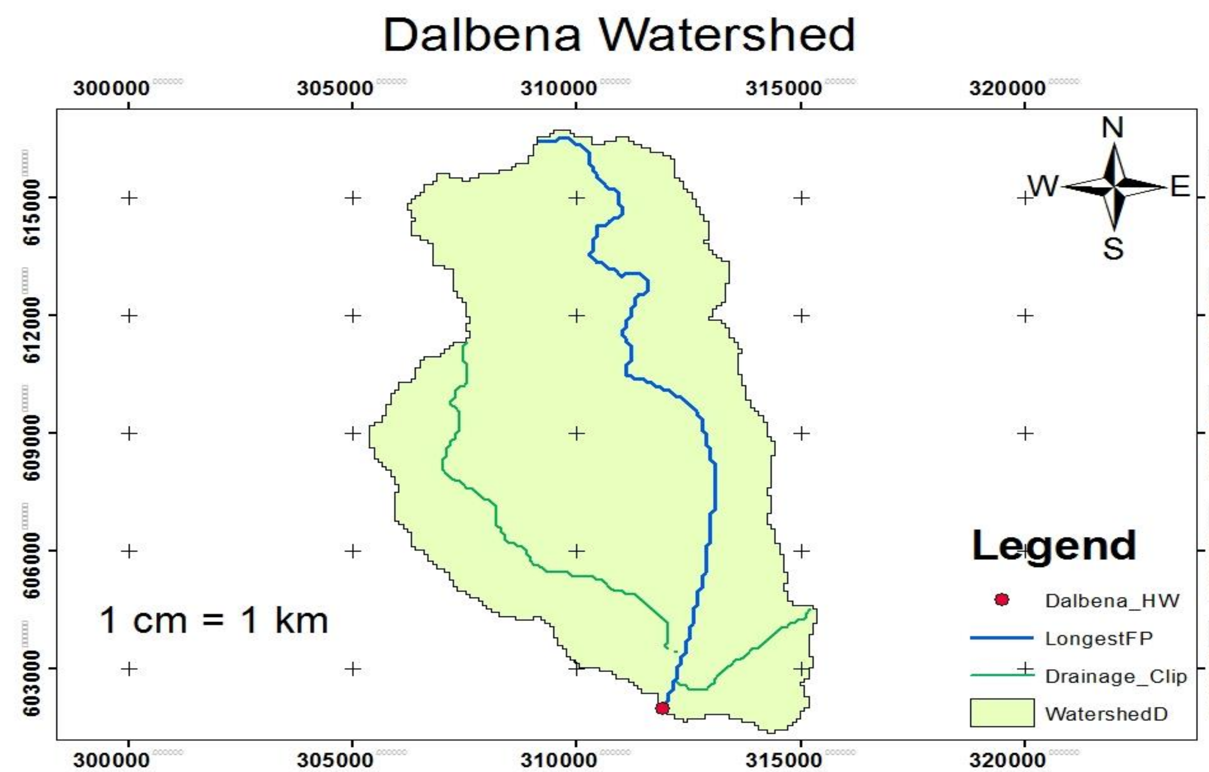
Southern Nations and Nationalities Peoples Regional State SNNPRS Irrigation Development and Schemes Administration Agency



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Dalbena Irrigation Project
Hydrology Feasibility Study
(Final Report)

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ABBREVIATIONS

AEP	Annual exceedance Probability
AEZ	Agro-ecological zone
CROPWAT	Crop Water Requirement
DEM	Digital Elevation Model
DW	Diversion Weir
ERA	Ethiopian Road Authority
FAO	Food and Agriculture Organization
GIS	Geographical Information System
IDF	Intensity Duration Frequency
MoWE	Ministry of Water Resources and Energy
NMSA	National Meteorological Services Agency
SD	Standard Deviation
SCS	Soil Conservation Service
USACE	Unites States Army Corp of Engineers
USDA	Unite States Department of Agriculture
WMO	World Meteorological Organization

EXCUTIVE SUMMARY

The hydro - climatological Study briefly indicated the availability of surface water resource potentials and the design flood at the irrigation diversion site of Dalbena Small Scale Irrigation Project. The watershed administratively located in SNNPRS, Gamo-Goffa Zone, Konso Woreda. The total size of the catchment that contributed to the diversion site is 19km2. The source of water for Dalbena catchment is Dalbena River, which are a perennial river and a tributary of the Segen River which drains to Weito River.

The main purpose of the project is to enhance income of the farmers through development of irrigation systems on suitable agricultural lands.

The annual maximum rainfall magnitudes of 24hr duration for 29 years of Konso station were extracted. This data were collected from NMSA and fitted to the probability distributions after which quantiles estimated for different return periods based on the best fitted distributions and the 50 years return period has been used for the peak flood calculations to form the composite unit hydrograph.

Careful planning is required when phasing in the proposed irrigation with the recommended development interventions in this Feasibility study, as separately these interventions are not constrained significantly by available surface water resources but together the capacity of the surface water resources to support them becomes less sustainable.

The design discharge computed by the SCS-Method is used for estimation of the discharge and the design discharge for 50 year return period is selected to be **149m3/s.**

1. Introduction

1.1 Background

Hydrology is a science dealing with the phenomenon of the continuous humidity circulation in the atmosphere and earth. In this study the hydrology is to deal with estimating flood magnitudes as the result of the maximum precipitation over the catchment. In the design of hydro structures, floods are usually considered in terms of peak runoff or discharge. Thus, the analysis of the peak rate of runoff and time distribution of flow is fundamental to the design of the weir. Errors in data analysis and interpretation will result in a proposed structure that is either undersized and causes more drainage problems resulting a catastrophe failure or oversized and costs more than necessary. Since the relationship between the rainfall on a drainage basin and the volume of runoff is complex a thorough analysis and collecting current and historic data that is relevant to the performance of the proposed Weir is critical.

Any irrigation project has to be considerate of the existing climatic and hydrologic parameters prevalent in its surrounding. In this case temperature, rainfall, sunshine duration, Wind speed, relative humidity and other climatic features has to be studied for selection and determination of fit to purpose agronomic practices and Irrigation structures construction.

On the other hand determination of dry season flow of the river and its capacity has to be studied before proposing water conveyance and distribution systems. Based on the characteristics of the catchment area of the stream and the rainfall amount expected, study of design flood has to be conducted to determine the headwork structure to be constructed for diverting the required irrigation water. Hence both office level and site level activities have been conducted so as to attain the required output of the study of the project. Dalbena small scale irrigation project is located at Segen Peoples zone of SNNP Regional State. The UTM location of headwork site selected for project is X= 311565, Y= 602049 and at elevation of = 1647meters above sea level.

Based on the above reasoning collection of nearby meteorological sites data of the catchment and command area has been conducted from national meteorological agency. For this project under consideration, Kemba Meteorological data has been selected because of its proximity and ability to represent the weather condition of both the catchment and the command area. Though meteorological stations like Arba Minch and Jinka have been situated on Eastern and Northern part of the headwork site respectively, their higher distant location problem excluded from consideration. Hence Konso station located at nearest air distance from the headwork site, possessing adequate meteorological data has been taken for all hydrologic and climatology studies and analyses.

On the other hand observation of catchment characteristics related to topography, vegetation cover, soil and other parameters have been done to incorporate in calculating the design flood of the headwork structure. In this case the overall rainfall pattern and maximum annual daily rainfall data has been collected from meteorological agency so as to evaluate expected probable rainfall within the selected return period and its expected flood in relation to the existing catchment characteristics.

Design flood (discharge) is the value of the instantaneous peak discharge adopted for the design of a particular project or any of its structure. In addition to the considerations of the flood characteristics, frequencies and potentialities of the contributing drainage area above the structure, social, economic, and other non-hydrological considerations which are likely to have influence are considered in deriving a design flood. The term ‘design flood’ is used to denote the maximum flood flow that could be passed within the proposed return period without or serious threat to the stability of engineering structures.

This report presents the hydrological analysis for the design of the diversion weir and irrigation infrastructures.

1.1.1 Project Location

The project area is found in Segen peoples Zone, Konso Woreda. Dalbena River is preferred for this study. The project site is set up at a distance of 380km from the regional capital of Hawassa, 30km from Zonal capital Gumaide and 27km from the Woreda town Konso. The road up to project area is best and accessible in all weather conditions.

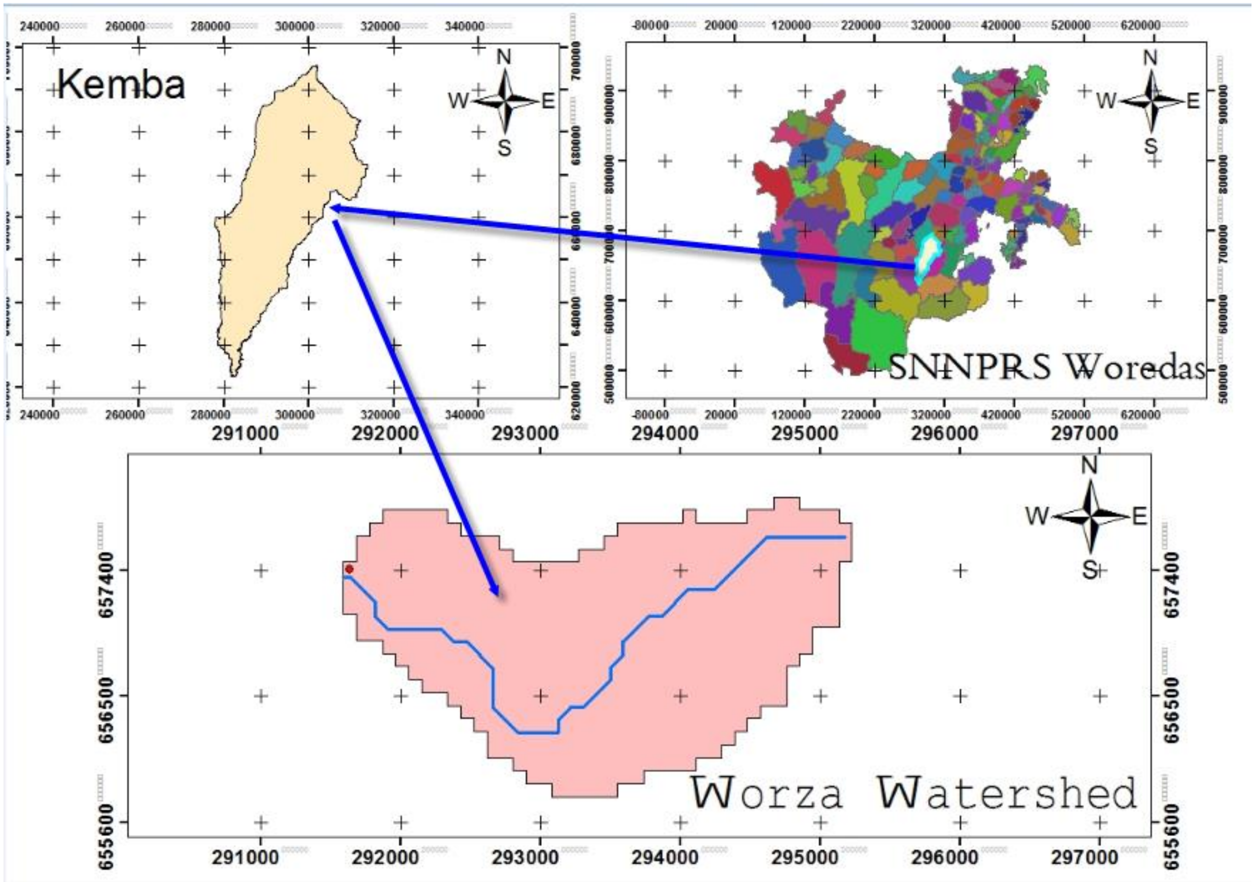


Figure-1.1: Location Map of Dalbena SSI project

1.1.2 Watershed Characteristics of the Study Area

The Dalbena catchment is a hydrologically open basin, contributed by small streams. The source of water for Dalbena catchment is Dalbena River, which are a perennial river and a tributary of the Segen River which drains to Weito River. It is a well-known that usually there is a relationship between rainfall and elevation. Consider for example the agro-ecological zone (AEZ) definitions used in Ethiopia. Interpolation methods that specifically take into account a rainfall – elevation relationship were considered, notwithstanding the fact that a simple correlation of rainfall and elevation is very poor the Dalbena catchment. However, methods described above were rejected if they did not take into account both the elevation correlation and the intrinsic variability in the rainfall patterns in some way. Many of these methods use exact interpolation techniques, that is, the rainfall surface must go through each measured sample value, without accounting directly for the correlation between elevation and rainfall (e.g. Radial Basis Functions).

Monthly estimates of rainfall were calculated using the 'raw' measured data obtained from the NMSA. Details of the rain stations data quality and the method for infilling gaps in monthly rainfall data is provided in detail in to the Dalbena catchment.

The size of the watershed that contributes runoff to Dalbena diversion site, as determined from topographic map (scale. 1:50,000), the catchment area is 96.5km2 (See Figure 1.2). The catchment has a general elevation of altitude ranges from 1480 m.a.sl at the head work to 2773m.a.sl at the remotest area from the head work. Geographically the weir site is located at 602049 N latitude and 311565 E longitudes. As per site visit in the project area and the 1:50,000 scaled topographic maps indicated that the surface water resources potential for the Dalbena project is considerable. The type and volume of runoff resulting from the catchment area are mainly influenced by climatic and geographic factors. Even though the geographic factors include both watershed characteristics in determine the time of concentration and the curve numbers, like land use /cover/, slope of watershed, soil type, and size of the watershed have been given due emphasis. Almost all part of the catchment is part of the cultivated land.

