4:15 AM	56.2	59.7	-3.5	12.25	54.143	2.057	4.231249
4:30 AM	55.3	59.1	-3.8	14.44	54.143	1.157	1.338649
4:45 AM	55.2	58.6	-3.4	11.56	54.143	1.057	1.117249
5:00 AM	55.2	58.1	-2.9	8.41	54.143	1.057	1.117249
5:15 AM	55.2	57.6	-2.4	5.76	54.143	1.057	1.117249
5:30 AM	55.2	57.1	-1.9	3.61	54.143	1.057	1.117249
5:45 AM	55.2	56.7	-1.5	2.25	54.143	1.057	1.117249
6:00 AM	55.2	56.2	-1	1	54.143	1.057	1.117249
6:15 AM	55.2	55.8	-0.6	0.36	54.143	1.057	1.117249
6:30 AM	55.2	55.4	-0.2	0.04	54.143	1.057	1.117249
6:45 AM	55.1	55	0.1	0.01	54.143	0.957	0.915849
7:00 AM	54.1	54.7	-0.6	0.36	54.143	-0.043	0.001849
7:15 AM	54	54.3	-0.3	0.09	54.143	-0.143	0.020449
7:30 AM	53	54	-1	1	54.143	-1.143	1.306449
7:45 AM	53	53.6	-0.6	0.36	54.143	-1.143	1.306449
8:00 AM	52.9	53.3	-0.4	0.16	54.143	-1.243	1.545049
8:15 AM	52	53	-1	1	54.143	-2.143	4.592449
8:30 AM	51.8	52.7	-0.9	0.81	54.143	-2.343	5.489649
8:45 AM	50.9	52.5	-1.6	2.56	54.143	-3.243	10.51705
9:00 AM	50.7	52.2	-1.5	2.25	54.143	-3.443	11.85425
9:15 AM	49.8	51.9	-2.1	4.41	54.143	-4.343	18.86165
9:30 AM	49.8	51.7	-1.9	3.61	54.143	-4.343	18.86165
9:45 AM	49.7	51.5	-1.8	3.24	54.143	-4.443	19.74025
10:00 AM	48.7	51.2	-2.5	6.25	54.143	-5.443	29.62625
10:15 AM	48.7	51	-2.3	5.29	54.143	-5.443	29.62625
10:30 AM	48.7	50.8	-2.1	4.41	54.143	-5.443	29.62625
10:45 AM	48.6	50.6	-2	4	54.143	-5.543	30.72485
11:00 AM	47.6	50.4	-2.8	7.84	54.143	-6.543	42.81085
11:15 AM	47.6	50.3	-2.7	7.29	54.143	-6.543	42.81085
11:30 AM	47.5	50.1	-2.6	6.76	54.143	-6.643	44.12945
11:45 AM	46.5	49.9	-3.4	11.56	54.143	-7.643	58.41545
$\sum Q_i$	4060.7	$\Sigma(Q_i - F_i)^2 =$		1099.3	$\sum(Q_i-Q_{ag})^2=$		2390.54

20/03/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	$(Qi\text{-}Fi)^2$	*Qag*	*Qi-Qag*	$(Qi\text{-}Qag)^2$
7:00 PM	64.8	64.5	0.3	0.09	73.195	-8.395	70.47602
7:15 PM	64	64.5	-0.5	0.25	73.195	-9.195	84.54802
7:30 PM	64.9	64.6	0.3	0.09	73.195	-8.295	68.80702
7:45 PM	65.1	64.8	0.3	0.09	73.195	-8.095	65.52903
8:00 PM	66	65.1	0.9	0.81	73.195	-7.195	51.76802
8:15 PM	66.1	65.4	0.7	0.49	73.195	-7.095	50.33903
8:30 PM	67.1	65.9	1.2	1.44	73.195	-6.095	37.14903
8:45 PM	67.2	66.4	0.8	0.64	73.195	-5.995	35.94002
9:00 PM	68.3	66.9	1.4	1.96	73.195	-4.895	23.96103
9:15 PM	69.4	67.5	1.9	3.61	73.195	-3.795	14.40202
9:30 PM	70.3	68.1	2.2	4.84	73.195	-2.895	8.381025
9:45 PM	70.4	68.7	1.7	2.89	73.195	-2.795	7.812025
10:00 PM	71.4	69.4	2	4	73.195	-1.795	3.222025
10:15 PM	71.4	70	1.4	1.96	73.195	-1.795	3.222025
10:30 PM	71.4	70.7	0.7	0.49	73.195	-1.795	3.222025
10:45 PM	71.6	71.4	0.2	0.04	73.195	-1.595	2.544025
11:00 PM	73.5	72.1	1.4	1.96	73.195	0.305	0.093025
11:15 PM	73.6	72.8	0.8	0.64	73.195	0.405	0.164025
11:30 PM	74.6	73.5	1.1	1.21	73.195	1.405	1.974025
11:45 PM	74.8	74.2	0.6	0.36	73.195	1.605	2.576025
12:00 AM	76.8	74.9	1.9	3.61	73.195	3.605	12.99603
12:15 AM	77.9	75.6	2.3	5.29	73.195	4.705	22.13703
12:30 AM	79	76.1	2.9	8.41	73.195	5.805	33.69803
12:45 AM	80	76.6	3.4	11.56	73.195	6.805	46.30803
1:00 AM	81	77.1	3.9	15.21	73.195	7.805	60.91803
1:15 AM	81	77.5	3.5	12.25	73.195	7.805	60.91803
1:30 AM	82	77.9	4.1	16.81	73.195	8.805	77.52803
1:45 AM	82.1	78.1	4	16	73.195	8.905	79.29903
2:00 AM	82	78.4	3.6	12.96	73.195	8.805	77.52803
2:15 AM	82	78.5	3.5	12.25	73.195	8.805	77.52803
2:30 AM	81.9	78.7	3.2	10.24	73.195	8.705	75.77703
2:45 AM	81.9	78.7	3.2	10.24	73.195	8.705	75.77703
3:00 AM	81.5	78.7	2.8	7.84	73.195	8.305	68.97303
3:15 AM	81	78.6	2.4	5.76	73.195	7.805	60.91803
3:30 AM	80.8	78.5	2.3	5.29	73.195	7.605	57.83603
3:45 AM	79.9	78.2	1.7	2.89	73.195	6.705	44.95703
4:00 AM	79.8	77.8	2	4	73.195	6.605	43.62603
4:15 AM	78.7	77.4	1.3	1.69	73.195	5.505	30.30503
4:30 AM	77.7	76.9	0.8	0.64	73.195	4.505	20.29503
4:45 AM	76.7	76.4	0.3	0.09	73.195	3.505	12.28503
5:00 AM	76.6	75.9	0.7	0.49	73.195	3.405	11.59403
5:15 AM	75.5	75.5	0	0	73.195	2.305	5.313025

5:30 AM	74.6	75	-0.4	0.16	73.195	1.405	1.974025
5:45 AM	74.5	74.6	-0.1	0.01	73.195	1.305	1.703025
6:00 AM	73.4	74.2	-0.8	0.64	73.195	0.205	0.042025
6:15 AM	72.3	73.8	-1.5	2.25	73.195	-0.895	0.801025
6:30 AM	71.4	73.4	-2	4	73.195	-1.795	3.222025
6:45 AM	71.2	73	-1.8	3.24	73.195	-1.995	3.980025
7:00 AM	70.3	72.7	-2.4	5.76	73.195	-2.895	8.381025
7:15 AM	70.1	72.4	-2.3	5.29	73.195	-3.095	9.579025
7:30 AM	68.2	72	-3.8	14.44	73.195	-4.995	24.95002
7:45 AM	68.2	71.7	-3.5	12.25	73.195	-4.995	24.95002
8:00 AM	68	71.4	-3.4	11.56	73.195	-5.195	26.98802
8:15 AM	67.1	71.1	-4	16	73.195	-6.095	37.14903
8:30 AM	67	70.9	-3.9	15.21	73.195	-6.195	38.37802
8:45 AM	65.9	70.6	-4.7	22.09	73.195	-7.295	53.21702
9:00 AM	64.9	70.4	-5.5	30.25	73.195	-8.295	68.80702
9:15 AM	64.9	70.1	-5.2	27.04	73.195	-8.295	68.80702
9:30 AM	64.8	69.9	-5.1	26.01	73.195	-8.395	70.47602
$\sum Qi$	4318.5	$\Sigma(Qi - Fi)^2 =$		387.58	$\sum(Qi\text{-}Qag)^2=$		2036.05

12/11/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
1:15 PM	34.5	34.4	0.1	0.01	60.666	-26.166	684.6596
1:30 PM	37.5	34.5	3	9	60.666	-23.166	536.6636
1:45 PM	40.6	34.8	5.8	33.64	60.666	-20.066	402.6444
2:00 PM	43.2	35.5	7.7	59.29	60.666	-17.466	305.0612
2:15 PM	45.6	36.3	9.3	86.49	60.666	-15.066	226.9844
2:30 PM	48.5	37.3	11.2	125.44	60.666	-12.166	148.0116
2:45 PM	50.2	38.5	11.7	136.89	60.666	-10.466	109.5372
3:00 PM	50.9	40.3	10.6	112.36	60.666	-9.766	95.37476
3:15 PM	51.3	42.6	8.7	75.69	60.666	-9.366	87.72196
3:30 PM	52	45.5	6.5	42.25	60.666	-8.666	75.09956
3:45 PM	52	48.8	3.2	10.24	60.666	-8.666	75.09956
4:00 PM	54.6	52.4	2.2	4.84	60.666	-6.066	36.79636
4:15 PM	55.7	56.2	-0.5	0.25	60.666	-4.966	24.66116
4:30 PM	57.2	60.1	-2.9	8.41	60.666	-3.466	12.01316
4:45 PM	59.8	64.1	-4.3	18.49	60.666	-0.866	0.749956
5:00 PM	62.6	68.2	-5.6	31.36	60.666	1.934	3.740356
5:15 PM	65	72.1	-7.1	50.41	60.666	4.334	18.78356
5:30 PM	67.5	76	-8.5	72.25	60.666	6.834	46.70356
5:45 PM	69	79.7	-10.7	114.49	60.666	8.334	69.45556
6:00 PM	69.9	83.3	-13.4	179.56	60.666	9.234	85.26676
6:15 PM	70	86.4	-16.4	268.96	60.666	9.334	87.12356
6:30 PM	71.6	89.2	-17.6	309.76	60.666	10.934	119.5524
6:45 PM	75.7	91.4	-15.7	246.49	60.666	15.034	226.0212
7:00 PM	81	93.2	-12.2	148.84	60.666	20.334	413.4716
7:15 PM	85.6	94.5	-8.9	79.21	60.666	24.934	621.7044
7:30 PM	89.1	95.2	-6.1	37.21	60.666	28.434	808.4924
7:45 PM	91.7	95.3	-3.6	12.96	60.666	31.034	963.1092
8:00 PM	92.9	95	-2.1	4.41	60.666	32.234	1039.031
8:15 PM	93.1	94.3	-1.2	1.44	60.666	32.434	1051.964
8:30 PM	92.4	93.2	-0.8	0.64	60.666	31.734	1007.047
8:45 PM	91.9	91.6	0.3	0.09	60.666	31.234	975.5628
9:00 PM	90.2	89.5	0.7	0.49	60.666	29.534	872.2572
9:15 PM	87.8	87.2	0.6	0.36	60.666	27.134	736.254
9:30 PM	85.9	84.9	1	1	60.666	25.234	636.7548
9:45 PM	84.3	82.6	1.7	2.89	60.666	23.634	558.566
10:00 PM	82.2	80.5	1.7	2.89	60.666	21.534	463.7132
10:15 PM	80.5	78.4	2.1	4.41	60.666	19.834	393.3876
10:30 PM	79.5	76.5	3	9	60.666	18.834	354.7196
10:45 PM	78	74.6	3.4	11.56	60.666	17.334	300.4676
11:00 PM	76.3	72.8	3.5	12.25	60.666	15.634	244.422
11:15 PM	75.2	71.1	4.1	16.81	60.666	14.534	211.2372
11:30 PM	74.1	69.5	4.6	21.16	60.666	13.434	180.4724

