MASTER'S THESIS

BY

ABDU YIMER

RAINFALL-RUNOFF PROCESS IN THE UPPER BLUE NILE BASIN: THE CASE OF DANGISHTA WATERSHED

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ABDU YIMER

Rainfall-Runoff Process in the Upper Blue Nile Basin: the Case of Dangishta Watershed

THESIS

Submitted to the Faculty of Civil and Water Resource Engineering in partial Fulfillment of the requirements for the Degree of Master of Science in Hydraulics Engineering

Supervised by: Seifu A. Tilahun (PhD)

Co-Supervised by: Prossie Nakawuka (PhD)

Petra Schmitter (PhD)

Bahir Dar, Ethiopia

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DECLARATION

I, Abdu Yimer Yimam, declare that this thesis is my own original work. In compliance with internationally accepted practices, I have duly acknowledged and referenced all materials used in this work. I understand that non-adherence to principles of academic honesty and integrity, misrepresentation/fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the university and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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Abdu Yimer Yimam

By Abdu Yimer

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Dedicated to my parents Yimer Yimam and Lubaba Jemal.

ABSTRACT

Besides agricultural intensification, deforestation, land use change etc, absence of comprehensive understanding of rainfall-runoff process in upper Blue Nile contributes to problem of watershed management. To improve understanding of the main drivers behind the rainfall- runoff process, this study focuses on Dangishta watershed a sub-watershed of the Upper Blue Nile basin. During the period of the study, stream flow at upstream sub watershed outlet and total watershed outlet, groundwater levels, infiltration tests, rainfall and soil moisture measurements were conducted. The result from these measurement showed that the median infiltration rate was exceeded by the rainfall intensity 2.5% of the time indicating that saturation excess runoff were the dominant runoff mechanism in the Dangishta watershed. The minimum infiltration rate was exceeded by the rainfall intensity 25% of the time which shows infiltration excess runoff also contributes the runoff response in some parts of the watershed. Soil moisture measurements done at 20cm depths at up, down and midslope areas of the watershed throughout the rainfall period show that the upslope area contributes to infiltration excess runoff. These result was also corroborated by the better correlation at the total watershed outlet (R^2 = 0.81) than upstream sub watershed outlet (R^2 = 0.54) using the SCS runoff equation. The annual runoff at the total watershed outlet was found to be 19% of the annual rainfall. The result from the groundwater level measurement shows that the total annual groundwater recharge were found to be 400mm which is 24% of the total annual rainfall. Quantifying the various hydrologic components can help the community better plan for measures to conserve soil and water in the watershed.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADSWE Amhara Design Supervision Works Enterprise

AGP Agricultural Growth Program

ARG Automatic rain gage

ET_O Reference Evapotranspiration

FC Field Capacity

GPS Geographical positioning system

GW Groundwater

Ha hectares

f Infiltration

ILSSI Innovation laboratory for small scale irrigation

IWMI International Water Management Institute

masl Meter above sea level

MRG Manual rain gage

Of Overland flow

P Precipitation

Pe Effective Rainfall

rf Return flow

SCS Soil conservation service

Se Effective available watershed storage

S_Y Specific yield

SW Surface water

TDR Time domain reflectometer

USAID United States Agency for International Development

WT Water table

WTF Water table fluctuation

1 INTRODUCTION AND JUSTIFICATION

1.1 Introduction

Runoff is a natural phenomenon of free water movement within land which is influenced by gravitational force. It is one form of precipitation which flows towards stream channels, lakes or oceans as surface flow.

To simulate the transport mechanisms of sediment, nutrient and pollutants basic understanding of storm runoff and its mechanisms in the landscape is useful (Tilahun et al., 2016). For planning, development and management of water resources basic knowledge of rainfall runoff relationship is needed.

Important findings so far in the Ethiopian highlands are that saturation-excess surface runoff is generated in the periodically saturated bottom lands and from the degraded areas on the hill sides (Liu et al., 2008; Steenhuis et al., 2009). Determination of runoff source areas is an important consideration in understanding where to implement watershed management (Guzman et al., 2013). For saturation-excess runoff conditions, management practices need to be situated in very different locations in the landscape than would be the case if infiltration-excess runoff was the dominant runoff generating mechanism.

Previously researchers have worked on the prediction of runoff for watershed management in the Ethiopian highlands using hydrological data from three (Anjeni, Andit Tid and Maybar) experimental watersheds established by the soil conservation research program (SCRP) and one watershed in Debre Mawi area. Among these researchers, Haregeweyn (2003), Mohammed et al. (2004), Setegn et al. (2008) and Zeleke (2000) used infiltration excess runoff mechanism to predict the runoff process whereas Steenhuis et al. (2009), Bayabil et al. (2010), Engda et al. (2011), Tilahun et al. (2013a) and Tilahun et al. (2013b), Tilahun et al. (2015) used saturation excess runoff mechanism to predict runoff.

The role of understanding runoff mechanism is not only in the watershed management but also about identifying areas of infiltration or recharge to groundwater. Any infiltrated water could led to generation of runoff through subsurface flow either as interflow or groundwater flow to streams or as a return flow to the surface when the subsurface flow encounters a seepage face (Dunne and Black, 1970). This groundwater from underground aquifers can be used for irrigation using deep and shallow wells.

Groundwater is a reliable and consistent resource for agriculture or domestic water supply throughout the year if its potential is effectively quantified. Groundwater recharge through rainfall infiltrating during the wet season is a major factor for sustainable groundwater utilization. There is however little information about groundwater recharge and it's potential for irrigation in Ethiopia which is a challenge for its use for wide scale irrigation.

There is use for simple farming activities like growing of vegetables and seedlings in small areas from ground water (Alemu, 2015). Therefore in order to promote increase in agricultural production and sustainable use of groundwater, location of recharge areas, and quantification of groundwater recharge is needed which is a fundamental component in the water balance of any watershed (Asmerom, 2008). Quantification of recharge rates are impossible to measure directly.

Previously efforts to predict ground water recharge were done on Ethiopian highlands by Walraevens et al. (2009) using MODFLOW and soil moisture balance (SMB), and Asmerom (2008) using different methods such as base flow analysis, BASF model, Hydro chemical analysis (i.e. chloride mass balance). In order to strengthen the knowledge of runoff mechanism, runoff source areas, recharge areas and rate of recharge, Dangishta watershed in the Blue Nile Basin was selected. This knowledge can improve identification of land management interventions to implement by locating runoff source areas. Groundwater recharge quantification would foster sustainable use of groundwater by balancing the recharge with the ground water use.

1.2 Statement of the problem

While rainfall in the Blue Nile basin has not changed significantly over the last 40 years, the annual runoff for a given amount of annual rainfall has increased (Tesemma et al., 2010), indicating that land degradation is intensifying. This is reducing the availability of water for crop production during dry period by reducing the stream low flow and groundwater (Enku et al., 2014), and removing resources of soil and nutrient by erosion (Zuazo and Pleguezuelo, 2008). To implement proper watershed management, proper knowledge on the rainfall-runoff relation is essential for design and planning of soil and water conservation structures.

The runoff mechanisms were studied in just a few watersheds in the last ten years in the Ethiopian highlands. In addition, degraded landscape restrict the infiltration rates and recharge of groundwater (Tebebu et al., 2016) for sustainable irrigation development through sustainable groundwater use in Ethiopia. Therefore for sustainable development of irrigation, knowing the amount of recharge to the ground water is important. For long-term sustainable use of groundwater, calculations need to be made on the recharge and withdrawal of water.

1.3 Research Questions

This study answers the following research questions:

i. Is infiltration excess or saturation excess the dominant runoff mechanism in Dangishta watershed?

ii. What percentage of rainfall recharges ground water annually in Dangishta watershed?

1.4 Hypothesis

The infiltration rates in the hill slopes of the Ethiopian Blue Nile basin are reported to be greater than rainfall intensity (Easton et al., 2012). Saturation excess runoff mechanism will thus dominate the watershed runoff responses when the soil surface layer becomes saturates.

1.5 Objective

1.5.1 General objective

The general objective of the study is to investigate the runoff generating processes and to quantify how much of the rainfall recharges ground water in the Dangishta watershed.

1.5.2 Specific objective

The specific objective of the study is to:

- Identify factors that influence surface runoff generation in Dangishta watershed in order to identify the dominant runoff mechanism(s).
- Estimate the shallow ground water recharge.

2 LITERATURE REVIEW

2.1 Runoff

Runoff is a natural phenomenon of free water movement within land under the influence of gravitational force which can be produced by different mechanisms in the watershed.

Depending on their sources, runoff may be classified as surface flow, interflow and baseflow in which their amount will be affected by several factors. These factors include:

a) Rainfall Duration and Intensity

Rainfall duration and intensity has a direct impact on the amount of runoff. Duration is the length of the storm and intensity is the ratio of the total depth of rain falling in a given amount of time. Since infiltration rates decreases with time at the beginning of the storm, runoff may not be produced for a storm of short duration as compared to storm of lesser intensity but long duration which could result in runoff. The intensity of the rainfall droplets falling on bare soil can cause surface sealing and thus decrease the infiltration rate of the soil.

b) Vegetation cover and soil moisture content

The extent of vegetation cover and moisture content of the soil are the major watershed factors that affect the amount of runoff. During the dry period the vegetation covers and the soil moisture content is significantly reduced and this affects the amount of runoff in a given area.

c) Meteorological conditions before the storm.

The climate conditions before the storm like high temperature, low humidity and high solar radiation increases evaporation and transpiration which reduces the soil moisture content. When the soil moisture content is reduced, the storage and infiltration rate increases lessening the surface runoff.

d) Land Slope

The rate of runoff is affected by land slope. On steeper slopes runoff will flow faster which results in higher peaks at downstream locations.

e) Soil

The type of soil has a major effect on runoff due to its infiltration rate. Different soils will have different infiltration rates. As rain falls, voids between soil particles become increasingly filled with water. If it continues to rain, the void spaces in a soil layer will be completely filled with water thus becoming saturated. Continuous rainfall falling on such a soil layer results in to runoff.

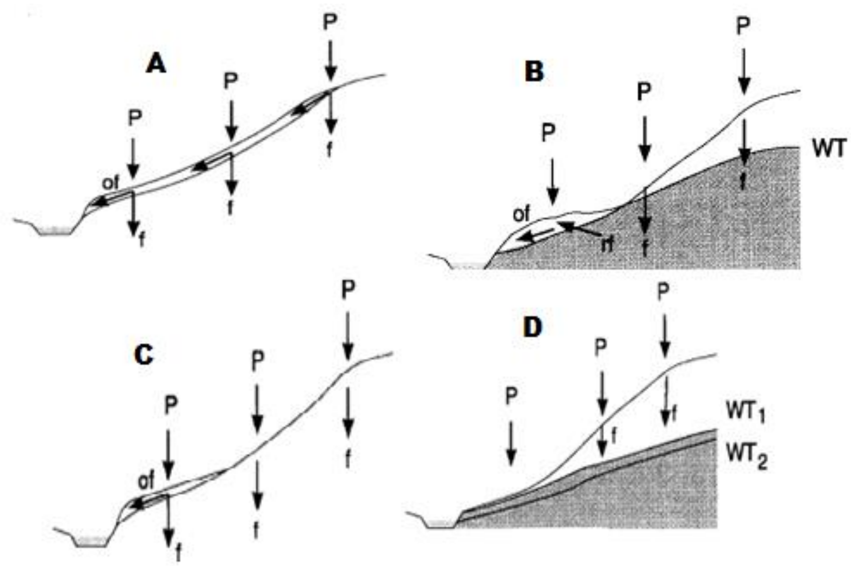
2.2 Runoff generation mechanisms

Runoff is produced within the watershed by three mechanisms, namely Horton overland flow (infiltration excess), saturation overland flow (saturation excess) and subsurface flow.

Horton overland flow runoff happens in areas having rainfall rates in excess of soil infiltration rates and it is common anywhere where rainfall rates exceed soil infiltration rates (Dune and Black 1970).

If the infiltration capacity of the soil is greater than the rainfall intensity, the infiltrating water with time saturates the soil profile leaving no space for any subsequent water to infiltrate. Saturation of the soil profile results in the rising water table to the surface. Any incoming precipitation at such a location changes to overland flow runoff which is called saturation overland flow which is common in areas where compacted subsoil underlies topsoil that is highly conductive or in areas where groundwater is close to the surface (Schneiderman et al., 2007).

Depending on the duration and intensity of a rainfall event, the antecedent soil moisture conditions in the watershed, and the soil conditions in the watershed, runoff generation may be dominated by a single mechanism or by a combination of mechanisms within the watershed (Liu et al., 2008).



A = infiltration excess overland flow, B = partial area overland flow, C = saturation excess overland flow and D = subsurface storm flow

Figure 2-1 Mechanism of runoff production adapted from Sophocleous (2002)

Different researchers point out that in most of the Ethiopian high lands, saturated overland flow mechanism was the dominating runoff generating mechanism than infiltration excess runoff mechanism (Steenhuis et al., 2009, Bayabil et al., 2010, Engda et al., 2011) in which the amount of saturation excess runoff can be estimated from the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) runoff equation which is best fitted for saturation excess overland flow (Steenhuis et al.,1995). The SCS runoff equation is a function of effective available storage and effective rainfall, P_e (i.e. rainfall minus initial abstraction) as shown below.

$$Q = \frac{(p - I_a)^2}{P + S - I_a} \quad \textbf{(2-1)}$$

Where P is the depth of rainfall (mm)

Q is the runoff depth (mm)

I_a is initial abstraction (mm) which represents losses due to interception, infiltration and surface storage (Baltas et al., 2007) which can be taken as 0.2S (Steenhuis et al.,1995) where

S (mm) is the maximum potential retention after runoff begins.

Effective rainfall (P_e) which is defined as the amount of precipitation after runoff starts and is mathematically estimated by rainfall minus initial abstraction in equation (2-1) gives the well-known SCS runoff equation below:

$$Q = \frac{{p_e}^2}{P_e + S_e} \quad \textbf{(2-2)}$$

Where Se (mm) is the depth of effective available storage, i.e. the spatially averaged available volume of retention in the watershed when runoff begins. Effective available storage, Se, depends on the moisture status of the watershed and can vary between some maximum Se, max when the watershed is dry and a minimum Se, min when the watershed is wet (Schneiderman et al., 2007). This parameter can be calibrated with the measured runoff in the watershed whether it represents the saturation excess runoff in the watershed or not. While calibrating the effective available storage, the effective rainfall can also be calculated by subtracting reference evapotranspiration (ET_O) from rainfall (Engda et al., 2011).

The daily reference evapotranspiration can be computed by different methods namely; Valiantzas method, Copais method, Hargreaves-Samani method, Hargreaves method (kisi 2013), Enku temperature method (Enku et al., 2014) and Penman-Monteith equation (Zotarelli et al., 2014).

a) Valiantzas method

$$ET_0 = 0.0393 R_s \sqrt{T + 9.5} - 0.19 R_s^{0.6} \varphi^{0.15} + 0.048 (T + 20) \left(1 - \frac{RH}{100}\right) u^{0.7} \quad \textbf{(2-3)}$$

Where R_s is solar radiation (MJ/m^{-2}day^{-1})

T is the mean air temperature (^oC)

RH is relative humidity (%)

ϕ is the altitude (rad)

u is the wind speed at 2m height (m/sec)

b) Copais method

$$ET_0 = m_1 + m_2 C_2 + m_3 C_1 + m_4 C_1 \quad \textbf{(2-4)}$$

Where m_1 = 0.057, m_2 = 0.277, m_3 = 0.643 and m_4=0.0124

$$C_1 = 0.6416 - 0.00784 RH + 0.372 R_s - 0.00264 R_s RH$$

$$C_2 = -0.0033 + 0.00812 T + 0.101 R_s - 0.00584 R_s T$$

Where RH is relative humidity (%)

T is the mean air temperature (^oC)

R_s is solar radiation (MJ/m^{-2}day^{-1})

c) Hargreaves-Samani method

$$ET_0 = 0.408*0.0023R_a\left(\frac{T_{\max} + T_{\min}}{2} + 17.8\right)(T_{\max} - T_{\min})^{0.5} \quad \textbf{(2-5)}$$

Where Tmax and Tmin are maximum and minimum temperature (^oC) and R_a is extraterrestrial radiation ($MJ/m^{-2}/day^{-1}$)

d) Hargreaves method

$$ET_0 = 0.0135*0.408R_s(T + 17.8) \quad \textbf{(2-6)}$$

Where R_s is solar radiation ($MJ/m^{-2}day^{-1}$)

T is the mean air temperature (^oC)

e) Enku's temperature method

$$ET_O = \frac{T_{\max}{}^{2.5}}{k} \quad \textbf{(2-7)}$$

Where, ET_O is the daily evapotranspiration (mm/day), $T_{\max}$ is the daily maximum temperature (^oC), k is estimated as, $K = 38*T_{mm} - 63$, where T_{mm} is the long term mean maximum daily temperature (^oC).

f) Penman-Monteith method

The Penman-Monteith equation uses different climatic parameters and gives more accurate result than other methods.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \textbf{(2-8)}$$

Where ET_O = Potential evapotranspiration (mm/day)

R_n = net radiation at the crop surface ($MJ/m^2/day$)

G = soil heat flux density ($MJ/m^2/day$)

T = mean daily air temperature at 2m height (^oC)

u_2 = wind speed at 2m height (m/sec)

e_s = Saturation vapor pressure (Kpa)

e_a = actual vapor pressure (Kpa)

$e_s - e_a$ = saturation vapor pressure deficit (kpa)

Δ = slope of vapor pressure curve (kpa/^oC)

γ = psychometric constant (kpa/^oC)

T_{max} and T_{min} are the daily maximum and minimum temperature (^oC)

2.3 Soil moisture and its measurement

Antecedent soil moisture as mentioned before, is one of the major factors that affect runoff generation.

Soil moisture can be determined by direct or indirect measurements (Johnson,1967).

a. Direct method (Gravimetric method):- Soil samples of about 50g are taken from the field and the soil moisture content is determined as follows:
    - Mass of can plus wet soil is measured and put to the oven at 105^oC
    - After 24 hours, mass of can plus dry soil is measured
    - Finally moisture content is determined from these readings.

b. Indirect method:- Radiological methods (i.e. Neutron scattering and gamma ray attenuation) and soil water dielectrics are the indirect method of estimating soil moisture. There are two methods which evaluate the soil moisture dielectrics which are commercially available and used extensively, namely time domain reflectometer (TDR) and frequency domain measurement.

   The soil water dielectrics uses electromagnetic radiation to sense the water content in the soil which is stored in the charge storing system of the instrument. The electromagnetic radiation is transmitted through the probe and produces reflection of energy as it passes through the sensor which is related to the water content of the soil.

   The Neutron scattering method of soil moisture measurement has a small radioactive source in the instrument which emits fast moving neutrons in the soil that collide with hydrogen atoms in the water in the soil and are slowed down. The detection of slow moving neutrons returning to the probe gives an estimate of the number of hydrogen atoms present in the soil and thus the amount of soil moisture.

2.4 Groundwater

Groundwater and surface water are not isolated components of the hydrologic system, but instead interact in a variety of physiographic and climatic landscapes.

Therefore, an understanding of the basic principles of interactions between groundwater and surface water is needed for effective management of water resources (Sophocleous 2002). The runoff generation mechanism in the watershed is also influenced by the subsurface flow. Therefore understanding the subsurface flow phenomena (i.e. ground water and its recharge) is needed. Groundwater is water found beneath the earth's surface in pores and fractures of soil and rocks. Ground water in Lake Tana basin is characterized by complex lithologic and techtonic features having four major aquifer systems; tertiary volcanics, quaternary volcanics, miocene sediments and alluvio lacustrine sediments (Kebede 2013). Fifteen percent of the annual flow in Upper Blue Nile basin is derived from shallow ground water in which the highest groundwater contribution to surface water takes place in the Gilgel Abay sub catchments having 305mm/yr ground water discharge (Kebede 2013).

2.4.1 Groundwater terms and definitions

Aquifer:

An aquifer may be defined as saturated fractured rock or sand from which usable volumes of groundwater can be pumped. Aquifer can be confined, unconfined or perched aquifer.

Aquitard:

An aquitard restricts the flow of water from one aquifer to another, for example clay layer or solid rock.

Unconfined aquifer:

An unconfined aquifer is a rock or sand that does not have a confining layer (e.g. clay aquitard) on top of it having shallow water level in the bore. The top of an unconfined aquifer is the water table that fluctuates up and down depending on the recharge and discharge rate.

Confined aquifer:

A confined aquifer is a rock or sand that is overlain by a confining layer that restricts movement of water into another aquifer which is under high pressure because of the confining layer on top of the aquifer. In a confined aquifer, the water level in a bore will rise to a level higher than the top of the aquifer because of the high pressure and in some instances the water level may be above the ground surface which is called artesian

Perched aquifer:

Perched aquifers occur where groundwater is located above unsaturated rock formations as a result of a discontinuous impermeable layer.

2.4.2 Groundwater recharge

Recharge is a hydrological process in which water enters in to the saturated zone (Freezer and Cherry, 1979). It can also be defined as water that reaches an aquifer from any direction (down, up, or laterally) (Lerner et al., 1997). Accurate quantification of recharge rates is needed for proper management and protection of valuable groundwater resources (Healy and Cook, 2002).

Recharge can be estimated using different methods, some of which include, water budget method, unsaturated zone method, groundwater (saturated zone) method, stream flow method.

a. Unsaturated zone method:- Involves measurement of drainage from gravity lysimeters by directly measuring the vertical flow of water through unsaturated zone at a depth below root systems (Scanlon, 2002).
b. Water budget method:- Recharge can be computed from the daily water balance as shown below (Allison et al., 1994).

$$R = P - \left[E_t + R_o + \Delta S\right] \quad \textbf{(2-9)}$$

Where R is recharge

P is precipitation

E_t is evapotranspiration

R_o is direct runoff

ΔS is change in storage

c. Water table fluctuations in wells (saturated zone method):- This method used to estimate recharge from the water level rise in a well multiplied by the specific yield of the aquifer.

$$R = S_y \left[\frac{\Delta h}{\Delta t}\right] \quad \textbf{(2-10)}$$

Where S_y is specific yield which is dimensionless.

Δt is change in time

Δh is change in water level rise

The specific yield, Sy, is the fraction of water that will drain by gravity from a volume of saturated soil or rock. It can also be defined as the difference between total porosity and the water content at field capacity (Atta-Darkwa et al., 2013). The specific yield can also be determined from drainage experiments on samples of aquifer material in the laboratory. In this method, the specific yield is taken to be the difference between the water content at saturation and the water content after the saturated soil is allowed to drain by gravity (Neuman, 1987). The water table fluctuation method (WTF) works for shallow water tables that display sharp water level rises and declines. It is attractive in its use because of its simplicity to apply although it's not suitable for wells having similar water level maintaining steady rate of recharge (Healy and Cook, 2002).

d. Recharge from streamflow records :- Streamflow is the amount of surface water flowing through streams, and rivers which is measured at gauging stations. Streamflow measured at a gauging location in the rainy season is a combination of both baseflow and surface runoff from the watershed.

In the dry season, streamflow is mostly baseflow. Therefore, baseflow is separated from part of the streamflow hydrograph attributed to groundwater discharge using either manual or computational separation methods can be used to estimate groundwater recharge if groundwater losses are minimal.

There are a number of methods used to separate streamflow from baseflow which is the first step in hydrograph analysis. These are manual separation techniques, use of chemical or isotopic tracers, and mass balance approaches.

All of these methods are subjective (Arnold et al., 1995). To remove the subjectivity and to reduce time for analysis different attempts have arose to automate baseflow separation processes with computers. Among these methods a baseflow filter program (Arnold et al., 1995), which uses signal analysis for separation, is easy to use. The program uses the following equation:

$$q_t = \beta q_{t-1} + \left[\frac{1+\beta}{2}\right] * (Q_t - Q_{t-1}) \quad \textbf{(2-11)}$$

Where q_t is the filtered surface runoff at t time step, Q_t is the original stream flow and β is the filter parameter which is taken as 0.925. Q_{t-1} is the stream flow at time t-1. Base flow b_t is calculated with the equation:

$$b_t = Q_t - q_t \quad \textbf{(2-12)}$$

The filter is made to pass over the stream flow data in one to three passes until the computed baseflow better matches the streamflow record during the dry season. Finally the recharge can be computed from recession curve displacement techniques or from the measured data using the separated flow (Arnold et al., 1999).

$$R = B_F + E_t + S + S_t \quad \textbf{(2-13)}$$

Where B_F is groundwater discharge (baseflow)

E_t is evapotranspiration

S is subsurface seepage out of the basin

S_t is change in groundwater storage

The baseflow time series is also estimated by using empirical equations derived from genetic programming as follows (Meshgi et al., 2014).

$$Q_{BF} = B_{B\min} + \sqrt{bA}.\Delta h^2{}_{P(t)} \quad \textbf{(2-14)}$$

Where Q_{BF} is the daily baseflow volume (m^3)

Q_{Bmin} is the minimum daily baseflow of the entire period (m^3)

A is the total unpaved surface area in the catchment (m^2)

$\Delta h_{P(t)}$ is the normalized daily average of pressure head with in a piezometer.

3 MATERIAL AND METHODS

3.1 Study Area

Dangila woreda is located in the north west highlands, in Awi zone in the Amhara region and is one of Agricultural Growth Program (AGP) and USAID Feed the Future woredas in the Amhara regional state. It is located about 80 km south west from Bahir Dar, 36.83° N and 11.25° E and on average 2000 m above sea level. In the woreda, there are 27 rural kebeles among which 16 of them have access to a perennial river. The climate is sub-tropical with average annual rainfall of about 1600 mm (Gowing et al., 2016) but varies between 1180-2000 mm where the rain starts in the middle of June and stops at the beginning of October. The mean annual reference evapotranspiration is about1250 mm.

The woreda have altitudes generally ranging from 1850m to 2350m. Part of Dangila woreda drains north-east towards Gilgel Abay river and Lake Tana. The remaining area drains either west or south west towards Beles River, which are the tributary of Blue Nile. The woreda's geology is predominantly quaternary basalt and trachyte above ecocene oligocene basalts and trachyte including massive, fractured and vescular basalts, weathered basalt regolith overlain by red soils which is more lithic and clayey with depth and other superficial materials underlying the flood plains which are often browner in color (Gowing et al., 2016).

From these 27 rural kebeles, Dangishta kebele was selected for this study. The kebele's population is about 5600. Dangishta has two major rivers; Brantie River whose watershed covers 3305ha and Kilti River whose watershed covers 1000 ha. This study was done in the Brantie watershed. The watershed area is divided in to grazing land, agricultural land, residential area, bush land and trees including small trees and big trees like acacia and eucalyptus. Agricultural land is the main land use in the watershed. The percentage of each land use in the watershed is 80.3% for agricultural land, 0.67% forest land, 0.13% wet land, 13.8% grazing land and 5% residential area (Dangila woreda agricultural office, 2016).

The main crops produced in the watershed are teff, millet, maize, chat and vegetables. The main vegetables grown in Dangishta watershed include onion, tomato and cabbage. Soil sample taken within the watershed show that the textural classification of soils in Dangishta to be clay and heavy clay. Most of the local people in Dangishta have wells use for irrigation, domestic use and livestock feeding. There are more wells in the downslope area as compared to the upslope and midslope areas. This is because in the downslope area, the water level is shallower and it is easier to extract water from shallow depths. The restricting layer is also deeper downslope making it easier for farmers to dig the wells by hand. The total watershed outlet area is 3305ha and 1338ha for the upstream sub watershed outlet.