Based on data obtained from the woreda agricultural development office, the watershed can have bimodal rainfall conditions, with having the short rainy season/ Belg/ starting August till October and the long rainy season / Kermet/ lasts from March to May. The annual rainfall range from 451mm- 1068 mm and mean daily maximum and minimum temperature can reach 25 and 15 degree Celsius respectively

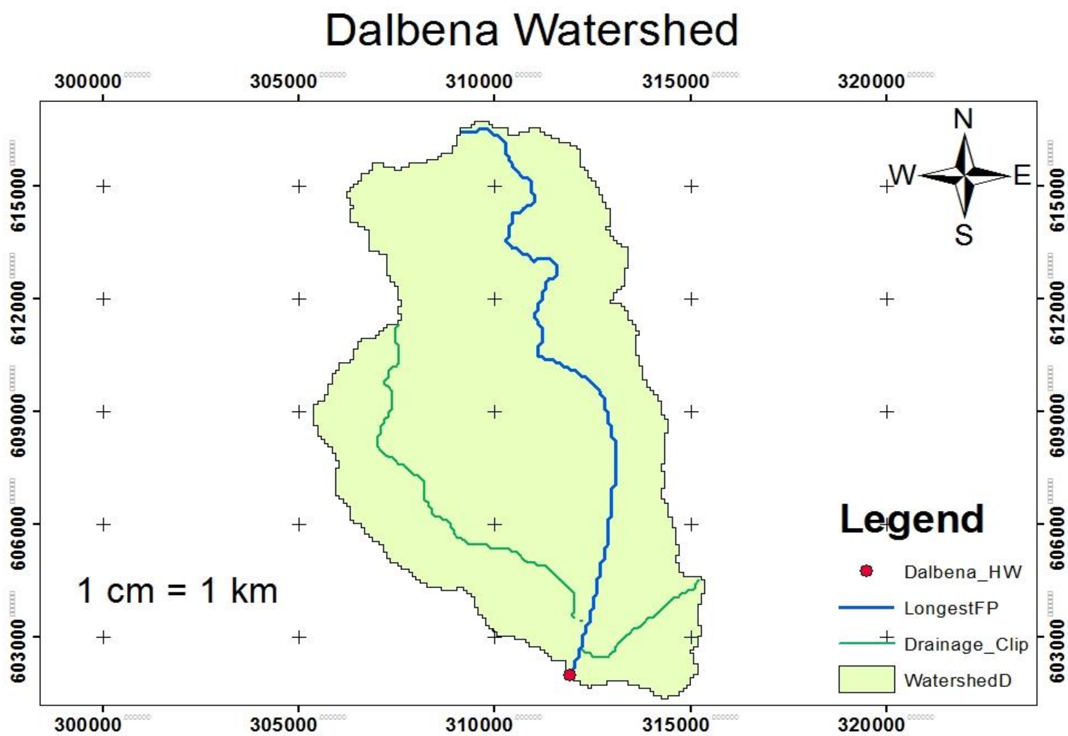


Figure-1.2: Dalbena catchment

1.2 Scope of the study

The scopes of the study are

- Compilation and analysis of the relevant hydro-meteorological data to utilize for the estimation of water resources potential of the project area;
- Estimate the flood magnitude at diversion site and design drainage flow to irrigation system,
- In the study provided availability of lean flow and its dependability,
- Water balance assessment for efficiently utilization of the available water resources.

1.3 Objectives

The main objective of the hydrology and climatologic studies of the project is to reassess the availability of surface water resources and estimates of floods in the diversion site and irrigation development area as well as the distribution of these resources in time and space. Dalbena irrigation based development study is to prepare the required design for utilizing the available water and land resources in the project area. The design focused on utilizing these resources for dry period and supplementing the rain fed agriculture during moisture stress in wet seasons. Particularly in this study it focuses the preparation of hydrology report for the project.

1.4 Methodology

The methods to Hydrological and Meteorological data study and analysis depends on the number of situations. For the development of Dalbena project, the data is collected form field, office, Metrological station, and executed projects near to the project. The data collected is refined before analysis. Here are the main data sources for the development of the project.

- Review of existing documents of other projects data in the neighborhood to these projects for better understandings.
- Collection of Hydrological and meteorological data from the regional meteorological offices, and other national sources.
- Digitization of topographic map with scale 1:50,000 of the project surroundings and catchments area.
- Delineation of catchment area to determine catchment features for further hydrological analysis.
- Measurement of stream flow data, surveying of maximum flood mark for further analysis.

2. Data requirement, Availability and Processing

All the available climatic and hydrologic data have been collected from the National Meteorological Agency in order to assess the potential evapo-transpiration and the surface water resources in the project area.

In the initial stage of the project study, all data has been checked and updated to the date available. It is presumed that the exact latitude, longitude and altitude of these stations are recorded but some of them was not stated, they have been identified using GPS during the field visits to representative hydro-meteorological stations. Verification and reconstitution of the existing data will comprise visual inspection of the data, graphical and statistical analysis in order to eliminate doubtful values from the records. Data gap filling in existing rainfall/runoff data records and extending records as necessary to the required historical sequence.

To successfully implement the Dalbena small scale irrigation Project sustainably, the data on climate, river flows and sedimentation become relevant with respect to hydrological modeling and water resources planning. The climate data like sunshine duration, relative humidity, wind speeds and temperature in the resolution levels of monthly means, become very important parameters with respect to the proposed command area development. These, in association with command area rainfall, form the basic inputs for the estimation of the crop water requirement and Estimation of maximum flood. WMO recommends a guideline for checking the adequacy of a meteorological network. It is important to note that to assess the adequacy of the network of stations in a basin, the number of stations as well as their spatial distribution play an important role.

It is important to carefully plan the location of rain gauges in relation to the location of stream flow gauging stations, in order to perform extension of stream flow records, flood forecasting, or hydrological analysis. As guide line, rainfall gauging should be located so that watershed rainfall can be estimated for each stream gauging station Meteorological data available at the two observation stations located in and around the project area have been collected from National Meteorological Agency (NMA). Accordingly for the estimation of different parameters all stations were not considered.

2.1 Water Availability

Dalbena Irrigation project is located in Om-Gibe River basin particularly in Zege sub catchment which is in the lower east periphery of the basin.

The Dalbena catchment has also been a food deficit area and the problem has been aggravated by continuous drought and unstable agriculture production in the semi-arid zone. It has diverse and substantial potential for the development of irrigated agriculture, hydropower, livestock, wildlife, fisheries and tourism

The Dalbena River is a tributary of Segen River. The mean annual specific discharge curves can be developed using gauging stations which have catchment areas much larger than that of the Dalbena watershed. From the curves, the mean annual specific discharge for the project area can be estimated. The overall development constraints are the lack of basic infrastructure and low level of economic activity that could serve as a base for take-off. This report presents the hydrological analysis for the design of the diversion weir and irrigation infrastructures.
There is no gauging station on the Dalbena River. For ungauged catchments, the methodology used to determine water availability in the project area is analyzing the nearby hydrological gauging stations, water balance of the project area based on inflow and outflow characteristics and continuity principle, and field observations/measurements.

2.2 Water Balance

The water balance computations for any irrigation scheme is carried out independently to other schemes that may exist upstream or downstream of the studied schemes. During site visit we have investigated there is no any other traditional irrigation scheme upstream and downstream of the proposed diversion site within 5kms upstream and downstream of the project area

The irrigation engineering design report of this study shows that the maximum flow diversion requirement for the command area of 100ha is 150l/s. The diversion requirement during the driest period is less than the base flow of the same duration 200l/s. For environmental purpose and downstream water users, 25% of the base flow 200l/s(100%) -150 l/s(75 %)= 50 l/s(25%) could be released. Moreover, the irrigation hour per day is only 12hrs, which means there will be no diversion for the rest of the time. There exists also some small stream to the nearest river downstream of the proposed project that would supply water to downstream of the proposed irrigation project. Hence, the available net base flow of the stream is adequate to satisfy the irrigation requirement for the proposed command area without causing any environmental effect downstream users.

There is no gauging station on the Dalbena River. For ungauged catchments, the methodology used to determine water availability in the project area is analyzing the nearby hydrological gauging stations, water balance of the project area based on inflow and outflow characteristics and continuity principle, and field observations/measurements.

2.3 Previous Study

Previous studies for the Dalbena Diversion irrigation project included design and construction of small scale irrigation on Dalbena River were carried out twenty five years ago by Lutherane Federation. The constructed diversion weir walls were washed away by flood and debris and boulders are accumulated upstream of the destructed part. It was basically planned to supply for Kebeles of Gelabo and Arfaite. So after failure of the structure there is no any kind of rehabilitations or upgrade work done.

Figure 2.1 Diversion weir constructed twenty Five years before by Lutheran

Figure 2.2 Failed Main canal structure at the left side.

2.4 Base flow measurements

The estimation is crucial for better planning and developing the given irrigable area and well-being of the ecosystem in the d/s portion of the river reach. For the purpose of irrigation usually 95% flow exceedance should be adequately meet the crop water needed. The estimation of this flow exceedance could only possible when direct measurements of flow are available in the case of gauged river or it can be estimated using a regionalization approach or different techniques. There are different methods or techniques available for the estimation of the base flow in the river. The automated base flow separation technique, graphical method, tracer methods using isotopes, and rainfall runoff models are some of the methods applicable if the river is gauged.

As far as Dalbena river is concerned there is no flow measurements are available in the river either u/s or d/s in close proximity of the headwork site to apply these methods. In such circumstances, the base flow can be estimated using float techniques by measurement of the discharge during the driest period using continuity equation. The Dalbena river Base flow of 0.2m3/sec was measured on November, 2017.

Figure 2.3 Downstream to Upstream view at headwork site

2.5 Rainfall

2.5.1 Rainfall regime and seasons in Ethiopia

In Ethiopia two major rainfall regimes are identified (D. Gemechu, 1977) viz. Type I and Type II. These regimes are further divided in to 14 sub-regimes i.e. 8 sub-regimes in type I and 6 sub-regimes in type II. Type I regimes are characterized by one rainy season, that is the rainy months are contiguously distributed. These regimes are found in western half of the country as well as in the southeastern highlands. While regime type II are found mainly in the eastern half of the country, including the northern half of the escarpment of the rift system but excluding the Harer highlands. This regime is characterized by two rainy seasons. The project area is located in Type II regime specifically in regime IIB sub classification. Based on the above rainfall regimes, generally the following seasons have been defined.

Kiremt: the main rainy season that covers the period from June to September. The air flow during this season is dominated by a zone of convergence in low pressure systems accompanied by the oscillatory Inter Tropical Convergence Zone (ITCZ) extending from West Africa through north of Ethiopia towards India.

Major rain producing systems during the season are northward migration of ITCZ; development and persistence of the Arabian and the Sudan thermal low along 20^{o} N latitude; development of quasi-permanent high pressure systems over south Atlantic and south Indian oceans; development of Tropical Easterly Jet and its persistence; and the generation of low level "Somali Jet" that enhance low level southwesterly flow.

Bega: Generally dry season that covers the period from October to January. However, there is occasionally untimely rain. During this season, the country predominantly falls under the influence of warm and cool north-easterly winds. These dry air masses originate either from the Saharan anticyclone and / or from the ridge of high pressure extending into Arabia from large high over central Asia (Siberia). However, very occasionally, north easterly winds get interrupted when migratory low pressure systems originating in the Mediterranean area move eastward and interact with the equatorial / tropical systems that result in rainfall over parts of central Ethiopia. In addition to this occasional development of Red-Sea Convergence Zone (RSCZ) affects coastal areas.

Belg: Small rainy season that covers the period from mid-February to mid-May. However the rainfall is highly characterized by inter-annual and inter-seasonal variations. This season coincides with domination of the Arabian high as it moves toward the North Arabian Sea. Major systems during the season are caused by the development of thermal lows over southern Sudan; the generation and propagation of disturbances over the Mediterranean, sometimes coupled with easterly waves; development of high pressure over the Arabian Sea; some interaction between mid-latitude depressions and tropical systems accompanied by troughs and Subtropical Jet; and occasional development of RSCZ.

2.5.2 Rainfall Intensity

The ERA (2013) IDF curves (10 to 120 minutes duration of rainfall) for different regions of Ethiopia were adopted in the current study. Figure 2.1 shows these regions. The Dalbena Head work site is located in Region B2 and the corresponding IDF curves for the region are given in Figure 2.1. These curves will be used to estimate design floods for farm structures such as cross drainage works.