11:45 PM	72.6	67.9	4.7	22.09	60.666	11.934	142.4204
12:00 AM	71.4	66.4	5	25	60.666	10.734	115.2188
12:15 AM	70.9	65	5.9	34.81	60.666	10.234	104.7348
12:30 AM	70	63.6	6.4	40.96	60.666	9.334	87.12356
12:45 AM	68.2	62.3	5.9	34.81	60.666	7.534	56.76116
1:00 AM	67.7	61.1	6.6	43.56	60.666	7.034	49.47716
1:15 AM	66.6	59.9	6.7	44.89	60.666	5.934	35.21236
1:30 AM	65.6	58.8	6.8	46.24	60.666	4.934	24.34436
1:45 AM	65.2	57.7	7.5	56.25	60.666	4.534	20.55716
2:00 AM	65	56.7	8.3	68.89	60.666	4.334	18.78356
2:15 AM	64.9	55.7	9.2	84.64	60.666	4.234	17.92676
2:30 AM	64.5	54.7	9.8	96.04	60.666	3.834	14.69956
2:45 AM	63.9	53.8	10.1	102.01	60.666	3.234	10.45876
3:00 AM	63	53	10	100	60.666	2.334	5.447556
3:15 AM	61.7	52.1	9.6	92.16	60.666	1.034	1.069156
3:30 AM	61.3	51.3	10	100	60.666	0.634	0.401956
3:45 AM	60.2	50.6	9.6	92.16	60.666	-0.466	0.217156
4:00 AM	59.5	49.9	9.6	92.16	60.666	-1.166	1.359556
4:15 AM	59.1	49.2	9.9	98.01	60.666	-1.566	2.452356
4:30 AM	58.5	48.5	10	100	60.666	-2.166	4.691556
4:45 AM	58	47.9	10.1	102.01	60.666	-2.666	7.107556
5:00 AM	56.9	47.3	9.6	92.16	60.666	-3.766	14.18276
5:15 AM	56.3	46.7	9.6	92.16	60.666	-4.366	19.06196
5:30 AM	56.3	46.2	10.1	102.01	60.666	-4.366	19.06196
5:45 AM	55.9	45.7	10.2	104.04	60.666	-4.766	22.71476
6:00 AM	55.2	45.2	10	100	60.666	-5.466	29.87716
6:15 AM	55.2	44.7	10.5	110.25	60.666	-5.466	29.87716
6:30 AM	54.8	44.2	10.6	112.36	60.666	-5.866	34.40996
6:45 AM	53.7	43.8	9.9	98.01	60.666	-6.966	48.52516
7:00 AM	53	43.4	9.6	92.16	60.666	-7.666	58.76756
7:15 AM	53	43	10	100	60.666	-7.666	58.76756
7:30 AM	53	42.6	10.4	108.16	60.666	-7.666	58.76756
7:45 AM	53	42.2	10.8	116.64	60.666	-7.666	58.76756
8:00 AM	52.6	41.9	10.7	114.49	60.666	-8.066	65.06036
8:15 AM	52	41.5	10.5	110.25	60.666	-8.666	75.09956
8:30 AM	52	41.2	10.8	116.64	60.666	-8.666	75.09956
8:45 AM	51.5	40.9	10.6	112.36	60.666	-9.166	84.01556
9:00 AM	50.9	40.6	10.3	106.09	60.666	-9.766	95.37476
9:15 AM	50.4	40.4	10	100	60.666	-10.266	105.3908
9:30 AM	49.8	40.1	9.7	94.09	60.666	-10.866	118.07
9:45 AM	49.8	39.8	10	100	60.666	-10.866	118.07
10:00 AM	49.8	39.6	10.2	104.04	60.666	-10.866	118.07
10:15 AM	49.8	39.4	10.4	108.16	60.666	-10.866	118.07
10:30 AM	49.3	39.1	10.2	104.04	60.666	-11.366	129.186

10:45 AM	48.7	38.9	9.8	96.04	60.666	-11.966	143.1852
11:00 AM	48.7	38.7	10	100	60.666	-11.966	143.1852
11:15 AM	48.7	38.5	10.2	104.04	60.666	-11.966	143.1852
11:30 AM	48.7	38.4	10.3	106.09	60.666	-11.966	143.1852
11:45 AM	48.2	38.2	10	100	60.666	-12.466	155.4012
12:00 PM	47.1	38	9.1	82.81	60.666	-13.566	184.0364
12:15 PM	46.5	37.9	8.6	73.96	60.666	-14.166	200.6756
12:30 PM	46.5	37.7	8.8	77.44	60.666	-14.166	200.6756
12:45 PM	46.5	37.6	8.9	79.21	60.666	-14.166	200.6756
1:00 PM	46.5	37.4	9.1	82.81	60.666	-14.166	200.6756
1:15 PM	46.5	37.3	9.2	84.64	60.666	-14.166	200.6756
1:30 PM	46.5	37.2	9.3	86.49	60.666	-14.166	200.6756
1:45 PM	46.5	37	9.5	90.25	60.666	-14.166	200.6756
2:00 PM	46.1	36.9	9.2	84.64	60.666	-14.566	212.1684
2:15 PM	45.4	36.8	8.6	73.96	60.666	-15.266	233.0508
2:30 PM	44.9	36.7	8.2	67.24	60.666	-15.766	248.5668
2:45 PM	44.1	36.6	7.5	56.25	60.666	-16.566	274.4324
3:00 PM	44.6	36.5	8.1	65.61	60.666	-16.066	258.1164
$\sum Q_i$	6309.3	$\Sigma(Q_i - F_i)^2 =$		7750.47	$\sum(Q_i - Q_{ag})^2=$		21128.35

13/11/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
3:15 PM	45.9	45	0.9	0.81	53.113	-7.213	52.02737
3:30 PM	46.5	45.1	1.4	1.96	53.113	-6.613	43.73177
3:45 PM	47	45.3	1.7	2.89	53.113	-6.113	37.36877
4:00 PM	48.1	45.7	2.4	5.76	53.113	-5.013	25.13017
4:15 PM	48.7	46.3	2.4	5.76	53.113	-4.413	19.47457
4:30 PM	48.7	47	1.7	2.89	53.113	-4.413	19.47457
4:45 PM	49.1	47.9	1.2	1.44	53.113	-4.013	16.10417
5:00 PM	50.2	48.8	1.4	1.96	53.113	-2.913	8.485569
5:15 PM	51.3	49.8	1.5	2.25	53.113	-1.813	3.286969
5:30 PM	52	51	1	1	53.113	-1.113	1.238769
5:45 PM	52	52.2	-0.2	0.04	53.113	-1.113	1.238769
6:00 PM	52.4	53.4	-1	1	53.113	-0.713	0.508369
6:15 PM	53.5	54.7	-1.2	1.44	53.113	0.387	0.149769
6:30 PM	54.6	56.1	-1.5	2.25	53.113	1.487	2.211169
6:45 PM	55.2	57.4	-2.2	4.84	53.113	2.087	4.355569
7:00 PM	56.3	58.6	-2.3	5.29	53.113	3.187	10.15697
7:15 PM	56.8	59.8	-3	9	53.113	3.687	13.59397
7:30 PM	57.4	60.8	-3.4	11.56	53.113	4.287	18.37837
7:45 PM	58	61.8	-3.8	14.44	53.113	4.887	23.88277
8:00 PM	58.5	62.6	-4.1	16.81	53.113	5.387	29.01977
8:15 PM	58.9	63.3	-4.4	19.36	53.113	5.787	33.48937
8:30 PM	59.5	63.8	-4.3	18.49	53.113	6.387	40.79377
8:45 PM	59.7	64.2	-4.5	20.25	53.113	6.587	43.38857
9:00 PM	59.7	64.4	-4.7	22.09	53.113	6.587	43.38857
9:15 PM	59.9	64.5	-4.6	21.16	53.113	6.787	46.06337
9:30 PM	60	64.3	-4.3	18.49	53.113	6.887	47.43077
9:45 PM	60	63.8	-3.8	14.44	53.113	6.887	47.43077
10:00 PM	60	63.3	-3.3	10.89	53.113	6.887	47.43077
10:15 PM	60	62.7	-2.7	7.29	53.113	6.887	47.43077
10:30 PM	60	62.1	-2.1	4.41	53.113	6.887	47.43077
10:45 PM	60	61.4	-1.4	1.96	53.113	6.887	47.43077
11:00 PM	59.5	60.8	-1.3	1.69	53.113	6.387	40.79377
11:15 PM	59.1	60.1	-1	1	53.113	5.987	35.84417
11:30 PM	58.5	59.5	-1	1	53.113	5.387	29.01977
11:45 PM	58.5	58.8	-0.3	0.09	53.113	5.387	29.01977
12:00 AM	58	58.2	-0.2	0.04	53.113	4.887	23.88277
12:15 AM	57.4	57.6	-0.2	0.04	53.113	4.287	18.37837
12:30 AM	57.4	57.1	0.3	0.09	53.113	4.287	18.37837
12:45 AM	57.2	56.5	0.7	0.49	53.113	4.087	16.70357
1:00 AM	57.1	56	1.1	1.21	53.113	3.987	15.89617
1:15 AM	57	55.5	1.5	2.25	53.113	3.887	15.10877
1:30 AM	56.9	55	1.9	3.61	53.113	3.787	14.34137

