1 INTRODUCTION

1.1 Background of Study:

Out of the different types of natural resources water resources is the most important and valuable resources of Nepal because of its excessive availability through out the country. Water plays an important role in the lives of living being. This water is especially known as fresh water. The water that reaches the earth surface as a part of water cycle is known as fresh water. For animals water is important for the drinking purpose and mankind being no different it is essential to us as well. There are many claims and disputes over the fresh water through out the world. Nepal, due to its geography, though being rich in water resources has a disadvantage; it is a challenge to provide the necessary water to the people living in small blocks in hilly areas. In this trend big city like Kathmandu is no escape to the scarcity of water. Water for Kathmandu is a big challenge to meet the demand.

Besides water for metabolism, it is also important to man kind as renewable resource of energy. Gradient of the water that is available in region, Mountains of Hindu Kush region, is potential to high amount of energy. This energy is environmentally friendly, green house gas is not emitted, while neglecting ecological and social effects of the electricity production plant. The generation of electricity is very essential to the developing country like Nepal where we have big deficit of the energy supply. Also the demand for the energy is growing day by day. Besides, there is a through challenge of the electrification in rural areas of the country.

Water in other from is the most serious issue to the living beings. This form of water can be recognized as the steam water in the form of the floods in the river channel and in the embankment areas as the flood plain. Flood is the natural digester caused by the heavy rain events like chained thunderstorm, monsoon flooding. Flood in our region is major due to monsoon rainfall in summer. This has an impact in both the hilly and the plain land of the region. Yearly flood induces erosion and land slide in hilly region that causes for the loss of the human lives. In plains flood enters the people’s houses potting them away from their homes streets are flooded too as a result no traffic can move around. It is ironic but the boats are seen instead of the vehicles.

The proper utilization of the water resources is an important thing to do. We need to identify our needs and give priority to different ideas and projects according to our current need and future purpose keeping the environment as the major factor to conserve. The modeling of the water resources project gives a huge advantage by simulating the process that can take place in the nature before actually they take place in the real time in nature.

1.2 Thesis Objectives

The main objectives of this study are as follows:

- Estimation of peak discharge using HEC-HMS model.
- Estimation of total losses using HEC-HMS model.
- To study the relationship between rainfall and runoff of the relevant basin.
- To optimize the hydrological parameter of Jhikhu khola basin.

1.3 Statement of problem

Middle mountainous region of Nepal occupies the two third part of the country. Most of the river and stream originates from this region. So the hydrological study of the rivers and streams of this region are most important to understand the hydrological condition of rivers of Nepal.

Jhikhu Khola watershed lies in the middle mountainous region of the Nepal. Due to the lack of sufficient hydrological and meteorological station, the hydrological study of these areas has not been done in the sufficient quantity. Very few hydrological studies have been done in limited river catchment for the specific purpose. Those studies are not enough to address the overall hydrological condition. In this context the present study will help to study the hydrological parameters and peak discharge of one of the major middle mountain basin of the country.

There are very few gauged river in Nepal, therefore the studies of hydrological parameter in ungauged rivers are also equally important for the implementation of different water resources schemes in such ungauged basin. In this context the estimated parameters of Jhikhu khola basin can be used in ungauged basin with similar hydrological and meteorological environment.

1.4 Limitations of study

Transformation of one day rainfall to half hour rainfall is done in this study, which might not exactly represent the true case.

Rainfall of only one station is taken, which might not represent the spatial variation of the rainfall of whole basin.

One biggest rainfall event is used to optimize the hydrological parameters.

2 LITERATURE REVIEW

2.1. **Literature Review:**

Various techniques are available for transformation of rainfall to runoff. Unit hydrograph was one of the powerful tool of hydrology, Clark (1945) used the idea given by routing the time area concentration curve through a single element of linear reservoir storage could derive the unit hydrograph for instantaneous rainfall.

Noorbakhsh et al., (2005) Clark,s Synthetic Unit hydrograph (SUH)model for determination of Instantaneous Unit Hydrograph (IUH) can derived from rainfall runoff data. In his study the required parameter for Clark,s SUH were derived using Geographic Information System (GIS) techniques. The result show good agreement between observed data hydrograph and Clark,s SUH.