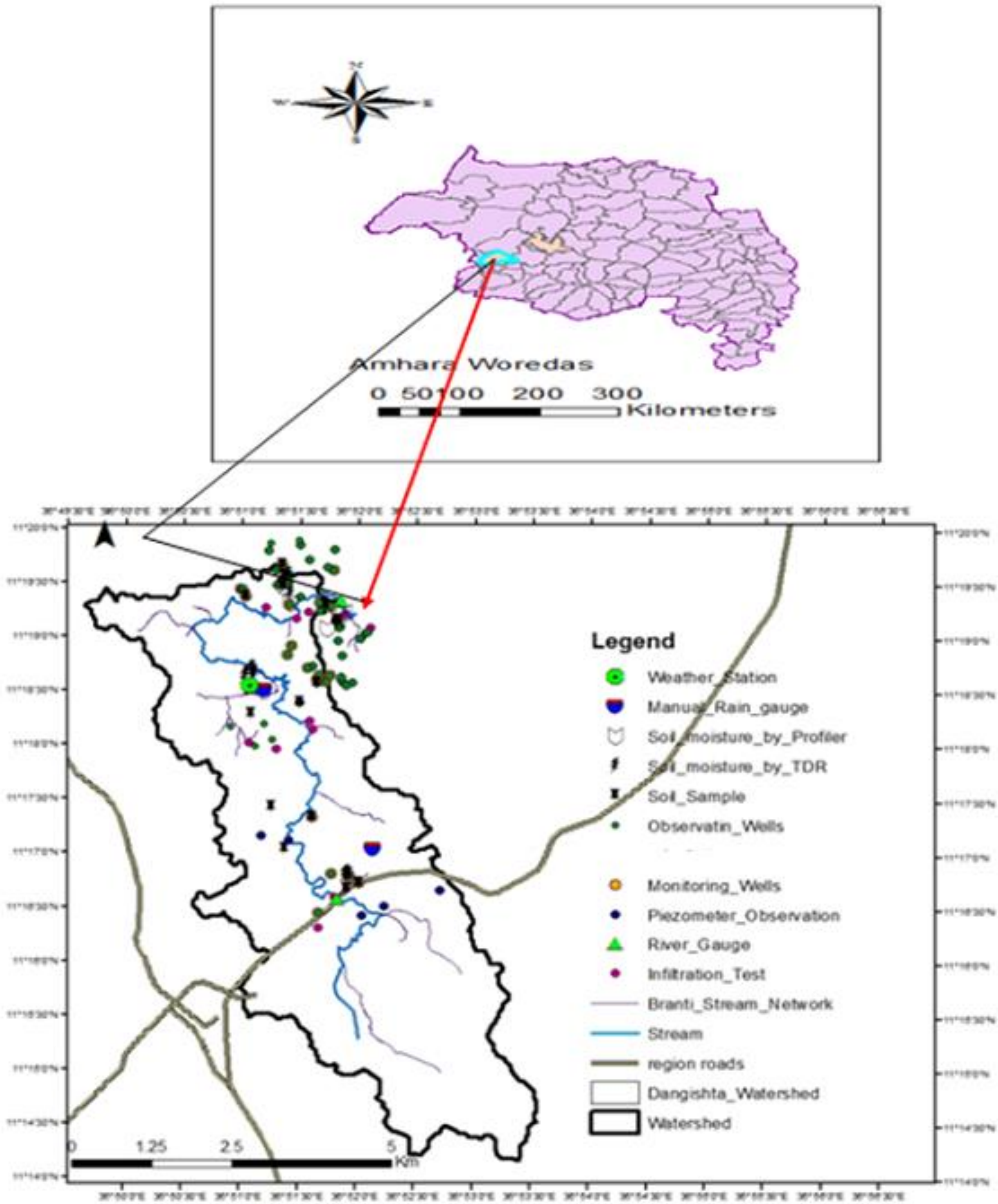


Figure 3-1 Watershed map of Dangishta delineated from total watershed outlet.

3.2 Data and methodology

Field work started during December 2014 after the rainy season in Dangishta Watershed. Rainfall, water depth at upstream sub watershed outlet and total watershed outlet, infiltration tests before and at the end of rainy season, soil moisture by TDR and shallow ground water levels were monitored starting from December 2014 to end of October 2015.

3.2.1 Rainfall measurement

- An automatic weather station was installed in March 2015 to measure rainfall, temperature, wind speed, relative humidity, solar radiation and atmospheric pressure at 10 minute interval.

Figure 3-2 Automatic weather station

- Manual rain gauges at the upslope and midslope area were also installed in order to capture the rainfall distribution in the watershed. Their locations within the watershed are shown in Figure 3.1

The rainfall data were recorded in the watershed at 10 minute intervals with automatic rain gauge. The measurement was taken from March 18, 2015 up to October 5, 2015.There were gaps in measurement due to instrument failure for some days in the rainy season. To fill the gaps in measurement, a manual rain gauge installed adjacent to the automatic rain gage was used. The manual rain gauge recorded data from September 11, 2014 up to November 10, 2015. From the rainfall readings, 10 minute rainfall intensity were computed.

3.2.2 Effective rainfall computation

Effective rainfall is the amount of rainfall which reaches the earth surface and finally may infiltrate to the soil or turn to runoff. Effective rainfall can be computed by subtracting the reference evapotranspiration from the total precipitation (Engda et al., 2011, Tilahun, 2012).

The reference evapotranspiration for the entire watershed was estimated by the Penman-Monteith method using climatic data from the automatic weather station installed in the watershed. There were gaps in measurement of climatic data due to the failure of instrument and as a result the data from the automatic weather station was supported by data from the Dangila meteorological station.

3.2.3 Infiltration measurement

Soil infiltration rates were measured at sixteen to eighteen different points throughout the watershed using 30cm diameter single ring infiltrometer before and during rainy season of 2015 respectively. The points were at different topographic location including upslope, downslope and midslope and at different land uses as shown in Appendix-C1 and C2.

Table 3-1: Number of repetition for each land use at different topography during infiltration measurement in the rainy season.

	Topography		
Land use	Upslope	Midslope	Downslope
Maize	3	2	1
millet	1	n.a	1

Teff	2	1	1
Eucalyptus	1	1	1
Vegetable	n.a	n.a	1
Grazing	1	1	1

The range of elevations for the measured infiltration were from 2102 to 2110 masl for upslope, 2068 to 2090 masl for midslope and 2035 to 2055 masl for down slope. The timing of the tests were as follows: on April 5 and 6, 2015 measurements at downslope were carried out. On April 17 and 18 of 2015, the measurements were focused on the midslope and upslope areas. Similar measurement in the rainy period of 2015 were conducted on August 29 and 30 of 2015 at upslope, and between August 31, 2015 and September 9,2015 for the midslope and downslope portions of the watershed.

The infiltration rate measurements were done at different land uses (i.e. maize, millet, teff, grazing land and eucalyptus tree). During each measurement, the ring was inserted in to the soil up to 10cm. A ruler with a spirit level was used to read the water depth fluctuation in the ring and to level the infiltrometer. Finally the steady state infiltration rate was taken as the infiltration capacity of the test area. The steady state infiltration rates were then compared with the probability of exceedance of rainfall intensities in order to evaluate the runoff generation mechanism. The probability of exceedance of rainfall intensity against soil infiltration rate was plotted to see the relation between soil infiltration rates and rainfall intensities.

3.2.4 Soil moisture measurement

To support the determination of the runoff generating mechanism in Dangishta watershed, soil moisture content measurements were taken once every week using TDR at the different land uses and topographic locations. The measurements were carried out at upslope, mid slope and downslope areas considering the dominant land uses: teff, maize, millet, grazing land and Eucalyptus trees.

The soil moisture content in the surface soil layer prior to a rainfall event strongly affects infiltration, and will thus affect the occurrence of runoff (Merz and Plate, 1997). For a rainfall event of high intensity or where soils are less permeable, runoff generation might not depend on the antecedent soil moisture content of the surface soil layer. In this case, infiltration excess overland flow will be predominant.

However, when rain storms are less intense and are falling on soils with high permeability, runoff is strongly controlled by the antecedent soil moisture of the surface soil layer (Dunne and Black , 1970). In this case saturation excess overland flow will be the dominant runoff generating mechanism. This is because, if the surface soil layer becomes saturated, any incoming rainfall will contribute to direct runoff. For this study, moisture status of the surface soil layer was monitored using 20cm long TDR roads.

The soil field capacity is the indicator used in this study to determine how wet or dry the surface soil layer was prior to rainfall events and also throughout the study period.

At the start of the study, a total of 8 undisturbed soil samples were taken from the various land uses at the various topographic positions from the top 10cm to (Amhara Design and Supervision Works Enterprise) laboratory to test for their field capacity. From the upslope 3 samples were taken from maize, grazing land and teff and 4 samples from grazing land, teff, millet and maize were taken from the downslope location. One sample was taken from a maize plot in the midslope area. The TDR readings were calibrated using the gravimetric method using six undisturbed soil samples as shown below.

Table 3-2 Calibration of TDR readings by gravimetric method

Can No	930	940	562	985	995	509
Can weight(g)	36	35.9	35.7	36	35.9	35.8
Can+ wet soil (g)	153.2	163.5	145.8	158.3	168.3	149.4

Can+ dry soil (g)	126.6	135	121.67	132	141.38	123.2
Gravimetric soil moisture content (Vol %)	29.36	28.76	28.07	27.40	25.52	29.98
TDR reading (Vol %)	44.5	39.5	35.7	31.8	21.8	45.9

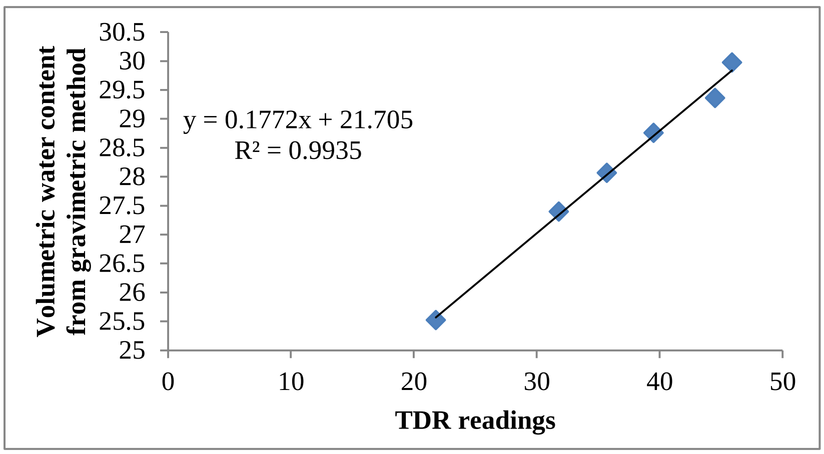


Figure 3-3 Graph showing the relation between volumetric soil moisture measured by TDR and gravimetric method.

3.2.5 Streamflow measurement

Staff gauges were installed in may 2015 at the total watershed outlet to be able to read the water level in the stream.

Figure 3-4 Staff gauge which was installed at the total watershed outlet

As shown in the above figure, the staff gage installed in the flood plain helps to read the water level when the maximum water level reaches the flood plain.

Streamflow discharge was measured from December 22, 2014 up to November 10, 2015 at the total watershed outlet and from January 19, 2015 up to November 10, 2015 at the upstream sub watershed outlet. Staff gauge measurements were done twice every day; at 6:00 am in the morning and at 6:00pm every evening. The cross section for the upstream sub watershed outlet and total watershed outlet were measured (i.e. depth to river bed for each chainage) was measured up to the expected flood extent during the rainy season to determine the area contained by the incoming flow. Surface flow velocity was also measured once every week at each control point using a float released along 5m to 15m straight reach of the river.

The time travelled by the float to finish the straight reach of the river was recorded. The surface flow velocity measurement was repeated three times each time. Finally, the mean surface velocity was determined by dividing the distance travelled by the average time taken to travel that distance. Each time the surface velocity were measured, the water depth at the control points was also recorded. Mean flow discharge was then calculated as: mean discharge = mean surface velocity x wetted cross sectional area.

From the above measurements and at both control points, the stage discharge relationship was computed according to best line of fit. The obtained equations at both stations were used to convert the measured water levels in to discharge shown below.

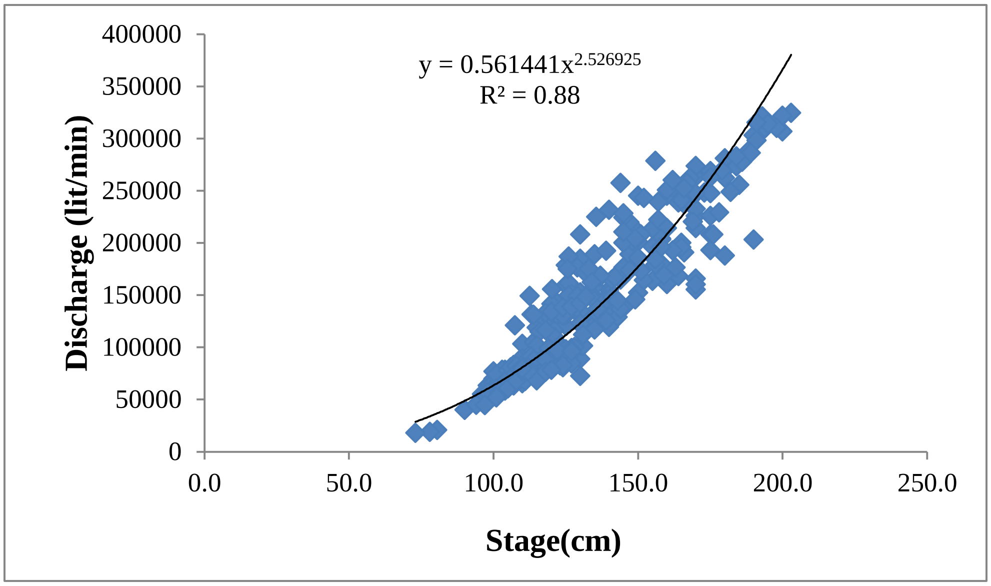


Figure 3-5 Stage discharge relationship at sub watershed outlet of Dangishta watershed

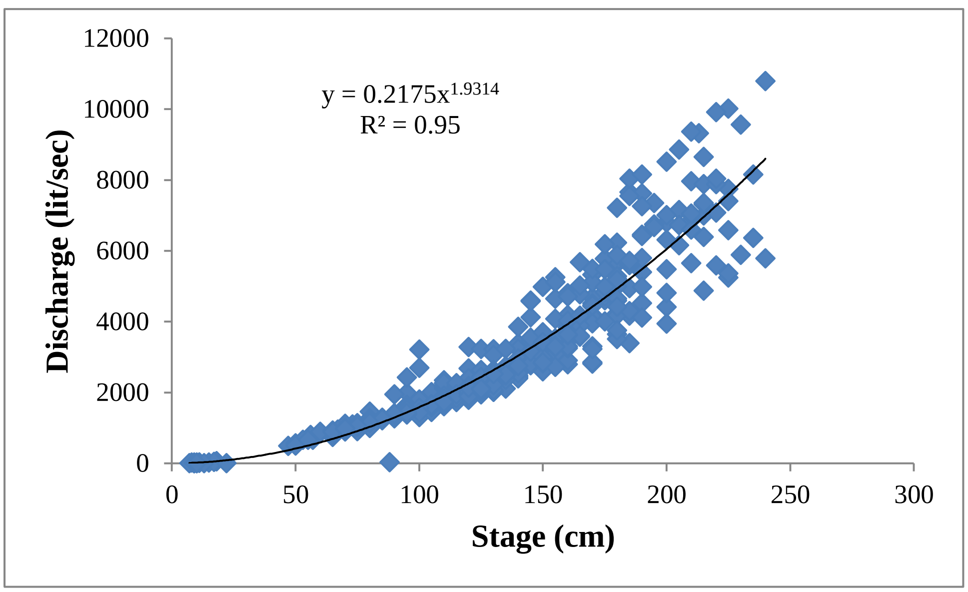


Figure 3-6 Stage discharge relationship at the total watershed outlet of Dangishta watershed

Since both baseflow and surface runoff contributes to streamflow during the rainy season separation of baseflow from streamflow was also performed. Finally, the amount of runoff depth in the watershed for each day was computed by dividing the runoff volume by the total watershed area.

3.2.6 Baseflow separation

The portion of streamflow that is not runoff and results from seepage of water from the ground in to the channel slowly over time is baseflow. For this research, a Bflow baseflow filter program *(http://swat.tamu.edu/software/baseflow-filter-program/)* (Arnold et al., 1995) was used to separate the baseflow from the streamflow. In this method, the interflow component is included in the surface runoff. This software has its own algorithm and it works for any local data with the following basic steps.

- The data was arranged as yyyy-mm-dd and flow values. Between successive streamflow data there were daily time step. At least one space between the date format and flow values is required. The format of the data was saved in space-delimited format.
- Master input file was created. In this step the name of the file containing the streamflow data was specified and a different daily output file name was also specified.
- The program was run by typing bflow.exe at the command prompt, and the daily baseflow was separated from the streamflow. The filter is made to pass over the streamflow data in one to three passes until the computed baseflow better matches the streamflow recorded during the dry season.

3.2.7 Runoff volume and determination of runoff coefficient

Runoff discharge at the control points of the watershed was computed by subtracting the baseflow discharge from the streamflow discharge and finally the runoff volume was computed by multiplying the runoff discharge with time. The runoff depth in the watershed was computed by dividing the runoff volume by the watershed area.

To show the relation between rainfall and runoff for different months in the rainy period, runoff coefficient i.e. ratio of runoff (mm) to rainfall (mm) was determined. The result was compared for the different months in the rainy season. An increase in runoff coefficient shows low infiltration and high runoff (Tilahun 2012).

3.2.8 SCS runoff equation

The watershed saturation excess runoff response for the rainfall events can be simulated using SCS runoff equation (2-2) where, Pe is the effective rainfall in mm and Se is the available watershed storage after runoff starts in mm. The measured weekly sum of runoff at the upstream sub watershed outlet and total watershed outlet, and weekly sum of effective rainfall were used to calibrate for the value of Se in the SCS runoff equation 2-2 using solver in excel.

The steps that were taken are as shown below.

a. Weekly cumulative runoff depth (i.e. runoff volume/watershed area) and weekly cumulative rainfall was computed.
b. Weekly cumulative reference evapotranspiration and weekly effective rainfall (i.e. weekly rainfall minus weekly reference evapotranspiration) were computed.
c. Finally using solver in Excel, the total runoff as estimated by the SCS runoff equation 2-2 for the whole rainy season was adjusted to match the total measured (observed) runoff by adjusting the Se value.
d. The simulated runoff from equation 2-2 using the developed Se value was plotted against the measured runoff and both R^2 and Nash Sutcliff Efficiency (NSE) calculated. NSE is a normalized statistics that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information") (Nash and Sutcliff, 1970) which indicates how well the plot of observed versus simulated data fits the 1:1 line.

It ranges from negative infinity to one. NSE = 1, corresponds to a perfect match of modeled to observed data. NSE = 0, indicates that the model predictions are as accurate as the mean of the observed data. $-\infty < NSE < 0$, indicates that the observed mean is better predictor than the model. The nash-sutcliffe model efficiency coefficient is used to assess the predictive power of hydrological models and is defined as

$$NSE = 1 - \frac{\sum (observed - simulated)^2}{\sum (observed - meanobserved)^2} \tag{3-1}$$

3.2.9 Groundwater level measurement

Reconnaissance study for the whole watershed was done before selecting monitoring wells in the watershed. During the reconnaissance study, after long walk from the upslope to the downslope area, physical observations on the existing wells were made. During this time, interview with well owners were also done. The interview questions included: the number of wells a household had, purpose of the well(s), date of construction, depth of the well, and if the wells have water all year round or not. For each household in the watershed having a well similar information were collected. During each interview, GPS coordinates were taken for each of the wells.

With these data, wells were selected for groundwater level monitoring, covering the spatial extent of the watershed using Google Earth. Based on this procedure, five wells from the upslope, five wells from the midslope and twenty wells from the downslope areas were selected. This activity was done during January of 2015 and the groundwater level measurement started in February 2015. For areas that did not have monitoring wells especially for the grazing land, seven piezometers up to maximum of 3.5m were installed in the wet season to monitor groundwater level.

During the dry season, the water table in this area was too deep and it was difficult to manually dig the earth up to the groundwater level in these areas without wells. For each of the wells mentioned above, there was measurement of water table from the ground level. During the dry season, since the water level fluctuations were not significant, water level measurement was taken once a week. During the rainy season, the measurement was done daily. During all seasons, all measurements were taken at 6:00 am in the morning using deep meter.

3.2.10 Determination of specific yield

In this study, specific yield was determined by two methods namely: by means of a pressure plate and by means of standing tubes of 10 cm in diameter and 50 cm height.

3.2.10.1 Standing tube

Specific yield was determined from the gravimetric moisture content difference of the soil at saturation and the moisture content retained by the soil sample in a standing tube after it was left to drain from saturation for two weeks without evaporation. The soil samples were put in the standing tubes. The soil column tubes were allowed to saturate in a tanker of water for 24 hours. The tubes were covered at the top to prevent evaporation loss, and the bottom left to stand on a perforated medium to allow drainage by gravity for two weeks and the retained soil moisture content was determined from the top and bottom of the soil column tube by gravimetric method. The saturated soil water content was also determined by oven drying the saturated soil sample at 105^{o}C for 24 hours. The average gravimetric water content difference between the saturation and the retained moisture was taken to be the specific yield.

Basic steps:

- Disturbed soil samples were taken from upslope, midslope and downslope wells at 60 cm depth vertically by an auger. One sample were taken from each topographic positions.
- Soil samples were placed in standing tubes and allowed to saturate for 24 hours in a tanker of water.
- The weight of saturated soil samples were measured and then the samples dried in the oven for 24 hours at 105^{o}C

- The moisture content of the saturated samples was then computed.
- The saturated soil samples in a standing tube were allowed to drain for two weeks by covering the top of the tube from evaporation. The bottom of the tube was covered by a perforated medium for drainage.
- The weight of soil samples in the tube after drain was measured and the soil sample then dried in the oven for 24 hours.
- The moisure content after draining was determined.
- Finally the specific yield was determined by subtracting the moisture content after draining from the moisture content at saturation.

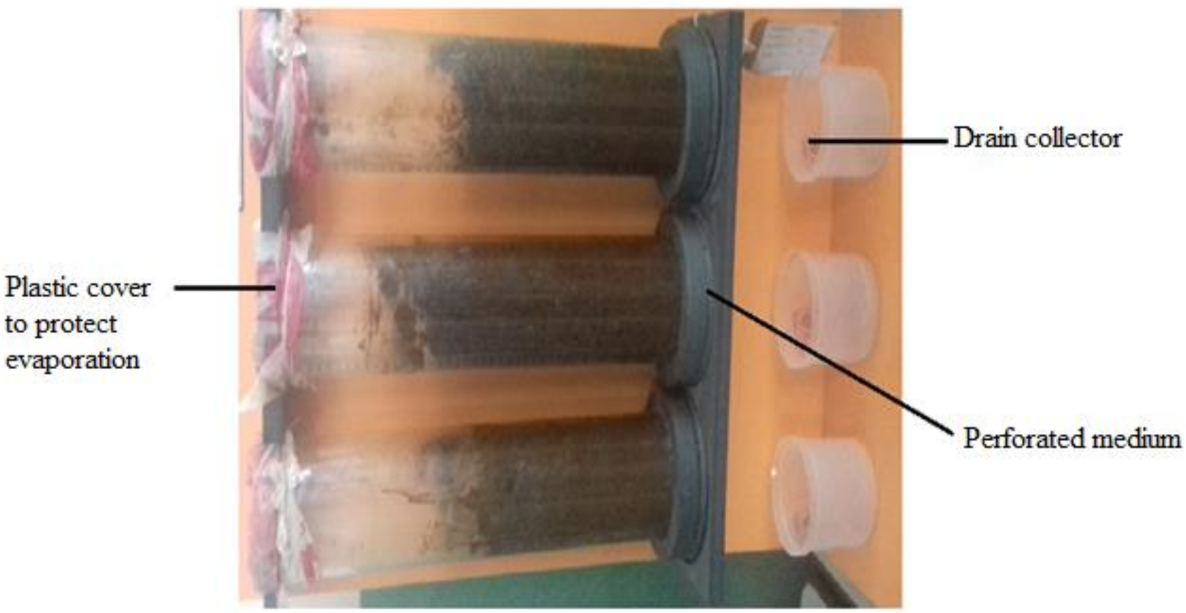


Figure 3-7 Soil sample in the standing tube

3.2.10.2 Pressure plate

Specific yield was also determined by pressure plate. The moisture content difference between soil at saturation and soil after draining when a pressure of 0.33bar was applied to it was taken as the specific yield.

Basic steps:

- The soil sample was passed in number two sieve size.
- Saturating pressure plate prior to use. The pressure plate were saturated at 1bar of pressure
- Paper filter was placed on a previously saturated ceramic plate
- Soil sampling ring was put on the paper filter.
- The disturbed soil sample was poured into the sampling ring and push down gently to compact the soil sample to the target bulk density.
- The ceramic plate with samples was then placed in the extractor.
- Using an outflow tube, the ceramic plate was connected with the outlet port.
- Soil samples were saturated with water.
- After saturating the soil samples, the samples were allowed to drain at 0.33 bar pressure. The weight of the samples at 0.33bar pressure were measured and then put in the oven at $105^{O}C$ for 24 hours.
- The moisture content of the soil afetr draining was determined
- The soil samples was saturated again and it's weight was measured. The saturated soil sample was then dried at $105^{o}C$ for 24 hours to determine the soil moisture content at saturation.
- The specific yield was estimated as the difference between the moisture content at saturation and the moisture content after draining.

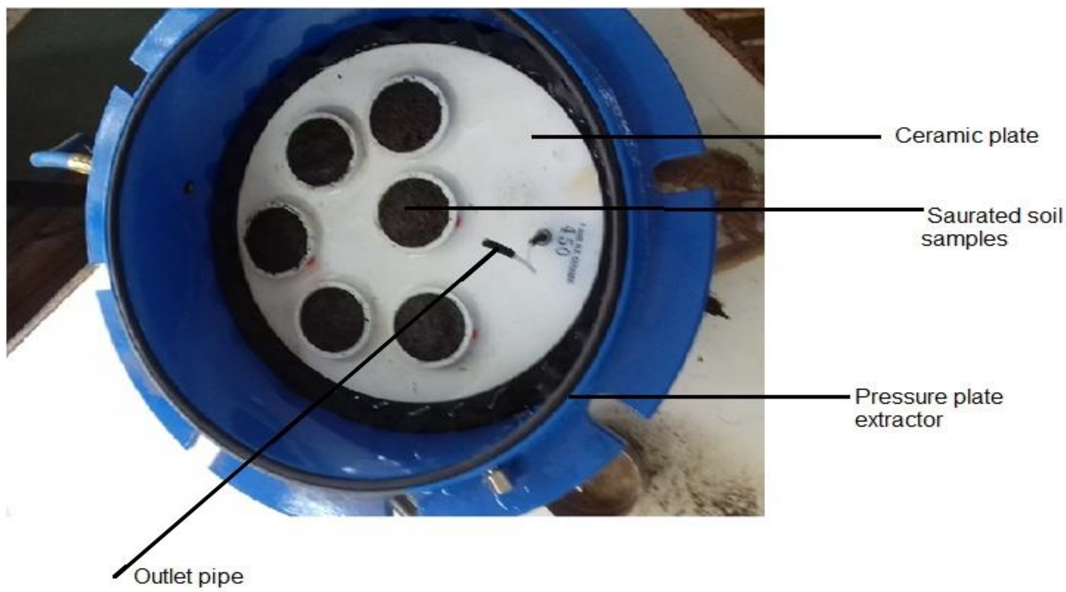


Figure 3-8 Soil sample preparation in pressure plate extractor

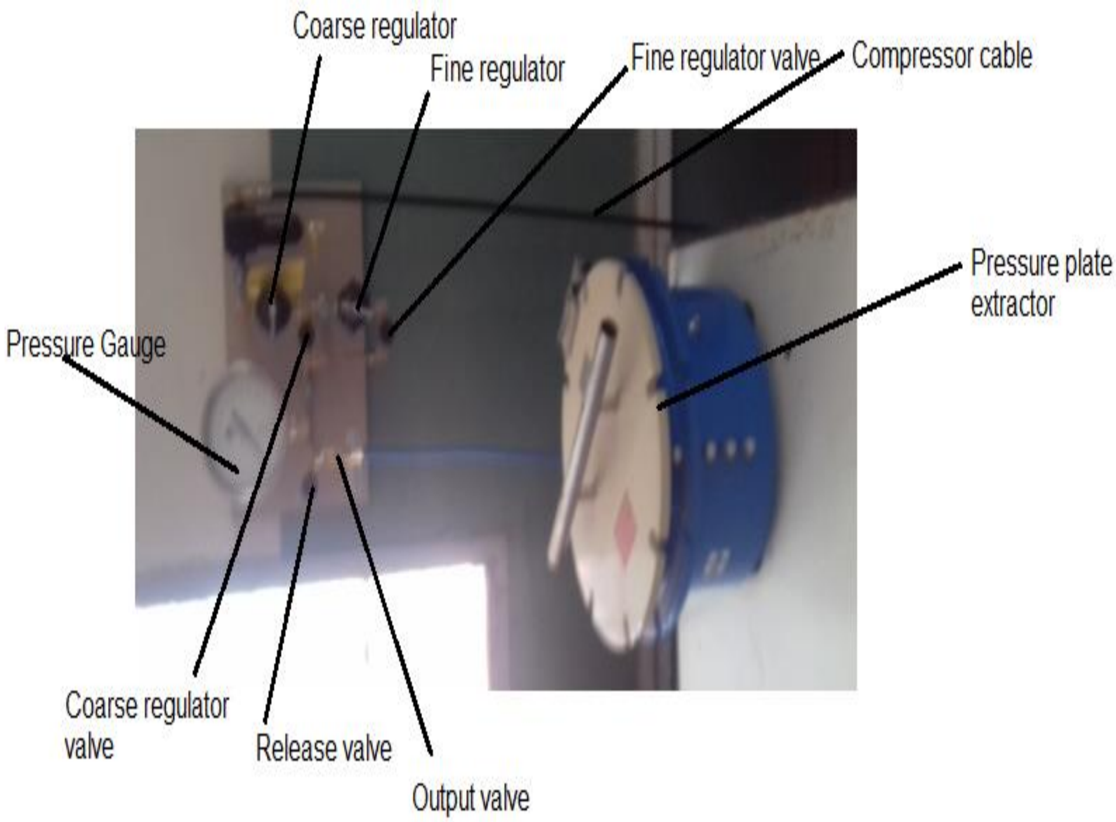


Figure 3-9 Basic components of pressure plate

Finally the average specific yield estimated by the two methods were taken for all monitoring wells.