1:45 AM	56.8	54.6	2.2	4.84	53.113	3.687	13.59397
2:00 AM	56.7	54.2	2.5	6.25	53.113	3.587	12.86657
2:15 AM	56.5	53.8	2.7	7.29	53.113	3.387	11.47177
2:30 AM	56.5	53.4	3.1	9.61	53.113	3.387	11.47177
2:45 AM	56	53	3	9	53.113	2.887	8.334769
3:00 AM	55.9	52.6	3.3	10.89	53.113	2.787	7.767369
3:15 AM	55.7	52.3	3.4	11.56	53.113	2.587	6.692569
3:30 AM	55.5	52	3.5	12.25	53.113	2.387	5.697769
3:45 AM	55.1	51.7	3.4	11.56	53.113	1.987	3.948169
4:00 AM	55	51.4	3.6	12.96	53.113	1.887	3.560769
4:15 AM	54.9	51.1	3.8	14.44	53.113	1.787	3.193369
4:30 AM	54.9	50.8	4.1	16.81	53.113	1.787	3.193369
4:45 AM	54.5	50.6	3.9	15.21	53.113	1.387	1.923769
5:00 AM	54	50.3	3.7	13.69	53.113	0.887	0.786769
5:15 AM	54	50.1	3.9	15.21	53.113	0.887	0.786769
5:30 AM	53.9	49.9	4	16	53.113	0.787	0.619369
5:45 AM	53.7	49.6	4.1	16.81	53.113	0.587	0.344569
6:00 AM	53.5	49.4	4.1	16.81	53.113	0.387	0.149769
6:15 AM	53.5	49.2	4.3	18.49	53.113	0.387	0.149769
6:30 AM	53.4	49	4.4	19.36	53.113	0.287	0.082369
6:45 AM	53	48.9	4.1	16.81	53.113	-0.113	0.012769
7:00 AM	53	48.7	4.3	18.49	53.113	-0.113	0.012769
7:15 AM	52.5	48.5	4	16	53.113	-0.613	0.375769
7:30 AM	52.3	48.4	3.9	15.21	53.113	-0.813	0.660969
7:45 AM	52	48.2	3.8	14.44	53.113	-1.113	1.238769
8:00 AM	51.5	48.1	3.4	11.56	53.113	-1.613	2.601769
8:15 AM	51	47.9	3.1	9.61	53.113	-2.113	4.464769
8:30 AM	50.8	47.8	3	9	53.113	-2.313	5.349969
8:45 AM	50.5	47.7	2.8	7.84	53.113	-2.613	6.827769
9:00 AM	50	47.6	2.4	5.76	53.113	-3.113	9.690769
9:15 AM	49.9	47.5	2.4	5.76	53.113	-3.213	10.32337
9:30 AM	49.9	47.3	2.6	6.76	53.113	-3.213	10.32337
9:45 AM	49.8	47.2	2.6	6.76	53.113	-3.313	10.97597
10:00 AM	49.8	47.1	2.7	7.29	53.113	-3.313	10.97597
10:15 AM	49.8	47	2.8	7.84	53.113	-3.313	10.97597
10:30 AM	49.5	47	2.5	6.25	53.113	-3.613	13.05377
10:45 AM	49.3	46.9	2.4	5.76	53.113	-3.813	14.53897
11:00 AM	49	46.8	2.2	4.84	53.113	-4.113	16.91677
11:15 AM	48.9	46.7	2.2	4.84	53.113	-4.213	17.74937
11:30 AM	48.9	46.6	2.3	5.29	53.113	-4.213	17.74937
11:45 AM	48.7	46.6	2.1	4.41	53.113	-4.413	19.47457
12:00 PM	48.7	46.5	2.2	4.84	53.113	-4.413	19.47457
12:15 PM	48.5	46.4	2.1	4.41	53.113	-4.613	21.27977
12:30 PM	48.3	46.4	1.9	3.61	53.113	-4.813	23.16497

12:45 PM	48	46.3	1.7	2.89	53.113	-5.113	26.14277
1:00 PM	47.6	46.2	1.4	1.96	53.113	-5.513	30.39317
1:15 PM	47.6	46.2	1.4	1.96	53.113	-5.513	30.39317
1:30 PM	47.1	46.1	1	1	53.113	-6.013	36.15617
1:45 PM	47	46.1	0.9	0.81	53.113	-6.113	37.36877
2:00 PM	47	46	1	1	53.113	-6.113	37.36877
2:15 PM	46.9	46	0.9	0.81	53.113	-6.213	38.60137
2:30 PM	46.9	45.9	1	1	53.113	-6.213	38.60137
2:45 PM	46.5	45.9	0.6	0.36	53.113	-6.613	43.73177
3:00 PM	46.2	45.9	0.3	0.09	53.113	-6.913	47.78957
3:15 PM	46.1	45.8	0.3	0.09	53.113	-7.013	49.18217
3:30 PM	46.1	45.8	0.3	0.09	53.113	-7.013	49.18217
$\sum Qi$	5205.1	$\Sigma(Qi - Fi)^2 =$		738.21	$\sum(Qi\text{-}Qag)^2=$		1888.65

12/10/2013							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
7:30 PM	28.2	27	1.2	1.44	65.413	-37.213	1384.807
7:45 PM	27.8	27.2	0.6	0.36	65.413	-37.613	1414.738
8:00 PM	31.2	28.4	2.8	7.84	65.413	-34.213	1170.529
8:15 PM	39.3	30.8	8.5	72.25	65.413	-26.113	681.8888
8:30 PM	43.6	34.3	9.3	86.49	65.413	-21.813	475.807
8:45 PM	44.1	38.6	5.5	30.25	65.413	-21.313	454.244
9:00 PM	46.1	43.5	2.6	6.76	65.413	-19.313	372.992
9:15 PM	47.4	49	-1.6	2.56	65.413	-18.013	324.4682
9:30 PM	48.5	54.8	-6.3	39.69	65.413	-16.913	286.0496
9:45 PM	49.6	61	-11.4	129.96	65.413	-15.813	250.051
10:00 PM	51.6	67.5	-15.9	252.81	65.413	-13.813	190.799
10:15 PM	55.6	74.2	-18.6	345.96	65.413	-9.813	96.29497
10:30 PM	59.9	81	-21.1	445.21	65.413	-5.513	30.39317
10:45 PM	63.3	88	-24.7	610.09	65.413	-2.113	4.464769
11:00 PM	67.4	94.8	-27.4	750.76	65.413	1.987	3.948169
11:15 PM	70.8	101.1	-30.3	918.09	65.413	5.387	29.01977
11:30 PM	76.7	106.9	-30.2	912.04	65.413	11.287	127.3964
11:45 PM	82.2	112	-29.8	888.04	65.413	16.787	281.8034
12:00 AM	86.8	116.4	-29.6	876.16	65.413	21.387	457.4038
12:15 AM	90.6	120.1	-29.5	870.25	65.413	25.187	634.385
12:30 AM	93.2	123	-29.8	888.04	65.413	27.787	772.1174
12:45 AM	95.7	125.3	-29.6	876.16	65.413	30.287	917.3024
1:00 AM	97.1	126.7	-29.6	876.16	65.413	31.687	1004.066
1:15 AM	98.4	127.3	-28.9	835.21	65.413	32.987	1088.142
1:30 AM	99.6	126.9	-27.3	745.29	65.413	34.187	1168.751
1:45 AM	99.8	125.2	-25.4	645.16	65.413	34.387	1182.466
2:00 AM	98.8	122.3	-23.5	552.25	65.413	33.387	1114.692
2:15 AM	97.5	118.6	-21.1	445.21	65.413	32.087	1029.576
2:30 AM	96.3	114.7	-18.4	338.56	65.413	30.887	954.0068
2:45 AM	95.1	110.9	-15.8	249.64	65.413	29.687	881.318
3:00 AM	93.8	107.2	-13.4	179.56	65.413	28.387	805.8218
3:15 AM	90.6	103.7	-13.1	171.61	65.413	25.187	634.385
3:30 AM	88	100.3	-12.3	151.29	65.413	22.587	510.1726
3:45 AM	85.6	97	-11.4	129.96	65.413	20.187	407.515
4:00 AM	83.4	93.9	-10.5	110.25	65.413	17.987	323.5322
4:15 AM	79.6	90.9	-11.3	127.69	65.413	14.187	201.271
4:30 AM	78	88.1	-10.1	102.01	65.413	12.587	158.4326
4:45 AM	75.1	85.4	-10.3	106.09	65.413	9.687	93.83797
5:00 AM	71.9	82.8	-10.9	118.81	65.413	6.487	42.08117
5:15 AM	69.6	80.3	-10.7	114.49	65.413	4.187	17.53097
5:30 AM	66.6	77.9	-11.3	127.69	65.413	1.187	1.408969
5:45 AM	64.2	75.7	-11.5	132.25	65.413	-1.213	1.471369

6:00 AM	61.2	73.5	-12.3	151.29	65.413	-4.213	17.74937
6:15 AM	58.8	71.4	-12.6	158.76	65.413	-6.613	43.73177
6:30 AM	56.7	69.5	-12.8	163.84	65.413	-8.713	75.91637
6:45 AM	54.5	67.6	-13.1	171.61	65.413	-10.913	119.0936
7:00 AM	51.4	65.8	-14.4	207.36	65.413	-14.013	196.3642
7:15 AM	50	64	-14	196	65.413	-15.413	237.5606
7:30 AM	47.1	62.4	-15.3	234.09	65.413	-18.313	335.366
7:45 AM	44.5	60.8	-16.3	265.69	65.413	-20.913	437.3536
8:00 AM	41.4	59.3	-17.9	320.41	65.413	-24.013	576.6242
8:15 AM	38.3	57.9	-19.6	384.16	65.413	-27.113	735.1148
8:30 AM	36.5	56.5	-20	400	65.413	-28.913	835.9616
8:45 AM	33.8	55.2	-21.4	457.96	65.413	-31.613	999.3818
9:00 AM	31	53.9	-22.9	524.41	65.413	-34.413	1184.255
9:15 AM	29.3	52.7	-23.4	547.56	65.413	-36.113	1304.149
$\sum Qi$	3663.1	$\Sigma(Qi - Fi)^2 =$		19453.53	$\sum(Qi\text{-}Qag)^2=$		29080