Yu Pao-Shan et al., applied distributed rainfall runoff model for the simulation of flow hydrographs at ungauged site in Taiwan. The result show that the, if the distributed rainfall runoff model can be adequately verified based on measurements both at the outlet and inside the studied area, than confidence that the model can accurately simulate the hydrological processes inside the studied area. This study calibrates the model parameters and simulated flow hydrograph at any ungauged site inside the study area.

Kull et al (1954) suggest Clark model widely used in hydrology to derivation from physical basin characteristics and translation hydrograph, the spatial variability of characteristics and processes are considered explicitly.

Shakya (2002) analysis is based on the storm data of the monsoon months. The most effective and extreme rainfall events within Nepal have been considered for the storm analysis. Different technique such as digital elevation model (DEM) ,GIS Arc View, Moisture Maximization Factor (MAF) and XL solver have been intensively used for the extreme rainfall distribution and Depth Area Duration (DAD) analysis. Finally, a combined set of equation has been developed for the estimation of Average depth of PMP of specified period.

3 HYDROLOGICAL MODEL

3.1General introduction of HEC-HMS

The US Army Corps of Engineers' Hydrologic Modeling System (HEC-HMS) is the precipitation-runoff model that supersedes the HEC-1 Flood Hydrograph Package. It is designed to simulate the precipitation-runoff processes of dendritic watershed system. It is designed to be applicable in a wide range of geographic area for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff.

HEC-HMS is a numerical model (computer program) that includes a large set of methods to simulate watershed, channel, and water-control structure behavior, thus predicting flow, stage, and timing. The HEC-HMS simulation methods, which are summarized in Table3.1, represent:

Table 3-1Summary of simulation methods included in HEC-HMS.

Category	Method
Precipitation	User-specified hyetograph
	User-specified gage weighting
	Inverse-distance-squared gage weighting
	Gridded precipitation
	Frequency-based hypothetical storms
	Standard Project Storm (SPS) for eastern
	U.S. Soil Conservation Service (SCS)
	hypothetical storm
Runoff-volume	Initial and constant-rate
	SCS curve number (CN)
	Gridded SCS CN
	Green and Ampt
	Deficit and constant rate
	Soil moisture accounting (SMA)
	Gridded SMA

Direct-runoff	User-specified unit hydrograph (UH)
	Clark’s UH
	Snyder’s UH
	SCS UH
	Mod Clark
	Kinematic wave
	User-specified s-graph
Base flow	Constant monthly
	Exponential recession
	Linear reservoir
Routing	Kinematic wave
	Lag
	Modified Puls
	Muskingum
	Muskingum-Cunge standard section
	Muskingum-Cunge 8-point section
	Confluence
	Bifurcation
Water control structures	Diversion
	Reservoir / detention pond

3.2 Components provides by HEC-HMS for precipitation-runoff-routing simulation,

Precipitation-specification options which can describe an observed (historical) precipitation event, a frequency-based hypothetical precipitation event, or a event that represents the upper limit of precipitation possible at a given location.

Loss models which can estimate the volume of runoff, given the precipitation and properties of the watershed.

Direct runoff models that can account for overland flow, storage and energy losses as water runs off a watershed and into the stream channels.

Hydrologic routing models that account for storage and energy flux as water moves through stream channels.

Models of naturally occurring confluences and bifurcations.

Models of water-control measures, including diversions and storage facilities.

These models are similar to those included in HEC-1. In addition to these, HECHMS includes:

A distributed runoff model for use with distributed precipitation data, such as the data available from weather radar.

A continuous soil-moisture-accounting model used to simulate the long-term response of a watershed to wetting and drying.

HEC-HMS also includes:

An automatic calibration package that can estimate certain model parameters and initial conditions, given Links to a database□□□□observations of hydro meteorological conditions. Management system that permits data storage, retrieval and connectivity with other analysis tools available from HEC and other sources.

3.2 HEC-HMS Representation of Runoff process

The runoff process of a watershed can be illustrated from the Figure 3.1. Simulation of this process is carried out in different steps using lumped and deterministic models. These models can be categorized according to their purpose of use as is represented in the Figure 3.2.