3.2.11 Recharge estimation

Among the various methods used to estimate recharge, the water table fluctuation method was used for this study. Wells selected for water table monitoring in Dangishta are in unconfined aquifers. Recharge was calculated as:

$$R = S_y * \frac{dh}{dt} = S_y * \frac{\Delta h}{\Delta t} \quad \textbf{(3-2)}$$

Where S_y is specific yield, h is water table height and t is time. In this method uncertainty in estimation of specific yield is one of the limitations in recharge estimation.

For each of the wells monitored, the change in water level was calculated by subtracting the water level measured on the second day from the water level measured on the first day. If the value is negative it indicates no recharge, if the value is positive it indicates recharge.

4 RESULT AND DISCUSSION

4.1Climatic conditions of the watershed

The Dangishta watershed covers an area of 3305ha with elevation ranging from 2032 to 2206 masl. Rainfall received during the period of the study, January to October 2015 was 1574.1mm. The average temperature within the study period ranged from 7.29 to 28.11^{O}C. The main climatic components of Dangishta watershed i.e. maximum temperature, minimum temperature and rainfall, on monthly basis are summarized as shown below.

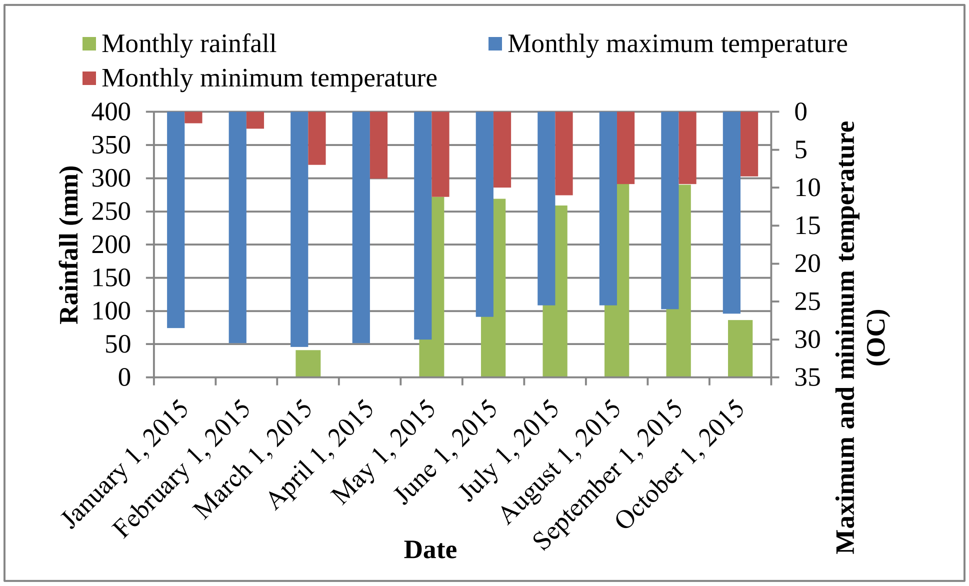


Figure 4-1 Monthly rainfall, maximum and minimum temperature of Dangishta watershed

4.2Runoff generating mechanisms analysis

4.2.1 Infiltration capacity and rainfall intensity

The steady state infiltration rate before the onset of rains ranged from 270 to 480mm/hr for upslope, 180 to 240mm/hr for midslope and 60 to 160mm/hr for the downslope areas (Appendix-C1). Dry season infiltration rates increased up the slope in the watershed. During dry period, the water table in the upslope areas was far from the ground level as compared to the downslope areas. In the downslope areas, the water table was not far from the ground level as compared to the upslope area which shows the moisture status of the upslope area was lower than the downslope. This may be the reason for the variation in infiltration rates from the downslope to upslope areas.

The median and average infiltration rate during dry period was 180mm/hr to 217mm/hr respectively. During the rainy season, infiltration rates ranged from 6 to 180mm/hr upslope, 6 to 240mm/hr midslope and 72 to 192mm/hr downslope (Appendix-C2). The median and average infiltration rate in the rainy season were 72mm/hr and 86mm/hr respectively. In the valley bottoms where the soils get saturated, lowest infiltration rates of 6 mm/hr was observed, which was consistent with similar studies conducted in the Ethiopian highlands where infiltration rates are limited in saturated soils (Bayabil et al., 2009; Tilahun et al., 2014).

In general, infiltration rates were lowest in the grass lands. This is due to the compaction in these areas caused by free grazing of animals. The rate of infiltration decreased in the rainy season when compared to the dry season measurements due to the increase in soil moisture in the soil profile that decreases infiltration of water into the soil. The difference in infiltration is similar with the studies conducted in Debre Mawi, Anjeni, Andit Tid, Maybar (Liu et al., 2008, Engda et al., 2011, Tilahun 2014).

Rainfall was recorded with an automatic rain gauge for 10-minute interval. A total of 606 rainfall events were recorded. From these recordings, the rainfall intensity was determined. The 10-minute rainfall intensities in 2015 rainy period in the watershed varied between 1.2mm/hr and 104mm/hr with an average of 6.86mm/hr. The probability of exceedance of each of the rainfall intensities was computed and plotted with the infiltration capacity of the soil.

In order to compare the rainfall intensities with the infiltration capacity, the median infiltration rate was compared with the exceedance probability of the rainfall intensity. This is because the median is the most meaningful term which represents the spatially averaged infiltration capacity of the watershed (Bayabil et al., 2010).

The steady state infiltration and rainfall intensity against probability of exceedance is shown in figure 4-2.

Table 4-1 Average steady state infiltration during the rainy season for different land use (mm/hr).

	Topography		
Land use	Upslope	Midslope	Downslope
Maize	105	180	144
millet	60	n.a	72
Teff	48	60	192
Eucalyptus	12	90	36
Vegetable	Not taken	Not taken	72
Grazing	24	6	Not taken

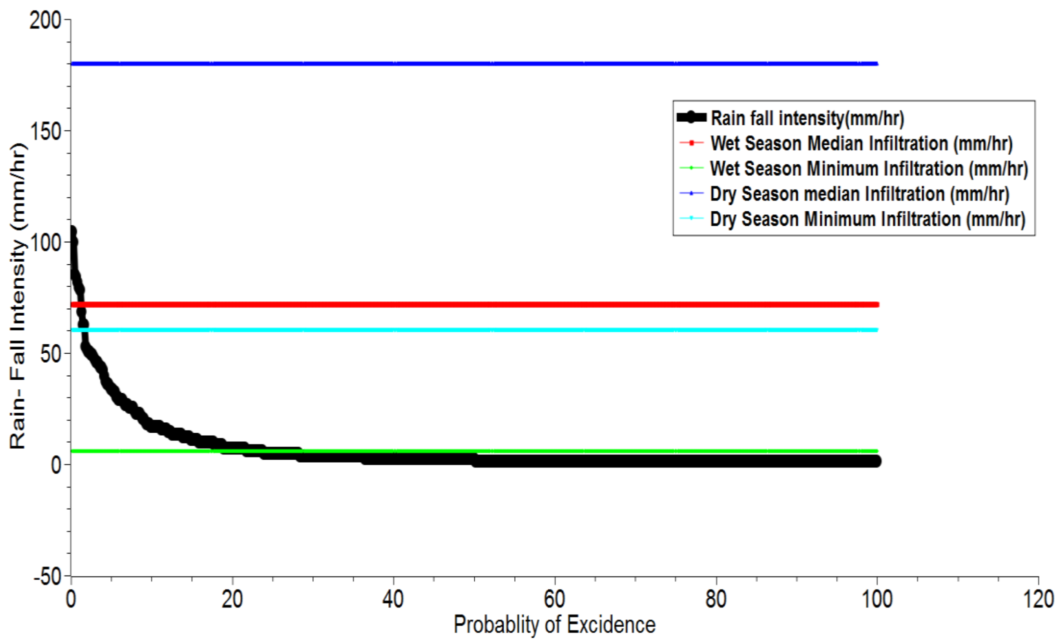


Figure4-2 Plot of the exceedance probability against ten minute rainfall intensity and steady state infiltration capacity

The median infiltration rate of the dry season of 2015 exceeded the rainfall intensity 100% of the time. The minimum infiltration rate for the same period was exceeded by the rainfall intensity only 2% of the time. This implies that for this period, saturated areas contribute to majority of the runoff (Bayabil et al., 2011). This implies that during the dry season, major portion of the rainfall would infiltrate except for a few storms with high intensities.

During the rainy period the median infiltration rate was exceeded by the rainfall intensity almost 2.5% of the time. This also shows that the most dominant runoff mechanism in the watershed during this period was saturation excess, but there were some portions of the watershed either in the upslope or downslope where the runoff contribution is due to infiltration excess as minimum infiltration rate during wet season was exceeded by rainfall intensity 25% of the time.

4.2.2 Soil moisture content monitoring

As mentioned earlier, the soil moisture content in the surface layer prior to a rainfall event can affect runoff generation. To confirm the above findings, soil moisture content measurements were taken once every week at different topographic positions and different land uses.

The moisture status of the upper 20cm of soil was measured at different landscapes (upslope, midslope and downslope) portions of the watershed by considering maize, millet, eucalyptus tree, teff and grazing land as the dominant land uses as shown from Appendix-D8 to Appendix-D10.

The measurement shows that the soil moisture status of the soil was dependent on the type of land use. As shown in the figure 4-3, the soil moisture content for each of the land uses was different indicating that land use and vegetation cover has an effect on the amount of runoff generated in the watershed. At the beginning of the rainy season the soil was drier i.e. higher storage capacity and thus infiltration rate was high.

The infiltration rate of these soils decreased as the soil moisture deficit decreased as it was being filled by the incoming precipitation. The soil moisture content was closer to or above the field capacity in the main rainy season indicating the void spaces in the surface soil profile were almost filled with water. This implies that as void spaces are increasingly filled with water, infiltration of incoming rain becomes limited and thus rainfall runs over the land as saturation excess runoff.

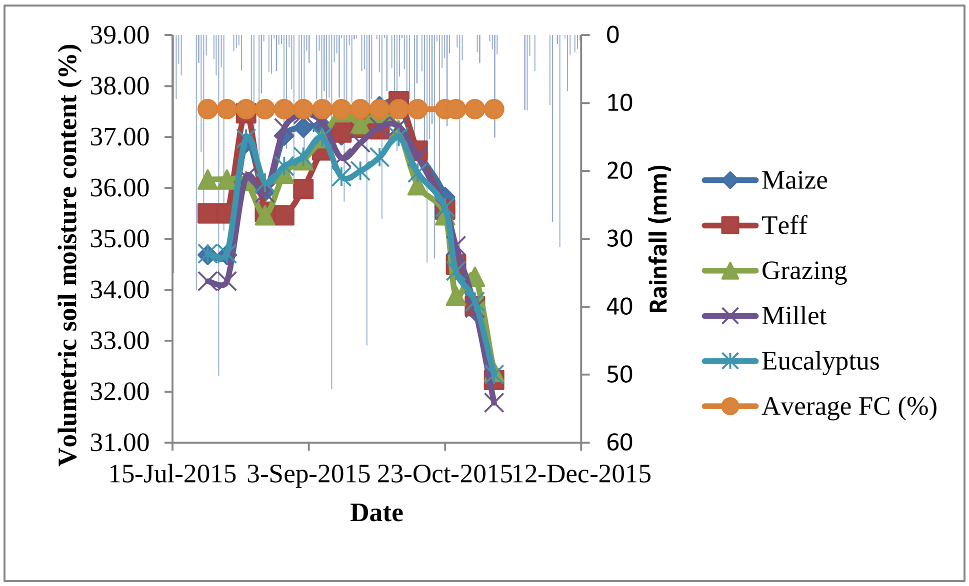


Figure 4-3 Plot of soil moisture (vol %) for each of the land uses in the upslope area.

As shown in figure 4-3, the soil moisture content was closer to or below the field capacity in various land uses in the watershed in the upslope. Rainfall raised the soil moisture content thus reducing space for water to infiltrate hence contributing to surface runoff (i.e. saturation excess flow). Any incoming precipitation on these areas produces runoff fast. In areas were soil moisture content was below field capacity but runoff was observed in the upslope areas suggest infiltration excess playing a role in runoff generation.

Generally in the upslope areas of the watershed there is much soil degradation as compared with downslope area and as a result the top soil is shallow thus limiting infiltration. The upslope areas show a more rapid drying response throughout the season due to lateral movement of water to lower slopes both on the soil surface and under the soil surface.

The minimum infiltration rate during rainy season in fig 4-2 shows 25% of the time the rainfall rate exceeds the infiltration rate which indicates there were places (for example in the upslope area as seen above) in the watershed which contributes infiltration excess runoff which support the above discussion on runoff generation mechanisms.

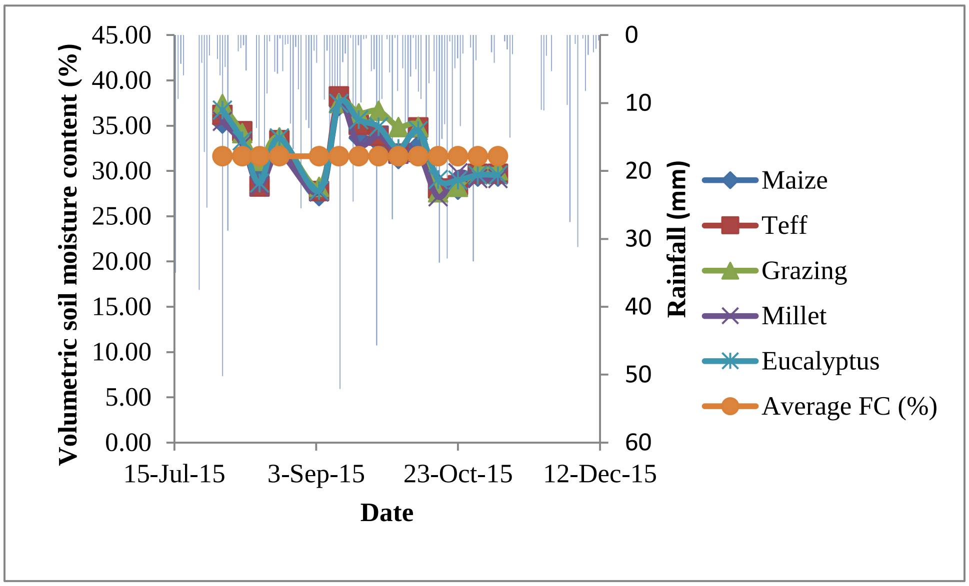


Figure 4-4 Plot of soil moisture (vol %) for each of the land uses in the midslope areas.

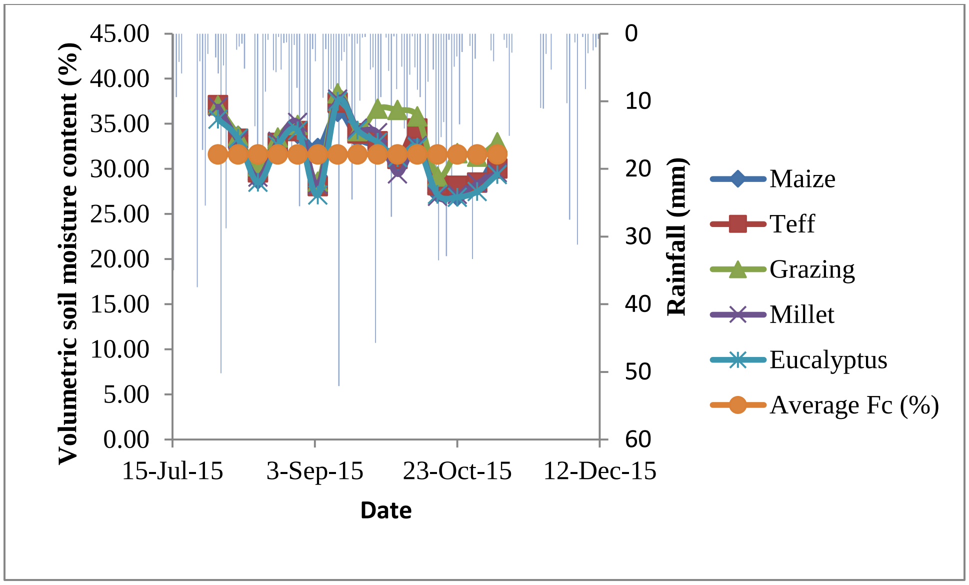


Figure 4-5 Plot of soil moisture (vol %) for each of the land uses in the downslope areas.

The moisture status of the soil in the midslope and downslope areas shows similar trends during the rainy season. The soil moisture content was greater than the field capacity for most of the time indicating that the soil was saturated and the main runoff mechanism for the measured runoff for these topographic positions was saturation excess.

Midslope and downslope areas receive water from both rainfall and both runoff and lateral subsurface flow from upper slopes. As a result soil moisture content in upslope was below field capacity while in the mid and downslope areas, the soil moisture was above field capacity almost throughout the rainy season.

4.3 Observed streamflow discharge

Stream flow was measured both at upstream sub watershed outlet and total watershed outlet as discussed in the methodology. The data including i.e. temporal water level depths, rating curves, graph of runoff depth vs rainfall depth, river cross section and measured velocity are shown in the Appendix-D, Appendix-E, Appendix-E1, Appendix-E2 and Appendix-E3 respectively. The observed streamflow discharge were separated from baseflow using BFlow software (Arnold et al., 1995). The total streamflow observed in the upstream sub watershed outlet and total watershed outlet of Dangishta watershed from the period of June 6, 2015 to November 12, 2015 were found to be 251.83 m^3/sec and 308 m^3/sec respectively.

The baseflow within the same time period was found to be 175.11m^3/sec for the upstream sub watershed outlet and 196m^3/sec for the total watershed outlet. The runoff therefore during the period of the study was found to be 76.84m^3/sec and 113.51m^3/sec for the upstream sub watershed outlet and total watershed outlet respectively. The result shows 31% and 37% of the streamflow was converted to runoff at the upstream sub watershed outlet and total watershed outlet respectively for the specified period. The runoff depth observed at the upstream sub watershed was 446mm and 213mm for the total watershed indicating that the upstream sub watershed was the more runoff source area. The result shows 36% and 19% of the rainfall was changed to runoff at the upstream sub watershed and at the total watershed respectively. The monthly streamflow, baseflow and runoff discharges is shown in Table 4-2 and Table 4-3 below.

Table 4-2: Monthly streamflow, Baseflow and Runoff discharge at the total watershed outlet of Dangishta watershed

Month	Streamflow (m3/sec)	Baseflow (m3/sec)	Runoff (m3/sec)
June	42.0	13.5	28.5
July	60.1	39.1	21.7
August	94.3	62.0	32.3
September	73.4	51.4	22.1
October	28.8	22.6	6.2
Sum	298.6	188.6	110.7

Table 4-3: Monthly streamflow, Baseflow and Runoff discharge at upstream sub watershed outlet of Dangishta watershed

Month	Streamflow (m3/sec)	Baseflow (m3/sec)	Runoff (m3/sec)
June	32.50	22.20	10.30
July	54.98	38.08	16.90
August	71.41	42.59	28.86
September	43.13	31.61	11.59
October	36.86	29.33	7.53
Sum	206.39	141.62	64.88

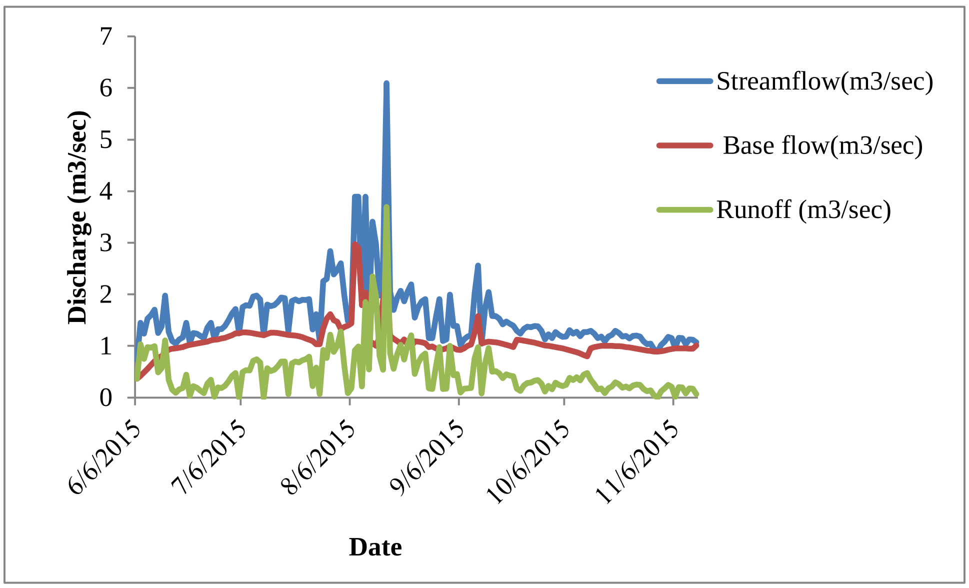


Figure 4-6 Separation of stream flow from base flow at upstream sub watershed outlet of Dangishta watershed

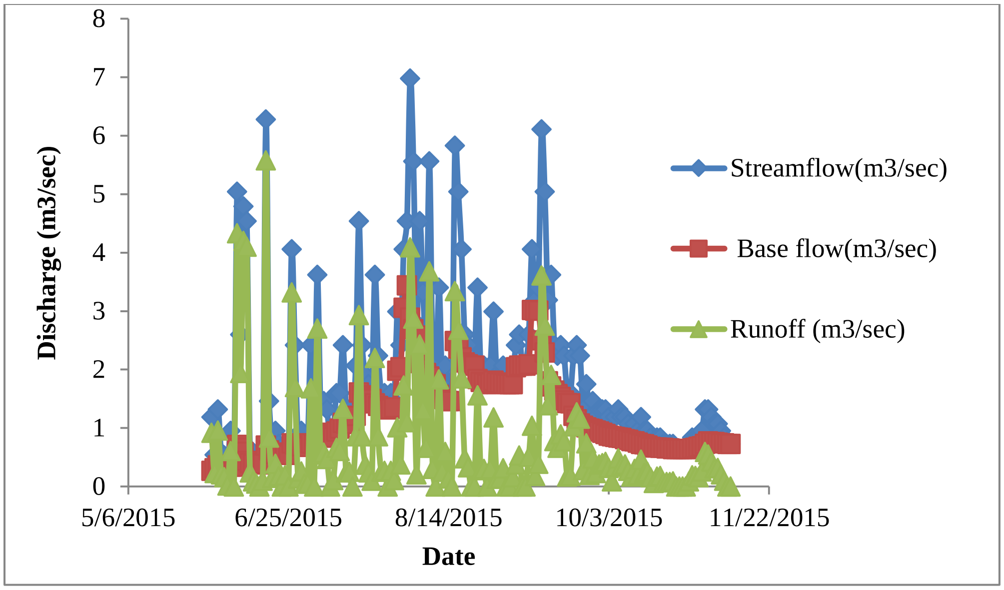


Figure 4-7 Separation of stream flow from base flow at total watershed outlet of Dangishta watershed

4.4 Runoff coefficient

In order to easily analyze runoff at the upstream sub watershed outlet and total watershed outlet, runoff coefficients defined as quotient of monthly runoff and rainfall were calculated for rainy period of 2015 for June, July, August and September (Figure 4-8). The result showed that June had the lowest runoff coefficient indicating that at the beginning of rainy period, the amount of runoff was smaller because the rainfall infiltrates to fill the soil moisture deficit which was greater at this time. Later as the rainfall season progressed, the amount of surface runoff was increased. As it continues to rain, the soil surface layer becomes saturated that other incoming precipitation was turned in to runoff as shown by the increasing runoff coefficients for the rest of the months. The result was similar with the findings of Tilahun (2012).

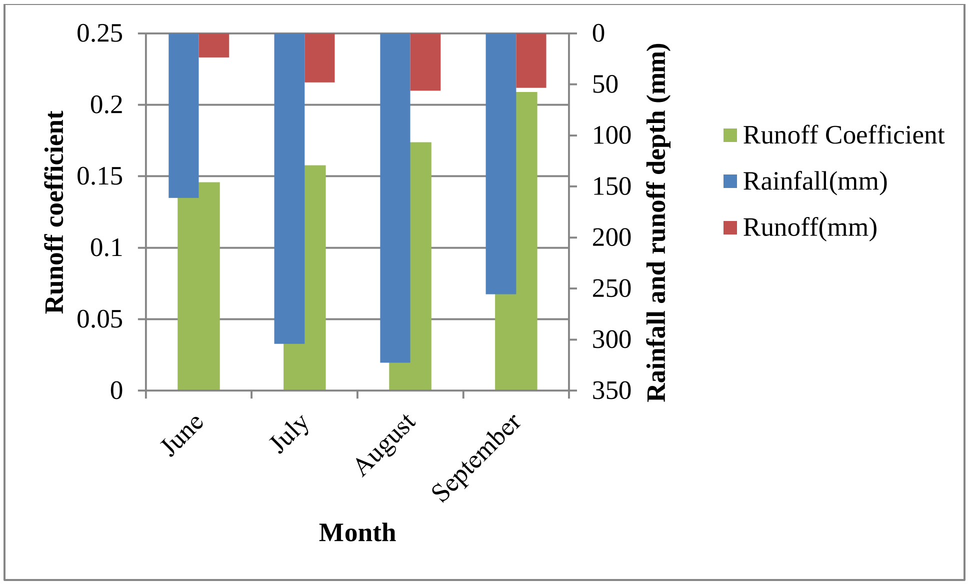


Figure 4-8 Runoff coefficient at total watershed outlet of Dangishta watershed

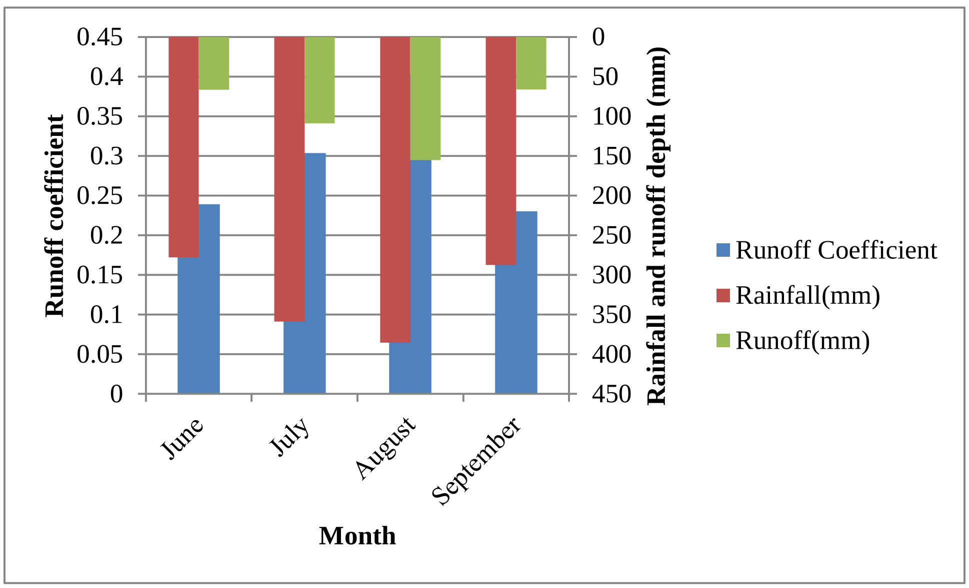


Figure 4-9 Runoff coefficient at sub watershed outlet of Dangishta watershed

4.5 SCS runoff equation

The measured runoff was used to calibrate the effective available storage, Se, for the Dangishta watershed. For the SCS runoff equation 2-2, weekly effective rainfall was computed as the difference between weekly rainfall and weekly reference evapotranspiration. Results are shown in Figure 4-10. Reference evapotranspiration was computed using Penman-Monteith as shown in appendix-G1. Using solver in excel, the value of Se was adjusted such that the simulated weekly runoff values from equation 2-2 have the closest fit to the measured weekly runoff.