Appendix E:

Efficiency Index Data

(Snyder UH Method)

Appendix E: Efficiency Index Data (Snyder UH Method)

04/09/2010							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
6:45 PM	22.4	21	1.4	1.96	35.536	-13.136	172.5545
7:00 PM	23.6	21.1	2.5	6.25	35.536	-11.936	142.4681
7:15 PM	25.8	21.5	4.3	18.49	35.536	-9.736	94.7897
7:30 PM	27.4	22.2	5.2	27.04	35.536	-8.136	66.1945
7:45 PM	28.7	23.3	5.4	29.16	35.536	-6.836	46.7309
8:00 PM	30.1	24.7	5.4	29.16	35.536	-5.436	29.5501
8:15 PM	32.5	26.3	6.2	38.44	35.536	-3.036	9.217296
8:30 PM	34.4	28	6.4	40.96	35.536	-1.136	1.290496
8:45 PM	35.8	29.9	5.9	34.81	35.536	0.264	0.069696
9:00 PM	37.4	31.9	5.5	30.25	35.536	1.864	3.474496
9:15 PM	38.9	33.9	5	25	35.536	3.364	11.3165
9:30 PM	41.6	36.1	5.5	30.25	35.536	6.064	36.7721
9:45 PM	43.7	38.3	5.4	29.16	35.536	8.164	66.6509
10:00 PM	45.9	40.5	5.4	29.16	35.536	10.364	107.4125
10:15 PM	48.9	42.7	6.2	38.44	35.536	13.364	178.5965
10:30 PM	51.4	44.7	6.7	44.89	35.536	15.864	251.6665
10:45 PM	53.5	46.5	7	49	35.536	17.964	322.7053
11:00 PM	55.7	48.1	7.6	57.76	35.536	20.164	406.5869
11:15 PM	57.9	49.5	8.4	70.56	35.536	22.364	500.1485
11:30 PM	59.3	50.6	8.7	75.69	35.536	23.764	564.7277
11:45 PM	60.3	51.6	8.7	75.69	35.536	24.764	613.2557
12:00 AM	60.6	52.3	8.3	68.89	35.536	25.064	628.2041
12:15 AM	60.6	52.7	7.9	62.41	35.536	25.064	628.2041
12:30 AM	59.8	52.8	7	49	35.536	24.264	588.7417
12:45 AM	59.5	52.5	7	49	35.536	23.964	574.2733
1:00 AM	58.8	51.8	7	49	35.536	23.264	541.2137
1:15 AM	58.5	50.9	7.6	57.76	35.536	22.964	527.3453
1:30 AM	56.9	49.9	7	49	35.536	21.364	456.4205
1:45 AM	56.3	49	7.3	53.29	35.536	20.764	431.1437
2:00 AM	55.5	48	7.5	56.25	35.536	19.964	398.5613
2:15 AM	53.6	47.2	6.4	40.96	35.536	18.064	326.3081
2:30 AM	53	46.3	6.7	44.89	35.536	17.464	304.9913
2:45 AM	52.3	45.5	6.8	46.24	35.536	16.764	281.0317
3:00 AM	51.2	44.7	6.5	42.25	35.536	15.664	245.3609
3:15 AM	50.1	43.9	6.2	38.44	35.536	14.564	212.1101
3:30 AM	49	43.1	5.9	34.81	35.536	13.464	181.2793
3:45 AM	48.7	42.4	6.3	39.69	35.536	13.164	173.2909
4:00 AM	47.9	41.7	6.2	38.44	35.536	12.364	152.8685
4:15 AM	46.8	41	5.8	33.64	35.536	11.264	126.8777

4:30 AM	46.5	40.4	6.1	37.21	35.536	10.964	120.2093
4:45 AM	45.7	39.7	6	36	35.536	10.164	103.3069
5:00 AM	45.4	39.1	6.3	39.69	35.536	9.864	97.2985
5:15 AM	44.5	38.5	6	36	35.536	8.964	80.3533
5:30 AM	44.1	37.9	6.2	38.44	35.536	8.564	73.3421
5:45 AM	44.1	37.4	6.7	44.89	35.536	8.564	73.3421
6:00 AM	42.9	36.8	6.1	37.21	35.536	7.364	54.2285
6:15 AM	42.5	36.3	6.2	38.44	35.536	6.964	48.4973
6:30 AM	42.5	35.8	6.7	44.89	35.536	6.964	48.4973
6:45 AM	41.3	35.3	6	36	35.536	5.764	33.2237
7:00 AM	40.9	34.9	6	36	35.536	5.364	28.7725
7:15 AM	39.7	34.4	5.3	28.09	35.536	4.164	17.3389
7:30 AM	39.3	34	5.3	28.09	35.536	3.764	14.1677
7:45 AM	39.3	33.5	5.8	33.64	35.536	3.764	14.1677
8:00 AM	39.3	33.1	6.2	38.44	35.536	3.764	14.1677
8:15 AM	38.2	32.7	5.5	30.25	35.536	2.664	7.096896
8:30 AM	37.8	32.3	5.5	30.25	35.536	2.264	5.125696
8:45 AM	37.8	32	5.8	33.64	35.536	2.264	5.125696
9:00 AM	37.8	31.6	6.2	38.44	35.536	2.264	5.125696
9:15 AM	37.8	31.3	6.5	42.25	35.536	2.264	5.125696
9:30 AM	37.8	30.9	6.9	47.61	35.536	2.264	5.125696
9:45 AM	36.7	30.6	6.1	37.21	35.536	1.164	1.354896
10:00 AM	36.3	30.3	6	36	35.536	0.764	0.583696
10:15 AM	36.3	30	6.3	39.69	35.536	0.764	0.583696
10:30 AM	36.3	29.7	6.6	43.56	35.536	0.764	0.583696
10:45 AM	35.2	29.4	5.8	33.64	35.536	-0.336	0.112896
11:00 AM	34.8	29.1	5.7	32.49	35.536	-0.736	0.541696
11:15 AM	34.8	28.9	5.9	34.81	35.536	-0.736	0.541696
11:30 AM	34.8	28.6	6.2	38.44	35.536	-0.736	0.541696
11:45 AM	34.8	28.3	6.5	42.25	35.536	-0.736	0.541696
12:00 PM	34.8	28.1	6.7	44.89	35.536	-0.736	0.541696
12:15 PM	34.8	27.9	6.9	47.61	35.536	-0.736	0.541696
12:30 PM	34.8	27.6	7.2	51.84	35.536	-0.736	0.541696
12:45 PM	34.8	27.4	7.4	54.76	35.536	-0.736	0.541696
1:00 PM	34.8	27.2	7.6	57.76	35.536	-0.736	0.541696
1:15 PM	34.8	27	7.8	60.84	35.536	-0.736	0.541696
1:30 PM	34.8	26.8	8	64	35.536	-0.736	0.541696
1:45 PM	34.8	26.6	8.2	67.24	35.536	-0.736	0.541696
2:00 PM	34.8	26.4	8.4	70.56	35.536	-0.736	0.541696
2:15 PM	34.8	26.3	8.5	72.25	35.536	-0.736	0.541696
2:30 PM	34.8	26.1	8.7	75.69	35.536	-0.736	0.541696
2:45 PM	34.8	25.9	8.9	79.21	35.536	-0.736	0.541696
3:00 PM	34.8	25.8	9	81	35.536	-0.736	0.541696
3:15 PM	34.8	25.6	9.2	84.64	35.536	-0.736	0.541696

3:30 PM	34.8	25.5	9.3	86.49	35.536	-0.736	0.541696
3:45 PM	34.8	25.3	9.5	90.25	35.536	-0.736	0.541696
4:00 PM	34.8	25.2	9.6	92.16	35.536	-0.736	0.541696
4:15 PM	34.8	25	9.8	96.04	35.536	-0.736	0.541696
4:30 PM	34.8	24.9	9.9	98.01	35.536	-0.736	0.541696
4:45 PM	34.8	24.8	10	100	35.536	-0.736	0.541696
5:00 PM	33.7	24.6	9.1	82.81	35.536	-1.836	3.370896
5:15 PM	33.3	24.5	8.8	77.44	35.536	-2.236	4.999696
5:30 PM	33.3	24.4	8.9	79.21	35.536	-2.236	4.999696
5:45 PM	33.3	24.3	9	81	35.536	-2.236	4.999696
6:00 PM	33.3	24.2	9.1	82.81	35.536	-2.236	4.999696
6:15 PM	34.4	24.1	10.3	106.09	35.536	-1.136	1.290496
6:30 PM	33.7	24	9.7	94.09	35.536	-1.836	3.370896
6:45 PM	33.3	23.9	9.4	88.36	35.536	-2.236	4.999696
7:00 PM	33.3	23.8	9.5	90.25	35.536	-2.236	4.999696
7:15 PM	33.3	23.7	9.6	92.16	35.536	-2.236	4.999696
7:30 PM	33.3	23.6	9.7	94.09	35.536	-2.236	4.999696
7:45 PM	33.3	23.5	9.8	96.04	35.536	-2.236	4.999696
8:00 PM	33.3	23.4	9.9	98.01	35.536	-2.236	4.999696
8:15 PM	33.3	23.4	9.9	98.01	35.536	-2.236	4.999696
8:30 PM	33.3	23.3	10	100	35.536	-2.236	4.999696
8:45 PM	33.3	23.2	10.1	102.01	35.536	-2.236	4.999696
9:00 PM	33.3	23.1	10.2	104.04	35.536	-2.236	4.999696
9:15 PM	32.3	23.1	9.2	84.64	35.536	-3.236	10.4717
9:30 PM	31.9	23	8.9	79.21	35.536	-3.636	13.2205
9:45 PM	31.9	22.9	9	81	35.536	-3.636	13.2205
10:00 PM	31.9	22.9	9	81	35.536	-3.636	13.2205
10:15 PM	31.9	22.8	9.1	82.81	35.536	-3.636	13.2205
10:30 PM	30.9	22.7	8.2	67.24	35.536	-4.636	21.4925
10:45 PM	31.5	22.7	8.8	77.44	35.536	-4.036	16.2893
11:00 PM	30.9	22.6	8.3	68.89	35.536	-4.636	21.4925
11:15 PM	30.5	22.6	7.9	62.41	35.536	-5.036	25.3613
11:30 PM	30.5	22.5	8	64	35.536	-5.036	25.3613
11:45 PM	30.5	22.5	8	64	35.536	-5.036	25.3613
12:00 AM	30.5	22.4	8.1	65.61	35.536	-5.036	25.3613
12:15 AM	30.5	22.4	8.1	65.61	35.536	-5.036	25.3613
12:30 AM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
12:45 AM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
1:00 AM	30.5	22.3	8.2	67.24	35.536	-5.036	25.3613
1:15 AM	30.5	22.2	8.3	68.89	35.536	-5.036	25.3613
1:30 AM	29.5	22.2	7.3	53.29	35.536	-6.036	36.4333
1:45 AM	29.1	22.1	7	49	35.536	-6.436	41.4221
2:00 AM	29.1	22.1	7	49	35.536	-6.436	41.4221
2:15 AM	29.1	22.1	7	49	35.536	-6.436	41.4221