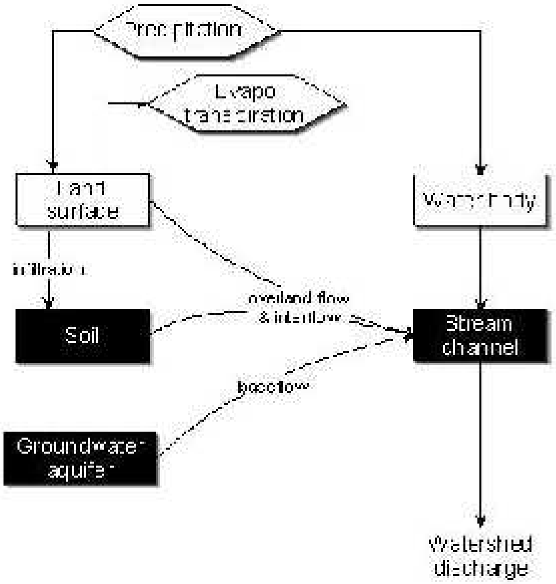

Figure 3-1 Representation of watershed runoff adopted by HEC HMS

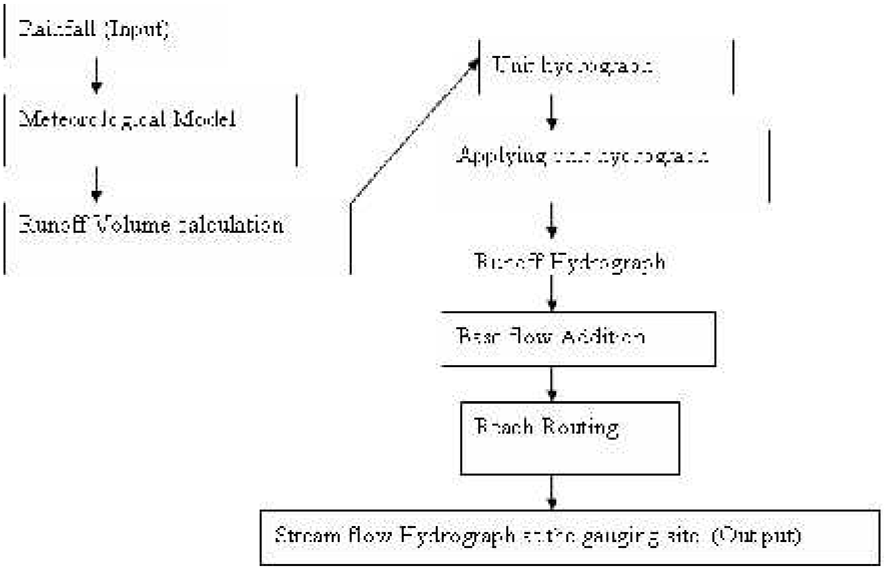

Figure 3-2:- A diagrammatic representation of runoff calculation in HEC-HMS

3.4 Search Method:

Two search methods are available for minimizing the objective function and finding optimal parameter values. The univariate gradient method evaluates and adjusts one parameter at a time while holding other parameters constant. The Nelder and Mead method uses a downhill simplex to evaluate all parameters simultaneously and determine which parameter to adjust. The default method is the univariate gradient method. Also, the univariate gradient method is always used if only one parameter is selected.

3.5 Initial Values and Constraints:

Initial values are required at the start of an optimization process. Parameter values from the basin model are used as default initial values. However, default values can be changed.

Hard constraints limit the range of values that a parameter can take during optimization. The constraints are used to keep parameter values within reasonable limits. They also preclude values that cause numeric instabilities or errors in computations.

Soft constraints can be used to limit the range of parameter values within the wider range allowed by hard constraints.

3.6Parameter optimization:

Parameter estimation is the process of adapting a general model to a specific watershed. Some parameters can be estimated directly from field measurements. Other parameters can be estimated indirectly from field measurements. In this case, the field measurement does not result in a value that can be input directly to the program. However, the field measurement can provide a strong recommendation for a parameter in the program based on previous experience. . Finally, there are parameters that can only be estimated by comparing computed results to observed results such as observed stream flow. Even for parameters of the first two types, there is often enough uncertainty in the true parameter value to require some adjustment of the estimates in order for the model to closely follow the observed stream flow.

The quantitative measure of the goodness-of-fit between the computed result from the model and the observed flow is called the **objective function.** An objective function measures the degree of variation between computed and observed hydrographs. It is equal to zero if the hydrographs are exactly identical. The key to automated parameter estimation is a search method for adjusting parameters to minimize the objective function value and find optimal parameter values. A minimum objective function is obtained when the parameter values best able to reproduce the observed hydrograph are found. Constraints are set to insure that unreasonable parameter values are not used.