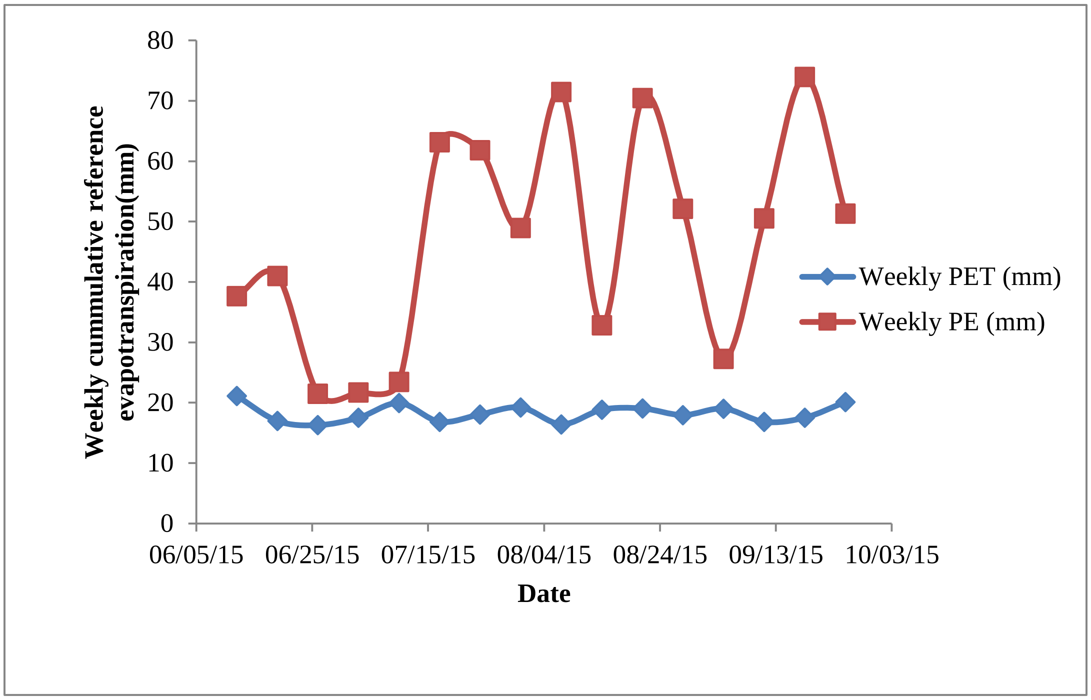


Figure 4-10 Weekly cumulative effective rainfall (Pe) and reference evapotranspiration (ETo) for Dangishta watershed.

The result shows that at the total watershed outlet, the measured weekly runoff best fits with the weekly simulated runoff when the effective available watershed, Se, is 190mm having 0.796 NSE, and R^2 of 0.81(Figure 4-12). At the upstream sub watershed outlet, the measured weekly runoff fits with the weekly simulated runoff when the effective available watershed, Se, is 100mm having 0.535 NSE, and R^2 of 0.536 (Figure 4-11).

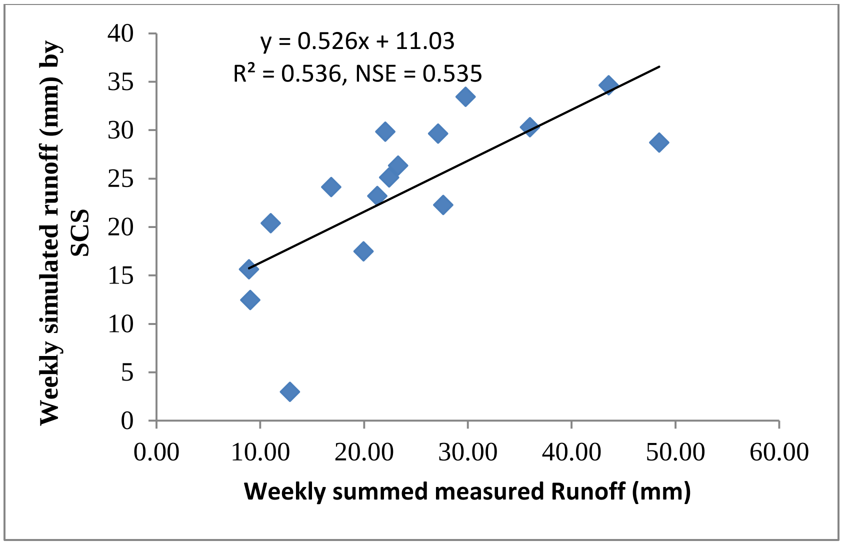


Figure 4-11 Plot of Measured cumulative runoff vs. cumulative runoff estimated by SCS at upstream sub watershed outlet.

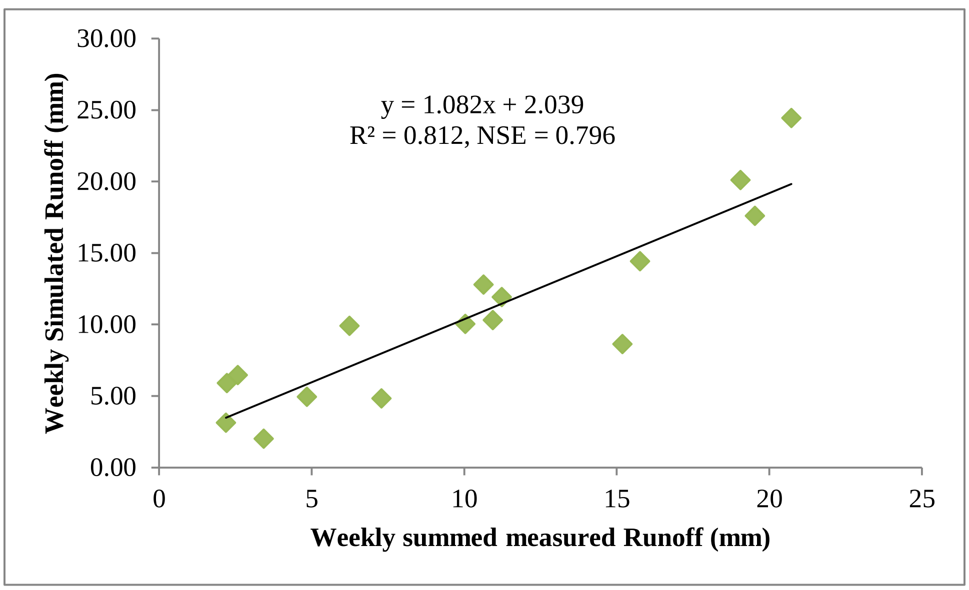


Figure 4-12: Plot of Measured cumulative runoff vs. cumulative runoff estimated by SCS at total watershed outlet.

The watershed consists of relatively deep soils at the bottom without lava intrusions and consequently can store a large amount of water before the sub watershed at the upstream of the watershed would be saturated and therefore, a high Se value (190mm). Similar finding is reported at Debre Mawi watershed (Tilahun et al., 2016). The better correlation at the total watershed outlet than upstream sub watershed outlet corroborates the fact that saturation excess runoff mechanism dominates while infiltration excess contributes in few cased for the upstream sub watershed.

4.6 Groundwater Recharge

The amount of groundwater recharge in the watershed is a function of soil surface characteristics i.e. vegetation cover, soil type, soil surface condition and antecedent soil moisture content. If the soil has better infiltration capacity then the recharge to the ground water through the unsaturated zone will be greater than soils having low infiltration. The moisture status of the soil also has a great impact on the amount of recharge. Saturated areas have lesser recharge potential because in these areas the infiltration capacity of the soil is minimum. To determine the amount of annual recharge in the watershed, groundwater level were monitored daily in the main rainy season of 2015. A total of thirty six wells were monitored. They were located at different topographies to represent their spatial extent in the watershed (Appendix-A2).

Disturbed soil sample from three wells; one from each topographic location were taken to determine the average specific yield. As mentioned earlier, specific yield was determined using two methods. The results of both methods are shown in Table 4-4 and 4-5. The average specific yield for all wells and from both methods was found to be 0.089. The detail result and analysis are shown in Appendices-D6 and D7.

Table 4-4 Specific yield determination by standing tube

Soil moisture at saturation (Vol %)	Soil moisture after water draining in a standing tube (Vol %)	Specific yield (%)

51.63	43.37	8.26
54.50	53.63	0.87
55.46	43.37	12.09
60.44	53.63	6.80
61.28	42.25	19.03
57.84	53.64	4.19
	Average	8.54

Table 4-5 Specific yield determination by pressure plate

Soil moisture at saturation (Vol %)	Soil moisture at 0.33 bar pressure (Vol %)	Specific yield (%)
50.0	37.5	12.5
51.1	48.6	2.4
56.8	44.0	12.7
	Average	9.2

The water level fluctuation for the upstream and downstream part of the watershed behaved in a similar pattern. Before the rainy season the water table was far from the ground level. When rainfall started in June 2015, water level in all monitoring wells started to rise.

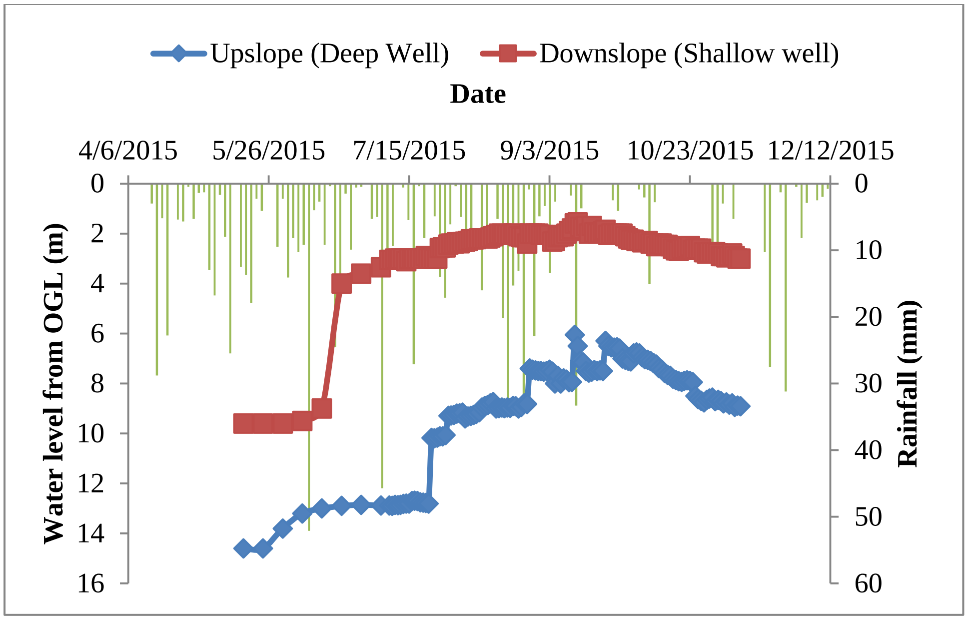


Figure 4-13: Trend of water level fluctuation for monitoring wells located upslope and downslope

Figure 4-13 shows a rise in water level was observed during the rainy season and that the water level starts to fall when rainfall declines. The amount of recharge for each of the monitoring wells selected in the watershed was calculated by water table fluctuation method as discussed in the methodology section. The average total annual recharge was found to be 400mm which is 24% of the annual rainfall. Spatially, there is a recharge of 380.6mm in the upslope and 501.1mm in the downslope. This estimate is within the range of 0 to 400mm per year recharge reported by Kebede (2013) for the Ethiopian high land. This is a significant amount of water which can be used for small scale farming activities like growing of vegetables like onion, cabbage and green pepper using small scale irrigation technologies. The result also shows the downslope parts of the watershed is a potential area than the upslope part of the watershed to irrigate plots from groundwater.

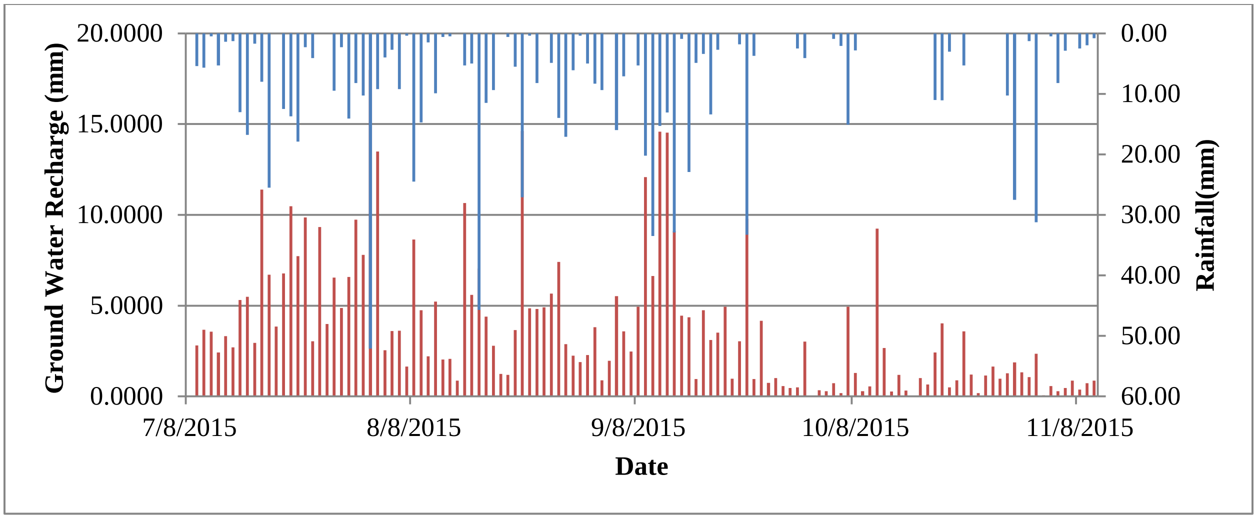


Figure 4-14: Plot of ground water recharge (mm) and Rainfall (mm)

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Rainfall-runoff relation is generally a function of different hydrological processes. It is a function of geomorphology (soil type, topography, land use) and sub-surface flow such as interflow, return flow etc. Accurate quantification of each component is often difficult which makes the relation between rainfall and runoff more complex. Generally the dominant runoff mechanism in Dangishta watershed was found to be saturation excess but it does not mean infiltration excess runoff was not occurring. The result shows 19% of the total annual rainfall was changed to runoff at the total watershed outlet. The minimum infiltration rate and the soil moisture content in the upstream part of the watershed as discussed in the result and discussion part of this thesis shows that infiltration excess was also occurring in some parts of the watershed.

At the downstream part of the watershed the water level for most of the wells were close to the surface during the main rainy season which could be one of the reasons for saturation excess runoff to happen because saturation excess runoff will happen when the soil is saturated from below due to a rise in water table. The applicability of the SCS runoff equation to represent the watershed runoff response was also tested at the upstream sub watershed outet and total watershed outlet of Dangishta by calibrating the effective available watershed storage.

The result showed that the equation is good at describing the runoff response in the watershed which supports the findings that saturation excess runoff was the dominating runoff generating mechanism in Dangishta watershed. This idea was also supported by the calculated runoff coefficient and soil moisture measurement at various land use at different topographies. The runoff coefficient was increasing as the rainfall season progresses which indicates that percent of rainfall changed to runoff increases after the soil profile is increasingly filled with water. Especially in the downstream part because an increased runoff coefficient in an area having shallow water level near to the surface indicates saturation excess runoff.

The result from soil moisture measurement shows that saturation excess runoff was dominating especially in the mid and downslope areas even if infiltration excess runoff was observed in the upslope. Subsurface flow also contribute to the streamflow, but accurate quantification of subsurface flow is complex. For this thesis, the baseflow contribution to streamflow was separated by a digital baseflow filter program. Runoff and baseflow were found to be 37% and 63% of streamflow respectively at the total watershed outlet. The amount of annual recharge to the shallow ground water was also quantified. The selected monitoring wells were all unconfined and the recharge was estimated using the water table fluctuation method. The total amount of recharge in the watershed was found to be 400mm which was 24 percent of the annual rainfall, which is significant groundwater storage for irrigation and domestic water supply during the dry period.

5.2 Recommendations

The annual groundwater recharge in Dangishta watershed was estimated using the water table fluctuation (WTF) method having uncertainty in estimation of specific yield of wells. So it is better to quantify the annual recharge of the watershed either by improving specific yield estimation or by using other methods than WTF.

The amount of annual groundwater recharge in the watershed is a significant amount, which gives sufficient water for one season irrigation of major crops like (maize and millet) or vegetables like onion having crop water requirement of 334.6 mm, 319.6 mm and 534.9 mm per cropping season. The crop water requirement of these crops were estimated by cropwat-8 software by accessing the crop information from:

http://www.fao.org/nr/water/cropinfo.html

For further utilization of ground water resources in the watershed there is a need to improve the amount of recharge among the different land uses. Introducing different water harvesting techniques like construction of dikes to hold the flooded water and thereby increasing infiltration, and facilitating afforestation within the watershed to increase the infiltration and reducing the surface runoff. Introducing other water resource management techniques like terraces, mulching, conservation tillage and stone bunds will increase the amount of recharge in the watershed.

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Appendix-A:LOCATIONS

Appendix-A1: Location of infiltration test areas in Dangishta watershed

S.N	Elevation (masl)	Remark
1	2070	Upslope, Grass land
2	2105	Upslope, Rain fed farm land & Plough for maize
3	2102	Upslope, Plough land for maize & Rain fed.
4	2110	Upslope, Plough land for Teff. Rain fed Farm.
5	2110	Upslope, Rain fed farm & plough for Teff
6	2073	Grazing land, mid slope
7	2090	Midslope, Rain fed farm, plough for maize
8	2074	Midslope, Eucalyptus tree
9	2068	Midslope, Rain fed field, plough for Teff
10	2049	Downslope, Rain fed field, plough land for Teff
11	2054	Downslope, Rain fed field, not plough
12	2040	Downslope, Grass land
13	2055	Downslope, vegetable and irrigation technology user
14	2046	Downslope, vegetable and irrigation technology user
15	2035	Downslope, vegetable and irrigation technology user
16	2043	Downslope, vegetable and Irrigation technology user

Appendix-A2: Location of all monitoring wells in Dangishta watershed

S.No	Well Id	Well depth(m)	Elevations (masl)	Location
1	W1	8	2105	Upslope
2	W2	4	2107	Upslope
3	W3	15	2123	Upslope

4	W4	16	2092	Upslope
5	W5	21	2123	Upslope
6	W6	11	2047	Downslope
7	W7	6.6	2047	Downslope
8	W8	11	2057	Downslope
9	W9	9	2054	Downslope
10	W10	3.2	2037	Downslope
11	W11	3	2042	Downslope
12	W12	14	2071	Downslope
13	W13	13	2067	Downslope
14	W14	6	2049	Downslope
15	W15	7.8	2044	Downslope
16	W16	14.8	2077	Downslope
17	W17	12	2072	Downslope
18	W18	11	2072	Downslope
19	W19	14	2073	Downslope
20	W20	14	2071	Downslope
21	W21	5	2035	Downslope
22	W22	5	2044	Downslope

23	W23	5	2049	Downslope
24	W24	5	2036	Downslope
25	W25	9.17	2071	Midslope
26	W26	8.44	2085	Midslope
27	W27	4.18	2078	Midslope
28	W28	6.89	2084	Midslope
29	W29	6	2085	Midslope
30	P1	11	2107	Upslope
31	P2	6	2113	Upslope
32	P3	3	2106	Upslope
33	P4	3.5	2105	Midslope
34	P5	2.4	2096	Midslope
35	P6	2.5	2058	Downslope
36	P7	2.5	2071	Downslope

Appendix-A3: Location of undisturbed soil sample taken for Field capacity determination within the watershed.

Elevation (masl)	Remark	Land use
2058	Downslope	Grazing Land
2072	Downslope	Teff

2047	Downslope	Maize
2049	Downslope	Millet
2105	Upslope	Grazing Land
2106	Upslope	Maize
2101	Upslope	Teff

Appendix-A4: Location of soil moisture measurement by TDR

Elevation (masl)	**Remark**	**Land use**
2116	Upslope	Eucalyptus
2124	Upslope	Grazing
2121	Upslope	Maize
2119	Upslope	Millet
2124	Upslope	Teff
2057	Downslope	Eucalyptus
2044	Downslope	Teff
2045	Downslope	Millet
2036	Downslope	Maize
2029	Downslope	Grazing
2075	Midslope	Millet

2073	Midslope	Eucalyptus
2071	Midslope	Teff
2068	Midslope	Maize
2066	Midslope	Grazing

Appendix-B: Laboratory determined values

Appendix-B1: Field capacity result of undisturbed soil sample for soil moisture analysis

S.No	Sampling Location & Land Use Type	FC (%)	Average Fc (%)
1	Downslope and Grazing	30.16	
2	Downslope and Teff	33.83	
3	Downslope and Millet	29.5	31.6
4	Down slope and Maize	33.01	
5	Upslope and Maize	33.15	
6	Upslope and grazing	53.88	37.5
7	Upslope and Teff	25.61	

Appendix-C: Infiltration measurement

Appendix-C1: Measured steady state infiltration before rainy season of 2015

S/no	Test Id	Infiltration Rate (mm/hr)	Topography	Land use
1	Test1	480	upslope	Grass land
2	Test2	390	upslope	Farm land
3	Test3	330	upslope	Farm land
4	Test4	330	upslope	Farm land
5	Test5	270	upslope	Farm land
6	Test6	240	Midslope	Farm land
7	Test7	192	Midslope	Farm land
8	Test8	180	Midslope	Farm land
9	Test9	180	Midslope	Farm land
10	Test10	160	Downslope	Farm land
11	Test11	156	Downslope	Farm land
12	Test12	150	Downslope	Grass land
13	Test13	144	Downslope	Vegetables
14	Test14	120	Downslope	Vegetables

15	Test15	90	Downslope	Vegetables
16	Test16	60	Downslope	Vegetables
	Mean	217		
	Median	180		
	Minimum	60		
	Maximum	480		

Appendix-C2: Measured steady state infiltration during rainy season of 2015

S/no	Test Id	Infiltration Rate (mm/hr)	Land Use	Topography
1	Test1	24	Grass land	Upslope
2	Test2	180	Maize	Upslope
3	Test3	30	Maize	Upslope
4	Test4	60	Millet	Upslope
5	Test5	6	Teff	Upslope
6	Test6	24	Eucalyptus	Upslope
7	Test7	96	Maize	Upslope

8	Test8	90	Teff	Upslope
9	Test9	144	Maize	Downslope
10	Test10	72	Millet	Downslope
11	Test11	72	Vegetable	Downslope
12	Test12	36	Eucalyptus	Downslope
13	Test13	192	Teff	Downslope
14	Test14	60	Teff	Midslope
15	Test15	240	Maize	Midslope
16	Test16	120	Maize	Midslope
17	Test18	6	Grazing	Midslope
18	Test19	90	Eucalyptus	Midslope
	Mean	86		
	Median	72		
	Max	240		
	Min	6		

Appendix-D: Water level measurement

Appendix-D1: Measured water level and computed runoff depth at upstream sub watershed outlet of Dangishta watershed

Date	Measured water level (cm)	Streamflow (m^3/sec)	Baseflow (m^3/sec)	Runoff (m^3/sec)	Runoff Volume(m^3)	Runoff Depth (mm)
6/6/2015	87.5	0.73	0.36	0.36	31407.61	2.35
6/7/2015	106	1.45	0.42	1.03	89203.51	6.67
6/8/2015	108	1.24	0.49	0.75	64814.34	4.84
6/9/2015	117.5	1.53	0.55	0.98	84388.18	6.31
6/10/2015	119.5	1.60	0.63	0.97	83607.55	6.25
6/11/2015	122.5	1.70	0.71	0.99	85929.90	6.42
6/12/2015	108.5	1.25	0.76	0.49	42117.24	3.15
6/13/2015	112.5	1.37	0.81	0.57	48932.64	3.66
6/14/2015	112.5	1.98	0.87	1.11	95579.48	7.14
6/15/2015	109.25	1.27	0.93	0.35	29947.88	2.24
6/16/2015	103	1.10	0.95	0.15	13048.13	0.98
6/17/2015	101	1.04	0.96	0.09	7656.25	0.57
6/18/2015	104	1.12	0.97	0.16	13751.42	1.03

6/19/2015	105.5	1.17	0.98	0.19	16167.86	1.21
6/20/2015	115	1.45	1.00	0.45	38568.10	2.88
6/21/2015	114	1.06	1.02	0.04	3036.96	0.23
6/22/2015	108.5	1.25	1.03	0.22	18957.02	1.42
6/23/2015	108	1.24	1.05	0.19	16327.01	1.22
6/24/2015	106.5	1.19	1.06	0.13	11529.22	0.86
6/25/2015	105	1.15	1.07	0.08	7166.88	0.54
6/26/2015	112	1.36	1.08	0.27	23605.34	1.76
6/27/2015	115	1.45	1.11	0.34	29628.29	2.21
6/28/2015	114.5	1.14	1.12	0.02	1486.94	0.11
6/29/2015	111	1.33	1.13	0.20	16973.28	1.27
6/30/2015	111	1.33	1.14	0.18	15699.74	1.17
7/1/2015	113	1.39	1.16	0.23	19613.66	1.47
7/2/2015	116.5	1.50	1.18	0.32	27388.80	2.05
7/3/2015	120.5	1.63	1.21	0.42	36432.29	2.72
7/4/2015	123	1.72	1.24	0.47	40971.74	3.06
7/5/2015	123	1.24	1.24	0.00	0.00	0.00
7/6/2015	124	1.75	1.26	0.49	42539.90	3.18

7/7/2015	125	1.79	1.26	0.53	45793.73	3.42
7/8/2015	124.65	1.78	1.26	0.52	45119.81	3.37
7/9/2015	129.5	1.96	1.25	0.71	61391.52	4.59
7/10/2015	130	1.98	1.23	0.74	64115.71	4.79
7/11/2015	128	1.90	1.22	0.68	59000.83	4.41
7/12/2015	125	1.21	1.21	0.00	0.00	0.00
7/13/2015	125.3	1.80	1.23	0.57	49282.56	3.68
7/14/2015	124.55	1.77	1.26	0.52	44554.75	3.33
7/15/2015	125	1.79	1.26	0.53	46190.30	3.45
7/16/2015	126.75	1.85	1.25	0.60	52242.62	3.90
7/17/2015	129	1.94	1.24	0.70	60368.54	4.51
7/18/2015	128.7	1.93	1.23	0.70	60581.09	4.53
7/19/2015	127.5	1.28	1.22	0.07	5670.43	0.42
7/20/2015	127.25	1.87	1.21	0.66	57328.13	4.28
7/21/2015	128	1.90	1.20	0.70	60561.22	4.53
7/22/2015	127	1.86	1.19	0.68	58510.08	4.37
7/23/2015	127.85	1.90	1.17	0.73	62783.42	4.69
7/24/2015	127.75	1.89	1.15	0.75	64374.05	4.81

7/25/2015	128.25	1.91	1.12	0.79	68303.52	5.10
7/26/2015	128.5	1.32	1.10	0.22	19309.54	1.44
7/27/2015	127.65	1.62	1.03	0.58	35438.43	2.65
7/28/2015	128.8	1.10	1.03	0.07	854.94	0.06
7/29/2015	131.5	2.26	1.33	0.92	20679.18	1.55
7/30/2015	130.25	2.30	1.53	0.77	66957.68	5.00
7/31/2015	136.5	2.84	1.62	1.22	73191.69	5.47
8/1/2015	142	2.38	1.50	0.88	98159.00	7.34
8/2/2015	142.5	2.47	1.47	1.01	3547.29	0.27
8/3/2015	141.5	2.61	1.32	1.28	102758.11	7.68
8/4/2015	138	1.98	1.37	0.61	1723.87	0.13
8/5/2015	137	1.48	1.39	0.09	7562.59	0.57
8/6/2015	143	1.62	1.44	0.18	12770.66	0.95
8/7/2015	144.5	3.89	2.98	0.92	68382.71	5.11
8/8/2015	160	3.89	2.90	0.99	80254.27	6.00
8/9/2015	172.5	1.79	1.79	0.21	31181.53	2.33
8/10/2015	171.15	3.89	2.04	1.85	22529.86	1.68
8/11/2015	166.2	1.65	1.10	0.54	139277.74	10.41

8/12/2015	161.25	3.41	1.06	2.35	202989.02	15.17
8/13/2015	152.75	2.97	1.00	1.97	170328.96	12.73
8/14/2015	133	1.98	1.17	0.81	1676.97	0.13
8/15/2015	127	2.61	1.89	0.54	51148.18	3.82
8/16/2015	126.5	6.10	2.40	3.69	52068.90	3.89
8/17/2015	124.3	2.05	1.20	0.86	263219.20	19.67
8/18/2015	122.3	1.69	1.14	0.55	47835.36	3.58
8/19/2015	128.8	1.93	1.10	0.84	72210.53	5.40
8/20/2015	132.3	2.07	1.05	1.02	88242.91	6.60
8/21/2015	127	1.86	1.13	0.74	8186.21	0.61
8/22/2015	129.25	2.05	1.03	1.03	68016.14	5.08
8/23/2015	133	2.20	0.99	1.21	104187.77	7.79
8/24/2015	131	1.55	1.09	0.46	2936.26	0.22
8/25/2015	124	1.75	1.08	0.67	58217.18	4.35
8/26/2015	127	1.86	1.07	0.80	68702.69	5.13
8/27/2015	128.2	1.91	1.05	0.86	74030.11	5.53
8/28/2015	126	1.15	0.98	0.18	22648.66	1.69
8/29/2015	126.85	1.15	0.99	0.16	4454.76	0.33