2:30 AM	29.1	22	7.1	50.41	35.536	-6.436	41.4221
2:45 AM	29.1	22	7.1	50.41	35.536	-6.436	41.4221
3:00 AM	29.1	22	7.1	50.41	35.536	-6.436	41.4221
3:15 AM	29.1	21.9	7.2	51.84	35.536	-6.436	41.4221
3:30 AM	29.1	21.9	7.2	51.84	35.536	-6.436	41.4221
3:45 AM	29.1	21.9	7.2	51.84	35.536	-6.436	41.4221
4:00 AM	29.1	21.8	7.3	53.29	35.536	-6.436	41.4221
4:15 AM	29.1	21.8	7.3	53.29	35.536	-6.436	41.4221
4:30 AM	28.1	21.8	6.3	39.69	35.536	-7.436	55.2941
4:45 AM	27.8	21.8	6	36	35.536	-7.736	59.8457
5:00 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:15 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:30 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
5:45 AM	27.8	21.7	6.1	37.21	35.536	-7.736	59.8457
6:00 AM	27.8	21.6	6.2	38.44	35.536	-7.736	59.8457
6:15 AM	27.8	21.6	6.2	38.44	35.536	-7.736	59.8457
6:30 AM	27.8	21.6	6.2	38.44	35.536	-7.736	59.8457
6:45 AM	27.8	21.6	6.2	38.44	35.536	-7.736	59.8457
7:00 AM	27.8	21.6	6.2	38.44	35.536	-7.736	59.8457
7:15 AM	27.8	21.5	6.3	39.69	35.536	-7.736	59.8457
7:30 AM	27.8	21.5	6.3	39.69	35.536	-7.736	59.8457
7:45 AM	26.8	21.5	5.3	28.09	35.536	-8.736	76.3177
8:00 AM	27.4	21.5	5.9	34.81	35.536	-8.136	66.1945
8:15 AM	26.8	21.5	5.3	28.09	35.536	-8.736	76.3177
8:30 AM	27.4	21.5	5.9	34.81	35.536	-8.136	66.1945
8:45 AM	26.8	21.4	5.4	29.16	35.536	-8.736	76.3177
9:00 AM	27.4	21.4	6	36	35.536	-8.136	66.1945
9:15 AM	26.8	21.4	5.4	29.16	35.536	-8.736	76.3177
9:30 AM	26.5	21.4	5.1	26.01	35.536	-9.036	81.6493
9:45 AM	26.5	21.4	5.1	26.01	35.536	-9.036	81.6493
10:00 AM	26.5	21.4	5.1	26.01	35.536	-9.036	81.6493
10:15 AM	26.5	21.4	5.1	26.01	35.536	-9.036	81.6493
10:30 AM	26.5	21.4	5.1	26.01	35.536	-9.036	81.6493
10:45 AM	26.5	21.3	5.2	27.04	35.536	-9.036	81.6493
11:00 AM	26.5	21.3	5.2	27.04	35.536	-9.036	81.6493
11:15 AM	26.5	21.3	5.2	27.04	35.536	-9.036	81.6493
11:30 AM	26.5	21.3	5.2	27.04	35.536	-9.036	81.6493
11:45 AM	26.5	21.3	5.2	27.04	35.536	-9.036	81.6493
12:00 PM	26.5	21.3	5.2	27.04	35.536	-9.036	81.6493
12:15 PM	25.5	21.3	4.2	17.64	35.536	-10.036	100.7213
12:30 PM	25.2	21.3	3.9	15.21	35.536	-10.336	106.8329
12:45 PM	25.2	21.3	3.9	15.21	35.536	-10.336	106.8329
1:00 PM	25.2	21.3	3.9	15.21	35.536	-10.336	106.8329
1:15 PM	25.2	21.2	4	16	35.536	-10.336	106.8329

1:30 PM	25.2	21.2	4	16	35.536	-10.336	106.8329
1:45 PM	25.2	21.2	4	16	35.536	-10.336	106.8329
2:00 PM	25.2	21.1	4.1	16.81	35.536	-10.336	106.8329
2:15 PM	24.3	21	3.3	10.89	35.536	-11.236	126.2477
2:30 PM	24.8	21	3.8	14.44	35.536	-10.736	115.2617
$\sum Qi$	6254.4	$\Sigma(Qi - Fi)^2 =$		8781.32	$\sum(Qi\text{-}Qag)^2=$		15460.75

19/03/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
5:15 PM	46.6	46	0.6	0.36	54.143	-7.543	56.89685
5:30 PM	47.6	46.1	1.5	2.25	54.143	-6.543	42.81085
5:45 PM	47.6	46.3	1.3	1.69	54.143	-6.543	42.81085
6:00 PM	47.7	46.8	0.9	0.81	54.143	-6.443	41.51225
6:15 PM	48.7	47.4	1.3	1.69	54.143	-5.443	29.62625
6:30 PM	48.7	48.1	0.6	0.36	54.143	-5.443	29.62625
6:45 PM	48.7	48.9	-0.2	0.04	54.143	-5.443	29.62625
7:00 PM	48.7	49.8	-1.1	1.21	54.143	-5.443	29.62625
7:15 PM	48.7	50.7	-2	4	54.143	-5.443	29.62625
7:30 PM	48.7	51.7	-3	9	54.143	-5.443	29.62625
7:45 PM	48.7	52.7	-4	16	54.143	-5.443	29.62625
8:00 PM	48.7	53.7	-5	25	54.143	-5.443	29.62625
8:15 PM	48.7	54.7	-6	36	54.143	-5.443	29.62625
8:30 PM	48.7	55.8	-7.1	50.41	54.143	-5.443	29.62625
8:45 PM	48.8	56.9	-8.1	65.61	54.143	-5.343	28.54765
9:00 PM	49.8	58	-8.2	67.24	54.143	-4.343	18.86165
9:15 PM	50	59.1	-9.1	82.81	54.143	-4.143	17.16445
9:30 PM	52.1	60.2	-8.1	65.61	54.143	-2.043	4.173849
9:45 PM	53	61.3	-8.3	68.89	54.143	-1.143	1.306449
10:00 PM	53.2	62.4	-9.2	84.64	54.143	-0.943	0.889249
10:15 PM	54.3	63.3	-9	81	54.143	0.157	0.024649
10:30 PM	55.2	64.2	-9	81	54.143	1.057	1.117249
10:45 PM	56.4	65	-8.6	73.96	54.143	2.257	5.094049
11:00 PM	57.5	65.7	-8.2	67.24	54.143	3.357	11.26945
11:15 PM	58.6	66.3	-7.7	59.29	54.143	4.457	19.86485
11:30 PM	59.5	66.8	-7.3	53.29	54.143	5.357	28.69745
11:45 PM	59.7	67.2	-7.5	56.25	54.143	5.557	30.88025
12:00 AM	60.8	67.5	-6.7	44.89	54.143	6.657	44.31565
12:15 AM	61.8	67.7	-5.9	34.81	54.143	7.657	58.62965
12:30 AM	62.9	67.9	-5	25	54.143	8.757	76.68505
12:45 AM	64	67.9	-3.9	15.21	54.143	9.857	97.16045
1:00 AM	64.9	67.8	-2.9	8.41	54.143	10.757	115.713
1:15 AM	64.9	67.7	-2.8	7.84	54.143	10.757	115.713
1:30 AM	64.9	67.4	-2.5	6.25	54.143	10.757	115.713
1:45 AM	64.9	66.9	-2	4	54.143	10.757	115.713
2:00 AM	64.9	66.2	-1.3	1.69	54.143	10.757	115.713
2:15 AM	64.9	65.4	-0.5	0.25	54.143	10.757	115.713
2:30 AM	64.8	64.6	0.2	0.04	54.143	10.657	113.5716
2:45 AM	63.9	63.8	0.1	0.01	54.143	9.757	95.19905
3:00 AM	63.4	63	0.4	0.16	54.143	9.257	85.69205
3:15 AM	59.4	62.2	-2.8	7.84	54.143	5.257	27.63605
3:30 AM	58.3	61.5	-3.2	10.24	54.143	4.157	17.28065