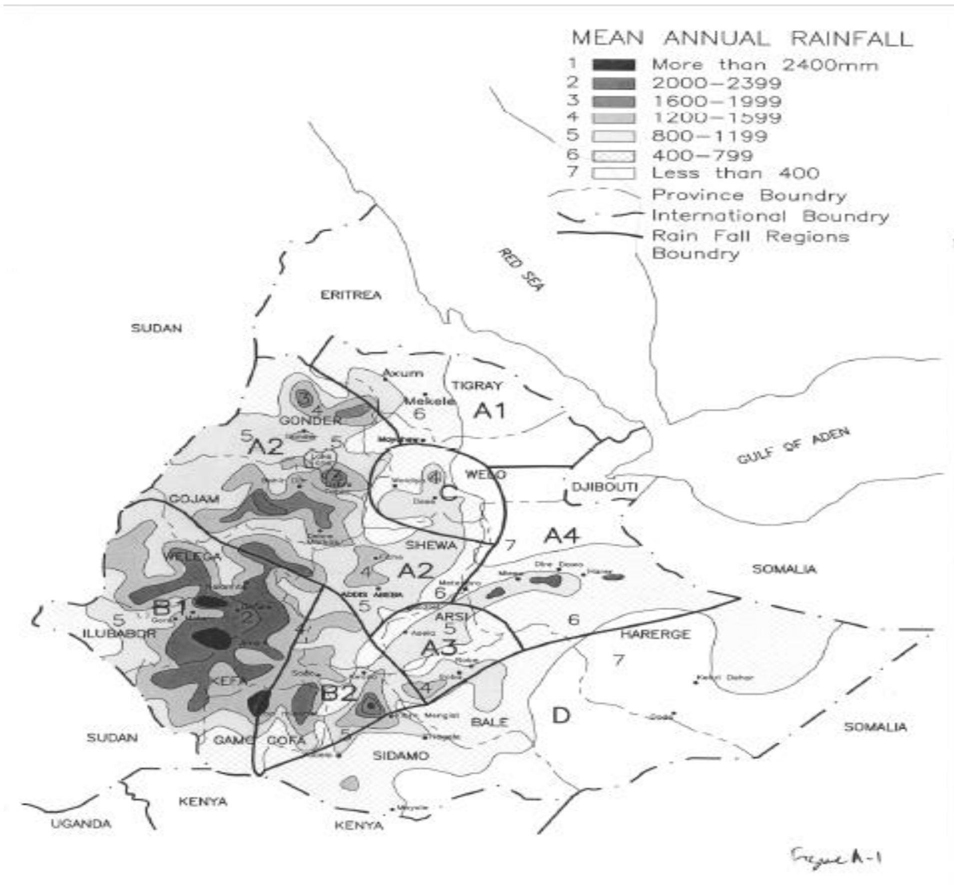
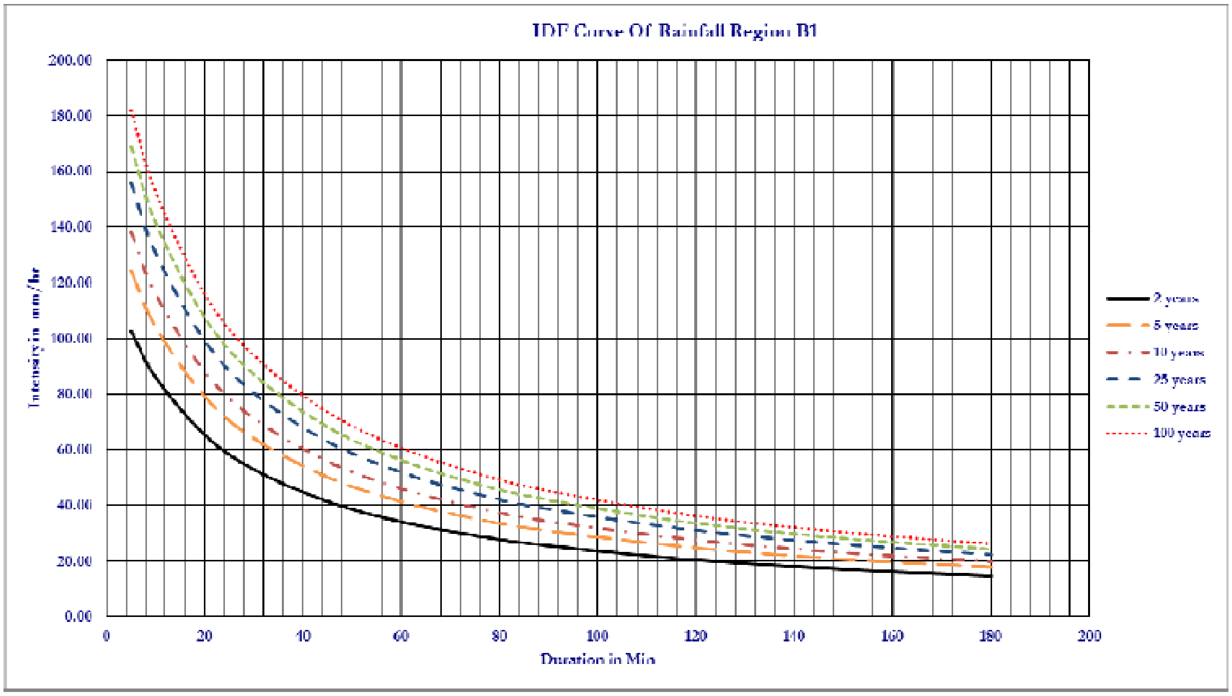
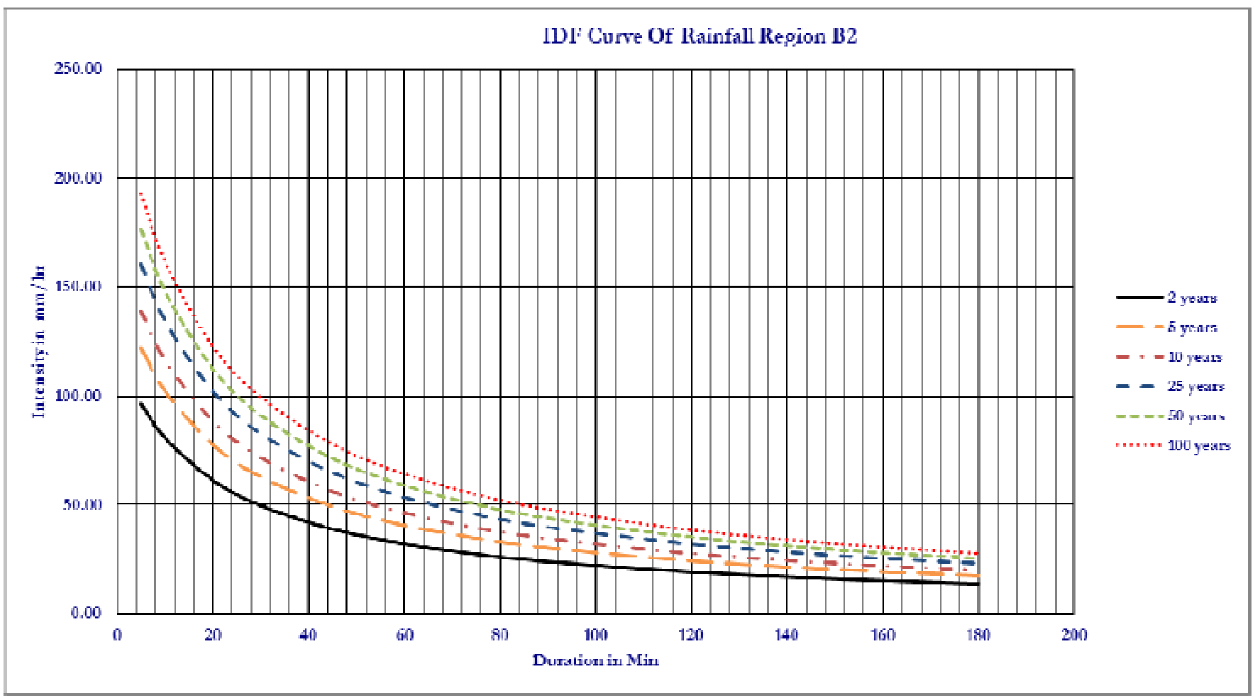


Fig2.4:- Rainfall Regions [ERA, 2013]



IDF Curve of Rainfall Region B1

Fig2.5:-IDF Curve of Rainfall Region B1



IDF Curve of Rainfall Region B2

Fig2.6:-IDF Curve of Rainfall Region B2

2.6 Hydro-meteorological Stations Network

Climate is one of the resources of an area, which can enhance or retard most economic activities. Thus, the knowledge of the climatic resource of an area is of paramount importance for the planning and execution of any project in general and agricultural projects in particular. In this regard, we have been investigating the most representative meteorological station for Dalbena Small scale irrigation project in order to use the representative meteorological data for our study objectives.

2.7 Meteorological stations Network

There are 3 Meteorological stations (Arba Minch, Jinka and Konso) located in the Dalbena sub-basin. As the basis for stability and consistency checking of rainfall data rough screening of the rainfall data series on nearby stations was undertaken and the data series employed for the analysis is found to be in good quality. The nearest meteorological station to Dalbena catchment is Dalbena meteorological station. This station has 29 years records of rainfall (from 1987 to 2016) which is sufficient for the analysis and highest rainfall recorded from this station (Konso) has been used to estimate the fifty-year recurrence interval point rainfall.

Table 2-1: Availability of rainfall data

Station Name	Lat	Long	Class	Start date	End Date
Arba Minch	6.05	37.55	1	1980	Active
Jinka	5.76	36.57	1	1983	Active
Konso	6.32	36.88	1	1987	Active

The Konso rainfall station is the ideal representative station for Dalbena SSI project area. Further, it has the reliable data for analysis with about 2% of gaps, which were filled up by screening and simple correlation techniques. It is however customary in hydrological analysis, to do certain consistency analysis for inferences from the data of a phenomenon. Konso is Class 4 station that includes only observations of rainfall.

Table 2. 2: Location of Konso Meteorological Station

S. No	Station Name	North (Deg.Min)	East (Deg.Min)	Data Record	No.Years	Class
	Konso	5.25	37.48	1989-2017	29	1

2.8 Filling Missing rainfall data

Daily Rain fall data for three stations has been collected from the National Meteorological Agency (NMA). The data series contains enormous missing data inside the record. Missing records of the rainfall stations were estimated by using normal ratio method which is recommended to estimate missing data in regions where annual rainfall among stations differ by more than 10% (Dingman, 2002). This approach enables an estimation of missing rainfall data by weighting the observation at N gauges by their respective annual average rainfall values as expressed by below Equation (Yemane, 2004).

$$P_X = \frac{1}{N}(\Sigma \frac{P_X}{P_i} * P_g)$$

Where:

Px = missing data,

PX = the annual average precipitation at the gauge with the missing data,

Pi = annual average values of neighboring stations

Pg = monthly rain fall data in station for the same month of missing station

3. Design Rainfall and Peak Flood Estimation

3.1 Estimation of Floods for Ungauged Catchments

In the hydrologic analysis for dams, weirs, bridges and drainage structures, it must be recognized that there are many variable factors that affect floods. Some of the factors that need be recognized and considered on an individual site by site basis are:

- rainfall amount and storm distribution;
- catchment area size, shape and orientation;
- ground cover;
- type of soil;
- slopes of terrain and stream(S);
- antecedent moisture condition;
- storage potential (over bank, ponds, wetlands, reservoirs, channel, etc.); and
- Catchment area.

In general, three types of estimation floods magnitudes (namely: the Rational Method, SCS method and Transferring Gauged Data method) can be applied for the project area.

A. Rational Method

The Rational Method can be applied to small catchments if they do not exceed 12.8 km2 (or 5 square mile) at the most (Gray, 1971). The consequences of applying the Rational Method to larger catchments is to produce an over estimate of discharge and a conservative design. The method is nevertheless frequently used in standard or modified form for much larger catchments. This is because of its relatively simplicity. The vast majority of catchments producing floods imposed on the command drainage system lie within the validity of the Rational Method and it has been used as the principal method of estimating design discharges of dykes, culverts, drainage channels, etc.

The Rational Method is based on the following formula:

Qm = 0.2778 C.I.A.Fr

Where

QM = peak flow corresponding to return period of T years in m3/sec;

C = a 'runoff' coefficient expressing the ratio of rate of runoff to rate of rainfall (see Annex C1 and C2);

I = average maximum intensity of rainfall in mm/hr, for a duration equal to the time of concentration;

A = drainage area in km2;

Fr = is the areal reduction factor (this factors improves the catchment limitations imposed on the use of rational method).

Coefficient of runoff C for the formula is given by many soil and water conservation texts. Information on rainfall intensity I in a time of concentration (time period required for flow to reach the outlet from the most remote point in the catchment) is required and can be estimated by the following formula. The selection of the correct value of ‘C’ presents some difficulty. It represents a parameter that can influence runoff including: soils type, antecedent soil conditions, land use, vegetation and seasonal growth. Therefore, the value of ‘C’ can vary from one moment to another according to changes, especially soil moisture conditions.

$Tc = (1/3080)xL1.155.H-0.385$ (Kirpich equation)

Where

Tc = time of concentration (in hours),

L = maximum length of main stream (in meters),

H = elevation difference of upper and outlet of catchment, (in meters).

The area reduction factor (Fr) is introduced to account for the spatial variability of point rainfall over the catchment. This is not significant for small catchments but becomes so as catchment size increases. The relationship adopted for ‘Fr’ is based on that developed for the East African condition (Fiddes, 1997). The relationship can be expressed as:

$Fr = 1 - 0.02 D-0.33 A 0.50$

Where

D = duration in hours;

A = drainage area in km2;

This equation applies for storms of up to 8 hours duration. For longer durations on large catchments the value of D can be taken as 8 for use in the above formula.

B. SCS Method

A relationship between accumulated rainfall and accumulated runoff was derived by SCS (Soil Conservation Service). The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour or 1-day storm rainfall. The equation is:

$Q = (P - Ia) 2 / (P - Ia) + S$

Where

Q = accumulated direct runoff, mm

P = accumulated rainfall (potential maximum runoff), mm

Ia = initial abstraction including surface storage, inception, and infiltration prior to runoff, mm

S = potential maximum retention, mm

The relationship between Ia and S was developed from experimental catchment area data. It removes the necessary for estimating Ia for common usage. The empirical relationship used in the SCS runoff equation is:

$Ia = 0.2xS$

Substituting 0.2xS for Ia in equation ---, the SCS rainfall-runoff equation becomes:

$Q = (P - 0.2S) 2 / (P+0.8S)$

S is related to soil and cover conditions of the catchment area through CN. CN has a range of 0 to 100 (can be obtained from Annex C3 and ERA 2002), and S is related to CN by:

$S = 254x [(100/CN) - 1]$

Conversion from average antecedent moisture conditions to wet conditions can be done by multiplying the average CN values by Cf [where Cf = (CN/100)-0.4]

C. Transferring Gauged Data

Gauged data may be transferred to an Ungauged site of interest provided such data are nearby (i.e., within the same hydrologic region, and there are no major tributaries or diversions between the gage and the site of interest). These procedures make use of the constants obtained in developing the regression equations. These procedures are adopted from the work of Admasu (1989) as follows:

Qu = Qg.(Au/Ag)0.70

Where:

Qu = mean annual daily maximum flow at Ungauged site (m3/s),

Qg = mean annual daily maximum flow at nearby gauged site (m3/s),

Au = ungauged site catchment area (km2),

Ag = gauged site catchment area (km2),

The estimate daily (or the 24-hr) annual maximum flood could be converted into a momentary peak as:

Qp = Cf. Qu

Here, Cf is factor estimated as Cf = 1 + 0.5/Tc (where, Tc is time of concentration).