8/30/2015	127.2	1.55	0.96	0.59	64327.32	4.81
8/31/2015	128.2	1.91	0.93	0.98	84364.76	6.31
9/1/2015	130.5	1.10	0.93	0.16	2485.93	0.19
9/2/2015	132.25	1.12	0.96	0.17	2608.23	0.19
9/3/2015	130.5	2.00	0.99	1.00	86711.30	6.48
9/4/2015	123.8	1.39	0.96	0.43	21844.35	1.63
9/5/2015	120	1.39	0.93	0.46	28511.46	2.13
9/6/2015	114.5	1.02	0.92	0.09	121.44	0.01
9/7/2015	114.5	1.12	0.95	0.17	5682.69	0.42
9/8/2015	118	1.18	1.00	0.18	7541.36	0.56
9/9/2015	115.85	1.21	1.03	0.18	9700.64	0.73
9/10/2015	118.2	2.02	1.25	0.76	15096.60	1.13
9/11/2015	121.7	2.56	1.58	0.98	54011.24	4.04
9/12/2015	123.5	1.04	1.04	0.08	62252.76	4.65
9/13/2015	123.45	1.73	1.07	0.66	57396.38	4.29
9/14/2015	131.7	2.04	1.09	0.96	82737.50	6.18
9/15/2015	119	1.58	1.08	0.50	43341.70	3.24
9/16/2015	119	1.58	1.07	0.51	44171.14	3.30

9/17/2015	117.4	1.53	1.06	0.47	40667.62	3.04
9/18/2015	114	1.42	1.04	0.38	32549.47	2.43
9/19/2015	115.8	1.48	1.02	0.45	39050.21	2.92
9/20/2015	114.4	1.43	1.00	0.43	36964.51	2.76
9/21/2015	113.25	1.40	0.98	0.41	35847.36	2.68
9/22/2015	115.25	1.30	1.12	0.17	5092.93	0.38
9/23/2015	108	1.24	1.11	0.13	10831.97	0.81
9/24/2015	111.25	1.33	1.10	0.23	20040.48	1.50
9/25/2015	112.5	1.37	1.09	0.28	24345.79	1.82
9/26/2015	112.25	1.36	1.08	0.29	24828.77	1.86
9/27/2015	113	1.39	1.06	0.33	28130.98	2.10
9/28/2015	112.8	1.38	1.04	0.34	29064.96	2.17
9/29/2015	110	1.30	1.03	0.27	23356.51	1.75
9/30/2015	104	1.12	1.01	0.11	9795.17	0.73
10/1/2015	107.7	1.23	1.00	0.23	19579.97	1.46
10/2/2015	105	1.15	0.99	0.16	13886.04	1.04
10/3/2015	109	1.27	0.98	0.29	24764.83	1.85
10/4/2015	107.25	1.22	0.97	0.25	21520.86	1.61

10/5/2015	105.75	1.17	0.95	0.22	19120.75	1.43
10/6/2015	106	1.18	0.94	0.24	21124.54	1.58
10/7/2015	110.25	1.30	0.92	0.39	33316.10	2.49
10/8/2015	107.95	1.24	0.90	0.34	29189.72	2.18
10/9/2015	109.25	1.27	0.88	0.40	34378.47	2.57
10/10/2015	106.2	1.19	0.85	0.33	28879.46	2.16
10/11/2015	109.2	1.27	0.83	0.45	38653.11	2.89
10/12/2015	109.2	1.27	0.80	0.48	41176.86	3.08
10/13/2015	109.7	1.30	0.95	0.34	1840.29	0.14
10/14/2015	107.95	1.24	0.98	0.26	22549.71	1.69
10/15/2015	105	1.15	0.99	0.16	13907.98	1.04
10/16/2015	106	1.18	1.00	0.18	15188.26	1.14
10/17/2015	102.75	1.09	1.01	0.09	7370.78	0.55
10/18/2015	106	1.18	1.00	0.18	15181.34	1.13
10/19/2015	107.25	1.22	1.00	0.21	18425.66	1.38
10/20/2015	110	1.30	1.00	0.30	25662.10	1.92
10/21/2015	108.5	1.25	0.99	0.26	22278.76	1.67
10/22/2015	106	1.18	0.99	0.19	16658.27	1.25

10/23/2015	106.5	1.19	0.98	0.21	18558.20	1.39
10/24/2015	104.75	1.15	0.97	0.17	15110.84	1.13
10/25/2015	106.5	1.19	0.96	0.23	20232.03	1.51
10/26/2015	106.75	1.20	0.95	0.25	21852.37	1.63
10/27/2015	106	1.18	0.94	0.24	21154.95	1.58
10/28/2015	102.7	1.09	0.92	0.17	14486.08	1.08
10/29/2015	100.5	1.03	0.91	0.12	10443.60	0.78
10/30/2015	101	1.04	0.90	0.14	12416.98	0.93
10/31/2015	96.75	0.94	0.89	0.04	3711.14	0.28

Appendix-D2: Measured water level and computed runoff depth at total watershed outlet of Dangishta watershed

Date	Measured water level (cm)	Streamflow (m^3/sec)	Baseflow (m^3/sec)	Runoff (m^3/sec)	Runoff Volume(m^3)	Runoff Depth (mm)
6/6/2015	50	0.4	0.4	0.0	1728.0	0.1
6/7/2015	95	1.0	0.3	0.6	81966.0	2.5
6/8/2015	47	0.3	0.3	0.0	0.0	0.0
6/9/2015	50	5.0	0.7	4.3	25080.0	0.8
6/10/2015	135	2.6	0.7	1.9	167616.0	5.1

6/11/2015	65	4.8	0.6	4.2	16410.0	0.5
6/12/2015	73	4.5	0.4	4.1	35340.0	1.1
6/13/2015	65	0.6	0.4	0.2	20736.0	0.6
6/14/2015	56	0.5	0.4	0.1	7776.0	0.2
6/15/2015	53	0.4	0.4	0.1	4320.0	0.1
6/16/2015	50	0.4	0.4	0.0	0.0	0.0
6/17/2015	57	0.5	0.4	0.1	8640.0	0.3
6/18/2015	55	6.3	0.7	5.6	46194.0	1.4
6/19/2015	100	1.5	0.6	0.8	72576.0	2.2
6/20/2015	70	0.7	0.6	0.2	12960.0	0.4
6/21/2015	80	1.0	0.6	0.4	33696.0	1.0
6/22/2015	70	0.7	0.6	0.2	15552.0	0.5
6/23/2015	60	0.5	0.5	0.0	0.0	0.0
6/24/2015	70	0.7	0.5	0.2	16416.0	0.5
6/25/2015	60	0.5	0.5	0.0	0.0	0.0
6/26/2015	70	4.1	0.7	3.3	25038.0	0.8
6/27/2015	130	2.4	0.7	1.7	146880.0	4.4
6/28/2015	75	0.8	0.7	0.1	12096.0	0.4

6/29/2015	80	1.0	0.7	0.3	22464.0	0.7
6/30/2015	70	0.7	0.7	0.0	4320.0	0.1
7/1/2015	70	0.7	0.7	0.0	4320.0	0.1
7/2/2015	67	2.4	0.7	1.7	5718.0	0.2
7/3/2015	70	0.7	0.7	0.0	0.0	0.0
7/4/2015	80	3.6	0.9	2.7	26520.0	0.8
7/5/2015	100	1.5	0.9	0.6	47520.0	1.4
7/6/2015	100	1.5	0.9	0.6	50112.0	1.5
7/7/2015	95	1.3	0.9	0.5	40608.0	1.2
7/8/2015	75	0.8	0.8	0.0	0.0	0.0
7/9/2015	80	1.0	0.8	0.1	9504.0	0.3
7/10/2015	95	1.6	0.9	0.7	40080.0	1.2
7/11/2015	105	1.6	1.0	0.6	52704.0	1.6
7/12/2015	95	2.4	1.1	1.3	28758.0	0.9
7/13/2015	95	1.3	1.1	0.2	20736.0	0.6
7/14/2015	95	1.3	1.1	0.3	21600.0	0.7
7/15/2015	85	1.1	1.1	0.0	0.0	0.0
7/16/2015	120	2.1	1.2	0.9	83292.0	2.5

7/17/2015	180	4.5	1.6	2.9	270198.0	8.2
7/18/2015	110	2.4	1.6	0.9	14874.0	0.5
7/19/2015	115	1.9	1.5	0.4	31968.0	1.0
7/20/2015	110	1.8	1.5	0.2	20736.0	0.6
7/21/2015	105	1.6	1.5	0.1	8640.0	0.3
7/22/2015	140	3.62	1.4	2.2	113688.0	3.4
7/23/2015	125	2.24	1.4	0.9	74304.0	2.2
7/24/2015	105	1.60	1.4	0.3	21600.0	0.7
7/25/2015	105	1.60	1.3	0.3	23328.0	0.7
7/26/2015	95	1.32	1.3	0.0	0.0	0.0
7/27/2015	105	1.60	1.3	0.3	23328.0	0.7
7/28/2015	100	1.46	1.4	0.1	9504.0	0.3
7/29/2015	150	2.99	2.0	1.0	148395.0	4.5
7/30/2015	130	2.42	2.0	0.4	32832.0	1.0
7/31/2015	150	4.06	3.1	1.7	95139.0	2.9
8/1/2015	170	4.54	3.44	1.10	80334.00	2.43
8/2/2015	155	6.98	2.89	4.09	20133.00	0.61
8/3/2015	200	5.56	2.69	2.87	247968.00	7.50

8/4/2015	140	2.79	2.58	0.21	18144.00	0.55
8/5/2015	145	4.54	2.11	2.43	45249.00	1.37
8/6/2015	153	3.32	2.01	1.31	113184.00	3.42
8/7/2015	135	2.60	1.94	0.66	57024.00	1.73
8/8/2015	115	5.56	1.88	3.68	27729.00	0.84
8/9/2015	120	2.07	1.77	0.30	25920.00	0.78
8/10/2015	110	1.75	1.75	0.00	0.00	0.00
8/11/2015	110	3.40	1.57	1.83	25269.00	0.76
8/12/2015	110	1.75	1.50	0.25	21600.00	0.65
8/13/2015	120	2.07	1.48	0.59	50976.00	1.54
8/14/2015	105	1.60	1.46	0.14	12096.00	0.37
8/15/2015	100	1.46	1.46	0.00	0.00	0.00
8/16/2015	165	5.83	2.49	3.34	203292.00	6.15
8/17/2015	190	5.04	2.36	2.68	231552.00	7.01
8/18/2015	170	4.06	2.21	1.85	159840.00	4.84
8/19/2015	135	2.60	2.12	0.48	41472.00	1.25
8/20/2015	130	2.42	2.09	0.33	28512.00	0.86
8/21/2015	120	2.07	2.07	0.00	0.00	0.00

8/22/2015	120	2.07	2.07	0.00	0.00	0.00
8/23/2015	170	3.40	1.84	1.56	166992.00	5.05
8/24/2015	120	2.07	1.79	0.28	24192.00	0.73
8/25/2015	120	2.07	1.77	0.30	25920.00	0.78
8/26/2015	110	1.75	1.75	0.00	0.00	0.00
8/27/2015	120	2.07	1.77	0.30	25920.00	0.78
8/28/2015	160	2.99	1.81	1.18	151092.00	4.57
8/29/2015	115	1.91	1.78	0.13	11232.00	0.34
8/30/2015	115	1.91	1.77	0.14	12096.00	0.37
8/31/2015	120	2.07	1.76	0.31	26784.00	0.81
9/1/2015	110	1.75	1.75	0.00	0.00	0.00
9/2/2015	110	1.75	1.75	0.00	0.00	0.00
9/3/2015	115	1.91	1.75	0.16	13824.00	0.42
9/4/2015	110	2.42	2.04	0.38	2937	0.08886
9/5/2015	135	2.6	2.07	0.53	45792	1.3855
9/6/2015	120	2.07	2.07	0	0	0
9/7/2015	150	2.07	2.07	0.00	90495.00	2.74
9/8/2015	135	2.60	2.09	0.51	44064.00	1.33

9/9/2015	180	4.06	3.02	1.04	193923.00	5.87
9/10/2015	150	3.19	3.01	0.18	15552.00	0.47
9/11/2015	155	3.40	3.01	0.39	33696.00	1.02
9/12/2015	190	6.11	2.50	3.61	176280.00	5.33
9/13/2015	190	5.04	2.29	2.75	237600.00	7.19
9/14/2015	130	3.19	1.80	1.39	28116.00	0.85
9/15/2015	160	3.62	1.71	1.91	165024.00	4.99
9/16/2015	130	2.42	1.64	0.78	67392.00	2.04
9/17/2015	125	2.24	1.58	0.66	57024.00	1.73
9/18/2015	130	2.42	1.53	0.89	76896.00	2.33
9/19/2015	125	2.24	1.47	0.77	66528.00	2.01
9/20/2015	105	1.60	1.43	0.17	14688.00	0.44
9/21/2015	105	1.60	1.42	0.18	15552.00	0.47
9/22/2015	100	2.24	1.21	1.03	10261.49	0.31
9/23/2015	130	2.42	1.15	1.27	109728.00	3.32
9/24/2015	125	2.24	1.08	1.16	100224.00	3.03
9/25/2015	95	1.32	1.04	0.28	24192.00	0.73
9/26/2015	110	1.75	1.01	0.74	63936.00	1.93

9/27/2015	90	1.19	0.99	0.20	17280.00	0.52
9/28/2015	100	1.46	0.98	0.48	41472.00	1.25
9/29/2015	90	1.19	0.96	0.23	19872.00	0.60
9/30/2015	95	1.32	0.94	0.38	32832.00	0.99
10/1/2015	95	1.32	0.92	0.40	34560.00	1.05
10/2/2015	95	1.32	0.90	0.42	36288.00	1.10
10/3/2015	90	1.19	0.87	0.32	27648.00	0.84
10/4/2015	80	0.95	0.86	0.09	7776.00	0.24
10/5/2015	90	1.19	0.85	0.34	29376.00	0.89
10/6/2015	95	1.32	0.84	0.48	41472.00	1.25
10/7/2015	90	1.19	0.83	0.36	31104.00	0.94
10/8/2015	90	1.19	0.81	0.38	32832.00	0.99
10/9/2015	85	1.07	0.80	0.27	23328.00	0.71
10/10/2015	80	0.95	0.78	0.17	14688.00	0.44
10/11/2015	85	1.07	0.77	0.30	25920.00	0.78
10/12/2015	80	0.95	0.75	0.20	17280.00	0.52
10/13/2015	90	1.19	0.73	0.46	39744.00	1.20
10/14/2015	80	0.95	0.72	0.23	19872.00	0.60

10/15/2015	80	0.95	0.70	0.25	21600.00	0.65
10/16/2015	75	0.84	0.68	0.16	13824.00	0.42
10/17/2015	70	0.73	0.67	0.06	5184.00	0.16
10/18/2015	75	0.84	0.67	0.17	14688.00	0.44
10/19/2015	75	0.84	0.66	0.18	15552.00	0.47
10/20/2015	70	0.73	0.66	0.07	6048.00	0.18
10/21/2015	70	0.73	0.65	0.08	6912.00	0.21
10/22/2015	70	0.73	0.65	0.08	6912.00	0.21
10/23/2015	70	0.73	0.64	0.09	7776.00	0.24
10/24/2015	65	0.64	0.64	0.00	0.00	0.00
10/25/2015	65	0.64	0.64	0.00	0.00	0.00
10/26/2015	65	0.64	0.64	0.00	0.00	0.00
10/27/2015	65	0.64	0.64	0.00	0.00	0.00
10/28/2015	70	0.73	0.64	0.09	7776.00	0.24
10/29/2015	75	0.84	0.65	0.19	16416.00	0.50
10/30/2015	75	0.84	0.66	0.18	15552.00	0.47
10/31/2015	75	0.84	0.68	0.16	13824.00	0.42

Appendix-D3: Measured and simulated runoff at upstream sub watershed outlet for effective available storage of 100mm

Date	Weekly Runoff (mm)	Weekly Rainfall (mm)	Weekly ETo (mm)	Weekly PE (mm)	Q by SCS (mm)
6/12/2015	35.98	93.40	21.12	72.28	30.32
6/19/2015	16.82	79.60	16.98	62.62	24.12
6/26/2015	8.91	64.40	16.29	48.11	15.63
7/3/2015	11.00	74.00	17.51	56.49	20.39
7/10/2015	22.42	84.20	19.95	64.25	25.13
7/17/2015	23.29	83.00	16.85	66.15	26.34
7/24/2015	27.64	77.70	18.07	59.63	22.28
7/31/2015	21.28	80.40	19.22	61.18	23.22
8/7/2015	22.04	88.00	16.44	71.56	29.85
8/14/2015	48.45	88.70	18.84	69.86	28.73
8/21/2015	43.57	97.70	19.05	78.65	34.63
8/28/2015	29.80	94.90	17.95	76.95	33.46
9/4/2015	19.94	70.50	19.02	51.48	17.49
9/11/2015	9.02	58.90	16.83	42.07	12.46
9/18/2015	27.14	88.80	17.53	71.27	29.66
9/25/2015	12.87	39.00	20.13	18.87	2.99

Appendix-D4: Measured and simulated runoff at total watershed outlet for effective available storage of 190mm

Date	Weekly Runoff (mm)	Weekly Rainfall (mm)	Weekly ETo (mm)	Weekly PE (mm)	Q by SCS (mm)
6/12/2015	9.93	58.80	21.12	37.68	6.234494
6/19/2015	4.85	58.00	16.98	41.02	7.285108
6/26/2015	3.1365	37.8000	16.2884	21.51	2.18781
7/3/2015	5.9243	39.2000	17.5102	21.69	2.222334
7/10/2015	6.4854	43.4000	19.9539	23.45	2.575457
7/17/2015	14.4414	80.0100	16.8513	63.16	15.757
7/24/2015	8.6478	79.9000	18.0684	61.83	15.18136
7/31/2015	10.0613	68.2000	19.2231	48.98	10.03754
8/7/2015	17.6108	87.9000	16.4387	71.46	19.53144
8/14/2015	4.9498	51.7000	18.8434	32.86	4.844161
8/21/2015	20.1110	89.5000	19.0476	70.45	19.05738
8/28/2015	11.9248	70.1000	17.9508	52.15	11.23085
9/4/2015	2.0234	46.3000	19.0243	27.28	3.424057
9/11/2015	12.8146	67.4000	16.8333	50.57	10.62903
9/18/2015	24.4579	91.5000	17.5310	73.97	20.7275
9/25/2015	10.3229	71.5000	20.1335	51.37	10.93157

Appendix-D5: Measured ground water level below ground level (m)

Depth of W	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
2/22/2015	0.8	0.95	1	1	0.7	1	1	3.5	1	0.7	3.8	8	6.45	4	4	3	1.5	2	2	2.5
3/1/2015	0.8	0.3	0.8	0.8	0.6	1.1	0.8	3.2	1	0.7	5.6	7.5	7	2.4	2.6	4.5	1.5	1.5	1.1	2.6
3/5/2015	0.7	0.4	0.7	0.5	0.6	0.9	0.6	2.8	0.8	0.75	2.7	7.7	6.1	2.92	2.8	4	1.7	1.85	1.95	2.5
3/15/2015	0.7	0.3	0.7	0.5	0.6	0.8	0.4	2.3	0.9	0.6	2.3	7.85	6.4	2.6	2.9	4.2	1.85	1.85	1.9	2.4
3/22/2015	0.8	0.3	0.75	0.5	0.5	0.8	0.4	2.25	0.7	0.6	2.5	7.5	7.9	2.1	1.8	3.5	1.6	0.9	1.6	2
3/29/2015	0.7	0.4	0.7	0.4	0.4	0.9	0.2	2	0.7	0.5	1.9	7.33	5	2.7	1.55	2.8	1.45	1	1.4	1.5
4/5/2015	0.7	0.4	0.6	0.2	0.4	0.7	0.1	1.7	0.7	0.5	1.95	7.4	5	2.72	1.57	2.8	1.4	0.9	1.95	1.6
4/12/2015	0.6	0.2	0.6	0.3	0.3	0.7	0.1	1.3	0.7	0.5	1.15	7	2.8	1.28	0.2	2.8	1.75	1.9	1.5	1.7
4/19/2015	0.5	0.2	0.5	0.3	0.3	0.6	0.2	1.5	0.6	0.4	1.1	5	1.3	1.7	1.4	2.7	1.8	2	1.6	1.8
4/26/2015	0.6	0.2	0.4	0.3	0.1	0.6	0.1	1.2	0.6	0.5	2.5	4	2	2	1.5	2.7	1.2	2	1.4	1.7
5/3/2015	0.6	0.3	0.5	0.3	0.1	0.5	0.1	1.2	0.5	0.5	2.4	3	1.5	2	2.5	3	1.5	2	1.2	1
5/10/2015	0.6	0.3	0.5	0.2	0.1	0.4	0.1	1	0.4	0.4	2	2	1.4	1.9	1.5	3	1.5	2	1	1
5/17/2015	0.55	0.4	0.5	0.25	0.1	0.5	0.1	1	0.5	0.45	1.8	0.9	1.4	1.8	1.5	3	1.6	2.4	1	1.2
5/24/2015	0.55	0.3	0.55	0.25	0.1	0.5	0.1	0.8	0.5	0.35	1.3	0.4	1.4	1.7	1.5	3	1.7	2.5	1	0.7
5/31/2015	0.6	0.9	0.5	0.2	0.2	0.8	0.1	0.6	0.45	0.4	1.3	4.6	1.4	1.8	1.9	3	1.8	2.5	1.2	1
6/7/2015	0.6	1.2	0.6	0.25	0.4	1.1	0.6	0.9	0.8	0.4	1.3	6.7	1.5	2.8	2	4	1.8	2.6	1.5	0.9
6/14/2015	0.7	2.3	1	0.7	0.7	1.7	1.9	1	1.5	0.6	1.8	8	2	5	3	5	2	2.7	2.2	2.8
6/21/2015	1	2.8	1.3	1	0.8	1.9	2.1	3.2	2.1	0.8	1.8	8.6	7	6.3	3.5	5	2.2	2.8	2.3	3
6/28/2015	1.1	2.4	1.2	0.9	0.9	1.7	1.5	9.2	2.1	1	2.2	8.8	7.4	6.5	4	4.9	2.3	3.3	2	3.5
7/5/2015	1.2	3.05	1.6	1.25	0.98	1.8	2.42	9.45	2.2	1.19	1.8	9.05	7.65	5.55	3	2.7	1.85	2.8	1.83	3.8

7/8/2015	1.33	2.8	1.6	1.27	1.03	1.7	2.35	9.65	2.3	1.28	1.8	9.12	7.94	5.7	3.55	2.75	2.5	3.27	1.93	3.35
7/9/2015	1.35	2.75	1.6	1.25	1.04	1.7	2.3	9.6	2.3	1.3	1.8	9.2	7.94	5.78	3.6	3	2.6	3.3	1.97	3.35
7/10/2015	1.35	2.7	1.5	1.18	1.04	1.72	1.98	9.63	2.35	1.25	1.8	9.4	8	5.83	3.6	3	2.54	3.35	2	3.4
7/11/2015	1.4	2.7	1.45	1.15	1.05	1.7	1.95	9.65	2.41	1.32	1.8	9.4	8	5.82	4	2.75	2.6	3.32	2.33	3.32
7/12/2015	1.43	2.65	1.43	1.13	1.05	1.68	1.83	9.68	2.45	1.32	1.6	9.5	8	5.53	4	2.9	2.6	3.4	2.4	3.35
7/13/2015	1.45	2.55	1.45	1.1	1.01	1.68	1.77	9.7	2.43	1.35	1.8	9.5	8	5.62	4.15	3	2.65	3.4	2.5	3.5
7/14/2015	1.44	2.53	1.45	1.1	1	1.7	1.77	9.72	2.4	1.35	1.8	9.5	7.9	5.74	4.5	3	2.65	3.4	2.3	3.5
7/15/2015	1.45	2.58	1.47	1.13	1.05	1.72	1.87	9.75	2.47	1.42	1.77	9.5	8	5.83	4.85	2.95	2.6	3.55	2.2	3.5
7/16/2015	1.5	2.7	1.48	1.15	1.12	1.75	2.05	9.8	2.5	1.45	1.8	9.5	8	6.1	4.95	2.9	2.7	3.55	2.4	3.55
7/17/2015	1.52	2.73	1.5	1.16	1.12	1.98	2	9.82	2.6	1.5	1.8	9.5	8	6.25	5	3	2.7	3.6	2.4	3.55
7/18/2015	1.58	2.9	1.53	1.23	1.15	1.84	1.84	9.9	2.63	1.55	1.86	9.8	8	6.4	7	2.94	2.77	3.55	2	3.6
7/19/2015	1.67	3.05	1.57	1.26	1.2	1.9	1.92	10	2.75	1.58	2.06	9.8	8	6.6	7	3	2.75	3.58	2.18	3.66
7/20/2015	1.65	3.1	1.6	1.28	1.2	2	2.2	10.06	2.78	1.65	2.1	9.85	8	6.62	7	2.91	2.8	3.6	2.2	3.7
7/21/2015	1.7	3.1	1.6	1.3	1.18	1.95	2.25	10.08	2.8	1.62	2.3	9.9	8.1	6.75	7.95	3	2.77	3.58	2.22	3.7
7/22/2015	1.71	3.25	1.66	1.34	1.27	1.94	2.45	10.15	2.85	1.56	2.6	10.2	8	6.8	9	3	2.76	3.65	2.42	3.7
7/23/2015	2	3.42	1.8	1.48	1.32	1.94	2.15	10.4	2.95	1.75	2.63	10.19	8	6.85	9.25	3	2.8	3.7	2.54	3.7
7/24/2015	2.15	3.8	1.92	1.53	1.43	1.96	3.25	10.47	3.07	2.17	2.6	10.16	7.98	6.85	9.3	3	2.76	3.71	2.6	3.65
7/25/2015	2.2	3.8	1.95	1.6	1.43	1.98	3.27	10.47	3.03	2.17	2.58	10.2	8	6.75	9.36	2.95	2.79	3.77	2.58	3.7
7/26/2015	2.3	3.75	2	1.65	1.41	2	3.31	10.5	3	2.2	2.6	10.4	8.42	6.76	9.5	4.3	2.8	3.2	2.64	3.73
7/27/2015	2.3	3.7	2.03	1.65	1.4	1.95	3.33	10.53	2.95	2.22	2.75	10.38	8.45	6.7	10.24	4.35	2.78	3.24	2.6	3.77
7/28/2015	2.35	3.77	2.05	1.67	1.4	1.896	3.15	10.5	2.93	2.25	2.77	10.4	8.44	7	10.25	4.4	2.85	3.5	2.62	3.77
7/29/2015	2.4	4.22	2.02	1.69	1.38	1.85	3.1	10.45	2.91	2.27	2.8	10.38	8.56	7	10.3	4.43	2.95	3.1	2.7	3.8