3:45 AM	57.3	60.9	-3.6	12.96	54.143	3.157	9.966649
4:00 AM	56.3	60.2	-3.9	15.21	54.143	2.157	4.652649
4:15 AM	56.2	59.6	-3.4	11.56	54.143	2.057	4.231249
4:30 AM	55.3	59	-3.7	13.69	54.143	1.157	1.338649
4:45 AM	55.2	58.4	-3.2	10.24	54.143	1.057	1.117249
5:00 AM	55.2	57.9	-2.7	7.29	54.143	1.057	1.117249
5:15 AM	55.2	57.4	-2.2	4.84	54.143	1.057	1.117249
5:30 AM	55.2	56.9	-1.7	2.89	54.143	1.057	1.117249
5:45 AM	55.2	56.4	-1.2	1.44	54.143	1.057	1.117249
6:00 AM	55.2	55.9	-0.7	0.49	54.143	1.057	1.117249
6:15 AM	55.2	55.5	-0.3	0.09	54.143	1.057	1.117249
6:30 AM	55.2	55.1	0.1	0.01	54.143	1.057	1.117249
6:45 AM	55.1	54.7	0.4	0.16	54.143	0.957	0.915849
7:00 AM	54.1	54.3	-0.2	0.04	54.143	-0.043	0.001849
7:15 AM	54	53.9	0.1	0.01	54.143	-0.143	0.020449
7:30 AM	53	53.6	-0.6	0.36	54.143	-1.143	1.306449
7:45 AM	53	53.3	-0.3	0.09	54.143	-1.143	1.306449
8:00 AM	52.9	52.9	0	0	54.143	-1.243	1.545049
8:15 AM	52	52.6	-0.6	0.36	54.143	-2.143	4.592449
8:30 AM	51.8	52.3	-0.5	0.25	54.143	-2.343	5.489649
8:45 AM	50.9	52.1	-1.2	1.44	54.143	-3.243	10.51705
9:00 AM	50.7	51.8	-1.1	1.21	54.143	-3.443	11.85425
9:15 AM	49.8	51.5	-1.7	2.89	54.143	-4.343	18.86165
9:30 AM	49.8	51.3	-1.5	2.25	54.143	-4.343	18.86165
9:45 AM	49.7	51.1	-1.4	1.96	54.143	-4.443	19.74025
10:00 AM	48.7	50.9	-2.2	4.84	54.143	-5.443	29.62625
10:15 AM	48.7	50.6	-1.9	3.61	54.143	-5.443	29.62625
10:30 AM	48.7	50.4	-1.7	2.89	54.143	-5.443	29.62625
10:45 AM	48.6	50.2	-1.6	2.56	54.143	-5.543	30.72485
11:00 AM	47.6	50.1	-2.5	6.25	54.143	-6.543	42.81085
11:15 AM	47.6	49.9	-2.3	5.29	54.143	-6.543	42.81085
11:30 AM	47.5	49.7	-2.2	4.84	54.143	-6.643	44.12945
11:45 AM	46.5	49.5	-3	9	54.143	-7.643	58.41545
$\sum Qi$	4060.7	$\Sigma(Qi - Fi)^2 =$		1353.3	$\sum(Qi\text{-}Qag)^2=$		2390.54

20/03/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
7:00 PM	64.8	64	0.8	0.64	73.195	-8.395	70.47602
7:15 PM	64	64	0	0	73.195	-9.195	84.54802
7:30 PM	64.9	64.1	0.8	0.64	73.195	-8.295	68.80702
7:45 PM	65.1	64.3	0.8	0.64	73.195	-8.095	65.52903
8:00 PM	66	64.6	1.4	1.96	73.195	-7.195	51.76802
8:15 PM	66.1	65	1.1	1.21	73.195	-7.095	50.33903
8:30 PM	67.1	65.5	1.6	2.56	73.195	-6.095	37.14903
8:45 PM	67.2	66	1.2	1.44	73.195	-5.995	35.94002
9:00 PM	68.3	66.6	1.7	2.89	73.195	-4.895	23.96103
9:15 PM	69.4	67.2	2.2	4.84	73.195	-3.795	14.40202
9:30 PM	70.3	67.9	2.4	5.76	73.195	-2.895	8.381025
9:45 PM	70.4	68.6	1.8	3.24	73.195	-2.795	7.812025
10:00 PM	71.4	69.2	2.2	4.84	73.195	-1.795	3.222025
10:15 PM	71.4	70	1.4	1.96	73.195	-1.795	3.222025
10:30 PM	71.4	70.7	0.7	0.49	73.195	-1.795	3.222025
10:45 PM	71.6	71.4	0.2	0.04	73.195	-1.595	2.544025
11:00 PM	73.5	72.2	1.3	1.69	73.195	0.305	0.093025
11:15 PM	73.6	72.9	0.7	0.49	73.195	0.405	0.164025
11:30 PM	74.6	73.7	0.9	0.81	73.195	1.405	1.974025
11:45 PM	74.8	74.4	0.4	0.16	73.195	1.605	2.576025
12:00 AM	76.8	75.1	1.7	2.89	73.195	3.605	12.99603
12:15 AM	77.9	75.8	2.1	4.41	73.195	4.705	22.13703
12:30 AM	79	76.4	2.6	6.76	73.195	5.805	33.69803
12:45 AM	80	76.9	3.1	9.61	73.195	6.805	46.30803
1:00 AM	81	77.3	3.7	13.69	73.195	7.805	60.91803
1:15 AM	81	77.7	3.3	10.89	73.195	7.805	60.91803
1:30 AM	82	78.1	3.9	15.21	73.195	8.805	77.52803
1:45 AM	82.1	78.4	3.7	13.69	73.195	8.905	79.29903
2:00 AM	82	78.6	3.4	11.56	73.195	8.805	77.52803
2:15 AM	82	78.7	3.3	10.89	73.195	8.805	77.52803
2:30 AM	81.9	78.8	3.1	9.61	73.195	8.705	75.77703
2:45 AM	81.9	78.8	3.1	9.61	73.195	8.705	75.77703
3:00 AM	81.5	78.8	2.7	7.29	73.195	8.305	68.97303
3:15 AM	81	78.7	2.3	5.29	73.195	7.805	60.91803
3:30 AM	80.8	78.4	2.4	5.76	73.195	7.605	57.83603
3:45 AM	79.9	78.1	1.8	3.24	73.195	6.705	44.95703
4:00 AM	79.8	77.6	2.2	4.84	73.195	6.605	43.62603
4:15 AM	78.7	77.1	1.6	2.56	73.195	5.505	30.30503
4:30 AM	77.7	76.6	1.1	1.21	73.195	4.505	20.29503
4:45 AM	76.7	76	0.7	0.49	73.195	3.505	12.28503
5:00 AM	76.6	75.5	1.1	1.21	73.195	3.405	11.59403
5:15 AM	75.5	75	0.5	0.25	73.195	2.305	5.313025

5:30 AM	74.6	74.5	0.1	0.01	73.195	1.405	1.974025
5:45 AM	74.5	74.1	0.4	0.16	73.195	1.305	1.703025
6:00 AM	73.4	73.6	-0.2	0.04	73.195	0.205	0.042025
6:15 AM	72.3	73.2	-0.9	0.81	73.195	-0.895	0.801025
6:30 AM	71.4	72.8	-1.4	1.96	73.195	-1.795	3.222025
6:45 AM	71.2	72.4	-1.2	1.44	73.195	-1.995	3.980025
7:00 AM	70.3	72.1	-1.8	3.24	73.195	-2.895	8.381025
7:15 AM	70.1	71.7	-1.6	2.56	73.195	-3.095	9.579025
7:30 AM	68.2	71.4	-3.2	10.24	73.195	-4.995	24.95002
7:45 AM	68.2	71	-2.8	7.84	73.195	-4.995	24.95002
8:00 AM	68	70.7	-2.7	7.29	73.195	-5.195	26.98802
8:15 AM	67.1	70.4	-3.3	10.89	73.195	-6.095	37.14903
8:30 AM	67	70.2	-3.2	10.24	73.195	-6.195	38.37802
8:45 AM	65.9	69.9	-4	16	73.195	-7.295	53.21702
9:00 AM	64.9	69.6	-4.7	22.09	73.195	-8.295	68.80702
9:15 AM	64.9	69.4	-4.5	20.25	73.195	-8.295	68.80702
9:30 AM	64.8	69.1	-4.3	18.49	73.195	-8.395	70.47602
$\sum Qi$	4318.5	$\Sigma(Qi - Fi)^2 =$		320.81	$\sum(Qi\text{-}Qag)^2=$		2036.05

12/11/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
1:15 PM	34.5	34.1	0.4	0.16	60.666	-26.166	684.6596
1:30 PM	37.5	34.2	3.3	10.89	60.666	-23.166	536.6636
1:45 PM	40.6	34.5	6.1	37.21	60.666	-20.066	402.6444
2:00 PM	43.2	34.9	8.3	68.89	60.666	-17.466	305.0612
2:15 PM	45.6	35.6	10	100	60.666	-15.066	226.9844
2:30 PM	48.5	36.4	12.1	146.41	60.666	-12.166	148.0116
2:45 PM	50.2	37.4	12.8	163.84	60.666	-10.466	109.5372
3:00 PM	50.9	38.8	12.1	146.41	60.666	-9.766	95.37476
3:15 PM	51.3	40.8	10.5	110.25	60.666	-9.366	87.72196
3:30 PM	52	43.1	8.9	79.21	60.666	-8.666	75.09956
3:45 PM	52	45.8	6.2	38.44	60.666	-8.666	75.09956
4:00 PM	54.6	48.8	2.7	7.29	60.666	-6.066	36.79636
4:15 PM	55.7	51.9	-1	1	60.666	-4.966	24.66116
4:30 PM	57.2	55.2	-3.9	15.21	60.666	-3.466	12.01316
4:45 PM	59.8	58.6	-6.6	43.56	60.666	-0.866	0.749956
5:00 PM	62.6	61.9	-9.5	90.25	60.666	1.934	3.740356
5:15 PM	65	65.3	-11.8	139.24	60.666	4.334	18.78356
5:30 PM	67.5	68.5	-13.9	193.21	60.666	6.834	46.70356
5:45 PM	69	71.7	-16	256	60.666	8.334	69.45556
6:00 PM	69.9	74.7	-17.5	306.25	60.666	9.234	85.26676
6:15 PM	70	77.3	-17.5	306.25	60.666	9.334	87.12356
6:30 PM	71.6	79.6	-17	289	60.666	10.934	119.5524
6:45 PM	75.7	81.5	-16.3	265.69	60.666	15.034	226.0212
7:00 PM	81	83	-14.6	213.16	60.666	20.334	413.4716
7:15 PM	85.6	84	-12.4	153.76	60.666	24.934	621.7044
7:30 PM	89.1	84.5	-8.8	77.44	60.666	28.434	808.4924
7:45 PM	91.7	84.7	-3.7	13.69	60.666	31.034	963.1092
8:00 PM	92.9	84.6	1	1	60.666	32.234	1039.031
8:15 PM	93.1	84.2	4.9	24.01	60.666	32.434	1051.964
8:30 PM	92.4	83.3	8.4	70.56	60.666	31.734	1007.047
8:45 PM	91.9	82	10.9	118.81	60.666	31.234	975.5628
9:00 PM	90.2	80.5	12.6	158.76	60.666	29.534	872.2572
9:15 PM	87.8	79	13.4	179.56	60.666	27.134	736.254
9:30 PM	85.9	77.5	14.4	207.36	60.666	25.234	636.7548
9:45 PM	84.3	76.1	14.1	198.81	60.666	23.634	558.566
10:00 PM	82.2	74.7	13.1	171.61	60.666	21.534	463.7132
10:15 PM	80.5	73.4	12.5	156.25	60.666	19.834	393.3876
10:30 PM	79.5	72.1	12.2	148.84	60.666	18.834	354.7196
10:45 PM	78	70.9	11.3	127.69	60.666	17.334	300.4676
11:00 PM	76.3	69.6	10.9	118.81	60.666	15.634	244.422
11:15 PM	75.2	68.5	11	121	60.666	14.534	211.2372
11:30 PM	74.1	67.3	10.7	114.49	60.666	13.434	180.4724