In general, three types of estimating flood magnitudes (namely: the Rational Method, SCS method and Transferring Gauged Data method) can be applied for ungauged catchments. Since, there is no any Gauged river around the project and since the catchment area of Dalbena diversion scheme is 96.5 km2, the SCS method is preferred.

3.2 Design Frequency

Since it is not economically feasible to design a hydro structure for the maximum runoff a watershed is capable of producing, a design frequency is established. The frequency is with which a given flood can be expected to occur is the reciprocal of the probability of that the flood will be equaled or exceeded in a given year. Mathematically, the probability of non-occurrence is:

$$P_n = \left(1 - \frac{1}{f}\right)^n$$

Where f is year flood; and n is return period

The probability of occurrence is:

$$P = 1 - P_n$$

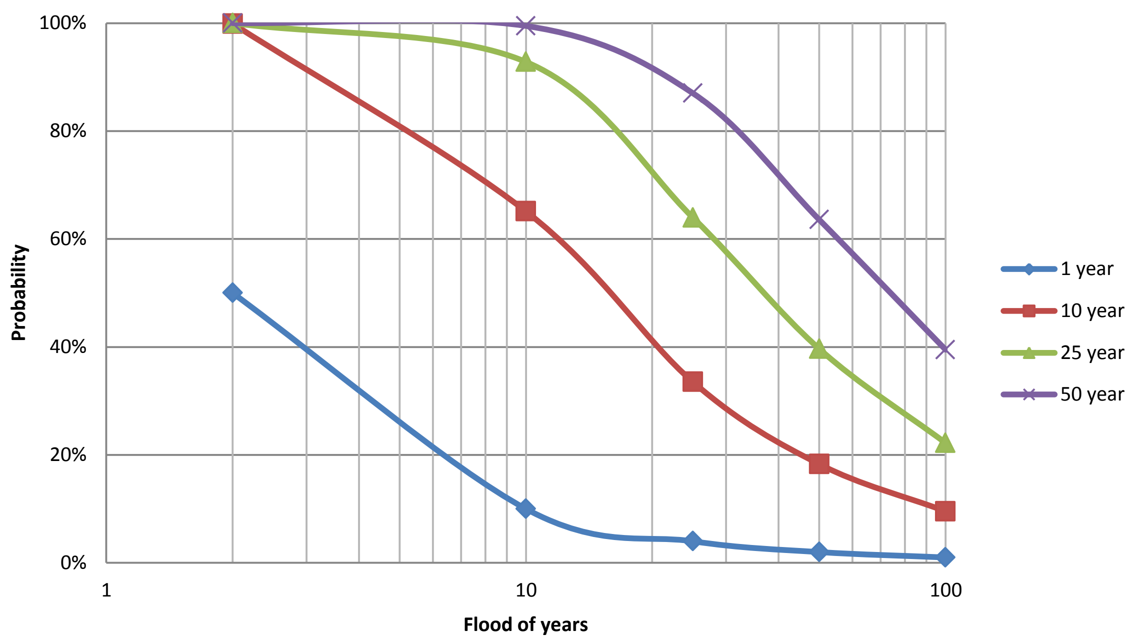


Figure3.1 Annual exceedance probability (AEP)

3.1.1 Return period selection

The selection of return period depends on the balance between the economic importance and expense incurred to construct or maintain the structure. Considering a longer duration will cost a lot for it needs the construction of massive structure capable of resisting the flood force coming once during the selected long return period. On the other hand shorter duration is preferred for structures having lower cost of construction and maintenance as frequent failures are inevitable. More over the cost of damage on the environment and property as a result of the structure's failure shall be also considered while determining return period especially for structures like dams. This shows compromising the cost and return period duration becomes essential. Hence for diversion weir structure mostly 50 years return period is adopted considering its economic advantage and service life. Therefore for designing diversion structure 50 years return period has been implemented for this project. For structures like culvert and flumes 10 to 25 years will be adopted depending on the extent and economic preference of the structure under consideration.

3.3 Estimation of design rainfall and Design Flood

3.3.1 Rational Method

Applying multiple linear regression model technique for 78 Ethiopian catchments ranging in size from 20 km2 to 66,000 km2, available flow data of gauged streams are related to their respective catchments, (Gebeyehu, 1989).

$$\text{Qmax} = 0.87\text{A}^{0.7}$$

Where, A = catchment area in km2

Qmax = Mean annual flood in m3 /s

$$\text{Qmax} = 0.87 * 96.5^{0.7}$$

$$\text{Qmax} = 21.3\text{m}^3/\text{s}$$

The above Equation is a regional relationship of stream flow. Characteristics and catchment characteristics in Ethiopia, which is expected to be more reliable for the Ethiopian conditions than empirical equations developed for other countries conditions.

The design discharge calculated based on rational method is **21.3m3/s**. But from the actual condition of the river channel and the catchment characteristics this flood is very small and should be removed from consideration.

3.3.2 SCS Method

3.3.2.1 Data Quality

Before hydrological analysis, the quality of the recorded data has to be checked to discard the data that may be recorded as error. Errors may occur during recording or reporting.

3.3.2.2. Rainfall consistency

As discussed above, Konso rainfall is the ideal representative data of Dalbena project area. Further, it has the reliable data for analysis with about 2% of gaps, which were filled up by screening and simple correlation techniques. It is however customary in hydrological analysis, to do certain consistency analysis for inferences from the data of a phenomenon.

Rolling means and Trend: The Konso rainfall was subjected to trend analysis, taking 3 year moving averages. This analysis results are shown in the figure 3.1. As seen there, one could notice that the data period years (1998 -2000 and 2012-2014) show a falling trend, indicating that rainfall is reducing. This causes some concern, though there is possibility that this pattern could change. If data had been available for 100 to 200 years, more insight could have been possible to check whether there could be any cyclic trend. In addition to Konso, it was felt that some other rain gauge station data, which is in the region, Which is in side Dalbena sub basin should be analyzed for such trend. Such a station, with adequate data length is Konso. Similar trend analysis of the data at Konso also depicts such a falling trend, establishing the external consistency of rainfall data. The trend of Konso rainfall is shown in figure 3.2.

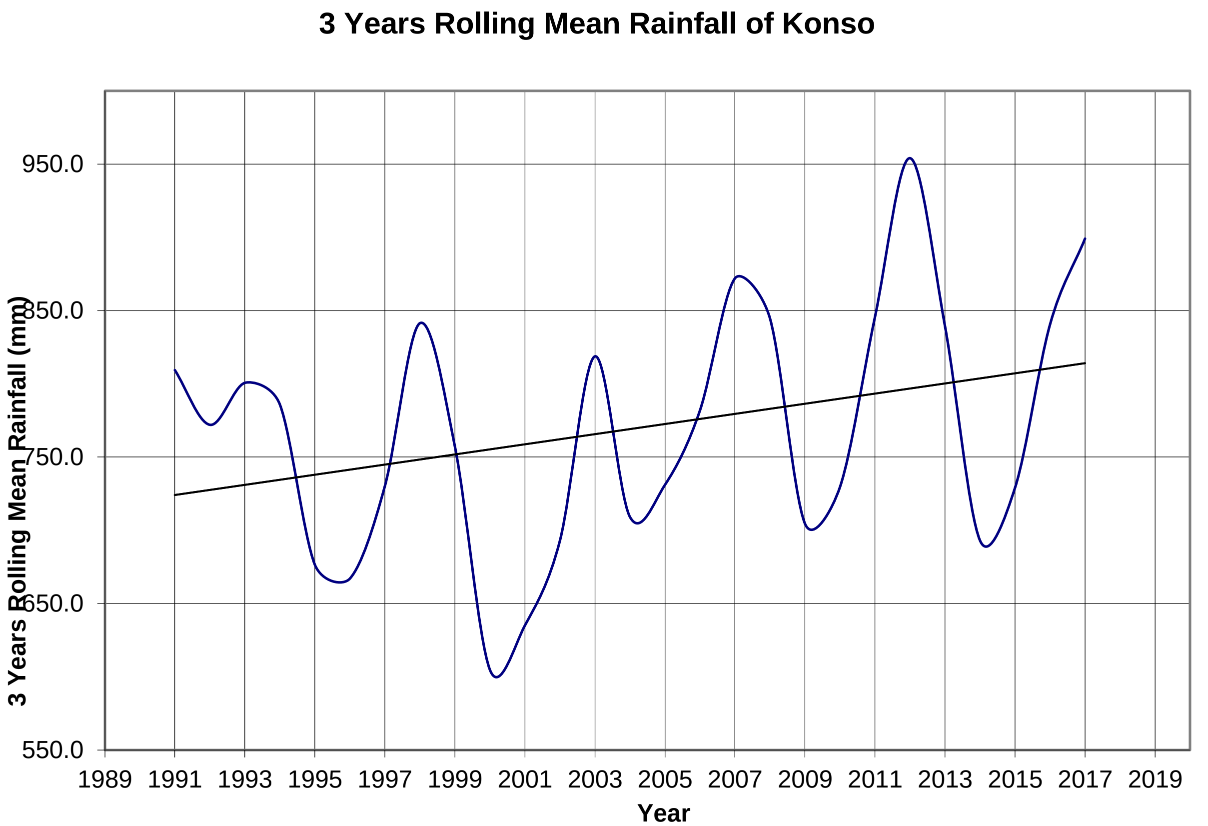


Fig 3.2:- Three Years Rolling Mean Rain Fall of Konso

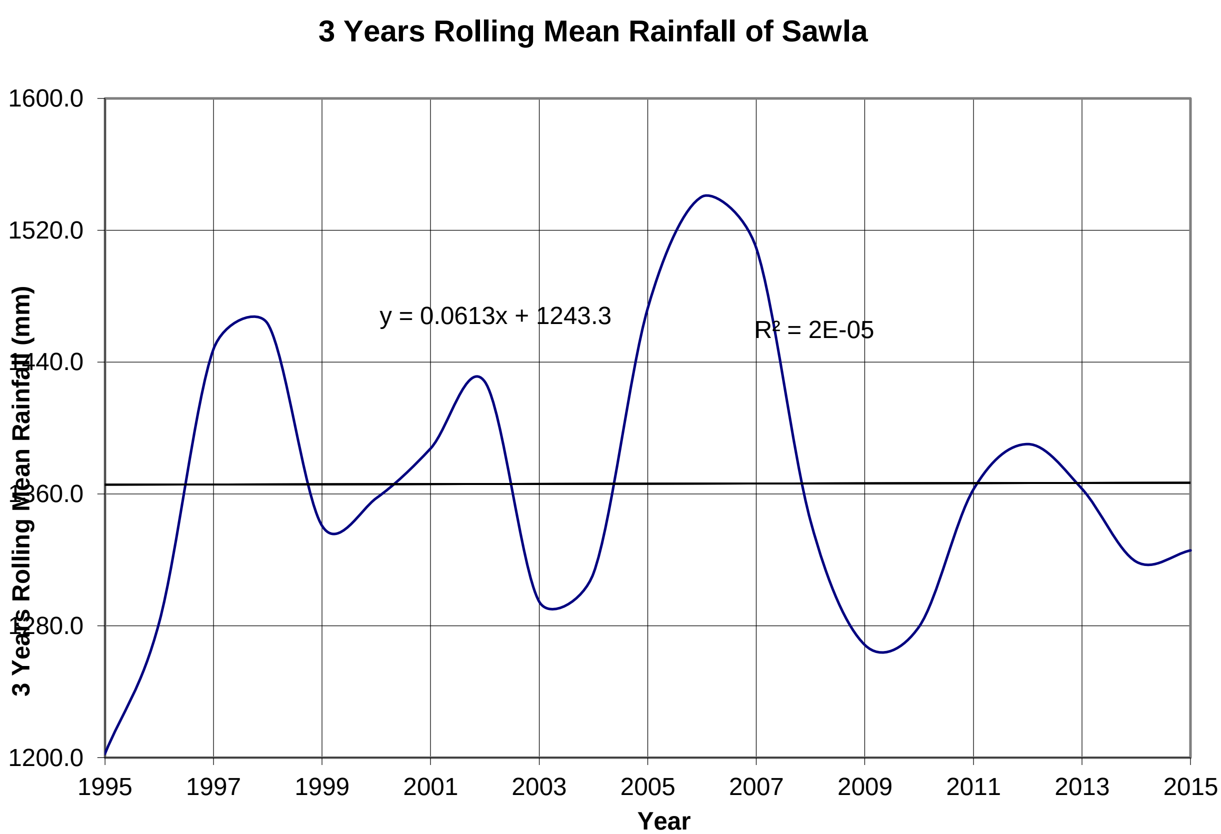


Fig 3.3:- Three Years Rolling Mean Rain Fall of Konso.