7/30/2015	2.44	4.25	2.06	1.71	1.4	1.9	3.2	10.5	2.96	2.31	2.8	10.38	8.6	7	10.32	5.5	2.92	3.12	2.67	3.78
7/31/2015	2.55	4.26	2.18	1.79	1.48	1.93	3.3	10.48	3.08	2.45	2.75	10.4	8.6	7.15	10.4	6.5	3.15	3.29	2.7	3.8
8/1/2015	2.7	4.28	2.23	1.84	1.6	1.95	3.34	10.4	3.2	2.6	2.8	10.4	8.65	7.2	10.49	7	3.14	3.3	2.7	3.77
8/2/2015	2.8	4.7	2.5	2.05	1.75	2	5.25	10.5	3.35	2.82	2.8	10.65	8.61	7.2	11.1	8.1	3.2	3.4	3	3.8
8/3/2015	3.06	5.2	2.75	2.18	1.9	1.95	5.34	10.7	3.4	3.04	2.8	10.65	8.66	7.26	11.17	8.18	3.5	3.95	3.23	4
8/4/2015	3.15	4.7	2.8	2.23	1.81	1.92	5.4	10.72	3.4	3.1	2.8	10.65	8.67	7.28	11.12	8.35	3.5	3.9	2.9	4
8/5/2015	3.3	4.5	2.85	2.3	1.7	1.9	5.44	10.65	3.44	3.13	2.8	10.7	8.7	7.3	11.16	8.4	3.5	3.88	2.9	4
8/6/2015	3.34	4.55	2.92	2.34	1.72	1.92	5.47	10.71	3.42	3.16	2.8	10.7	8.76	7.32	11.2	8.4	3.5	3.9	2.92	4
8/7/2015	3.28	4.48	2.82	2.25	1.7	1.9	5.45	10.7	3.4	3.11	3.05	10.7	8.77	7.39	11.22	8.5	3.44	3.82	2.9	4
8/8/2015	3.34	4.52	2.75	2.25	1.78	1.89	5.5	10.7	3.38	3.17	3.8	10.7	8.78	7.98	11.25	8.58	3.47	3.85	2.9	4
8/9/2015	3.36	4.58	2.72	2.27	1.83	1.95	5.45	10.71	3.4	3.2	4.3	10.7	8.8	8	11.25	8.6	3.5	3.85	2.95	4
8/10/2015	3.4	4.5	2.66	2.25	1.8	1.95	5.52	10.69	3.45	3.23	4.3	10.75	8.8	8	11.4	8.65	3.53	3.87	3	4
8/11/2015	3.45	4.49	2.65	2.2	1.8	1.93	5.6	10.66	3.55	3.25	4.3	10.8	8.8	8	11.44	9.25	3.6	3.87	3	4
8/12/2015	3.48	4.42	2.7	2.25	1.75	1.92	5.63	10.62	3.62	3.28	4.3	10.8	8.8	8	11.48	9.4	3.7	3.9	3	4
8/13/2015	3.51	4.32	2.7	2.25	1.72	1.9	5.55	10.53	3.65	3.35	4.3	10.8	8.84	8	11.9	9.4	3.7	3.9	3	3.95
8/14/2015	3.5	4.3	2.7	2.24	1.7	1.9	5.45	10.4	3.67	3.2	4.35	10.8	8.9	8.05	11.9	9.4	3.5	3.95	3	3.95
8/15/2015	3.52	4.32	2.65	2.22	1.68	1.88	5.4	10.35	3.7	3.2	5.6	10.85	8.95	7.27	11.9	10.25	3.6	3.95	3	3.95
8/16/2015	3.54	4.32	2.65	2.22	1.7	1.85	5.42	10.43	3.65	3.22	5.9	10.89	9	7.4	11.9	10.7	3.6	3.95	3	3.97
8/17/2015	3.55	4.35	2.7	2.25	1.78	1.95	5.8	10.45	3.62	3.28	5.95	10.9	9	7.75	11.92	10.75	3.68	3.97	3	3.93
8/18/2015	3.57	4.4	2.7	2.29	1.82	2	6.07	10.55	3.65	3.36	6.05	10.9	8.98	7.79	11.9	10.8	3.5	3.97	3	3.98
8/19/2015	3.6	4.35	2.8	2.33	1.85	2	6.1	10.6	3.7	3.45	6.15	10.9	8.95	7.8	11.9	10.8	3.35	3.8	2.9	3.95
8/20/2015	3.6	4.35	2.75	2.33	1.85	1.95	6.13	10.58	3.68	3.45	6.08	10.92	8.95	7.82	11.86	10.85	3.2	3.8	2.9	3.96

8/21/2015	3.58	4.3	2.74	2.31	1.8	1.9	6.17	10.54	3.66	3.42	6.1	10.94	9	7.87	11.85	10.9	3.15	3.77	2.92	3.96
8/22/2015	3.58	4.22	2.73	2.3	1.77	1.91	6.24	10.6	3.65	3.38	6.1	10.94	9	7.85	11.85	10.9	3.8	3.77	2.97	3.96
8/23/2015	3.57	4.55	2.75	2.3	1.9	2	7.38	10.75	3.63	3.38	7.8	10.93	8.9	7.95	11.8	10.88	3.2	3.74	3	3.8
8/24/2015	3.65	4.35	2.78	2.32	1.85	1.98	7.4	10.75	3.65	3.45	8.8	10.5	8.85	7.96	11.85	10.85	3.15	3.74	2.85	3.9
8/25/2015	3.63	4.29	2.8	2.35	1.82	1.92	7.28	10.7	3.7	3.52	8.7	10.45	8.85	7.96	11.8	10.85	3.15	3.7	2.86	3.9
8/26/2015	3.7	4.22	2.8	2.38	1.81	1.9	7.28	10.67	3.72	3.5	9.4	10.45	8.6	8.3	11.6	10.8	3.25	3.75	2.7	3.25
8/27/2015	3.65	4.2	2.77	2.35	1.78	1.95	7.14	10.6	3.72	3.45	9.8	10.6	9	8.36	11.65	10.83	3.27	3.74	2.68	3.87
8/28/2015	3.62	4.1	2.75	2.32	1.78	2.02	7.02	10.5	3.67	3.4	10.8	10.6	9	8.38	11.7	10.8	3.3	3.73	2.7	3.4
8/29/2015	3.59	4.08	2.77	2.34	1.86	2.02	7.05	10.6	3.6	3.37	10.8	10.7	9	8.37	11.7	10.74	3.35	3.8	2.6	3.9
8/30/2015	3.55	4.06	2.75	2.32	1.8	1.97	6.96	10.66	3.63	3.34	11.05	10.7	9	8.4	11.68	10.73	3.3	3.8	2.6	3.89
8/31/2015	3.55	4.02	2.75	2.33	1.8	1.95	6.94	10.65	3.63	3.33	11.3	10.7	8.94	8.3	11.7	10.74	3.25	3.78	2.6	3.9
9/1/2015	3.51	3.98	2.73	2.28	1.8	1.94	6.85	10.6	3.65	3.31	11.1	10.63	8.95	8.3	11.68	10.8	2.2	3.78	2.76	3.88
9/2/2015	3.45	3.93	2.7	2.24	1.8	1.92	6.75	10.54	3.65	3.3	11.15	10.63	8.95	8.35	11.64	10.8	3	3.74	2.75	3.92
9/3/2015	3.3	3.85	2.66	2.24	1.77	1.9	6.74	10.52	3.63	3.22	11.1	10.35	8.95	7.85	11.4	10.8	2.97	3.74	2.75	3.92
9/4/2015	3.3	3.83	2.63	2.22	1.75	1.9	6.72	10.5	3.64	3.2	11.15	10.45	8.67	8.24	11.24	10.8	2.96	3.74	2.45	3.9
9/5/2015	3.37	3.9	2.65	2.25	1.78	1.92	6.78	10.59	3.66	3.2	11.1	10.46	8.7	8	11.4	10.79	2.94	3.7	2.9	3.85
9/6/2015	3.36	3.95	2.67	2.28	1.83	1.92	6.85	10.62	3.7	3.2	11.55	10.7	8.85	7.94	11.44	10.75	2.85	3.78	2.85	3.9
9/7/2015	3.28	3.93	2.67	2.28	1.8	1.9	6.85	10.6	3.65	3.18	10.8	10.8	8.9	7.98	11.47	10.75	2.85	3.7	2.5	3.9
9/8/2015	3.37	3.88	2.65	2.27	1.77	2.1	7.15	10.68	3.65	3.23	10.8	10.8	8.9	7.86	11.35	10.7	2.63	3.75	2.85	3.88
9/9/2015	3.45	5	2.86	2.45	2.06	2.38	7.6	10.73	3.75	3.3	10.85	10.75	9	8	11.52	10.8	2.65	3.85	3.05	3.95
9/10/2015	3.75	4.9	3.05	2.68	1.98	2.15	8.08	10.8	3.82	3.45	10.3	10.7	9.1	8	11.5	10.9	2.7	3.9	3.2	3.94
9/11/2015	4	4.75	3.3	2.86	1.91	2	8.63	10.88	3.88	3.75	11.1	10.5	9.2	7.5	11.66	10.75	3.77	4	3.5	4.2

9/12/2015	4.25	5.1	3.55	3.05	2.1	2.03	9.85	10.92	3.92	4.1	11.55	10.7	9.4	8.7	11.64	11	3.8	4	3.47	4
9/13/2015	4.62	5.4	3.7	3.24	2.2	2.06	10.91	10.05	3.98	4.4	11.3	10.8	9.45	8.8	11.75	11	3.67	4	3.57	4
9/14/2015	4.8	5.25	3.9	3.33	2.21	1.98	11	10.1	4.05	4.47	11.55	10.8	9.26	8.9	11.5	10.6	3.8	4.05	3.15	4.25
9/15/2015	4.83	5.25	3.9	3.33	2.22	1.98	10.23	10.96	4.03	4.5	11.55	10.75	9.2	8.95	10.55	10.59	3.7	4	3.15	4.25
9/16/2015	4.9	5.23	3.9	3.34	2.21	2	10.15	10.91	4	4.49	11.4	10.7	9.3	8.9	10.25	10.6	3.65	4	3.15	4.2
9/17/2015	4.88	5.1	3.88	3.35	2.2	2.02	11	10.87	3.99	4.42	11.4	10.5	9	8.95	10.25	10.62	3.6	4	3.15	4.1
9/18/2015	4.85	4.87	3.88	3.35	2.2	2.01	10.92	10.85	3.99	4.33	11.2	10.7	9.3	8.9	10.1	10.9	3.5	3.91	3.21	4.2
9/19/2015	4.77	4.81	3.81	3.31	2.15	1.99	10.75	10.84	3.97	4.4	13.02	10.8	9.05	8.85	10.27	10.13	3.51	3.88	3.1	4.1
9/20/2015	4.76	4.75	3.7	3.28	2.12	1.97	10.5	10.84	3.97	4.35	11.9	10.65	9	8.8	10.3	11	3.51	3.88	3.35	4.25
9/21/2015	4.75	4.72	3.67	3.22	2.1	2	10.15	10.82	3.95	4.3	11.82	10.6	9.02	8.82	10.27	10.95	3.5	3.81	3.3	4.15
9/22/2015	4.64	4.7	3.63	3.16	2.15	2	10.08	10.78	3.95	4.24	11.8	10.5	9.1	8.8	10.4	10.95	3.5	3.8	3.2	4.1
9/23/2015	4.55	4.67	3.6	3.1	2.2	2.02	10	10.75	3.93	4.2	12	10.7	9.15	8.83	11.64	10.95	3.45	3.8	3.2	4.05
9/24/2015	4.6	4.65	3.55	3.07	2.2	2	9.8	10.75	3.93	4.15	12	10.6	8.95	8.85	10.3	11	3.5	3.85	3.1	4.1
9/25/2015	4.53	4.6	3.49	3.03	2.17	2	9.6	10.73	3.89	4.12	11.7	10.1	9	8.8	11.6	11	3.5	3.6	3.1	4.2
9/26/2015	4.42	4.52	3.47	3	2.13	1.98	9.35	10.73	3.84	4.08	11.68	10.2	9	8.8	11.55	11	3.4	3.7	3	4.24
9/27/2015	4.34	4.47	3.44	2.95	2.1	1.98	9.15	10.7	3.8	4.05	11.7	10.1	9	8.85	11.6	10.9	3.42	3.85	3	4.2
9/28/2015	4.22	4.42	3.39	2.89	2.08	1.97	9.11	10.68	3.78	3.98	11.8	10.1	9	8.9	11.4	10.9	3.4	3.85	3.05	4.1
9/29/2015	4.18	4.35	3.32	2.85	2.05	1.97	8.85	10.65	3.78	3.9	11.6	10	9	8.85	11.5	10.5	3.3	3.9	3	4
9/30/2015	4.11	4.32	3.25	2.8	2.03	1.97	8.63	10.63	3.77	3.83	11.55	9.85	8.9	8.7	11.2	10.45	3	3.9	2.9	4
10/1/2015	4.05	4.24	3.18	2.74	2	1.97	8.51	10.55	3.75	3.78	11.45	9.85	8.8	8.6	11.1	10.85	2.9	3.85	2.85	3.95
10/2/2015	4	4.15	3.12	2.7	1.98	1.96	8.36	10.5	3.73	3.73	11.35	9.8	8.75	8.55	10.9	10.3	2.8	3.75	2.8	3.95
10/3/2015	3.95	4.08	3.04	2.65	1.97	1.96	8.28	10.5	3.7	3.66	11.3	9.7	8.75	8.5	10.8	10.22	2.7	3.7	2.8	4

10/4/2015	3.88	4	2.98	2.57	1.94	1.96	8.15	10.5	3.68	3.6	11.15	9.55	8.7	8.4	10.8	10.2	2.6	3.8	2.8	4
10/5/2015	3.85	3.95	2.94	2.52	1.92	1.96	8.02	10.48	3.68	3.56	11.15	9.55	8.7	8.4	10.75	10.2	2.5	3.75	2.75	4
10/6/2015	3.75	3.87	2.88	2.43	1.9	1.94	7.9	10.46	3.66	3.46	11.1	9.53	8.65	8.3	10.7	10.1	2.45	3.7	2.7	4
10/7/2015	3.7	3.95	2.85	2.4	1.9	1.97	7.82	10.45	3.64	3.41	11	9.5	8.7	8.3	10.7	10	2.7	3.6	2.65	4
10/8/2015	3.64	3.9	2.8	2.4	1.92	1.97	7.7	10.42	3.63	3.35	11	9.4	8.7	8.15	10.5	10	2.6	3.7	2.65	4
10/9/2015	3.6	3.85	2.77	2.37	1.9	1.97	7.65	10.4	3.63	3.32	10.8	9.45	8.6	8	10.2	10	2.1	3.7	2.7	4
10/10/2015	3.5	3.79	2.73	2.35	1.86	1.94	7.56	10.37	3.6	3.3	10.8	9.4	8.6	8	10	9.9	2.15	3.75	2.7	4
10/11/2015	3.42	3.79	2.68	2.28	1.85	1.96	7.38	10.4	3.54	3.25	10.3	10.1	8.5	7.65	11.2	10.9	2.3	3.6	2.55	4
10/12/2015	3.4	3.7	2.65	2.25	1.83	1.95	7.3	10.42	3.53	3.23	10.25	10.2	8.6	7.65	11.2	11	2.35	3.55	2.54	4
10/13/2015	3.37	3.62	2.62	2.22	1.83	1.95	7.18	10.42	3.53	3.2	10.2	10	8.6	7.6	11	10.44	2.3	3.5	2.55	4
10/14/2015	3.3	3.55	2.58	2.2	1.8	1.95	7.1	10.4	3.51	3.17	10.2	10	8.55	7.6	11	10.85	2.25	3.5	2.5	4
10/15/2015	3.26	3.49	2.54	2.16	1.76	1.94	7	10.4	3.5	3.12	10.1	9.9	8.55	7.5	10.8	10.7	2.3	3.5	2.5	4
10/16/2015	3.2	3.42	2.5	2.13	1.73	1.93	6.82	10.36	3.5	3.05	10	9.9	8.5	7.45	10.8	10.6	2.3	3.4	2.5	4
10/17/2015	3.14	3.37	2.47	2.1	1.7	1.92	6.77	10.33	3.45	3	10.15	9.95	8.4	7.4	10.9	10.25	2.35	3.4	2.5	4
10/18/2015	3.06	3.31	2.43	2.05	1.67	1.92	6.68	10.3	3.37	2.94	9.8	10	8.33	7.3	11	9.3	2.3	3.3	2.4	3.95
10/19/2015	3.02	3.27	2.42	2.02	1.67	1.92	6.6	10.3	3.35	2.85	9.4	10	8.3	7.2	11	9.9	2.25	3.25	2.3	4
10/20/2015	2.97	3.21	2.39	1.97	1.66	1.92	6.5	10.28	3.33	2.78	9.3	10	8.4	7.4	11	9.9	2.6	3.4	2.35	4
10/21/2015	2.95	3.15	2.37	1.95	1.63	1.92	6.45	10.26	3.33	2.75	9.2	10	8.4	7.35	11	9.92	2.4	3.4	2.3	3.95
10/22/2015	2.9	3.08	2.34	1.95	1.61	1.91	6.36	10.25	3.27	2.73	9.15	9.95	8.45	7.4	10.93	9.8	2.4	3.45	2.4	3.9
10/23/2015	2.85	3.02	2.3	1.93	1.59	1.91	6.22	10.23	3.22	2.7	9.1	9.95	8.5	7.35	10.9	9.85	2.64	3.4	2.3	3.95
10/24/2015	2.8	2.95	2.28	1.9	1.57	1.91	6.14	10.2	3.18	2.64	9	9.9	8.34	7.45	10.9	9.8	2.55	3.35	2.54	3.84
10/25/2015	2.75	2.9	2.25	1.87	1.55	1.91	6.05	10.18	3.14	2.6	9	9.9	8.4	7.3	10.85	9.8	2.5	3.34	2.4	3.9

10/26/2015	2.73	2.85	2.22	1.85	1.53	1.9	5.94	10.18	3.14	2.56	8.9	9.85	8.4	7.15	10.75	9.75	2.5	3.5	2.5	4
10/27/2015	2.69	2.82	2.19	1.83	1.5	1.9	5.88	10.16	3.12	2.5	8.8	10	8.4	6.67	10.75	9.6	2.65	3.67	2.4	4
10/28/2015	2.66	2.8	2.17	1.82	1.48	1.9	5.85	10.15	3.1	2.48	8.4	10	8.25	6.55	10.75	9.6	2.8	3.5	2.15	4
10/29/2015	2.6	2.75	2.16	1.8	1.48	1.92	5.77	10.15	3.08	2.46	8.1	10	8.2	6.55	10.7	9.75	2.75	3.55	2.2	3.9
10/30/2015	2.55	2.72	2.14	1.77	1.47	1.92	5.68	10.15	3.07	2.45	8	10	8.25	6.6	10.8	9.75	2.7	3.5	2.1	3.8
10/31/2015	2.54	2.65	2.1	1.77	1.47	1.9	5.6	10.15	3.07	2.36	7.9	10	8.25	6.55	10.75	9.75	2.75	3.52	1.7	3.75
11/1/2015	2.48	2.6	2.07	1.75	1.46	1.9	5.55	10.15	3.05	2.33	7.85	10	8.25	6.5	10.73	9.55	2.7	3.5	2	3.6
11/2/2015	2.45	2.55	2.06	1.75	1.46	1.9	5.52	10.15	3.05	2.29	7.8	10	8.2	6.5	10.72	9.55	2.75	3.4	2	3.5
11/3/2015	2.42	2.52	2.06	1.75	1.46	1.9	5.5	10.15	3.05	2.24	7.3	10	8.1	6.4	10.7	9.53	2.7	3.35	1.9	3.45
11/4/2015	2.38	2.48	2.05	1.75	1.45	1.9	5.4	10.15	3	2.2	7.25	9.9	8.1	6.35	10.64	9.52	2.75	3.5	1.4	3.4
11/5/2015	2.33	2.44	2.04	1.73	1.45	1.9	5.26	10.15	2.94	2.18	7	9.8	8.05	6.4	10.6	9.52	2.6	3.45	1.4	3.3
11/6/2015	2.3	2.4	2.02	1.7	1.45	1.9	5.21	10.16	2.9	2.16	6.58	9.8	8.1	6.3	10.55	9.5	2.5	3.4	1.35	3.35
11/7/2015	2.27	2.38	2	1.7	1.42	1.9	5.1	10.16	2.87	2.15	6.5	9.7	8.2	6.23	10.7	9.5	2.5	3.45	1.4	3.35
11/8/2015	2.25	2.35	1.98	1.67	1.4	1.89	5	10.15	2.85	2.13	6.25	9.75	8.1	6.2	10.6	9.45	2.45	3.35	1.3	3.3
11/9/2015	2.22	2.32	1.95	1.65	1.36	1.88	4.92	10.14	2.83	2.08	6.2	9.7	8	6.15	10.55	9.4	2.64	3.3	1.3	3.2
11/10/2015	2.2	2.3	1.9	1.62	1.35	1.88	4.85	10.14	2.8	2.02	6.15	9.95	8	6	10.5	9.35	2.5	3.15	1.3	3.2

W stands for well

Appendix-D6: Determination of specific yield by standing tube

Moisture content before draining										
Can ID	Can wt(g)	Sample name	Remark	Can+Wet soil(g)	Can + dry soil(g)	Weight of wet soil(g)	Weight of Dry soil(g)	Mass of water(g)	Water content before drain(%)	
998	35.9	2T	Midslope	175.7	128.1	139.8	92.2	47.6	51.63	
T	37.5	2B	Midslope	188.6	135.3	151.1	97.8	53.3	54.50	
B	37	3T	Down slope	141	103.9	104	66.9	37.1	55.46	
A	37.9	3B	Down slope	163.2	116	125.3	78.1	47.2	60.44	
D6	38	1B	Upslope	223.8	153.2	185.8	115.2	70.6	61.28	
GR4	37.8	1T	Upslope	177.8	126.5	140	88.7	51.3	57.84	
Moisture content after draining										
Can Id	Can weight	Sample name	Remark	Can+wet soil	Can+Dry soil	Weight of wet soil (g)	Weight of dry soil (g)	Mass of water (g)	Water content after drain(%)	Sy (%)
T	37.5	2T	Midslope	165.1	126.5	127.6	89	38.6	43.37	8.26
B	37	2B	Midslope	157.6	115.5	120.6	78.5	42.1	53.63	0.87
998	35.9	3T	Down slope	147	114	127.6	89	38.6	43.37	12.09
A	37.9	3B	Down slope	194	139.5	120.6	78.5	42.1	53.63	6.80
D6	38	1T	Upslope	135	103.5	111.1	78.1	33	42.25	19.03
GR4	37.8	1B	Upslope	179.9	130.5	156.1	101.6	54.5	53.64	4.19
									Average specific yield	8.54

Appendix-D7: Determination of specific yield by Pressure plate

Moisture content before draining									
Can Id	Remark	Can weight (g)	Can+saturated soil(g)	Can+dry soil (g)	Weight of wet soil (g)	Weight of dry soil (g)	Mass of water (g)	Water content before drain(%)	
B	Midslope	37	66.7	56.8	29.7	19.8	9.9	50	
A	Downslope	37.9	66.3	56.7	28.4	18.8	9.6	51.06	
983	Upslope	35.8	65.9	55	30.1	19.2	10.9	56.77	
Moisture content after draining									
Can Id	Remark	Can weight (g)	Can+wetsoil (g)	Can+dry soil (g)	Weight of wet soil (g)	Weight of dry soil (g)	Mass of water (g)	Water content after drain(%)	Sy (%)
T	Midslope	37.5	65	57.5	27.5	20	7.5	37.5	12.50
D6	Downslope	38	65.5	56.5	27.5	18.5	9	48.65	2.42
GR4	Upslope	37.8	64.3	56.2	26.5	18.4	8.1	44.02	12.75
								Average Specific yield	9.22

Appendix-D8: Measured soil moisture content by TDR which was calibrated by Gravimetric method at upslope

Date	Maize	Teff	Grazing	Millet	Eucalyptus
7/28/2015	34.69	35.50	36.17	34.17	34.71
8/4/2015	34.69	35.50	36.17	34.17	34.71
8/11/2015	36.89	37.46	36.13	36.21	36.97
8/18/2015	35.92	35.53	35.46	35.90	36.10
8/25/2015	37.02	35.46	36.28	37.18	36.43
9/1/2015	37.18	35.98	36.54	37.45	36.61
9/8/2015	37.22	36.74	36.98	37.29	36.99
9/15/2015	37.03	37.09	37.49	36.59	36.22
9/22/2015	37.22	37.18	37.25	36.89	36.33
9/29/2015	37.60	37.15	37.47	37.19	36.60
10/6/2015	37.64	37.70	37.13	37.21	37.00
10/13/2015	36.73	36.73	36.05	36.62	36.30
10/23/2015	35.82	35.58	35.46	35.60	35.62
10/27/2015	34.50	34.50	33.89	34.86	34.37
11/3/2015	33.59	33.68	34.26	33.64	33.77
11/10/2015	32.34	32.23	32.39	31.78	32.34

Appendix-D9: Measured soil moisture content by TDR which was calibrated by Gravimetric method at midslope

Maize	Teff	Grazing	Millet	Eucalyptus
35.24	36.20	37.38	35.48	36.73
33.67	34.40	34.16	32.90	33.33
29.38	28.26	31.10	28.28	28.66
32.70	33.40	33.72	31.88	33.64
27.22	27.79	28.26	27.66	27.81

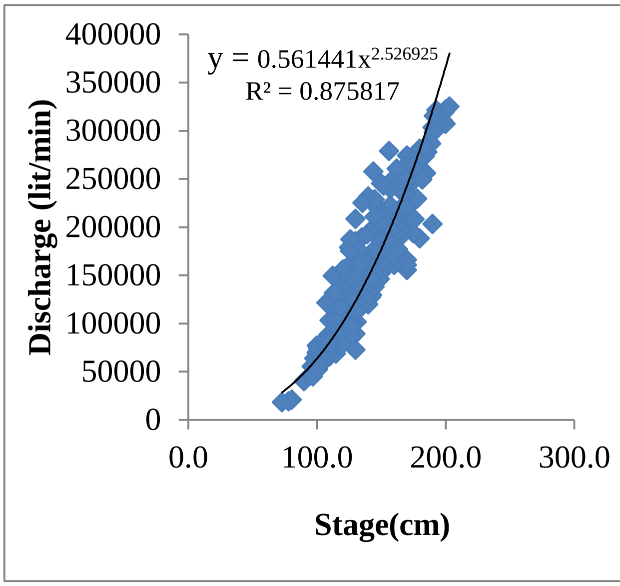
37.19	38.22	37.49	37.48	37.46
33.66	35.10	36.38	32.88	35.65
33.07	33.90	36.63	33.88	34.88
31.32	31.90	34.86	31.86	32.47
32.84	34.81	34.88	32.01	34.44
28.59	28.08	27.63	27.13	29.04
27.91	28.43	28.24	29.78	28.99
29.37	29.70	30.08	29.16	29.55
29.37	29.70	30.08	29.16	29.55

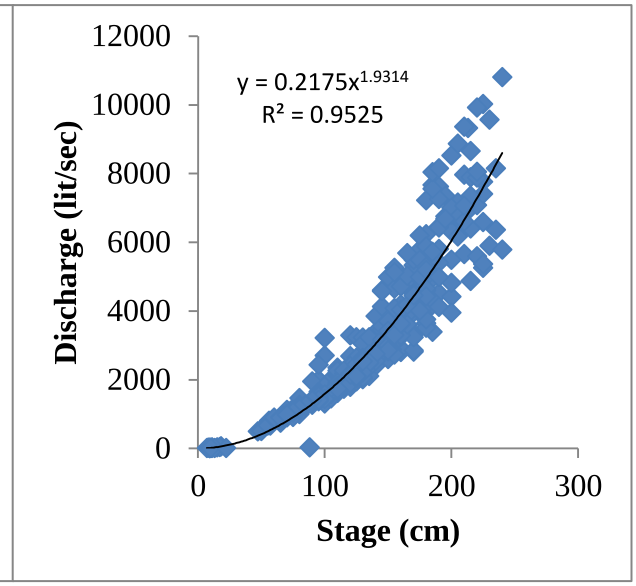
Appendix-D10: Measured soil moisture content by TDR which was calibrated by Gravimetric method at downslope

Date	Maize	Teff	Grazing	Millet	Eucalyptus
7/31/2015	36.63	37.09	37.03	36.90	35.52
8/7/2015	33.68	33.36	33.68	33.10	33.39
8/14/2015	28.85	29.63	30.28	29.10	28.51
8/21/2015	32.92	32.88	33.49	33.05	32.62
8/28/2015	33.88	34.18	34.86	35.17	34.25
9/4/2015	32.32	28.09	28.60	28.28	27.10
9/11/2015	36.33	37.36	38.39	37.75	37.49
9/18/2015	33.42	33.94	34.21	34.51	34.29
9/25/2015	32.40	33.05	36.68	34.03	32.97
10/2/2015	30.53	31.10	36.53	29.43	31.24
10/9/2015	33.19	34.50	35.83	32.61	32.41
10/16/2015	27.36	28.21	29.18	26.97	27.18
10/23/2015	26.97	28.14	31.74	27.18	26.86
10/30/2015	28.13	28.50	31.37	28.44	27.48
11/6/2015	31.84	30.05	32.97	29.58	29.37

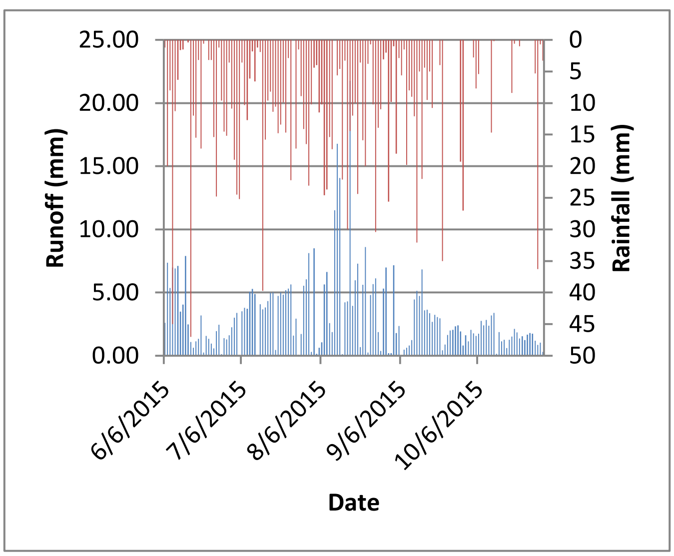
Appendix-D11: Calibration of TDR by gravimetric method