Optimization trials are one of the three different components that can compute results: simulation runs, optimization trials, and analyses. Each trial is based on a simulation run. The run provides the basic framework of a basin model, meteorological model, and control specifications within which parameters are estimated. A variety of result graphs and tables are available from the Watershed Explorer for evaluating the quality of the estimation.

The iterative parameter estimation procedure used by the program is often called optimization. Initial values for all parameters are required at the start of the optimization trial window. A hydrograph is computed at a target element by computing all of the upstream elements. The target must have an observed hydrograph for the time period over which the objective function will be evaluated. Only parameters for upstream elements can be estimated. The value of the objective function is computed at the target element using the computed and observed hydrographs. Parameter values are adjusted by the search method and the hydrograph and objective function for the target element are recomputed. This process is repeated until the value of the objective function is sufficiently small, or the maximum number of iterations is exceeded. Results can be viewed after the optimization trial is complete.

3.7 Hydrograph:

Hydrograph is a graphical representation of discharge flowing in river at given location with time. It is thus, a plot between time (on X-axis) and discharge (on Y- axis), such a graph is capable of representing discharge fluctuation in the river at a given location, and can also indicate the peak flow.

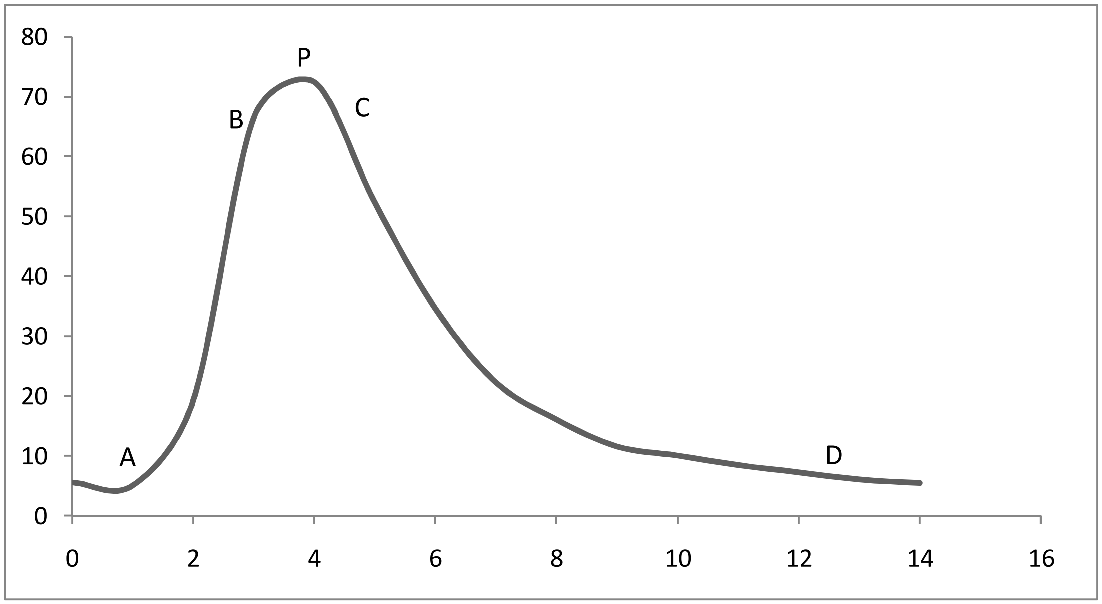

Figure 3-3:- Typical single peaked hydrograph

As shown as figure 3.3, a typical single peaked hydrograph produced by an isolated storm consists of a rising limb, a crest segment and a recession limb

Rising limb is the portion from A to B of the hydrograph represents the ascending portion of the curve. It is mainly influenced by the storm and basin characteristics. In general, it is concave, rising slowly in the early stage of flood but more rapidly towards the end portion. This is due to the fact that at the initial stage of a storm, losses are variable and high.

The crest segment is represented by the portion from B to C of the curve showing points of inflection of the rising and the falling limb. The crest segment contains the peak discharge with in it. Peak of the hydrograph occurs when all portions of the basin contributes at the outlet simultaneously at the maximum rate. The point of inflection represents the change point of contribution of the catchment to the channel system.