Linear Correlation of Monthly Rainfall for Daramalo and Sawla

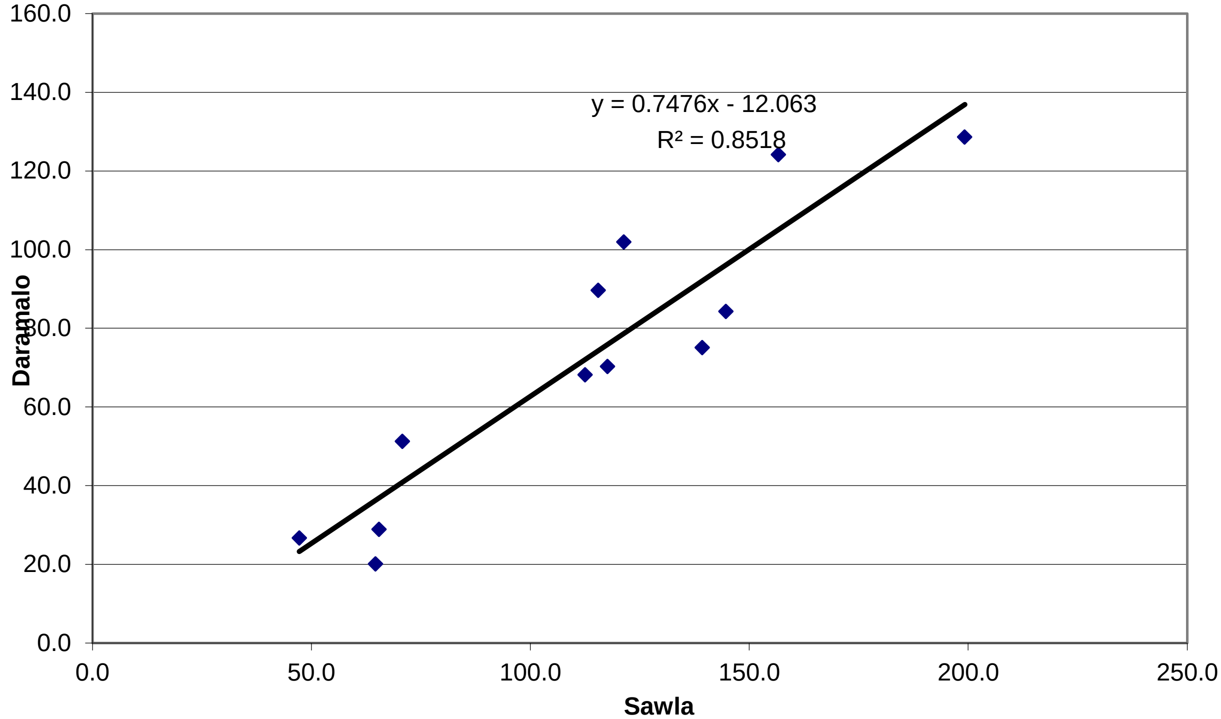


Fig3.4:-Monthly Correlation for Konso and Konso Rainfall

3.3.3 Outliers test

The U.S. water resource council recommends that adjustment should be made for outliers. Outliers are data points depart significantly from the trend of the remaining data. The retention or deletion of these outliers can significantly affect the magnitude of statistical parameters computed from the data, especially for small samples. Procedures for treating outliers require judgment involving both mathematical and hydrologic consideration. According to the U.S water resource council (1981), if the station skew is greater than +0.4, tests for high outliers are considered first ; if the station skew is less than -0.4 ,tests for low outliers are considered first . Where the station skew is between +_ 0.4, tests for both high and low outliers should be applied before eliminating any outliers from the dataset.

Table 3.1: Computation of data consistency

Sr. No	Year	Daily Maximum RF(mm)	Y=Log(Rf)	$(Y-Y_m)^2$	$(Y-Y_m)^3$
1	2003	71.4	1.8537	0.0131	0.0015
2	2004	40.8	1.6107	0.0165	-0.0021
3	2005	40.8	1.6107	0.0165	-0.0021
4	2006	60.0	1.7782	0.0015	0.0001
5	2007	78.6	1.8954	0.0244	0.0038
6	2008	36.9	1.5670	0.0296	-0.0051
7	2009	52.0	1.7160	0.0005	0.0000
8	2010	66.9	1.8254	0.0075	0.0006
9	2011	55.1	1.7412	0.0000	0.0000
10	2012	61.1	1.7860	0.0022	0.0001
11	2013	54.1	1.7332	0.0000	0.0000
12	2014	45.5	1.6580	0.0066	-0.0005
13	2015	45.6	1.6590	0.0064	-0.0005
14	2016	60.2	1.7796	0.0016	0.0001
15	2017	53.6	1.7292	0.0001	0.0000
Sum		**822.60**	2.9152	1.3832	1.6268
Average (Ym)		**54.84**	1.7391	0	0.0000
STDEV		11.8854	0.0946	0.0095	0.0019

Lower outlier

$$Yl = \bar{Y} - Kn * Sy$$

k_n -Depends on the number of data, form Applied Hydrology/Ven Te Chow, the value is 2.247 for 15 data.

Sy - is the standard deviation and is given by the equation below:

$$Sy = \left(\frac{1}{n-1} \sum_{n}^{i} (yi - \bar{y})^2 \right)^{1/2} \quad =0.0946$$

$$Yl = \bar{Y} - Kn * Sy$$

=1.67-2.247*0.0946 = 1.45

Minimum rainfall $X = 10^{Yl}$

Minimum Rain fall $X = 10^{1.44}$

$$\text{Minimum Rain fall X} = 28.2\text{mm}$$

As shown from the record, there is no data having a value less than 28.18mm, and hence there is no lower outlier.

Higher Outlier

$Ym = \bar{Y} + Kn * Sy$ =1.67+2.247*0.0946=1.9

$$X = 10^{Ym} = 10^{1.9} = 79.43mm$$

$$\text{Maximuu Rain fall X} = 10^{1.9}$$

$$\text{Minimum Rain fall X} = 79.43\text{mm}$$

All the data in the series have less than the higher outlier value and hence, no data is considered for higher outlier. Hence, the data on the above table can be taken for the determination of point design rainfall.

3.4 Rainfall

The entire available climatic data, in association with command area rainfall forms the basic inputs for the estimation of the crop water requirement. A vivid analysis follows on these important parameters in the subsequent sections.

The mean annual rainfall of the project area (as measured at Konso meteorological station for the period of 1988-2017 is 1381.9mm. This is the closest meteorological station to the project area, which is located at nearer areal distance from the project area. The monthly rainfall distribution as measured at Konso station is a sort of bimodal where the main rainy season extends over the period of mid-March to mid-October with its peak in May. The area also experiences small peak during the period of June and July. The main rainy season contributes about 16 % of the annual total rainfall. The seasonal distribution of rainfall and the intra month variability is shown in Figure 3.5.

Table-3.2: Seasonal distribution of rainfall at Konso Meteorological station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	21.53	34.6	80.15	167.7	115.6	40.01	23.9	37.31	63.49	101.3	68.84	37.81

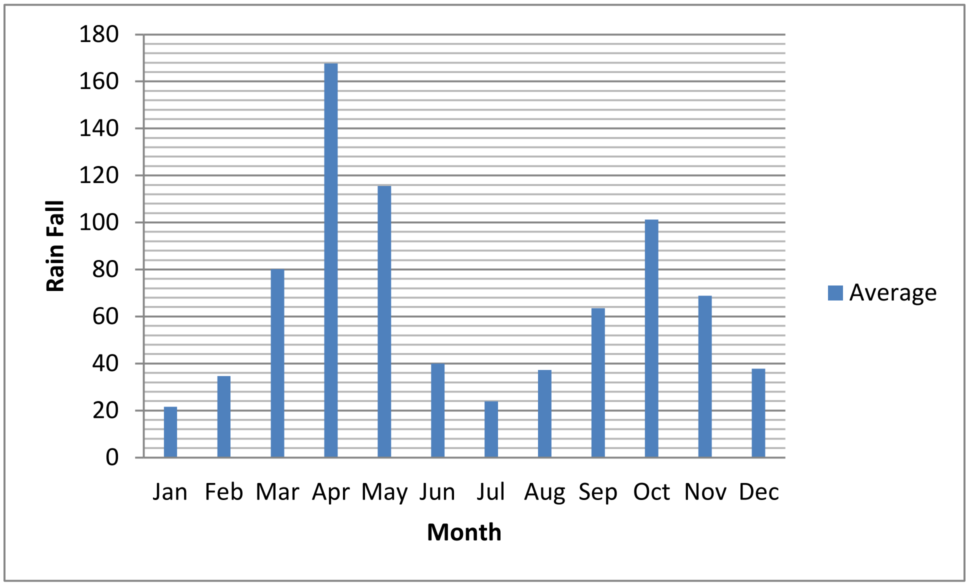


Figure 3.5 Seasonal distribution of rainfall at Konso Meteorological station

3.5 Temperature

For the analysis of temperature conditions of the project catchment and command areas, meteorological data of Konso station has been utilized as gathered by NMA. The stated station is 15km-332km air distance away from most of the river's catchment and command areas. As computed from the stated meteorological station data, monthly mean maximum and mean minimum temperature of the area was found to be **30.6 c^{0}** and **16.5 C^{0}** respectively. This shows the mean temperature of the site ranges in between these two limits throughout the year. Relatively high temperatures were observed during the months of January, February and March. The season starting from November to December also show mean high temperature values of more than **28 C^{0}** as shown on the underneath table. As observed from meteorological data of the stated station, the highest mean monthly maximum temperature was observed during the month of February whereas the lowest mean minimum monthly temperature was recorded in July. The overall pattern of mean monthly minimum and maximum temperature of the project area can be visualized from the table and graph shown below.

Table-3.3: Avg. Min. monthly temperatures at Konso Meteorological station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TMP MIN	17.9	18.8	18.7	17.7	17.4	16.9	16.5	16.8	17.2	17.1	17.0	17.2

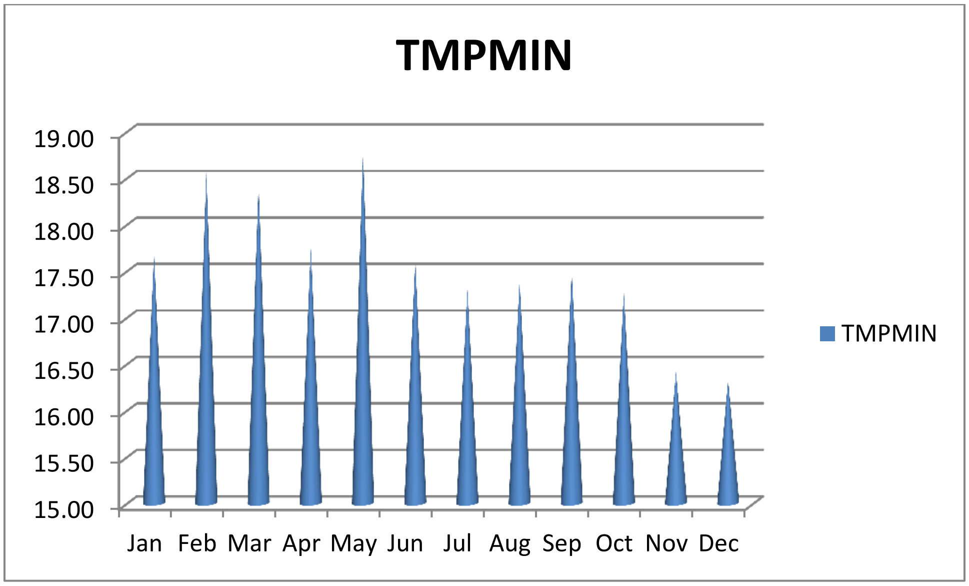


Figure 3.6 Avg. Min. monthly temperatures

Table-3.4: Avg. Max. Monthly temperatures at Konso Meteorological station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TMP MAX	29.7	30.6	29.9	27.3	26.5	25.9	25.7	26.5	27.7	27.4	28.0	28.6

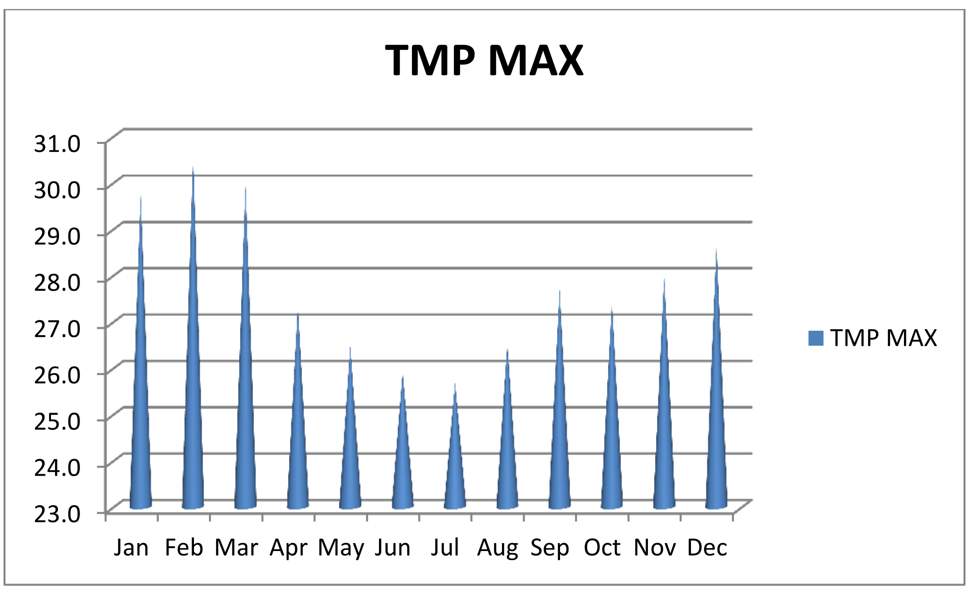


Figure 3.7 Avg. Min. monthly temperatures

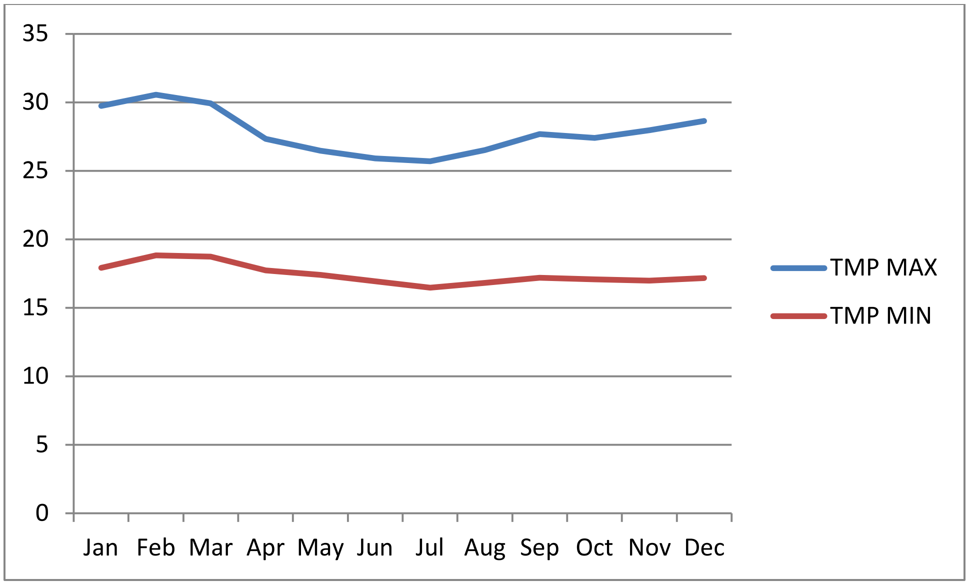


Figure 3.8 Mean Monthly maximum and minimum Temperature graph

3.6 Wind Speed

A wind movement creates turbulence and replaces air at the water surface with less moist air and increase evaporation. Hence, the higher the wind speed is the more the evaporation. There is wind speed data at Konso Station. For analyses Konso data adopted. Monthly wind speed variation is from 1.17 – 1.6 Km/hr; the yearly average is 1.34 Km/hr. Table 3.5 shows the average monthly wind speed at Konso meteorological station which has been adopted for the project site.