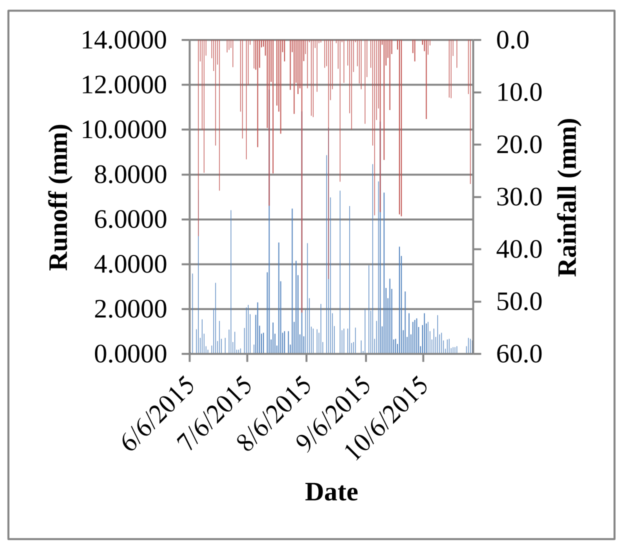
Can No	930	940	562	985	995	509
Can weight(g)	36	35.9	35.7	36	35.9	35.8
Can + wet soil(g)	153.2	163.5	145.8	158.3	168.3	149.4
Can+dry soil(g)	126.6	135	121.67	132	141.38	123.2
Calibrated TDR	29.36	28.76	28.07	27.40	25.52	29.98
Measured TDR	44.5	39.5	35.7	31.8	21.8	45.9



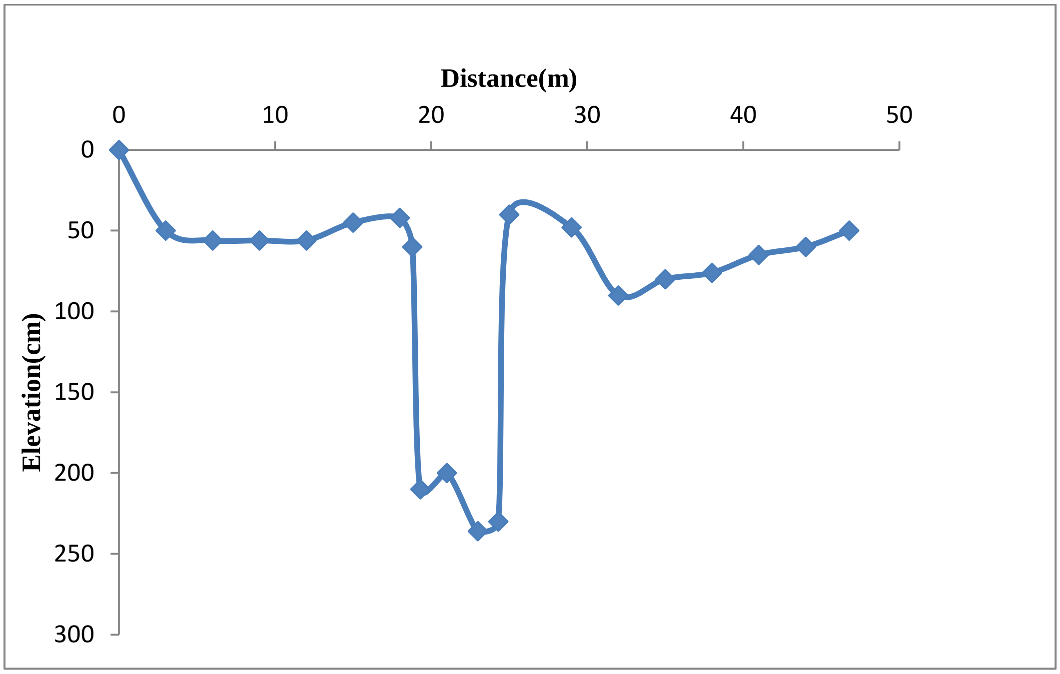


Appendix-E: Stage discharge relation at upstream watershed outlet and total watershed outlet of Dangishta watershed respectively

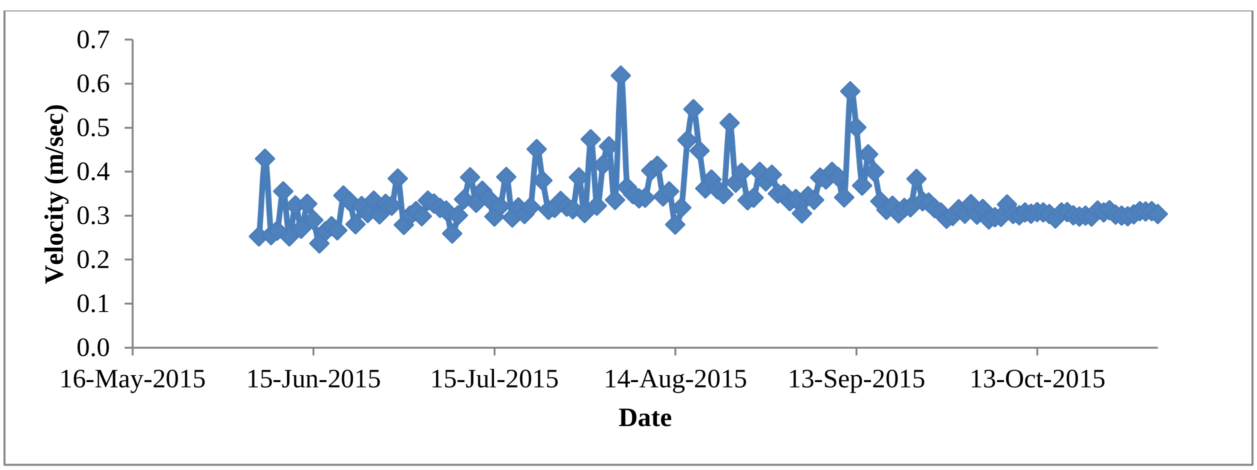




Appendix-E1: Relation between rainfall depth (mm) and runoff depth(mm) at upstream sub watershed outlet and total watershed outlet respectively



Appendix-E2: River cross section at total watershed outlet of Dangishta watershed



Appendix-E3: Measured velocity at total watershed outlet of Dangishta watershed

Appendix-F: Photograph of monitoring instruments and land use type

Appendix-F1: Photo showing staff gauge, Automatic rain gauge, Manual rain gauge and TDR in Dangishta watershed

Appendix-F2: Dominant land use in Dangishta watershed (maize, millet, teff, grazing land, eucalyptus tree and small bush land)

Appendix-G: Penman evapotranspiration estimation

The reference evapotranspiration (mm/day) was calculated by Penman Monteith evapotranspiration estimation method.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where, ET_O is the reference evapotranspiration (mm/day)

T is the mean air temperature (^oC)

U_2 is wind speed (m/sec) at 2m above the ground.

e_s and e_a are saturation and actual vapor pressure(kpa).

Rn is net radiation flux ($MJm^{-2}D^{-1}$).

G is soil heat flux density ($MJm^{-2}d^{-1}$)

Δ is saturation vapor pressure curve and γ is psychrometric constant, Kpa^{o}c-1

Steps fallowed to calculate ET_o

1. Mean daily temperature

$$T_{mean} = \frac{T_{\max} + T_{\min}}{2}$$

2. Slope of saturation vapor pressure curve

$$\Delta = \frac{4098[0.6108\exp\{\frac{17.27T_{mean}}{T_{mean} + 237.3}\}]}{(T_{mean} + 273.3)^2}$$

3. Atmospheric pressure

$$P = 101.3\left(\frac{293 - 0.0065Z}{293}\right)^{5.26}$$

Where, Z is elevation above sea level (m).

4. Psychometric constant

$$P = 0.000655p$$

Where p is atmospheric pressure (kpa)

5. Mean saturation vapor pressure (e_s)

$$e_T = 0.6108\exp\left(\frac{17.27T}{T+237.3}\right)$$

Where e_T = saturation vapor pressure at air temperature and T is air temperature ^{O}C

$$e_{T\max} = 0.6108\exp\left(\frac{17.27T_{\max}}{T_{\max}+237.3}\right)$$

$$e_{T\min} = 0.6108\exp\left(\frac{17.27T_{\min}}{T_{\min}+237.3}\right)$$

$$e_s = \left(\frac{e_{T\max}+e_{T\min}}{2}\right)$$

6. Actual vapor pressure (e_a)

$$e_a = \frac{e_{T\min}\left[\frac{R_{H\max}}{100}\right]+e_{T\max}\left[\frac{R_{H\min}}{100}\right]}{2}$$

Where $e_{T\min}$ and $e_{T\max}$ are saturation vapor pressure at daily maximum and minimum temperature, R_H is relative humidity (%). In the absence of relative humidity maximum and minimum actual evapotranspiraion can be calculated by

$$e_a = \frac{R_H}{100}\left[\frac{e_{T\min} + e_{T\max}}{2}\right]$$

7. Inverse relative distance earth sun (dr) and solar declination (δ)

$$d_r = 1 + 0.033\cos\left(\frac{2\Pi}{365}J\right)$$

$$\delta = 1 + 0.409\sin\left(\frac{2\Pi}{365}J - 1.39\right)$$

Where J is the number of days in the year

8. Sunset hour angle

$$\omega_s = \arccos\left[-\tan(\Phi)\tan(\delta)\right]$$

Where ∅ is latitude expressed in radians = (3.14/180)*Latitude and δ is solar declination

9. Extraterrestrial radius

$$R_a = \frac{24*60}{\Pi}G_{sc}d_r\left[(\omega_s \sin\Phi\sin\delta) + (\cos\Phi\cos\delta\sin\omega_s)\right]$$

Where R_a is extraterrestrial radius in MJ/m2/day

G_{SC} = solar constant which can be taken as 0.082MJ/m2/min

d_r = Inverse relative distance earth sun

ω_s is the sunset hour angle measured in rad

∅ is latitude measured in rad

δ is solar declination in rad

10. Maximum possible duration of sunshine hour (N)

$N = \frac{24}{\Pi}\omega_s$ Where ω_s is the sunset hour angle measured in rad

11. Solar radiation (Rs)

$$R_s = \left[0.25 + 0.5\frac{n}{N}\right]R_a$$

Where n = sunshine hour and N = maximum possible duration of sunshine hour

Ra = extraterrestrial radiation

12. Net solar or net short wave radiation (R_{ns})

$$R_{ns} = [1-\alpha]R_s$$

Where ∝ is albedo which is 0.23 for hypothetical crop

13. Clear sky solar radiation (R_{so})

$$R_{nso} = 0.75R_a$$

14. Net outgoing long wave solar radiation (Rnl)

$$R_{nl} = \sigma\left[(T_{\max} + 273.16)^4 + (T_{\min} + 273.16)^4 (0.34 - 0.14\sqrt{e_a})\left[1.35\frac{R_s}{R_{so}} - 0.35\right]\right]$$

Where σ is Stefan Boltzmann constant which is 4.903*10-9MJ/K^4/m^2/day?

15. Net radiation (Rn)

$$R_n = R_{ns} - R_{nl}$$

16. Soil heat flux (G)

$$R_{month} = 0.07\left(T_{month,i+1} - T_{month,i-1}\right)$$

Where T is the average temperature

17. Wind speed at 2m height

$$u_2 = u_h \frac{4.87}{\ln(67.8h - 5.42)}$$

Where U_2 is wind speed at 2 m height in m/sec and U_h is wind speed measured at h meter distance from the ground in m/sec

Appendix-G1: Daily reference evapotranspiration estimated by Penman- Monteith method.

Date	Tmax, ^oC	Tmin, ^oC	sunshine (hour)	Humidity, %	Wind speed, m/s	ETo (mm/day)
1/1/2014	25.5	4.0	9.7	44	0.53	3.13
1/2/2014	26	3.5	10	49	0.53	3.19
1/3/2014	26	4.0	9.3	48	0.40	3.02
1/4/2014	26.5	5.0	9	47	0.43	3.05
1/5/2014	25.4	4.8	10	46	0.63	3.25
1/6/2014	26.2	4.5	10	45	0.60	3.27
1/7/2014	25.6	5.4	8.2	52	0.55	2.98

1/8/2014	24.6	7.4	4.5	50	0.46	2.43
1/9/2014	25.8	7.0	2.4	52	0.39	2.12
1/10/2014	26	8.6	5.6	53	0.61	2.75
1/11/2014	25.2	6.0	9.1	53	0.73	3.20
1/12/2014	26	4.0	9.6	51	0.70	3.26
1/13/2014	25.5	6.0	9.3	50	0.66	3.21
1/14/2014	25.4	7.2	7.5	50	0.58	2.95
1/15/2014	26.5	8.0	9.1	49	0.56	3.22
1/16/2014	26.6	7.5	8.8	45	0.49	3.12
1/17/2014	27	6.0	9.5	51	0.68	3.33
1/18/2014	26.6	6.5	9.7	47	0.64	3.33
1/19/2014	26.5	5.5	10.3	51	0.58	3.34
1/20/2014	27.5	5.4	10	45	0.47	3.26
1/21/2014	27.6	7.5	10.1	42	0.66	3.47
1/22/2014	28	6.0	10.2	44	0.48	3.33
1/23/2014	27.8	6.3	10.2	42	0.65	3.47
1/24/2014	27.5	6.4	10	40	0.55	3.34
1/25/2014	27.6	6.0	10.1	45	0.68	3.46

1/26/2014	26.6	5.5	10	44	0.55	3.27
1/27/2014	27	5.0	10.1	43	0.49	3.25
1/28/2014	28	5.6	10	42	0.40	3.22
1/29/2014	28	8.4	8.5	47	0.40	3.10
1/30/2014	28.3	9.5	10	46	0.73	3.60
1/31/2014	28.8	7.0	9.5	40	0.52	3.33
2/1/2014	28	7.0	10	43	0.62	3.44
2/2/2014	27	6.6	10.3	43	0.69	3.47
2/3/2014	27.5	8.0	9	42	0.70	3.37
2/4/2014	28.5	6.0	10.1	38	0.69	3.52
2/5/2014	28.6	6.2	9.9	39	0.73	3.54
2/6/2014	28	5.5	10.3	41	0.89	3.68
2/7/2014	27.4	6.0	8.9	43	0.84	3.43
2/8/2014	25.4	5.0	10.5	40	0.83	3.48
2/9/2014	26	4.0	10.3	42	0.72	3.38
2/10/2014	25.8	3.2	10.1	41	0.97	3.53
2/11/2014	26.5	3.0	10	41	0.97	3.57
2/12/2014	26	2.5	10.4	39	0.93	3.55

2/13/2014	26.5	3.0	8.5	34	0.93	3.40
2/14/2014	26.5	2.0	10.6	41	0.80	3.48
2/15/2014	26.8	3.0	10.3	38	0.76	3.45
2/16/2014	28	4.0	10	36	0.92	3.67
2/17/2014	26.5	6.5	9	49	0.93	3.42
2/18/2014	26.6	5.6	9.1	45	0.81	3.36
2/19/2014	27	6.5	9.5	49	0.64	3.32
2/20/2014	28	6.8	8.8	42	0.66	3.31
2/21/2014	27.5	8.0	6.5	42	0.56	2.93
2/22/2014	27.6	7.6	10.4	43	0.79	3.62
2/23/2014	28.4	6.5	10.6	41	0.82	3.71
2/24/2014	28.6	5.5	10.4	41	0.62	3.50
2/25/2014	29.5	8.5	9.1	37	0.68	3.48
2/26/2014	30	9.0	9	51	0.83	3.62
2/27/2014	29.5	10.0	6.4	48	0.62	3.08
2/28/2014	28.6	11.2	7	52	0.73	3.21
3/1/2014	28	13.8	3.7	59	0.72	2.68
3/2/2014	28.2	13.5	6.2	58	0.84	3.15

3/3/2014	27	13.4	3.2	60	0.47	2.41
3/4/2014	24.5	12.0	1.7	74	0.64	2.04
3/5/2014	26	13.2	4	70	0.84	2.59
3/6/2014	27	11.6	8.6	60	0.87	3.41
3/7/2014	27	13.6	4.7	59	0.72	2.79
3/8/2014	27.2	13.5	5.7	47	0.49	2.83
3/9/2014	28.5	11.2	6.2	55	0.59	2.98
3/10/2014	27	14.5	4.8	74	0.83	2.75
3/11/2014	26.5	13.0	5	78	0.73	2.68
3/12/2014	23.8	12.2	6.1	71	0.60	2.73
3/13/2014	25	12.0	5.2	76	0.75	2.64
3/14/2014	24.6	9.6	8.6	62	0.98	3.26
3/15/2014	26.5	7.5	10.8	48	0.87	3.64
3/16/2014	27.2	8.0	7	58	0.65	3.00
3/17/2014	26.5	11.0	4.7	56	0.60	2.67
3/18/2014	27	14.0	6.1	55	0.47	2.88
3/19/2014	28.5	10.4	9.4	53	0.75	3.55
3/20/2014	29.5	11.5	8.4	53	0.82	3.53

3/21/2014	29	10.0	10	45	0.72	3.64
3/22/2014	29.6	11.8	8.9	39	0.86	3.69
3/23/2014	29.6	10.0	7.2	42	0.63	3.21
3/24/2014	29.7	8.0	10.6	35	0.96	3.96
3/25/2014	28	6.6	10.3	36	1.05	3.86
3/26/2014	29.5	6.0	10.2	33	0.91	3.82
3/27/2014	29.6	6.0	10.4	33	0.98	3.93
3/28/2014	30	8.0	10.5	30	0.93	3.95
3/29/2014	28.5	7.0	10.5	30	1.08	3.99
3/30/2014	29	5.5	10.7	25	0.72	3.62
3/31/2014	30	6.0	10.9	29	0.72	3.73
4/1/2014	29.5	8.0	10.9	27	1.02	4.06
4/2/2014	29	10.8	7.4	41	1.03	3.59
4/3/2014	27.6	11.0	9.7	50	1.06	3.77
4/4/2014	26.5	10.0	0.5	38	0.52	2.12
4/5/2014	29	11.0	8.2	42	0.91	3.59
4/6/2014	28	11.2	4.4	42	0.82	2.95
4/7/2014	29	14.0	6	56	0.85	3.20

4/8/2014	28	14.0	6.3	46	0.94	3.33
4/9/2014	29	12.5	9.2	42	0.92	3.75
4/10/2014	26	15.0	3.7	63	0.94	2.71
4/11/2014	23.7	13.0	5.8	77	0.80	2.71
4/12/2014	24.5	13.0	3.2	75	0.67	2.31
4/13/2014	27.2	11.5	8	56	0.66	3.24
4/14/2014	27.5	14.0	4.4	61	0.70	2.75
4/15/2014	28	12.5	8.5	56	0.91	3.52
4/16/2014	27	12.4	8.1	60	0.74	3.30
4/17/2014	26.6	14.2	7.7	60	0.95	3.37
4/18/2014	26.5	13.0	8	60	0.68	3.24
4/19/2014	28.5	14.0	10.6	49	0.77	3.84
4/20/2014	29	12.0	8.1	47	0.61	3.33
4/21/2014	28	10.0	8.7	54	0.87	3.48
4/22/2014	28.2	12.5	7.5	49	1.00	3.50
4/23/2014	25	12.0	2	72	0.57	2.10
4/24/2014	26	14.0	7.3	55	0.88	3.26
4/25/2014	26	14.5	5.7	58	1.08	3.12

4/26/2014	25.6	13.0	7	70	0.90	3.07
4/27/2014	25.5	13.0	6.3	76	0.81	2.88
4/28/2014	24.5	12.6	3.6	72	0.84	2.44
4/29/2014	25	14.0	7.5	72	0.60	3.06
4/30/2014	25.5	13.5	8	65	0.42	3.09
5/1/2014	24.7	13.0	4.5	73	1.20	2.68
5/2/2014	24	12.6	3	70	0.63	2.28
5/3/2014	26.5	13.0	9.1	57	0.60	3.37
5/4/2014	26.4	13.2	9.7	58	0.69	3.51
5/5/2014	27.5	12.5	9.8	53	0.53	3.47
5/6/2014	27	12.5	7.6	53	0.64	3.19
5/7/2014	26	13.5	3.4	69	0.64	2.44
5/8/2014	24.3	13.6	2.5	75	0.33	2.10
5/9/2014	23.5	14.0	0.2	82	0.52	1.71
5/10/2014	23.5	14.2	7.7	79	0.94	3.05
5/11/2014	24	14.0	4.8	78	0.96	2.61
5/12/2014	25.2	13.5	5.9	76	0.74	2.80
5/13/2014	25.5	13.0	8.2	71	1.18	3.32

5/14/2014	25.8	13.0	9	67	0.63	3.33
5/15/2014	26.5	12.8	8	64	0.85	3.30
5/16/2014	27	12.0	9.5	60	0.93	3.59
5/17/2014	26	13.0	9.1	69	1.00	3.47
5/18/2014	25.5	13.5	7.2	69	0.99	3.15
5/19/2014	27	11.4	7.5	62	0.84	3.21
5/20/2014	25	14.0	7	75	0.59	2.97
5/21/2014	24.5	13.5	3.3	76	0.91	2.38
5/22/2014	19	13.4	0	87	0.33	1.53
5/23/2014	24	13.0	2.1	87	0.42	1.99
5/24/2014	23.6	13.0	4.6	87	0.58	2.42
5/25/2014	21.2	12.0	3.1	89	0.57	2.05
5/26/2014	25	11.0	6.9	77	1.03	2.93
5/27/2014	24.5	13.0	8.9	76	0.74	3.25
5/28/2014	26.5	12.5	10.9	63	0.88	3.75
5/29/2014	25.2	12.0	8	69	0.75	3.14
5/30/2014	26.5	11.0	10.2	68	0.98	3.60
5/31/2014	26	12.5	6.1	77	0.61	2.81

6/1/2014	24.8	12.0	6.2	82	0.75	2.75
6/2/2014	27	12.0	7.8	68	0.70	3.19
6/3/2014	27.5	12.5	8.3	67	0.73	3.33
6/4/2014	27	11.6	7.4	66	0.57	3.08
6/5/2014	26.5	12.0	8	69	0.91	3.26
6/6/2014	26.3	12.0	5.5	70	0.72	2.78
6/7/2014	23.5	13.6	3.6	81	0.70	2.31
6/8/2014	24.2	14.0	5.6	79	0.60	2.68
6/9/2014	25	13.5	9	72	1.33	3.45
6/10/2014	22.6	12.5	6.1	81	0.82	2.67
6/11/2014	24.6	14.0	8.3	73	0.95	3.25
6/12/2014	25	12.5	6.6	71	0.93	2.96
6/13/2014	25.6	12.5	9.1	62	0.89	3.43
6/14/2014	23.2	14.0	3.9	86	0.80	2.32
6/15/2014	24.6	13.5	8.4	68	0.95	3.29
6/16/2014	24.8	11.5	7.7	75	0.87	3.05
6/17/2014	24.5	13.0	5.4	82	0.72	2.63
6/18/2014	25.6	11.5	9.6	71	1.14	3.49

6/19/2014	24.5	12.6	1.6	76	0.68	2.03
6/20/2014	23.5	13.0	2.5	80	0.56	2.10
6/21/2014	21.6	13.2	0	84	0.50	1.61
6/22/2014	21.5	12.5	4.8	80	0.82	2.43
6/23/2014	23.5	12.8	7.1	78	0.79	2.90
6/24/2014	22	13.5	6.2	81	1.03	2.71
6/25/2014	23.5	14.0	5.7	82	0.82	2.68
6/26/2014	20.4	14.5	1.4	91	0.84	1.78
6/27/2014	22.6	13.5	5.5	85	0.73	2.56
6/28/2014	23.5	14.0	3.5	83	0.49	2.26
6/29/2014	24	14.5	7	78	0.79	2.96
6/30/2014	23.5	12.2	6.3	81	0.87	2.74
7/1/2014	25	13.5	6	84	0.84	2.76
7/2/2014	25.5	14.0	8.5	77	1.00	3.31
7/3/2014	25.4	13.5	6.6	80	0.97	2.93
7/4/2014	24	12.8	7.2	77	1.33	3.02
7/5/2014	21.6	13.5	2	84	1.01	1.99
7/6/2014	24	14.0	6.8	74	0.78	2.93

7/7/2014	22.5	13.0	4	83	0.95	2.33
7/8/2014	24	11.5	6.3	75	1.04	2.83
7/9/2014	22.6	13.4	6	82	0.78	2.67
7/10/2014	23	14.0	5.1	70	0.94	2.70
7/11/2014	23.2	13.5	5.4	82	1.16	2.63
7/12/2014	21.5	14.5	2.9	83	0.86	2.15
7/13/2014	23.5	12.5	6.6	76	0.73	2.81
7/14/2014	22.4	12.6	3.3	80	0.66	2.21
7/15/2014	21	13.0	1.4	88	1.06	1.81
7/16/2014	23.5	14.0	5.4	74	0.73	2.68
7/17/2014	22.5	13.0	3	83	0.72	2.15
7/18/2014	23.5	12.0	4.8	75	0.83	2.54
7/19/2014	20	14.0	0.8	92	0.89	1.65
7/20/2014	22.5	14.0	2.1	84	0.88	2.03
7/21/2014	22.6	13.5	2.9	81	0.65	2.16
7/22/2014	22.5	13.0	1.6	83	0.48	1.89
7/23/2014	22.6	13.2	1.2	82	0.55	1.85
7/24/2014	22	12.5	3.8	81	0.84	2.28

7/25/2014	20	12.0	0.6	85	0.61	1.66
7/26/2014	20.5	12.8	0.1	87	0.46	1.57
7/27/2014	23.4	13.0	5	82	0.67	2.52
7/28/2014	22	11.5	2.2	92	0.60	1.89
7/29/2014	23.5	12.6	4	85	0.66	2.32
7/30/2014	22	13.0	2.5	89	1.09	2.00
7/31/2014	18.5	13.4	0.2	92	0.75	1.52
8/1/2014	20.5	13.6	0.6	85	0.68	1.70
8/2/2014	22.5	13.5	7	84	0.77	2.82
8/3/2014	20	14.0	2.4	91	1.08	1.92
8/4/2014	19.5	13.5	0	90	0.79	1.53
8/5/2014	21.2	12.5	3	76	0.52	2.12
8/6/2014	22.2	13.5	0.8	83	0.89	1.82
8/7/2014	20.2	13.0	2	83	0.77	1.93
8/8/2014	21.5	12.5	1.9	80	0.56	1.94
8/9/2014	21	13.8	3	86	0.67	2.10
8/10/2014	24	13.0	4.6	79	0.61	2.48
8/11/2014	22.5	12.0	6.7	81	1.02	2.76

8/12/2014	20.2	11.5	1	83	0.38	1.70
8/13/2014	23.2	10.5	6.8	81	0.81	2.75
8/14/2014	24.4	12.5	5.8	75	0.97	2.78
8/15/2014	22.6	12.0	4.7	83	0.71	2.41
8/16/2014	23	11.4	6.3	81	0.84	2.69
8/17/2014	23.5	13.5	5	75	0.83	2.61
8/18/2014	24	13.0	2.2	74	0.73	2.16
8/19/2014	22	12.0	4.2	83	0.88	2.32
8/20/2014	23	12.6	2.8	83	0.62	2.11
8/21/2014	22.5	10.5	4.8	81	0.66	2.39
8/22/2014	22.5	12.0	4.4	81	0.65	2.36
8/23/2014	23.5	12.2	2.2	86	1.17	2.03
8/24/2014	23.8	11.5	4.1	74	0.85	2.45
8/25/2014	23	11.0	0	85	0.88	1.63
8/26/2014	21.5	12.5	0.1	84	0.86	1.65
8/27/2014	21.5	9.5	7.4	87	0.49	2.70
8/28/2014	24	9.6	9.7	74	0.63	3.23
8/29/2014	21	12.0	0.5	84	1.02	1.71

8/30/2014	23.5	13.0	8.2	85	0.68	3.04
8/31/2014	21.5	12.5	4.4	83	0.50	2.32
9/1/2014	21.6	12.5	6	88	0.72	2.56
9/2/2014	22.2	12.0	6.3	79	0.95	2.70
9/3/2014	22	13.5	9.2	86	1.07	3.13
9/4/2014	23.2	12.5	3.7	80	0.68	2.30
9/5/2014	22.5	12.5	5.8	84	0.54	2.58
9/6/2014	21.5	13.5	3.2	92	0.86	2.08
9/7/2014	21.6	13.5	8	86	0.66	2.93
9/8/2014	22	12.5	4.4	88	0.56	2.31
9/9/2014	21.5	12.5	8.5	85	0.86	2.97
9/10/2014	22.2	11.0	8.1	83	0.61	2.90
9/11/2014	24	10.5	7.7	77	0.87	2.96
9/12/2014	24.2	13.0	8	84	0.75	3.05
9/13/2014	24	10.5	10.6	76	1.06	3.44
9/14/2014	23	13.0	8.1	81	0.63	3.01
9/15/2014	23.2	11.5	8.7	79	0.72	3.08
9/16/2014	23	10.5	7.5	83	0.67	2.83