Recession limb from point C to D of the curve represents the decreasing discharge. Point C is the inflection points on the recession limb represents the starting of withdraw of water from storage. Point D represents where the contribution to the channel is purely from ground water. The slope of recession limb indicates the rate of withdrawal of water from the channel storage. The curve is mathematically represented as

$$Q_t = Q_0 K_r^t \quad \text{……………………………..(3.1)}$$

Where, Q_0 is a initial discharge, Q_t is discharge after time t which may be taken as the discharge at point C and K_r^t the recession constant with a value of less then unity.The recession constant is taken as the product of three components (Surface storage, subsurface flow and ground water flow) as

$$K_r^t = K_s K_i K_g \quad \text{…………………….(3.2)}$$

Where K_s represents the recession constant for surface storage, K_i the recession constant for subsurface flow and K_g is recession constant for ground water storage.

3.7.1 Unit Hydrograph:

A unit hydrograph is the hydrograph of direct runoff resulting from unit depth of 1 cm of rainfall excess generated uniformly over the basin for a specified duration. The term unit depth of rainfall excess means excess rainfall over and above all losses in the basin under consideration. The duration is the period of rainfall excess which is assumed to be uniformly distributed over the basin area.

3.7.2 Instantaneous Unit Hydrograph:

In a limiting case , when the duration of rainfall excess becomes infinitesimally small, i.e., 1 cm of rainfall excess is spread over the catchment uniformly and instantaneously, the resulting D.R.H is called an instantaneous unit hydrograph (IUH).It is impossible for a basin to get rainfall excess of 1cm in zero time. IUH is only a concept used to investigate rainfall – runoff process of a basin theoretically and is defined as a fictitious unit hydrograph representing the surface hydrograph from a basin resulting from instantaneous rainfall excess volume of 1cm over the basin. Instantaneous unit hydrograph can be derived by either of the following approaches.

- From S-Hydrograph

- From conceptual models
- By fitting harmonic series to DRH and ERH
- Theoretically from Laplace transform function

Conceptual models are widely used for determination of instantaneous unit hydrograph. Various investigators have proposed various methods for the derivation of IUH. The approaches by Nash and Clark are more practical and widely used models. Only Clark unit hydrograph model is discussed in this paper.

4 STUDY AREA

4.1 Study Area:

The study area Jhikhu Khola watershed is located in the middle mountainous regions of Nepal. It is situated in the Kabhrepalanchowk district about 45 km east of Katmandu and cover11000 ha. The watershed lies between 27° 33’ and 27° 42’ N, and 85° 31’ and 85° 41’ E with an altitude range from 800msl to 2200msl. The Jhikhu Khola watershed is a main valley with a large flat valley bottom of alluvial origin, where the major land use is irrigated agriculture. Short and steep slopes confine it on the southern and northern sides. There are many pockets like valleys on the flanks, which makes the watershed very heterogeneous. The general aspect of the watershed is south east.

A dense network of meteorological stations has been established in the Jhikhu watershed. A total of 10 stations in Jhikhu Khola watershed are used for climatological measurements in particular rainfall and temperature. The meteorological measurements in the Jhikhu watershed focus on some sub- catchments of interest. Measurement in Jhikhu watershed was started 1992.

Figure 4-1:- Study Area Jhikhu Khola Watershed

5 METHODOLOGY

5.1General

Runoff is a general term used to indicate the accumulation of precipitation excess. Runoff volume from a storm or for some other time period or peak discharge for the event are greater interest. Sometimes, time to the peak discharge or the duration of the hydrograph might be of special interest. The total volume of runoff water occurring over a period of time is expressed (Singh, 1994) as

$V_Q = \int_0^t Q(t).dt$ ………………………… (5.1)

V_Q is the runoff volume from catchment acting over a period of time ‘t’ is expressed as where, Q(t) is the discharge at time ‘t’ (one time period of special interest is the volume of runoff over the duration of the hydrograph)

‘dt’ is the incremental time step.

This volume of the runoff is comparable to the precipitation falling on the drainage basin. However the rainfall runoff phenomenon is large scale and quite complex. The variables of the routing process may either related to storm characteristics or catch characteristics. That intensity duration and aria extent of the storm is among the first category of variables. While, size topography, soil and vegetation cover are later type. The temporal and spatial interaction of above variables make difficult to determine computation of flow hydrograph accurately. Therefore, estimation of runoff hydrograph is based on using methods that reflect combined effect of variables on an individual drainage basin. Because no two drainage basin are exactly alike, no to solution are exactly alike. The general approach to the solutions however can be alike.