Table 3.5 Average Monthly Wind Speed (Km/hr) at Konso

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave.Wind Speed	1.41	1.57	1.60	1.42	1.23	1.28	1.32	1.38	1.28	1.24	1.21	1.17

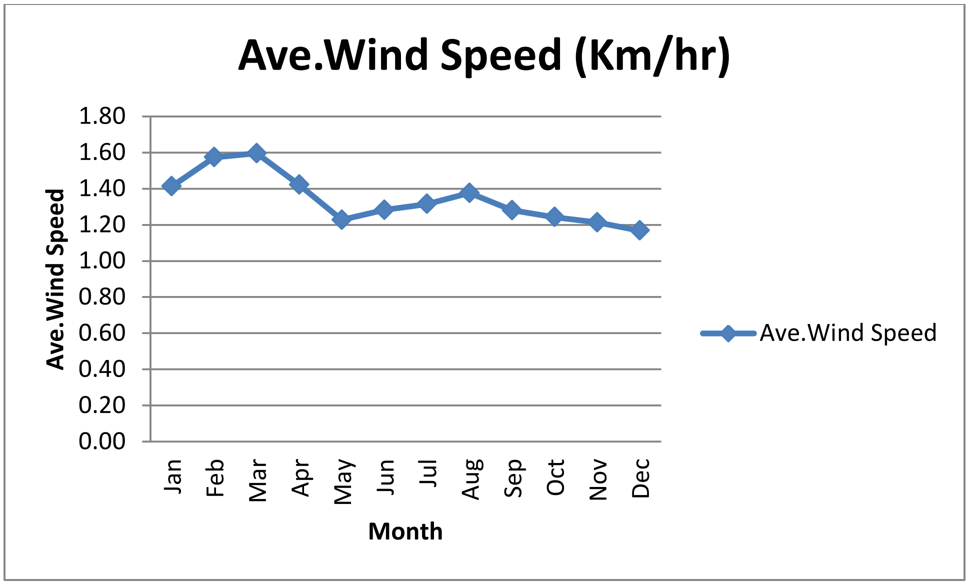


Figure 3.9 Average Monthly Wind Speed

3.7 Sunshine duration

Solar radiation provides nearly all of the energy that reaches the earth surface. Daily sunshine hour's duration is thus a factor to determine radiation and the potential evapo-transpiration. The longer the sunshine hour is the more the evapo-transpiration. There is no sunshine hour's data at the project area, hence the Konso data is considered. The average daily duration of sunshine hours at Konso is 6.60 hours. Sunshine hour's duration is Maximum in the dry season, November to March, and minimum in the rainy season June to August. The maximum sunshine hour's duration of 9.2 hours occurs in December. Mean daily sunshine hour's duration is shown in Table 3.6

Table 3.6: Mean Daily Sunshine Hours Duration at Konso

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave.SH	8.2	8.9	8.1	7.2	7.5	6.0	4.6	5.5	6.2	6.7	8.0	9.2

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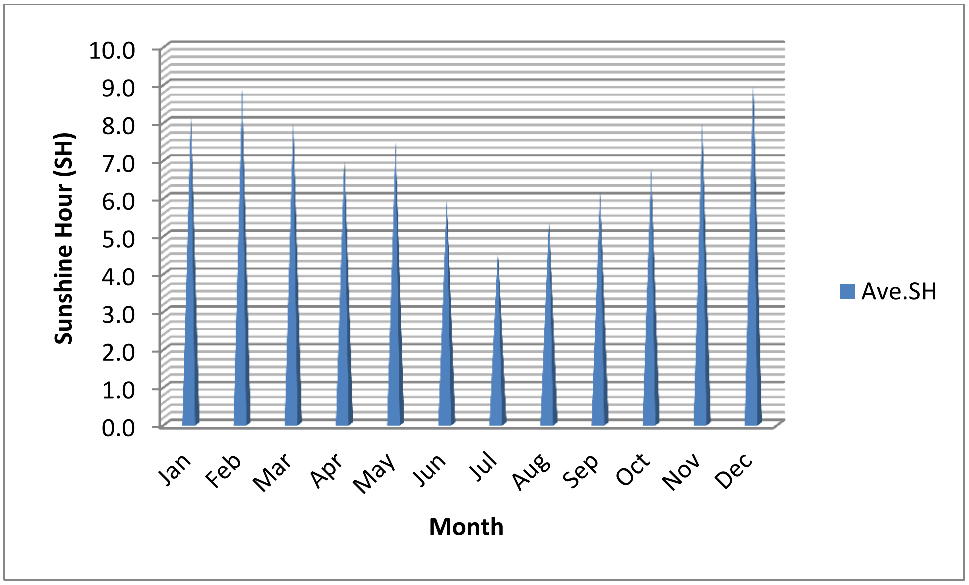

Figure 3.10 Average Sunshine hour

3.8 Relative humidity

Relative humidity, the water vapour contained in the atmosphere, is expressed as the percentage of the ratio of actual to saturation vapour pressure. More evaporation takes place in a dry air than in air with high relative humidity. The relative humidity data for the project area is also taken from Konso station. The average relative humidity data at Konso as shown in Table 3.7 varies from about 70% in May to 45% in February. Relative humidity is the maximum in May. The yearly average is 60%.

Table 3.7: Average Relative Humidity at Konso in %

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Relative Humidity	47	45	51	66	70	65	64	64	61	66	64	53

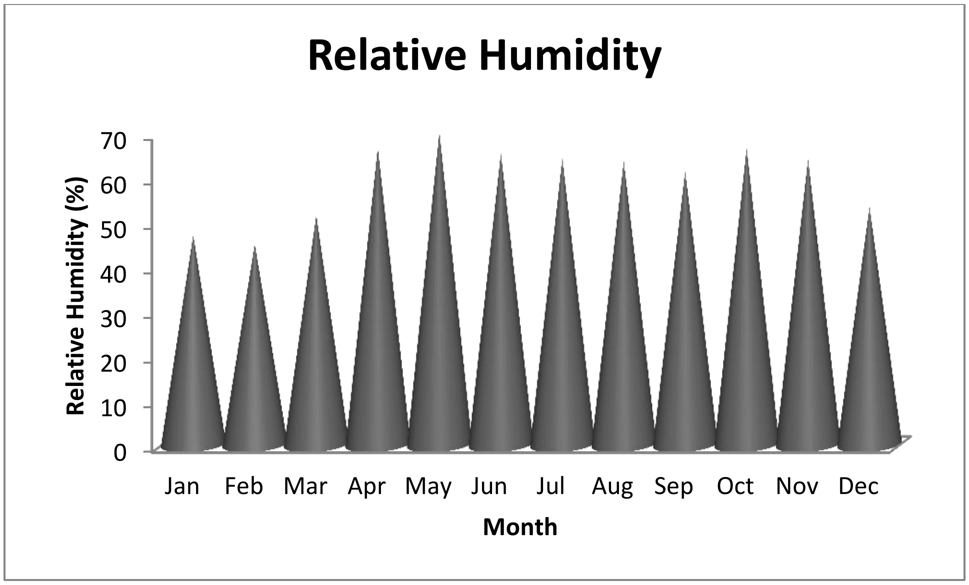

Figure 3.11 Average Relative humidity

As described before the river Dalbena is not gauged, therefore no flood record data are available along its course. Precipitation records are more plentifully available and are, therefore, used in a majority of designs, especially for small and large watershed. Therefore, a frequency analysis of rainfall data is performed to estimate the design storm, which is then converted to the design flood. Rainfall data recorded during 1989-2017, 29 years, at Konso’s metrological station have been used for estimation of peak flood at the weir site for 50 years return period.

Table 3.8: Highest Rainfall from Konso's Meteorological Station

Year	Daily Max RF(mm)
1989	74.3
1990	54.3
1991	62.3
1992	56.5
1993	59.0
1994	39.3
1995	45.3
1996	40.0
1997	96.9
1998	54.2
1999	47.5
2000	33.0
2001	55.6
2002	40.5
2003	53.6
2004	61.5
2005	47.8
2006	50.0
2007	76.8
2008	70.3
2009	58.0
2010	68.9
2011	49.0
2012	55.2
2013	51.6
2014	45.2
2015	50.8
2016	51.0
2017	82.5

3.9 Statistical analysis of maximum one-day rainfall data

For a flood computation at the Dalbena a 29 years maximum one-day rainfall data of station at Konso have been subjected to statistical analysis as follows:

Table 3.9 Flood computation of a maximum one day rainfall data

Rank	Natural Series Order	Decreasing Order	Plotting position (m/(n+1))*100	Reduced Variate	EVI (Gumbel probability exceeding)
1	74.30	96.90	1.40	4.32	1.32
2	54.30	82.50	2.81	2.99	4.89
3	62.30	76.80	4.21	2.47	8.12
4	56.50	74.30	5.61	2.24	10.11
5	59.00	70.30	7.01	1.87	14.27
6	39.30	68.90	8.42	1.74	16.07
7	45.30	62.30	9.82	1.13	27.49
8	40.00	61.50	11.22	1.06	29.25
9	96.90	59.00	12.62	0.83	35.30
10	54.20	58.00	14.03	0.74	37.96
11	47.50	56.50	15.43	0.60	42.19
12	33.00	55.60	16.83	0.52	44.87
13	55.60	55.20	18.23	0.48	46.08
14	40.50	54.30	19.64	0.40	48.88
15	53.60	54.20	21.04	0.39	49.20
16	61.50	53.60	22.44	0.33	51.12
17	47.80	51.60	23.84	0.15	57.70
18	50.00	51.00	25.25	0.10	59.71
19	76.80	50.80	26.65	0.08	60.39
20	**70.3**	50.00	28.05	0.00	63.09
21	**58**	49.00	29.45	-0.09	66.47
22	**68.9**	47.80	30.86	-0.20	70.49
23	**49**	47.50	32.26	-0.23	71.48
24	**55.2**	45.30	33.66	-0.43	78.48
25	**51.6**	45.20	35.06	-0.44	78.78
26	**45.2**	40.50	36.47	-0.87	90.83
27	**50.8**	40.00	37.87	-0.92	91.80
28	**51**	39.30	39.27	-0.98	93.06
29	**82.5**	33.00	40.67	-1.56	99.15
n	**29**				
Mean	**56.2**				
Std. Dev.	**13.94**				
Coef. Of var.	**0.25**				

Weibull developed the plotting position formula, Eq-1 that is used to obtain the values in table 3.2 (Column 4).

$$P_p = \frac{m}{(n+1)} \times 100 \qquad \text{Eq-1}$$

Where, P_p = position of probability of exceedance of empirical points,

m = Rank number

n = total number of observations

Extreme value Type I distribution (Gumbel) has been considered in fitting the empirical points that are obtained by Eq-1.

The Gumbel distribution is given by:

$$P = 1 - e^{-e^{-y}} \qquad \text{Eq-2}$$

Where, P = probability of a given event being equaled or exceeded,

e = the base of Napierian logarithms,

y = the reduced variate.

$$y = \frac{(x_i - \mu)}{\alpha} \qquad \text{Eq-3}$$

Where, x_i = probability of a given event being equaled or exceeded,

$$\alpha = \frac{\sqrt{6}\sigma_x}{\pi}$$

σ_x = standard deviation.

$$\mu = \bar{x} - 0.5772\alpha$$

$\bar{x}$ = mean value of x_i

The reduced variate can be related to the return period:

$$y_T = -\ln\left[\ln\left(\frac{T}{T-1}\right)\right] \qquad \text{Eq-4}$$

Then, X_T and Y_T are related as follows:

$$x_T = \mu + \alpha y_T \qquad \text{Eq-5}$$

Using the data presented in Table 3.2, the following parameters are defined,

$$\bar{x} = 56.2$$

$$\sigma_x = 13.94$$

$$\sigma = \frac{(\sqrt{6} \times 13.94)}{\pi}$$

$$\sigma = 10.87$$

$\mu = 56.2 - 0.5772 \times 10.87$

$\mu = 49.9$

$y = \frac{(x_i - 49.9)}{8.604}$

Table 3.10 Expected rainfall amount in mm for different return periods of Dalbena proposed head work.

Time (hr)	Return Period (Years)							
	2	5	10	25	50	100	500	1000
24	55	71	81.3	95	104	114	137	146

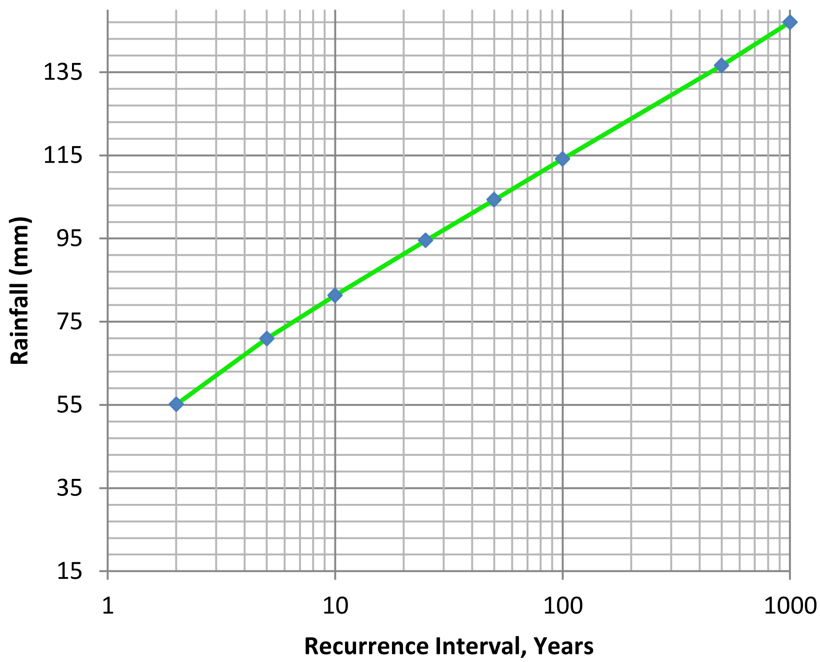

Fig 3.12 Flood Frequency Curve, Dalbena River

Hence, for the 50 years return period it can be taken 104 mm to compute the peak runoff at the head work.