9/17/2014	23.6	10.0	2	82	0.56	1.95
9/18/2014	23.5	10.0	7.3	81	0.59	2.81
9/19/2014	23	11.0	5.7	74	0.56	2.58
9/20/2014	24	11.8	7	83	0.65	2.83
9/21/2014	24.5	10.5	6.3	74	1.03	2.83
9/22/2014	24.5	12.0	3.6	70	0.72	2.41
9/23/2014	24.4	12.0	7.5	73	0.99	3.06
9/24/2014	24.6	12.5	8	68	0.91	3.18
9/25/2014	24	11.4	4.5	76	0.79	2.48
9/26/2014	24.6	11.0	3	74	0.80	2.28
9/27/2014	20	12.5	9.1	84	0.95	3.00
9/28/2014	23	12.5	9.7	80	0.62	3.26
9/29/2014	24.5	10.5	9.8	77	0.68	3.30
9/30/2014	24.6	13.5	7.6	73	0.83	3.09
10/1/2014	24.5	12.0	3.4	76	0.73	2.32
10/2/2014	23.2	13.5	2.5	77	0.67	2.15
10/3/2014	24.5	13.5	0.2	81	0.67	1.76
10/4/2014	22	13.4	7.7	80	0.59	2.92

10/5/2014	23.5	13.5	4.8	86	0.58	2.47
10/6/2014	22.5	12.6	5.9	86	0.55	2.59
10/7/2014	24	12.0	8.2	77	1.11	3.12
10/8/2014	24	13.0	9	76	0.58	3.22
10/9/2014	24.2	13.2	8	79	0.74	3.08
10/10/2014	24.3	12.6	9.5	82	0.34	3.29
10/11/2014	24	13.5	9.1	78	0.65	3.26
10/12/2014	23	13.0	7.2	83	0.61	2.86
10/13/2014	23.5	11.5	7.5	81	0.74	2.90
10/14/2014	24.5	14.0	7	79	0.48	2.92
10/15/2014	24	13.5	3.3	75	0.69	2.32
10/16/2014	25	13.0	0	76	0.68	1.78
10/17/2014	24.6	11.0	2.1	71	0.53	2.08
10/18/2014	24.7	11.0	4.6	77	0.38	2.42
10/19/2014	24.6	10.5	3.1	73	0.65	2.25
10/20/2014	24	11.0	6.9	85	0.76	2.78
10/21/2014	25	12.5	8.9	79	0.79	3.25
10/22/2014	25.2	11.0	10.9	61	0.66	3.54

10/23/2014	25	10.5	8	61	0.56	3.05
10/24/2014	25	10.0	10.2	70	0.55	3.36
10/25/2014	25.5	8.0	6.1	67	0.54	2.70
10/26/2014	25	10.0	6.2	74	0.38	2.68
10/27/2014	25.6	11.5	7.8	78	0.41	3.02
10/28/2014	24	10.5	8.3	74	0.46	3.00
10/29/2014	24.5	9.5	7.4	72	0.48	2.86
10/30/2014	24.6	8.5	8	66	0.55	2.96
10/31/2014	24.5	10.5	5.5	74	0.42	2.57
11/1/2014	24.5	8.3	3.6	71	0.41	2.22
11/2/2014	24.5	9.0	5.6	70	0.45	2.56
11/3/2014	26	10.5	9	66	0.49	3.22
11/4/2014	26	9.0	6.1	61	0.44	2.71
11/5/2014	26.5	10.0	8.3	57	0.53	3.14
11/6/2014	25.5	9.2	6.6	62	0.52	2.81
11/7/2014	25	10.0	9.1	66	0.58	3.20
11/8/2014	25.5	9.5	3.9	69	0.55	2.39
11/9/2014	26	8.5	8.4	58	0.44	3.04

11/10/2014	26	7.5	7.7	58	0.40	2.89
11/11/2014	26.2	7.5	5.4	55	0.46	2.61
11/12/2014	26.2	8.0	9.6	62	0.52	3.26
11/13/2014	25	8.5	1.6	58	0.53	2.07
11/14/2014	24.5	8.5	2.5	60	0.39	2.09
11/15/2014	24.2	10.0	3.1	63	0.31	2.15
11/16/2014	25.5	8.0	7.4	65	0.46	2.87
11/17/2014	23.6	9.5	5.7	75	0.53	2.56
11/18/2014	25	9.0	8	66	0.46	2.96
11/19/2014	24.5	10.0	7	62	0.61	2.88
11/20/2014	24.5	7.5	4.2	69	0.37	2.29
11/21/2014	24.2	10.0	6.9	66	0.57	2.82
11/22/2014	25.2	10.0	7.7	68	0.49	2.96
11/23/2014	25.4	8.5	9.2	65	0.60	3.20
11/24/2014	25	8.0	10.3	57	0.58	3.32
11/25/2014	24.6	6.0	9.3	57	0.48	3.06
11/26/2014	23.6	7.0	7.8	59	0.49	2.83
11/27/2014	24.5	7.5	7	63	0.51	2.77

11/28/2014	25.6	6.5	9	58	0.75	3.22
11/29/2014	24.6	7.5	7.8	61	0.42	2.86
11/30/2014	25.4	9.0	9.6	56	0.63	3.29
12/1/2014	24.6	5.0	10.4	53	0.42	3.14
12/2/2014	24.8	4.6	8.8	57	0.59	3.02
12/3/2014	24.6	8.4	9.9	57	0.41	3.17
12/4/2014	25.2	6.6	7.8	63	0.25	2.79
12/5/2014	25.6	7.5	10.3	57	0.40	3.25
12/6/2014	24.8	6.0	9.8	54	0.43	3.11
12/7/2014	24	5.0	9.5	59	0.43	3.01
12/8/2014	25.5	6.0	7.5	54	0.43	2.82
12/9/2014	24.5	7.2	7.5	59	0.35	2.77
12/10/2014	25.2	8.0	6	54	0.30	2.56
12/11/2014	26.5	6.5	10	53	0.34	3.17
12/12/2014	25.7	6.0	9.5	54	0.36	3.07
12/13/2014	26	5.0	9.3	50	0.42	3.06
12/14/2014	26.2	5.0	9	51	0.56	3.12
12/15/2014	26.3	5.5	8.7	57	0.62	3.13

12/16/2014	24	5.0	7.4	57	0.42	2.72
12/17/2014	24.5	6.6	7.8	58	0.57	2.90
12/18/2014	24	8.5	7.3	54	0.50	2.83
12/19/2014	26	6.5	7.5	48	0.43	2.85
12/20/2014	25.6	6.0	9.2	55	0.52	3.12
12/21/2014	26.2	6.5	8.9	54	0.73	3.24
12/22/2014	27	5.2	9.2	51	0.72	3.31
12/23/2014	25.5	5.5	8.6	58	0.68	3.09
12/24/2014	26	6.0	9	56	0.51	3.10
12/25/2014	24.5	6.6	7	50	0.47	2.75
12/26/2014	25.4	8.5	4.5	52	0.43	2.45
12/27/2014	25.2	6.0	8.7	57	0.63	3.08
12/28/2014	26.2	6.0	9.4	49	0.70	3.29
12/29/2014	26.5	4.5	9.5	45	0.50	3.15
12/30/2014	27	4.4	9.7	42	0.40	3.10
12/31/2014	26	4.0	9.6	41	0.51	3.12
1/1/2015	26.5	3.5	10	41.6	0.49	3.17
1/2/2015	26	1.5	10.2	42.8	0.50	3.14

1/3/2015	26.2	2.0	10.1	38	0.45	3.09
1/4/2015	25	3.0	10.1	42	0.74	3.29
1/5/2015	25.5	2.5	9.7	49.2	0.68	3.20
1/6/2015	26	3.5	8.9	49.8	0.71	3.17
1/7/2015	25.5	5.0	9.1	57.6	0.83	3.22
1/8/2015	26.2	4.8	9.4	60.2	0.77	3.26
1/9/2015	23.8	6.0	7.3	66.6	1.05	2.91
1/10/2015	23.5	5.0	9	61.4	1.06	3.15
1/11/2015	24	5.0	4.9	59.2	0.47	2.40
1/12/2015	24.6	3.0	6.8	59	0.75	2.78
1/13/2015	24.2	5.0	3.5	57.6	0.45	2.21
1/14/2015	25.2	6.5	8	60.4	0.77	3.05
1/15/2015	25.5	7.0	7.9	52.4	1.03	3.26
1/16/2015	26.2	6.5	9.7	53.8	0.84	3.41
1/17/2015	25.5	5.0	10.1	51.8	0.88	3.42
1/18/2015	25.5	5.0	9.8	53.8	0.82	3.33
1/19/2015	25	5.5	9.5	52.4	0.66	3.19
1/20/2015	25.5	4.5	9	49.8	0.52	3.05

1/21/2015	26.5	7.0	7.4	46.4	0.50	2.92
1/22/2015	27.5	7.0	7.9	50.4	0.50	3.04
1/23/2015	28	8.0	9.1	48	0.62	3.34
1/24/2015	27.6	6.5	9.9	46.2	0.61	3.39
1/25/2015	27.2	7.0	9.9	46.6	0.66	3.42
1/26/2015	28	7.5	10	43.4	0.63	3.46
1/27/2015	27.6	7.5	10.3	47.2	0.52	3.40
1/28/2015	27.5	6.0	10	44.2	0.56	3.34
1/29/2015	27.8	5.5	10.4	34	0.45	3.25
1/30/2015	28.5	5.5	10.5	33.6	0.54	3.40
1/31/2015	28.5	4.0	10.6	34.8	0.51	3.36
2/1/2015	28.2	2.2	10.1	32.6	0.63	3.39
2/2/2015	29	3.5	10.6	33	0.51	3.37
2/3/2015	29.2	3.3	10.7	37	0.51	3.42
2/4/2015	29.6	5.0	10.5	30.8	0.52	3.41
2/5/2015	29.8	5.5	10.5	29.2	0.63	3.56
2/6/2015	28.5	6.5	10.6	35	0.68	3.58
2/7/2015	29.5	6.6	10.5	33.2	0.64	3.58

2/8/2015	29.5	6.8	10.2	33.2	0.59	3.49
2/9/2015	28.5	6.3	10.1	34.8	0.77	3.61
2/10/2015	29.6	6.6	10.4	28.4	0.64	3.55
2/11/2015	29	6.8	10.2	31	0.85	3.74
2/12/2015	28.5	7.0	9.7	38.4	0.92	3.70
2/13/2015	28.5	7.4	9.5	41.8	1.06	3.79
2/14/2015	28	7.8	8.1	48.4	0.83	3.35
2/15/2015	26.5	9.5	4	52.4	0.52	2.50
2/16/2015	27.5	10.5	7.3	42	0.45	2.98
2/17/2015	28	10.0	4.5	50.2	0.54	2.67
2/18/2015	28.6	13.5	4.2	49.4	0.65	2.79
2/19/2015	29.8	13.0	9.3	42	0.65	3.59
2/20/2015	29.8	9.0	10.8	39.8	0.86	3.91
2/21/2015	28.6	8.5	7.6	42	0.98	3.50
2/22/2015	29.2	8.5	9.1	40.8	0.88	3.65
2/23/2015	29	9.5	7.5	42.4	0.65	3.23
2/24/2015	29.5	7.4	8	35.6	0.78	3.44
2/25/2015	29.6	9.5	10.6	34.2	0.93	3.95

2/26/2015	30	8.4	9	33	0.85	3.68
2/27/2015	30.5	11.0	9.6	32.2	1.03	4.02
2/28/2015	30	11.0	8.7	40.4	0.52	3.36
3/1/2015	29	10.0	7.9	40.2	0.68	3.33
3/2/2015	29.5	11.0	7.4	47.2	0.62	3.25
3/3/2015	30	12.5	9.1	36.4	0.66	3.56
3/4/2015	30.2	7.0	9.8	34	0.73	3.65
3/5/2015	30	12.0	9	44	0.87	3.73
3/6/2015	29.5	11.0	9.5	40.8	0.89	3.78
3/7/2015	28.5	10.0	7.4	60.8	0.61	3.14
3/8/2015	29	12.0	6.7	42.8	0.48	3.02
3/9/2015	29.8	8.0	9.9	38.6	0.69	3.61
3/10/2015	30	8.2	11	37	0.61	3.68
3/11/2015	30.5	9.5	10.5	35.8	0.71	3.77
3/12/2015	29.2	10.8	8	31.2	0.66	3.34
3/13/2015	30.5	11.5	10.5	35.6	0.74	3.83
3/14/2015	30.6	14.0	7.7	35.4	0.74	3.51
3/15/2015	30.2	13.8	9.8	34	0.73	3.75

3/16/2015	31	14.0	9.7	35.4	0.97	4.04
3/17/2015	29.5	15.0	4	48.2	0.84	2.99
3/18/2015	29.5	15.0	5.6	49.4	0.90	3.26
3/19/2015	28	14.0	5.3	56.2	0.68	2.93
3/20/2015	27	11.0	6.2	54	0.67	2.96
3/21/2015	29	12.0	10	48.6	0.80	3.75
3/22/2015	28.5	11.5	8.4	46.6	0.70	3.41
3/23/2015	28.6	10.0	9.3	44.8	0.76	3.56
3/24/2015	28.6	9.5	10.5	40.4	0.82	3.76
3/25/2015	29	8.0	10	44.6	0.72	3.61
3/26/2015	29.5	9.0	10	34.8	0.65	3.57
3/27/2015	30	9.0	11	42.2	0.83	3.92
3/28/2015	29.6	12.0	8	38.4	1.00	3.71
3/29/2015	28	14.5	8.2	48.4	1.00	3.64
3/30/2015	28.5	11.0	8.4	57.2	1.14	3.62
3/31/2015	29.2	11.0	9.6	59.6	1.31	3.91
4/1/2015	29.5	10.5	10.5	50.2	1.54	4.30
4/2/2015	28	11.2	10.2	46.8	1.06	3.88

4/3/2015	29.6	8.8	9.7	40.8	1.28	4.11
4/4/2015	28.5	13.5	9.5	40.2	1.41	4.20
4/5/2015	28.5	11.0	8.8	47.8	0.95	3.64
4/6/2015	30.2	12.5	7.3	43.8	1.03	3.66
4/7/2015	28.2	9.0	7.6	48.4	0.99	3.44
4/8/2015	29.4	9.5	9.8	31.8	1.12	4.04
4/9/2015	29.5	11.0	10.4	27	1.02	4.04
4/10/2015	28.6	11.0	10.1	26.2	1.19	4.13
4/11/2015	28.5	13.0	10.1	35	1.24	4.16
4/12/2015	28.2	9.0	9	29.2	1.20	3.95
4/13/2015	28.5	9.0	6.7	40	1.18	3.58
4/14/2015	27.5	13.0	6.6	39.2	1.24	3.63
4/15/2015	27.5	10.5	8.4	28.8	0.98	3.64
4/16/2015	30	9.0	10.4	28.8	1.13	4.16
4/17/2015	29	11.0	9.2	31.6	1.23	4.08
4/18/2015	29.5	10.5	10.2	38	1.73	4.60
4/19/2015	29.2	11.0	10.6	37.2	1.28	4.26
4/20/2015	29.6	13.5	10.5	32.6	1.16	4.24

4/21/2015	30.2	11.0	9.5	29.2	1.31	4.30
4/22/2015	29.6	13.0	10.3	26	1.20	4.26
4/23/2015	30	10.0	10.9	29.8	1.31	4.42
4/24/2015	30.5	10.5	9.2	30.8	1.48	4.45
4/25/2015	29.2	14.0	6	25.6	1.70	4.35
4/26/2015	30	13.5	8.6	30.2	1.42	4.32
4/27/2015	29	15.0	10.8	27	1.14	4.24
4/28/2015	30	11.0	10.6	23	1.02	4.09
4/29/2015	30	13.5	8	25.4	1.09	3.92
4/30/2015	30.5	14.5	5.8	33.6	0.80	3.34
5/1/2015	27	16.0	4.3	43.2	1.07	3.18
5/2/2015	28.6	12.0	6.8	41.8	1.06	3.53
5/3/2015	26.5	14.0	4.4	77.8	1.00	2.65
5/4/2015	25.6	12.0	4.1	67	0.80	2.58
5/5/2015	24.5	14.0	0.9	82.2	1.03	1.93
5/6/2015	24.6	11.6	5.5	67.2	0.91	2.79
5/7/2015	25.4	14.0	3.8	60.2	1.05	2.76
5/8/2015	25.6	14.5	7.5	61.8	1.17	3.37

5/9/2015	25.4	14.0	4.9	70.4	0.75	2.70
5/10/2015	23.5	14.5	1.1	78.2	0.58	1.91
5/11/2015	25.5	14.2	3.3	72.6	0.79	2.44
5/12/2015	28	13.0	5.8	67.2	1.03	3.07
5/13/2015	27.5	12.5	9.8	62.4	1.13	3.75
5/14/2015	29	13.5	10.1	59.2	0.80	3.80
5/15/2015	28.6	14.0	8.4	60.4	0.99	3.60
5/16/2015	30	14.5	8.5	62.2	1.12	3.76
5/17/2015	27	13.5	5.8	63.8	0.90	3.02
5/18/2015	26.5	13.0	9.7	66.2	1.30	3.71
5/19/2015	27	12.5	6.3	70.2	0.74	2.96
5/20/2015	27	12.0	9.5	59	0.84	3.55
5/21/2015	26.5	11.8	7.5	57	1.33	3.48
5/22/2015	25.6	12.6	5.8	66.2	0.79	2.86
5/23/2015	25.5	11.2	8.3	62.6	0.94	3.29
5/24/2015	24	13.0	4.6	78.4	0.51	2.47
5/25/2015	26.5	12.2	7.4	69.8	1.36	3.29
5/26/2015	25	13.0	5.5	73.6	0.89	2.77

5/27/2015	24.8	12.8	5.7	78.4	0.66	2.70
5/28/2015	23.5	13.0	1	88.8	0.70	1.78
5/29/2015	25.5	13.5	6.4	76.6	0.77	2.90
5/30/2015	26	12.5	8.3	67.2	0.79	3.27
5/31/2015	26	12.0	7.1	76	1.11	3.07
6/1/2015	24	13.4	4.1	84	0.88	2.40
6/2/2015	24.5	13.5	9.9	69	0.93	3.50
6/3/2015	25.2	14.0	6.4	88	0.75	2.82
6/4/2015	27	11.0	8.6	61	0.73	3.33
6/5/2015	27	11.3	7.6	71	0.77	3.15
6/6/2015	26.5	12.2	6.8	70	0.8	3.03
6/7/2015	25.7	12.0	9.1	69	0.96	3.40
6/8/2015	25.5	12.3	5.5	74	0.78	2.74
6/9/2015	26	13.0	6.4	73	0.79	2.94
6/10/2015	25.2	12.5	6.8	76	1.15	3.00
6/11/2015	23.5	12.5	7.5	77	0.73	2.95
6/12/2015	24.5	12.0	7.6	74	0.95	3.06
6/13/2015	23.5	13.0	7.3	82	1.02	2.92

6/14/2015	23	13.5	5.7	78	0.95	2.70
6/15/2015	25.5	13.0	5.8	69	0.82	2.86
6/16/2015	22.5	15.0	2.7	87	0.62	2.10
6/17/2015	22.5	12.4	0.6	85	0.38	1.69
6/18/2015	23.5	13.5	2.2	86	0.91	2.04
6/19/2015	25	12.5	5.3	76	0.71	2.66
6/20/2015	25.2	13.5	6	75	1.02	2.89
6/21/2015	23.2	13.0	3.2	80	0.88	2.26
6/22/2015	19.6	13.8	0	86	0.42	1.56
6/23/2015	21	13.6	0.6	74	0.52	1.78
6/24/2015	24	13.5	4.2	74	0.63	2.46
6/25/2015	23.5	10.0	9.3	75	1.03	3.21
6/26/2015	24.5	13.0	2.5	79	0.6	2.14
6/27/2015	21.2	12.5	0.9	86	0.83	1.75
6/28/2015	20.2	13.4	2.2	84	0.46	1.93
6/29/2015	24	12.0	7.9	67	0.74	3.07
6/30/2015	25	11.5	5.4	77	0.72	2.65
7/1/2015	24.0	13.5	5.4	75.6	0.8	2.69

7/2/2015	23.5	12.0	4.9	77	0.8	2.53
7/3/2015	24.0	12.0	6.7	71.4	0.8	2.89
7/4/2015	24.5	12.2	6.0	77.4	0.8	2.75
7/5/2015	24.0	14.0	3.1	81.6	1.1	2.30
7/6/2015	24.4	12.0	5.0	75.2	0.8	2.60
7/7/2015	25.0	12.5	6.6	73.8	1.0	2.96
7/8/2015	24.5	13.0	8.8	72.4	1.0	3.30
7/9/2015	25.0	12.5	8.2	70	1.0	3.23
7/10/2015	25.5	13.0	6.0	77.8	0.8	2.81
7/11/2015	25.0	12.5	6.9	72.2	0.8	2.97
7/12/2015	23.6	13.0	4.7	84.4	0.9	2.47
7/13/2015	17.6	14.0	0.0	88.2	0.9	1.53
7/14/2015	23.5	13.0	3.2	75.2	0.7	2.28
7/15/2015	23.0	12.5	2.9	78.6	0.7	2.18
7/16/2015	24.0	13.5	4.7	75.4	0.8	2.56
7/17/2015	24.5	13.4	6.3	77.2	0.9	2.86
7/18/2015	25.0	12.5	8.0	74.2	1.1	3.18
7/19/2015	23.5	12.0	5.1	76.2	1.0	2.60

7/20/2015	24.0	13.5	5.8	77.2	1.0	2.78
7/21/2015	23.0	11.0	7.1	80.2	0.9	2.81
7/22/2015	24.0	13.0	3.7	80	0.8	2.35
7/23/2015	23.0	12.6	2.4	80.8	0.6	2.07
7/24/2015	21.5	13.5	4.0	85.2	0.8	2.28
7/25/2015	24.5	12.0	7.0	77.6	0.7	2.89
7/26/2015	24.0	13.0	8.3	71.8	0.7	3.14
7/27/2015	24.0	13.0	3.6	87.2	0.8	2.26
7/28/2015	25.5	11.5	6.5	76	0.8	2.88
7/29/2015	24.5	12.5	7.2	79	0.7	2.94
7/30/2015	24.0	12.8	5.2	81.4	0.9	2.59
7/31/2015	23.5	12.5	5.0	82.8	0.9	2.52
8/1/2015	25.4	13.0	4.4	77.8	0.7	2.53
8/2/2015	23.6	12.5	0.3	79.8	0.4	1.70
8/3/2015	24.0	13.5	4.1	78	0.5	2.40
8/4/2015	23.6	14.0	5.9	81.6	0.7	2.71
8/5/2015	20.5	13.5	2.4	87.6	1.3	1.98
8/6/2015	22.0	13.0	3.4	84.6	0.6	2.18

8/7/2015	22.5	13.5	7.3	77.8	1.0	2.94
8/8/2015	23.5	12.0	5.0	76.8	1.0	2.59
8/9/2015	21.6	12.0	4.2	86.4	0.8	2.27
8/10/2015	23.5	12.2	3.5	78.2	0.8	2.31
8/11/2015	24.0	10.5	6.7	74.6	1.0	2.86
8/12/2015	25.5	10.0	6.6	81	1.1	2.84
8/13/2015	25.0	13.5	6.2	73.4	0.6	2.83
8/14/2015	25.2	12.0	8.2	77	0.9	3.16
8/15/2015	24.0	13.0	7.1	70.6	0.8	2.99
8/16/2015	25.0	13.0	7.0	76.2	1.0	3.00
8/17/2015	23.0	12.8	4.3	74	1.0	2.51
8/18/2015	23.5	12.0	5.0	81	1.0	2.53
8/19/2015	24.5	12.5	5.8	79.2	0.7	2.71
8/20/2015	23.5	12.5	6.4	80.6	0.7	2.75
8/21/2015	25.5	12.0	4.7	78.2	0.8	2.57
8/22/2015	23.5	11.5	6.4	76.4	0.8	2.77
8/23/2015	23.7	12.0	5.8	77	0.6	2.66
8/24/2015	23.6	11.5	6.7	84.8	0.8	2.75

8/25/2015	25.0	13.0	9.3	71.4	1.1	3.44
8/26/2015	21.5	13.5	0.1	85.6	0.5	1.61
8/27/2015	22.5	13.2	3.2	83.8	0.5	2.17
8/28/2015	23.6	11.6	5.2	71.6	0.6	2.56
8/29/2015	23.5	12.5	4.5	72.8	0.6	2.47
8/30/2015	23.6	9.5	6.5	80	0.8	2.70
8/31/2015	24.5	12.5	4.8	74.8	1.0	2.63
9/1/2015	24.4	12.0	5.3	76.2	0.9	2.66
9/2/2015	25.6	11.0	7.6	78.2	0.9	3.04
9/3/2015	25.4	10.8	8.0	74.8	1.1	3.15
9/4/2015	23.6	13.0	4.0	79.2	0.6	2.37
9/5/2015	24.5	11.5	6.9	72.2	0.7	2.89
9/6/2015	24.5	11.2	5.0	84.2	0.7	2.49
9/7/2015	25.0	11.0	6.4	75	0.7	2.80
9/8/2015	23.5	13.5	4.7	85	1.1	2.48
9/9/2015	21.2	12.6	1.3	90.6	0.5	1.76
9/10/2015	23.0	12.0	1.9	81.6	0.4	1.93
9/11/2015	24.0	13.0	4.5	78.4	0.7	2.48

9/12/2015	23.5	12.5	4.6	83.6	0.4	2.41
9/13/2015	21.5	12.3	2.3	82.4	0.6	1.98
9/14/2015	22.5	11.5	3.3	81.4	0.5	2.16
9/15/2015	23.5	11.5	4.6	84.4	0.6	2.39
9/16/2015	24.6	12.0	7.7	78.8	0.8	3.02
9/17/2015	25.0	12.5	7.2	78.4	0.8	2.98
9/18/2015	25.0	12.0	5.2	82	0.7	2.59
9/19/2015	24.6	11.2	9.0	70.8	0.8	3.25
9/20/2015	25.5	10.8	6.3	69.6	0.7	2.84
9/21/2015	26.0	10.5	7.4	72.4	0.7	3.01
9/22/2015	24.0	13.5	4.5	85.2	0.6	2.44
9/23/2015	24.0	9.5	6.7	79.6	0.7	2.74
9/24/2015	24.5	13.0	7.0	74.8	0.9	2.98
9/25/2015	25.0	12.0	6.6	73.2	0.6	2.85
9/26/2015	24.6	9.5	6.2	73.6	0.7	2.72
9/27/2015	25.0	12.0	6.0	77.6	0.6	2.74
9/28/2015	25.2	12.0	5.7	75.4	0.6	2.71
9/29/2015	25.5	10.5	4.7	79.4	0.6	2.49

9/30/2015	25.5	12.5	5.6	78	0.8	2.74
10/1/2015	25.6	13.0	6.6	68.0	0.6	2.92
10/2/2015	25.5	8.5	7.9	61.0	0.5	2.97
10/3/2015	25.5	10.0	10.2	71.0	0.6	3.41
10/4/2015	26.0	10.0	9.8	64.0	0.5	3.32
10/5/2015	26.0	10.5	9.1	68.0	0.7	3.31
10/6/2015	25.0	12.5	5.5	76.0	0.9	2.73
10/7/2015	24.5	12.6	3.0	75.0	0.6	2.24
10/8/2015	25.0	10.0	6.0	75.0	0.4	2.65
10/9/2015	24.6	10.6	7.2	74.0	0.5	2.88
10/10/2015	26.2	11.0	6.6	75.0	0.4	2.84
10/11/2015	25.4	10.0	2.5	83.0	0.6	2.08
10/12/2015	24.0	13.0	0.5	85.0	0.4	1.71
10/13/2015	25.5	11.5	8.0	68.0	0.5	3.06
10/14/2015	26.0	11.0	8.8	70.0	0.5	3.22
10/15/2015	25.8	11.5	8.6	60.0	0.5	3.16
10/16/2015	25.5	12.5	6.0	66.0	0.4	2.72
10/17/2015	26.4	11.0	6.9	74.0	0.4	2.89

10/18/2015	25.2	11.2	6.7	76.0	0.6	2.85
10/19/2015	23.0	13.0	1.8	84.0	0.5	1.93
10/20/2015	26.0	12.5	6.7	73.0	0.4	2.88
10/21/2015	23.6	12.5	6.8	79.0	0.5	2.81
10/22/2015	26.6	10.0	6.4	70.0	0.5	2.81
10/23/2015	25.5	12.5	4.9	77.0	0.5	2.57
10/24/2015	25.6	12.5	9.1	70.0	0.6	3.30
10/25/2015	24.5	11.5	7.0	78.0	0.6	2.86
10/26/2015	25.5	11.5	4.8	81.0	0.6	2.53
10/27/2015	24.5	13.5	5.0	82.0	0.5	2.55
10/28/2015	24.6	12.0	4.7	80.0	0.5	2.47
10/29/2015	24.0	12.5	5.5	83.0	0.7	2.61
10/30/2015	23.0	12.0	3.8	80.0	0.3	2.24
10/31/2015	24.0	10.0	6.0	81.0	0.5	2.61