11:45 PM	72.6	66.3	10	100	60.666	11.934	142.4204
12:00 AM	71.4	65.2	10	100	60.666	10.734	115.2188
12:15 AM	70.9	64.2	9.9	98.01	60.666	10.234	104.7348
12:30 AM	70	63.2	9.4	88.36	60.666	9.334	87.12356
12:45 AM	68.2	62.2	9.2	84.64	60.666	7.534	56.76116
1:00 AM	67.7	61.3	9.6	92.16	60.666	7.034	49.47716
1:15 AM	66.6	60.4	9	81	60.666	5.934	35.21236
1:30 AM	65.6	59.6	8.6	73.96	60.666	4.934	24.34436
1:45 AM	65.2	58.7	9	81	60.666	4.534	20.55716
2:00 AM	65	57.9	8.7	75.69	60.666	4.334	18.78356
2:15 AM	64.9	57.1	8.5	72.25	60.666	4.234	17.92676
2:30 AM	64.5	56.4	8.1	65.61	60.666	3.834	14.69956
2:45 AM	63.9	55.6	8.3	68.89	60.666	3.234	10.45876
3:00 AM	63	54.9	8.1	65.61	60.666	2.334	5.447556
3:15 AM	61.7	54.2	7.5	56.25	60.666	1.034	1.069156
3:30 AM	61.3	53.6	7.7	59.29	60.666	0.634	0.401956
3:45 AM	60.2	52.9	7.3	53.29	60.666	-0.466	0.217156
4:00 AM	59.5	52.3	7.2	51.84	60.666	-1.166	1.359556
4:15 AM	59.1	51.7	7.4	54.76	60.666	-1.566	2.452356
4:30 AM	58.5	51.1	7.4	54.76	60.666	-2.166	4.691556
4:45 AM	58	50.6	7.4	54.76	60.666	-2.666	7.107556
5:00 AM	56.9	50	6.9	47.61	60.666	-3.766	14.18276
5:15 AM	56.3	49.5	6.8	46.24	60.666	-4.366	19.06196
5:30 AM	56.3	49	7.3	53.29	60.666	-4.366	19.06196
5:45 AM	55.9	48.5	7.4	54.76	60.666	-4.766	22.71476
6:00 AM	55.2	48	7.2	51.84	60.666	-5.466	29.87716
6:15 AM	55.2	47.6	7.6	57.76	60.666	-5.466	29.87716
6:30 AM	54.8	47.1	7.7	59.29	60.666	-5.866	34.40996
6:45 AM	53.7	46.7	7	49	60.666	-6.966	48.52516
7:00 AM	53	46.3	6.7	44.89	60.666	-7.666	58.76756
7:15 AM	53	45.9	7.1	50.41	60.666	-7.666	58.76756
7:30 AM	53	45.5	7.5	56.25	60.666	-7.666	58.76756
7:45 AM	53	45.1	7.9	62.41	60.666	-7.666	58.76756
8:00 AM	52.6	44.8	7.8	60.84	60.666	-8.066	65.06036
8:15 AM	52	44.4	7.6	57.76	60.666	-8.666	75.09956
8:30 AM	52	44.1	7.9	62.41	60.666	-8.666	75.09956
8:45 AM	51.5	43.8	7.7	59.29	60.666	-9.166	84.01556
9:00 AM	50.9	43.4	7.5	56.25	60.666	-9.766	95.37476
9:15 AM	50.4	43.1	7.3	53.29	60.666	-10.266	105.3908
9:30 AM	49.8	42.8	7	49	60.666	-10.866	118.07
9:45 AM	49.8	42.5	7.3	53.29	60.666	-10.866	118.07
10:00 AM	49.8	42.3	7.5	56.25	60.666	-10.866	118.07
10:15 AM	49.8	42	7.8	60.84	60.666	-10.866	118.07
10:30 AM	49.3	41.7	7.6	57.76	60.666	-11.366	129.186

10:45 AM	48.7	41.5	7.2	51.84	60.666	-11.966	143.1852
11:00 AM	48.7	41.2	7.5	56.25	60.666	-11.966	143.1852
11:15 AM	48.7	41	7.7	59.29	60.666	-11.966	143.1852
11:30 AM	48.7	40.8	7.9	62.41	60.666	-11.966	143.1852
11:45 AM	48.2	40.6	7.6	57.76	60.666	-12.466	155.4012
12:00 PM	47.1	40.4	6.7	44.89	60.666	-13.566	184.0364
12:15 PM	46.5	40.1	6.4	40.96	60.666	-14.166	200.6756
12:30 PM	46.5	39.9	6.6	43.56	60.666	-14.166	200.6756
12:45 PM	46.5	39.8	6.7	44.89	60.666	-14.166	200.6756
1:00 PM	46.5	39.6	6.9	47.61	60.666	-14.166	200.6756
1:15 PM	46.5	39.4	7.1	50.41	60.666	-14.166	200.6756
1:30 PM	46.5	39.2	7.3	53.29	60.666	-14.166	200.6756
1:45 PM	46.5	39	7.5	56.25	60.666	-14.166	200.6756
2:00 PM	46.1	38.9	7.2	51.84	60.666	-14.566	212.1684
2:15 PM	45.4	38.7	6.7	44.89	60.666	-15.266	233.0508
2:30 PM	44.9	38.6	6.3	39.69	60.666	-15.766	248.5668
2:45 PM	44.1	38.4	5.7	32.49	60.666	-16.566	274.4324
3:00 PM	44.6	38.3	6.3	39.69	60.666	-16.066	258.1164
$\sum Qi$	6309.3	$\Sigma(Qi - Fi)^2 =$		8861.14	$\sum(Qi-Qag)^2=$		21128.35

13/11/2011							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
3:15 PM	45.9	46	-0.1	0.01	53.113	-7.213	52.02737
3:30 PM	46.5	46	0.5	0.25	53.113	-6.613	43.73177
3:45 PM	47	46.2	0.8	0.64	53.113	-6.113	37.36877
4:00 PM	48.1	46.6	1.5	2.25	53.113	-5.013	25.13017
4:15 PM	48.7	47.1	1.6	2.56	53.113	-4.413	19.47457
4:30 PM	48.7	47.6	1.1	1.21	53.113	-4.413	19.47457
4:45 PM	49.1	48.3	0.8	0.64	53.113	-4.013	16.10417
5:00 PM	50.2	49.1	1.1	1.21	53.113	-2.913	8.485569
5:15 PM	51.3	49.9	1.4	1.96	53.113	-1.813	3.286969
5:30 PM	52	50.9	1.1	1.21	53.113	-1.113	1.238769
5:45 PM	52	51.9	0.1	0.01	53.113	-1.113	1.238769
6:00 PM	52.4	52.9	-0.5	0.25	53.113	-0.713	0.508369
6:15 PM	53.5	54	-0.5	0.25	53.113	0.387	0.149769
6:30 PM	54.6	55.2	-0.6	0.36	53.113	1.487	2.211169
6:45 PM	55.2	56.2	-1	1	53.113	2.087	4.355569
7:00 PM	56.3	57.3	-1	1	53.113	3.187	10.15697
7:15 PM	56.8	58.2	-1.4	1.96	53.113	3.687	13.59397
7:30 PM	57.4	59.1	-1.7	2.89	53.113	4.287	18.37837
7:45 PM	58	59.9	-1.9	3.61	53.113	4.887	23.88277
8:00 PM	58.5	60.6	-2.1	4.41	53.113	5.387	29.01977
8:15 PM	58.9	61.2	-2.3	5.29	53.113	5.787	33.48937
8:30 PM	59.5	61.7	-2.2	4.84	53.113	6.387	40.79377
8:45 PM	59.7	62	-2.3	5.29	53.113	6.587	43.38857
9:00 PM	59.7	62.2	-2.5	6.25	53.113	6.587	43.38857
9:15 PM	59.9	62.1	-2.2	4.84	53.113	6.787	46.06337
9:30 PM	60	61.9	-1.9	3.61	53.113	6.887	47.43077
9:45 PM	60	61.6	-1.6	2.56	53.113	6.887	47.43077
10:00 PM	60	61.3	-1.3	1.69	53.113	6.887	47.43077
10:15 PM	60	60.9	-0.9	0.81	53.113	6.887	47.43077
10:30 PM	60	60.5	-0.5	0.25	53.113	6.887	47.43077
10:45 PM	60	60.1	-0.1	0.01	53.113	6.887	47.43077
11:00 PM	59.5	59.7	-0.2	0.04	53.113	6.387	40.79377
11:15 PM	59.1	59.2	-0.1	0.01	53.113	5.987	35.84417
11:30 PM	58.5	58.8	-0.3	0.09	53.113	5.387	29.01977
11:45 PM	58.5	58.4	0.1	0.01	53.113	5.387	29.01977
12:00 AM	58	58	0	0	53.113	4.887	23.88277
12:15 AM	57.4	57.6	-0.2	0.04	53.113	4.287	18.37837
12:30 AM	57.4	57.2	0.2	0.04	53.113	4.287	18.37837
12:45 AM	57.2	56.8	0.4	0.16	53.113	4.087	16.70357
1:00 AM	57.1	56.5	0.6	0.36	53.113	3.987	15.89617
1:15 AM	57	56.1	0.9	0.81	53.113	3.887	15.10877
1:30 AM	56.9	55.8	1.1	1.21	53.113	3.787	14.34137