Step by step computation Peak flood by the SCS method

Table 3.11 Hydrograph Analysis For Peak Flood Estimation

Step	Description	Symbol	Unit	Measured/computed	Remark
1	Catchment area	A	Km^2	96.5	Measured from 1:50,000 topographic map
2	Length of water course from water shade to proposed diversion site	L1	m	1001.00	Measured value from topographic map of (1:50,000)
		L2		1150.00	
		L3		935.00	
		L4		945.00	
		L5		962.00	
		L6		985.00	
		L7		913.00	
		L8		950.00	
		L9		914.00	
		L10		931.00	
		L11		944.00	
		L12		963.00	
		L13		941.00	
		L14		964.00	
		L15		998.00	
		L16		923.00	
		L17		1052.00	
		L18		988.00	
		L19		1007.00	
		L20		988.00	
3	Stream Bed Level	H1	m	2773	Taken from topographic Map of the area (1:50,000)
		H2		2705	
		H3		2637	
		H4		2569	
		H5		2501	
		H6		2433	
		H7		2365	
		H8		2297	
		H9		2229	
		H10		2161	
		H11		2092	
		H12		2024	
		H13		1956	
		H14		1888	
		H15		1820	
		H16		1752	

		H17		1684	
		H18		1616	
		H19		1548	
		H20		1480	
4	Slope of Main Water Course S = (H1-H2)/L	S1	m/m	0.068	Computed Value
		S2		0.059	
		S3		0.073	
		S4		0.072	
		S5		0.071	
		S6		0.069	
		S7		0.075	
		S8		0.072	
		S9		0.074	
		S10		0.073	
		S11		0.072	
		S12		0.071	
		S13		0.072	
		S14		0.071	
		S15		0.068	
		S16		0.074	
		S17		0.065	
		S18		0.069	
		S19		0.068	
		S20		1.498	
5	Time of Concentration $Tci = (Li/\sqrt{Si})^{0.77}/3000$	TC1	Hr	0.192	Computed Value
		TC2		0.225	
		TC3		0.177	
		TC4		0.179	
		TC5		0.183	
		TC6		0.188	
		TC7		0.172	
		TC8		0.181	
		TC9		0.173	
		TC10		0.176	
		TC11		0.179	
		TC12		0.183	
		TC13		0.179	
		TC14		0.184	
		TC15		0.191	
		TC16		0.175	
		TC17		0.203	
		TC18		0.189	
		TC19		0.193	
		TC20		0.058	

6	TC = ∑Tci	TC	Hr	3.58	Computed Value
7	Rainfall Excess Duration if Tc<3 hrs D=Tc/6 hr,D=1 hr, if T c > 3 hrs	D	Hr	1.00	Computed Value
8	Time of Peak Tp = 0.5D + 0.6TC	Tp	Hr	2.6	Computed Value
9	Time of Base Hydrograph Tb = 2.67 Tp	Tb	Hr	7.1	Computed Value
10	Lag Time T_L = 0.6 Tc	T_L	Hr	2.1	Computed Value
11	Peak Rate of Discharge Created by 1mm Rainfall Excess on Whole of the Catchment Qp = 0.27A /Tp	Qp	m^3/s.mm	9.8	Computed Value

Table 3.12:-Rainfall computation at Head work.

1	2	3	4	5	6
Duration	Rainfall	Rainfall	Rainfall	Areal to point	Areal RF
(hour)	T50 (mm)	profile (%)	profile (mm)	RF ratio (%)	rainfall (mm)
C1	C2	C3	C4	C5	C6
0-1hr	105	45	47.25	65	30.7
1hr-2hr		59	61.95	73	45.2
2hr-3hr		66	69.3	78	54.1
3hr-4hr		69	72.45	80	58.0
4hr-5hr		72	75.6	82	62.0
5hr-6hr		74	77.7	83	64.5

7	8	9	10	11	12	13	14	15
Incremental	Descending order		Rearranged	Rearranged	Cumulative	Time of incremental hydrograph		
RF (mm)	№		№	Incremental RF (mm)	RF (mm)	beginning	peak	end
C7	C8	C9	C10	C11	C12	C13	C14	C15
30.7	1	30.7	6	2.5	2.5	0	2.65	7.1
14.5	2	14.5	4	4.0	6.5	1	3.65	8.1
8.8	3	8.8	3	8.8	15.4	2	4.6	9.1
3.9	4	4.0	1	30.7	46.1	3	5.6	10.1
4.0	5	3.9	2	14.5	60.6	4	6.65	11.1

2.5	6	2.5	5	3.9	64.5	5	7.65	12.1

Table 3.13 Land cover classification and curve number of Dalbena watershed

C16	C17	C18	C19	C20	C21	
Land use cover	Area Ratio	Hydrologic Soil group	CN	Weighted CN	Sum weighted CN	
Contoured & terraced (C & T)	0.48	B	70	33.6	AMC	CN
Intensively Cultivated	0.23	B	70	16.1	II	64.4
Meadow-continuous grass, protected from grazing	0.15	B	48	7.2		
Shrub Land	0.129	B	58	7.482		
Total	1.0			64.4	III	80

Maximum potential difference (S) between Rainfall (P) and direct Runoff (Q):

$$S = \frac{25400}{CN} - 254, where\ CN = value\ corresponding\ to\ AMC\ III$$

$$S = 63.5\ mm$$

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)}$$

$$Q = \frac{(P-12.7)^2}{(P+12.7)}$$

Table 3.14:-Direct runoff (Q) in function of rainfall (P) of Dalbena watershed.

Rainfall, P (mm)	2.50	6.5	15.4	46.1	60.6	64.5
Direct Runoff, Q (mm)	2.0	0.7	0.1	11.5	20.6	23.3

The system of linear equation can be used to compute the ordinate values for the composite hydrograph.

Y = mx+b, where Y is the discharge (m3/s), m is the slope of the line +ve for rising limb of the hydrograph and –Ve for the falling limb of the hydrograph, and b is the intercept. The computed values for each triangular and composite hydrograph are provided in table below.

Table 3.15 Summary of peak flood computation of triangular and composite hydrograph in Dalbena Catchment for 50 years return period

Time(hr)	Ordinate of Hydrograph(m^3/s)						Total
	1	2	3	4	5	6	
0	**0.00**						0
1.00	5.64	**0**					6
2.00	11.29	0	**0.00**				11
2.65	14.94	0	-1.04	**-11.59**			2
3.00	16.93	0	-1.61	0.00	**-26.27**		-11
3.65	**11.56**	0	-2.65	21.33	-9.25		21
4.00	10.37	0	-3.22	32.92	0.00	**-7.74**	32
4.65	8.18	**0**	-4.26	54.25	17.02	-2.73	72
5.00	6.99	0	**-3.92**	65.84	26.27	0.00	95
5.65	4.81	0	-3.30	**87.17**	43.29	5.02	137
6.65	1.4	0	-2.33	67.46	**69.55**	12.76	**149**
7.07	0.0	0	-1.9	59.1	62.92	**23.19**	143
7.65	**-2.0**	0	-1.4	47.7	53.83	20.51	119
8.07		**0**	-1.0	39.4	47.19	18.55	104
9.07			**0.0**	19.7	31.46	13.91	65
10.07				**0.0**	15.73	9.27	25
11.07					**0.00**	4.64	5
12.07						**0.00**	0

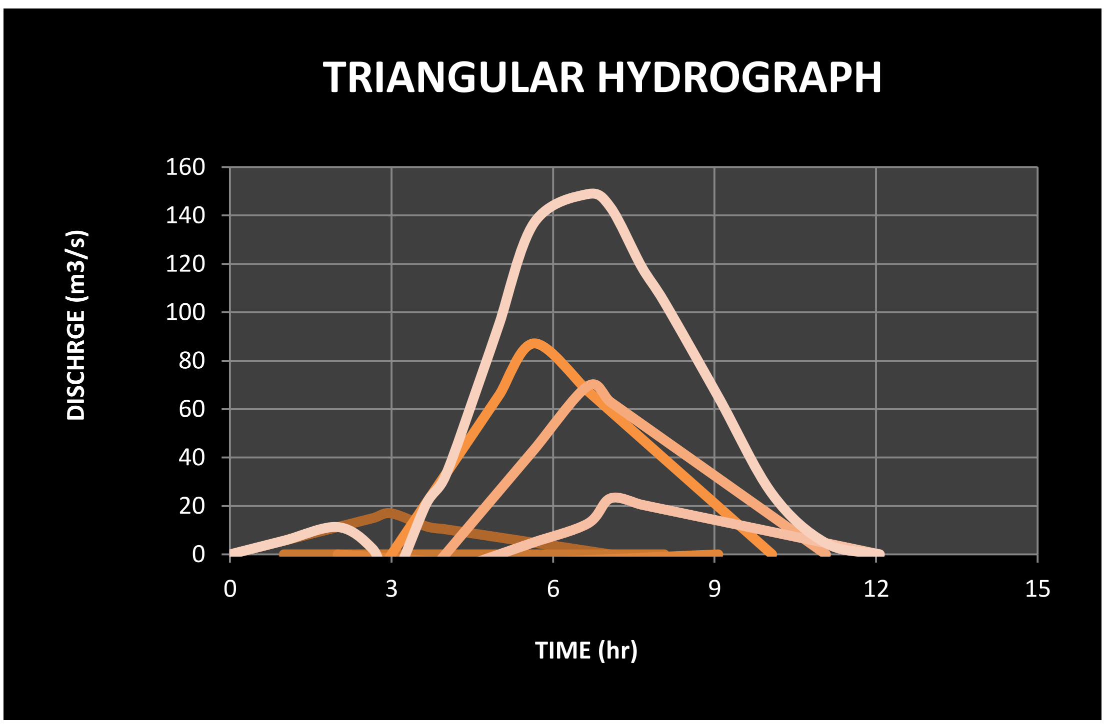

Fig 3.13 Triangular Hydrograph for different duration in Dalbena catchment

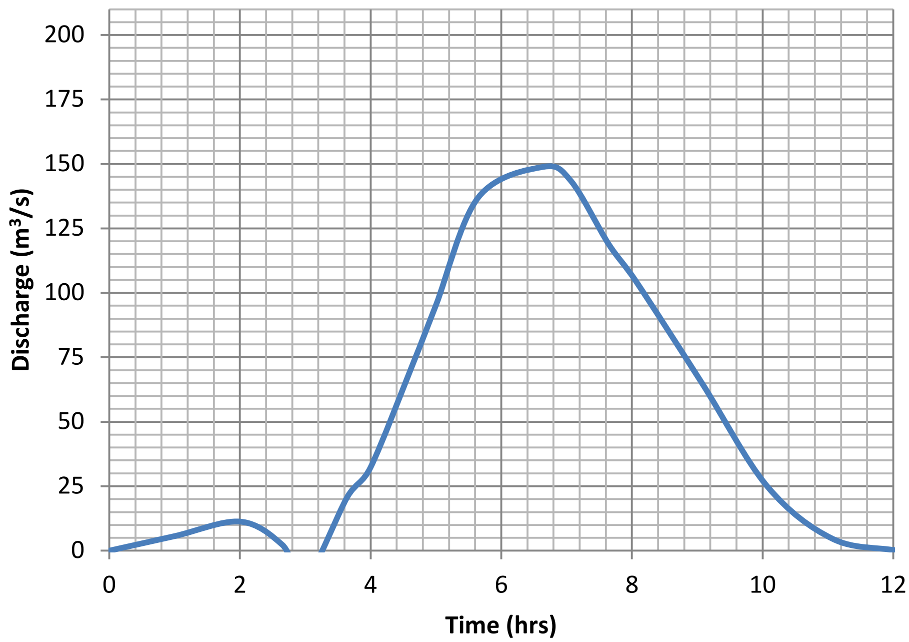

Fig 3.14 Composite Hydrograph for different duration in Dalbena catchment

The peak runoff for the design period of 50years return period Q50 is:

$$Q_{50} = 149\frac{m^3}{s}$$

The design discharge computed by the SCS-Method is used for estimation of the discharge.

Hence, the design flood computed by SCS-Method is used for the design of the diversion weir as is relates to the actual situation of the flood. Based on the above consideration, the design discharge for 50 year return period is selected to be **149m3/s.**

4. Conclusions, Recommendations and Training Needs

4.1 CONCLUSIONS

For the full feasibility study, the consultants have re-done from previous study, with: (i) improved flow inputs, including water demand estimates that take into consideration reduced effective rainfall in dry years.

Even if the discharge during dry season is very low, the hydrology result shows that the water resource potential is enough to irrigate the land. It is also known that at least a portion of the low dry season flows are required to meet existing demands by small holders, as well as to maintain the aquatic environment, so the flows available for irrigation may well be less than the required estimates.

For the same farm areas and same total net irrigation area of 100 ha an alternative cropping pattern is better considered. The different cropping combination affects the demand for water. So for this scarce area during dry season, it is better to cultivate crops that demand less water.

The consultant has made recommendations for monitoring programs for flow and water level, and climate. Specifically it is proposed to install the following gauge or climate stations:

- Installation of a station to record river water levels, flows, sediment transport, upstream the falls in the Dalbena River.
- Installation of climate station to measure precipitation and class A pan evaporation near the project

The gauge stations should be operated and/or be under the supervision of the MoWE /SNNP concerned unit. In the future there may need building of storage dam. So these data will be fundamental.

Despite the consultants best effects to estimate dry flow using a variety of techniques there still exists uncertainty in flows estimated for Dalbena River. This introduces some uncertainty in the available water resources for the Dalbena Diversion Irrigation Project which is not easy to quantify. The consultant therefore suggest that before implementation of the project a minimum of 3 years of additional flow and level data are collected and a reliable rating relationship has been established particularly at high flows.

4.2 Recommendations

The following recommendations are made to improve the water resources analysis to investigate the capacity of the surface water resources development interventions and to determine whether these are sustainable:

- The installation of the hydro meteorological network and upgrading data collection operations is needed. This should include the improvement of the hydrometric data processing and management capacity. By improving the monitoring of rivers the impacts of development interventions within the analysis can be better assessed.

- Rating curves at many flow gauges within the analysis should continue to be improved. This will reduce uncertainty in current flow estimates. In turn this will allow a better assessment of the capacity of the available water resources to support development interventions and to determine the impact of those interventions on water resources.

4.2.1 Irrigation and Development Interventions

Any development will require water and it becomes a question of how much and what types of developments are supportable and sustainable in the basin. Water resources analysis combined with economic analysis of the system can develop the understanding needed to make good development decisions. The following recommendations are made:

- There is a need to prevent uncontrolled water use in Dalbena catchment and restrict large scale irrigation through good management of water resources. Without restricting uncontrolled abstractions the remaining flow will be further affected.
- Good management of the available water resources in the Dalbena catchment in a sustainable manner requires an integrated approach for developing future agriculture, industry and services that involves all stakeholders.

- Irrigation poses the largest water demand in the Dalbena catchment. Any significant increases in irrigations should be restricted, as it is generally an inefficient use of scarce water resources, and significantly decreases the catchment surface water resources even when only a relatively small area is developed.
- Groundwater fed irrigation would allow an increase of the irrigable area in the Dalbena catchment but a complete and accurate assessment of the groundwater resources is recommended.
- It is recommended that water for domestic use (i.e. drinking water) should be prioritized with excess available water used for the most economical industries rather than irrigation which is water inefficient.
- Careful planning is required when phasing in the proposed irrigation with the recommended development interventions in this Feasibility study, as separately these interventions are not constrained significantly by available surface water resources but together the capacity of the surface water resources to support them becomes less sustainable.

4.3 Training Needs

It is very heartening development that the water resources exploitation for optimal utilization towards economic stability is getting the major thrust in Ethiopia. With phase of activities, soon, the rich river basins will be impounded in different storages associated with a number of runoff the river schemes either for irrigation or power or in a multi objective sense. As such, in the present scenario, the hydrological planning and design are in the usage. However, when the basins, in the near future, become stuffed with many projects, then, the real time operation of those projects will be the dire necessity. Judicial operation of a multi reservoir /project system has a lot of benefits in combating floods, tiding over drought, reduction in water losses and others. However, such real time operation would require a complete knowledge (in the hydrological sense) of the basin system, and hydrology and simulation techniques (simulation coupled with optimization models). Such a scenario of real time operation will have to be backed up by flood forecasting networks, advance prediction of seasonal rainfall, adequate telemetry (for transfer of data), dedicated computers, telecommunication software in addition to subject matter (hydrology/simulation) software. The personnel heading such operations in a basin, and those working in such a team need to be trained in the above mentioned aspect, so as to undertake operation which has immerse advantages. Hence, it is recommended that experts on Hydrology and Hydrological modeling should be identified for undergoing such trainings in Institutions/universities in appropriate countries. Though there could be many such institutes, the consultant feels for such multi system operation, adequate expertise is available in countries like U.S.A and India, where many institutions, Universities, River basin authorities, and research stations could be identified for offering such trainings. Such trained personnel, with expertise in hydrology will be able to head future river basin authorities for optimal real time operation of the systems.

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14. Appendix

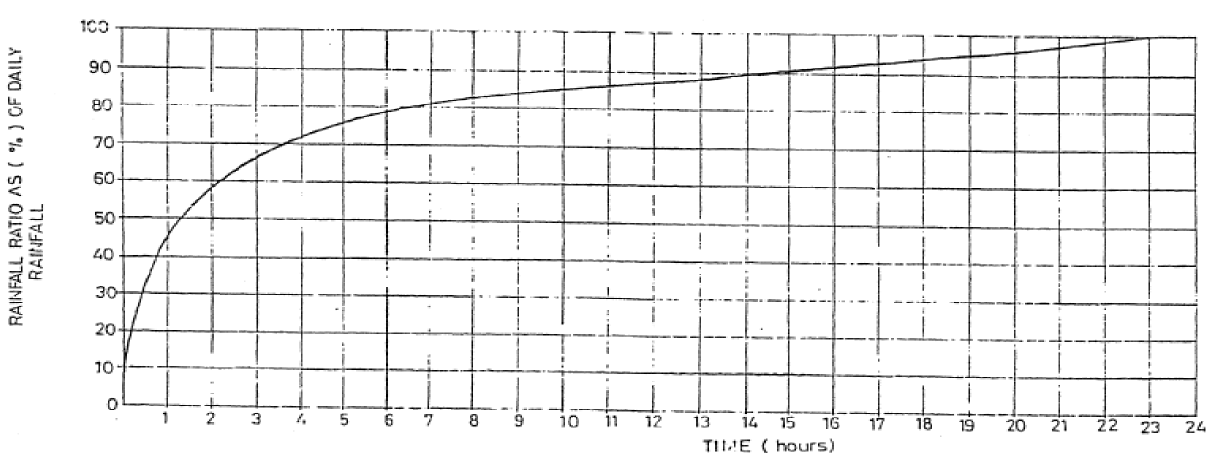
A1. Mean Monthly Rainfall at Konso (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1984	0.0	4.4	0.0	0.0	112.0	85.0	91.3	112.6	105.4	6.8	25.6	60.1	603.2
1985	0.6	0.5	83.0	270.0	140.0	61.7	122.6	127.2	128.8	55.2	9.4	14.3	1013.3
1986	0.4	59.5	69.0	149.8	168.7	182.2	81.5	163.0	138.4	59.6	12.8	24.0	1108.9
1987	0.0	49.3	164.8	108.1	300.1	79.7	91.0	202.5	179.3	145.3	0.0	10.5	1330.6
1988	18.9	55.5	28.0	198.8	103.4	84.1	211.4	192.7	230.5	117.2	0.0	2.3	1242.8
1989	32.9	147.1	133.9	176.6	66.5	133.2	185.6	223.0	186.5	90.0	25.8	180.0	1581.1
1990	41.2	202.2	100.5	74.0	166.5	58.3	109.3	114.9	95.9	68.4	6.7	0.0	1037.9
1991	20.7	79.3	159.8	94.6	222.3	120.1	211.8	126.3	176.2	27.2	3.1	35.9	1277.3
1992	55.9	133.4	99.8	113.8	67.3	115.3	122.5	241.9	126.7	201.6	42.6	5.9	1326.7
1993	64.8	72.3	11.2	207.9	270.6	116.1	44.4	142.4	93.9	76.9	16.7	0.0	1117.2
1994	0.0	0.7	100.9	84.9	154.1	126.2	130.2	129.6	89.4	0.0	7.5	6.9	830.4
1995	0.0	44.4	56.3	199.1	57.3	55.0	88.0	164.5	114.5	89.0	0.0	27.3	895.4
1996	28.3	41.5	126.5	133.4	168.1	20.8	56.3	112.0	64.8	40.6	15.7	0.0	808.0
1997	31.1	0.0	36.4	126.9	109.1	140.4	100.5	144.0	141.0	179.8	163.3	21.5	1194.0
1998	31.8	73.6	103.6	164.4	183.1	96.9	182.4	197.4	107.7	204.8	30.9	0.0	1376.6
1999	26.2	2.2	118.8	87.0	92.4	170.3	166.7	107.9	101.6	188.0	3.5	1.4	1066.0
2000	0.0	0.0	28.8	202.9	114.7	134.3	145.6	146.6	156.9	115.7	96.2	29.4	1171.1
2001	11.3	53.9	144.8	104.4	143.1	103.7	257.3	205.4	107.5	163.4	12.9	10.3	1318.0
2002	57.3	49.1	132.1	156.0	101.8	103.7	116.9	209.2	120.6	23.0	0.0	120.3	1190.0
2003	23.7	12.1	77.7	205.8	77.2	131.3	200.5	120.6	123.7	20.7	44.2	15.6	1053.1
2004	99.3	29.2	57.8	183.9	80.2	54.2	159.1	126.5	109.7	150.0	10.6	6.0	1066.5
2005	50.1	25.9	127.8	322.3	269.2	35.8	67.1	100.9	285.0	117.1	59.7	0.0	1460.9
2006	2.5	47.1	78.7	196.8	83.9	40.2	113.0	228.2	37.2	95.7	20.0	10.0	953.3
2007	34.5	59.0	84.5	127.0	158.6	97.3	157.5	94.4	170.1	32.2	0.0	0.0	1015.1
2008	0.0	0.0	33.6	46.0	145.1	112.9	174.0	124.1	148.3	117.2	103.4	0.0	1004.6
2009	43.4	7.4	30.9	101.3	65.2	56.8	133.8	123.9	74.2	97.2	29.7	88.0	851.8
2010	30.2	40.0	101.3	100.7	158.2	89.7	134.5	98.2	198.3	26.6	9.2	0.0	986.9
2011	1.8	4.4	46.0	96.4	267.4	156.0	219.0	225.5	108.0	0.0	76.7	0.0	1201.2
2012	0.0	0.0	38.2	176.9	55.6	175.7	160.6	117.5	180.3	6.5	23.8	71.2	1006.3
2013	20.10	8.20	108.20	130.40	245.10	166.60	137.20	233.50	121.80	130.02	79.50	5.30	1385.92

A2. Areal to Point Ratio (%)

Area km^2	Duration I(hrs)	0.50	1.00	2.00	3.00	4.00	5.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00
25		88	78	82	85	87	88	88	91	92	93	93	94	94
50		61	71	78	82	84	85	87	89	90	91	92	92	93
75		57	67	75	79	82	84	83	87	89	90	91	91	92
100		54	65	73	78	80	82	83	86	88	89	90	91	91
125		52	63	72	76	79	81	82	85	87	88	89	90	91
150		50	61	70	75	78	80	61	84	86	88	89	89	90
175		48	59	69	74	77	79	81	84	86	87	88	89	90
200		46	58	68	73	76	78	80	83	85	87	88	88	89
225		45	57	57	72	75	77	72	82	85	86	87	88	89
250		44	55	66	71	74	77	78	82	84	86	87	88	88
275		42	54	65	70	74	76	78	81	84	85	86	87	88
300		41	53	54	70	73	75	77	81	83	65	86	87	88
325		40	53	63	58	72	73	77	80	83	84	86	87	87
350		38	52	63	68	72	74	76	80	82	84	85	86	87
375		39	51	62	68	71	74	78	80	82	84	85	86	87
400		38	50	61	67	71	73	75	79	82	83	85	86	87
425		37	50	61	67	70	73	75	79	81	83	84	85	86
450		36	49	60	66	70	72	74	79	81	83	84	85	86
475		36	48	60	66	69	72	74	78	81	83	84	85	86
500		35	48	59	66	69	72	74	78	80	82	84	85	86
525		34	47	59	65	68	71	73	78	80	82	83	85	85
550		34	47	58	64	68	71	73	77	80	82	83	84	85
575		33	46	58	64	68	71	73	77	80	82	83	84	85
600		33	45	57	63	67	70	72	77	79	81	83	84	85
625		32	45	57	63	67	70	72	76	79	81	83	84	85
680		32	45	56	63	67	69	72	76	79	81	82	84	84
675		31	41	56	62	66	69	71	76	79	81	82	83	84
700		31	44	56	62	66	69	71	76	78	80	82	83	84
725		31	45	55	62	66	69	71	75	78	80	82	83	84
750		30	43	55	61	65	68	71	75	78	80	82	83	84
						49								

A3. Rainfall Ratio as (%) of daily rainfall.



A4. Runoff curve number for hydrologic soil cover complexes

Runoff curve number for hydrologic soil cover complexes (for catchment condition II and $I_a = 0.2S$) after U.S soil conservation service, 1964.

(Antecedent moisture condition II, and $I_a = 0.2S$)

Land use	Cover Treatment or Practice	Hydrologic Condition	Hydrologic Soil Group A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	Contoured & terraced	Poor	66	74	80	82
	" "	Good	62	71	78	81
Small Grain	Straight row	Poor	65	76	84	88
		Good	63	75	84	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded Legumes * Or	Straight row	Poor	66	77	85	89
	"	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
Rotation Meadow	Contoured & terraced	Poor	63	73	80	83
	" "	Good	51	67	76	80
Pasture or Range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		-----	59	74	82	86
Roads (dirt) **		-----	72	82	87	89
Roads (hard surface) **		-----	74	84	90	92

* Close-drilled or broadcast

** Including right-of-way

Table A-4: Runoff curve Number (CN), Conversions and Constants
(After U.S Soil Conservation Service, 1964)

CN for Condition II	CN for AMC	
	I	III
100	100	100
98	94	99
96	89	99
94	85	98
92	81	97
90	78	96
88	75	95
86	72	94
84	68	93
82	66	92
80	63	91
78	60	90
76	58	89
74	55	88
72	53	86
70	51	85
68	48	84
66	46	82
64	44	81
62	42	79
60	40	78
58	38	76
56	36	75
54	34	73
52	32	71
50	31	70
48	29	68
46	27	66
44	25	64
42	24	62
40	22	60
38	21	58
36	19	56
34	18	54
32	16	52
30	15	50
25	12	48
20	9	37
15	6	30
10	4	22
5	2	13
0	0	0