1:45 AM	56.8	55.5	1.3	1.69	53.113	3.687	13.59397
2:00 AM	56.7	55.1	1.6	2.56	53.113	3.587	12.86657
2:15 AM	56.5	54.8	1.7	2.89	53.113	3.387	11.47177
2:30 AM	56.5	54.6	1.9	3.61	53.113	3.387	11.47177
2:45 AM	56	54.3	1.7	2.89	53.113	2.887	8.334769
3:00 AM	55.9	54	1.9	3.61	53.113	2.787	7.767369
3:15 AM	55.7	53.7	2	4	53.113	2.587	6.692569
3:30 AM	55.5	53.5	2	4	53.113	2.387	5.697769
3:45 AM	55.1	53.2	1.9	3.61	53.113	1.987	3.948169
4:00 AM	55	53	2	4	53.113	1.887	3.560769
4:15 AM	54.9	52.8	2.1	4.41	53.113	1.787	3.193369
4:30 AM	54.9	52.5	2.4	5.76	53.113	1.787	3.193369
4:45 AM	54.5	52.3	2.2	4.84	53.113	1.387	1.923769
5:00 AM	54	52.1	1.9	3.61	53.113	0.887	0.786769
5:15 AM	54	51.9	2.1	4.41	53.113	0.887	0.786769
5:30 AM	53.9	51.7	2.2	4.84	53.113	0.787	0.619369
5:45 AM	53.7	51.5	2.2	4.84	53.113	0.587	0.344569
6:00 AM	53.5	51.4	2.1	4.41	53.113	0.387	0.149769
6:15 AM	53.5	51.2	2.3	5.29	53.113	0.387	0.149769
6:30 AM	53.4	51	2.4	5.76	53.113	0.287	0.082369
6:45 AM	53	50.8	2.2	4.84	53.113	-0.113	0.012769
7:00 AM	53	50.7	2.3	5.29	53.113	-0.113	0.012769
7:15 AM	52.5	50.5	2	4	53.113	-0.613	0.375769
7:30 AM	52.3	50.4	1.9	3.61	53.113	-0.813	0.660969
7:45 AM	52	50.2	1.8	3.24	53.113	-1.113	1.238769
8:00 AM	51.5	50.1	1.4	1.96	53.113	-1.613	2.601769
8:15 AM	51	50	1	1	53.113	-2.113	4.464769
8:30 AM	50.8	49.8	1	1	53.113	-2.313	5.349969
8:45 AM	50.5	49.7	0.8	0.64	53.113	-2.613	6.827769
9:00 AM	50	49.6	0.4	0.16	53.113	-3.113	9.690769
9:15 AM	49.9	49.5	0.4	0.16	53.113	-3.213	10.32337
9:30 AM	49.9	49.4	0.5	0.25	53.113	-3.213	10.32337
9:45 AM	49.8	49.2	0.6	0.36	53.113	-3.313	10.97597
10:00 AM	49.8	49.1	0.7	0.49	53.113	-3.313	10.97597
10:15 AM	49.8	49	0.8	0.64	53.113	-3.313	10.97597
10:30 AM	49.5	48.9	0.6	0.36	53.113	-3.613	13.05377
10:45 AM	49.3	48.8	0.5	0.25	53.113	-3.813	14.53897
11:00 AM	49	48.7	0.3	0.09	53.113	-4.113	16.91677
11:15 AM	48.9	48.7	0.2	0.04	53.113	-4.213	17.74937
11:30 AM	48.9	48.6	0.3	0.09	53.113	-4.213	17.74937
11:45 AM	48.7	48.5	0.2	0.04	53.113	-4.413	19.47457
12:00 PM	48.7	48.4	0.3	0.09	53.113	-4.413	19.47457
12:15 PM	48.5	48.3	0.2	0.04	53.113	-4.613	21.27977
12:30 PM	48.3	48.2	0.1	0.01	53.113	-4.813	23.16497

12:45 PM	48	48.2	-0.2	0.04	53.113	-5.113	26.14277
1:00 PM	47.6	48.1	-0.5	0.25	53.113	-5.513	30.39317
1:15 PM	47.6	48	-0.4	0.16	53.113	-5.513	30.39317
1:30 PM	47.1	48	-0.9	0.81	53.113	-6.013	36.15617
1:45 PM	47	47.9	-0.9	0.81	53.113	-6.113	37.36877
2:00 PM	47	47.8	-0.8	0.64	53.113	-6.113	37.36877
2:15 PM	46.9	47.8	-0.9	0.81	53.113	-6.213	38.60137
2:30 PM	46.9	47.7	-0.8	0.64	53.113	-6.213	38.60137
2:45 PM	46.5	47.7	-1.2	1.44	53.113	-6.613	43.73177
3:00 PM	46.2	47.6	-1.4	1.96	53.113	-6.913	47.78957
3:15 PM	46.1	47.6	-1.5	2.25	53.113	-7.013	49.18217
3:30 PM	46.1	47.5	-1.4	1.96	53.113	-7.013	49.18217
$\sum Qi$	5205.1	$\Sigma(Qi - Fi)^2 =$		187.34	$\sum(Qi\text{-}Qag)^2=$		1888.65

12/10/2013							
Time	*Qi*	*Fi*	*(Qi-Fi)*	*(Qi-Fi)²*	*Qag*	*Qi-Qag*	*(Qi-Qag)²*
7:30 PM	28.2	27	1.2	1.44	65.413	-37.213	1384.807
7:45 PM	27.8	27.2	0.6	0.36	65.413	-37.613	1414.738
8:00 PM	31.2	28.1	3.1	9.61	65.413	-34.213	1170.529
8:15 PM	39.3	30	9.3	86.49	65.413	-26.113	681.8888
8:30 PM	43.6	32.8	10.8	116.64	65.413	-21.813	475.807
8:45 PM	44.1	36.3	7.8	60.84	65.413	-21.313	454.244
9:00 PM	46.1	40.3	5.8	33.64	65.413	-19.313	372.992
9:15 PM	47.4	44.8	2.6	6.76	65.413	-18.013	324.4682
9:30 PM	48.5	49.6	-1.1	1.21	65.413	-16.913	286.0496
9:45 PM	49.6	54.8	-5.2	27.04	65.413	-15.813	250.051
10:00 PM	51.6	60.2	-8.6	73.96	65.413	-13.813	190.799
10:15 PM	55.6	65.8	-10.2	104.04	65.413	-9.813	96.29497
10:30 PM	59.9	71.6	-11.7	136.89	65.413	-5.513	30.39317
10:45 PM	63.3	77.5	-14.2	201.64	65.413	-2.113	4.464769
11:00 PM	67.4	83.2	-15.8	249.64	65.413	1.987	3.948169
11:15 PM	70.8	88.4	-17.6	309.76	65.413	5.387	29.01977
11:30 PM	76.7	93.2	-16.5	272.25	65.413	11.287	127.3964
11:45 PM	82.2	97.5	-15.3	234.09	65.413	16.787	281.8034
12:00 AM	86.8	101.2	-14.4	207.36	65.413	21.387	457.4038
12:15 AM	90.6	104.3	-13.7	187.69	65.413	25.187	634.385
12:30 AM	93.2	106.9	-13.7	187.69	65.413	27.787	772.1174
12:45 AM	95.7	108.8	-13.1	171.61	65.413	30.287	917.3024
1:00 AM	97.1	110.1	-13	169	65.413	31.687	1004.066
1:15 AM	98.4	110.5	-12.1	146.41	65.413	32.987	1088.142
1:30 AM	99.6	109.8	-10.2	104.04	65.413	34.187	1168.751
1:45 AM	99.8	108.1	-8.3	68.89	65.413	34.387	1182.466
2:00 AM	98.8	105.8	-7	49	65.413	33.387	1114.692
2:15 AM	97.5	103.4	-5.9	34.81	65.413	32.087	1029.576
2:30 AM	96.3	101	-4.7	22.09	65.413	30.887	954.0068
2:45 AM	95.1	98.6	-3.5	12.25	65.413	29.687	881.318
3:00 AM	93.8	96.2	-2.4	5.76	65.413	28.387	805.8218
3:15 AM	90.6	93.9	-3.3	10.89	65.413	25.187	634.385
3:30 AM	88	91.7	-3.7	13.69	65.413	22.587	510.1726
3:45 AM	85.6	89.6	-4	16	65.413	20.187	407.515
4:00 AM	83.4	87.6	-4.2	17.64	65.413	17.987	323.5322
4:15 AM	79.6	85.6	-6	36	65.413	14.187	201.271
4:30 AM	78	83.6	-5.6	31.36	65.413	12.587	158.4326
4:45 AM	75.1	81.8	-6.7	44.89	65.413	9.687	93.83797
5:00 AM	71.9	80	-8.1	65.61	65.413	6.487	42.08117
5:15 AM	69.6	78.2	-8.6	73.96	65.413	4.187	17.53097
5:30 AM	66.6	76.6	-10	100	65.413	1.187	1.408969
5:45 AM	64.2	74.9	-10.7	114.49	65.413	-1.213	1.471369

6:00 AM	61.2	73.4	-12.2	148.84	65.413	-4.213	17.74937
6:15 AM	58.8	71.8	-13	169	65.413	-6.613	43.73177
6:30 AM	56.7	70.4	-13.7	187.69	65.413	-8.713	75.91637
6:45 AM	54.5	68.9	-14.4	207.36	65.413	-10.913	119.0936
7:00 AM	51.4	67.6	-16.2	262.44	65.413	-14.013	196.3642
7:15 AM	50	66.2	-16.2	262.44	65.413	-15.413	237.5606
7:30 AM	47.1	64.9	-17.8	316.84	65.413	-18.313	335.366
7:45 AM	44.5	63.7	-19.2	368.64	65.413	-20.913	437.3536
8:00 AM	41.4	62.5	-21.1	445.21	65.413	-24.013	576.6242
8:15 AM	38.3	61.3	-23	529	65.413	-27.113	735.1148
8:30 AM	36.5	60.2	-23.7	561.69	65.413	-28.913	835.9616
8:45 AM	33.8	59.1	-25.3	640.09	65.413	-31.613	999.3818
9:00 AM	31	58	-27	729	65.413	-34.413	1184.255
9:15 AM	29.3	57	-27.7	767.29	65.413	-36.113	1304.149
$\sum Qi$	3663.1	$\Sigma(Qi - Fi)^2$ =		9412.96	$\sum(Qi\text{-}Qag)^2$=		29080