Transformation of rainfall excess to direct runoff hydrograph can be achieved by different methods. The use of the computers has led increased emphasis on watershed modeling . these model simulates stream flow at outlet of drainage basins either for individual storm events or continuous simulation models (CSM) has been developed to simulate flow hydrograph, but here the famous event based HEC(HMS) model is used. Some of the important steps of HEC-HMS model to be followed during analysis are described below.

5.2 Watershed representation

A watershed is usually a complex and heterogeneous system. The sub basin represents an average condition of its variable characteristics in time and space. The basin should have rain gauge to provide independent data. For lump models such as the unit hydrograph, the whole catchment can be represented as a unit.

5.3 Precipitation hydrograph:

Precipitation hydrograph is used as input for all runoff (flow) calculation in most of the event based simulation models (EBSM). The specified precipitation is assumed uniformly distributed over the sub basin. Some of the sub basin may not have recording gauge and may involved extrapolation rainfall data from neighboring gauges. Some of the methods applicable to determine basin average precipitation are as follows (HEC, 1991)

5.3.1 Users specified hyetograph:

Precipitation data for an observed storm event can be supplied by specifying any storm as total amount of precipitation or incremental precipitation from recorded data

5.3.2 Weighted Precipitation Gauge:

This method is used for the precipitation averaging over the entire basin by the means of a weighting method. Once the weights are known the method is easy to apply. Weights are the key to this method. Thiessen polygon is one of the methods for applying the weight to the averaging method.

5.3.3 Inverse-distance-squared Method:

This method can be used to supply the precipitation data in HEC-HMS hydrological model.

5.3.4 Grid based Precipitation:

In some of the models gridded or radar based precipitation data may be the input to the models.

5.3.5 Frequency based design storm:

Frequency analysis of rainfall data is preformed to estimate the design storm. Once the design frequency has been established the design storm is to be analyzed next. This analysis involves storm selection determination of rainfall duration. Areal and point rainfall depth adjustment, rainfall intensity, time distribution of rainfall and areal distribution of rainfall pattern (Singh, 1994)

5.4 Estimation of effective rainfall:

A part of the rainfall falling over the catchment reaches gauging site as runoff and the other part infiltrates into soil and add to the ground water storage or is retained as surface retention. Or in other words, loss in ground surface and beneath the ground is an important hydrological process. Therefore the rainfall runoff models require the separation of rainfall into effective rainfall causing the flood and infiltrated rain. Only limited works has been reported to take account of erratic intermittent characteristics of rainfall conditions. However, different models demand determination of initial losses, assessment of soil moisture condition, determination of long term constant loss rate and infiltration loss during rainfall runoff event.

5.4.1 Constant Loss Rate:

The loss rate at average rainfall intensity above which the rainfall volume equals runoff volume at a constant ratio is called constant loss rate.

5.4.2 Initial loss:

Most rainfall runoff models including HMS-HEC refers initial loss such as land surface interception, depression storage etc. Exact determination of initial loss is difficult. However, tentative estimation can be done based on the methods developed by soil conservation service (SCS). In this method initial obstruction (I_a) is a function of maximum potential obstruction S and given as I_a = .2Sa. However, This ‘S_a’ is also a parameter dependent on soil vegetation land use characteristics and antecedent soil moisture condition in a watershed. SCS expressed ‘S_a’ as a function of Curve Number(CN) and

$$Sa = \frac{25400}{CN} - 254 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5.2)$$

Where, S_a in mm,

The initial loss can be relating antecedent soil moisture condition index as done by Hamon,Singh and Dickinson (Singh, 1994)

5.4.3 Infiltration Loss:

When water falls on the surface of a soil a part of it seeps into the soil, and becomes ground water. This movement of water through the soil surface is known as infiltration and plays an very significant role in the runoff process by affecting the timing, distribution and magnitude of the surface runoff.

The water that is percolated to the ground surface goes further into the soil and is lost to direct runoff in the form of infiltration loss.

5.5 Estimation of direct runoff:

Runoff is defined as the portion of the precipitation that makes its way towards rivers or oceans etc as surface or subsurface flow. Various methods can be used for computing runoff, which are given below.

- Fundamental equation for runoff computation.
- Computing runoff by using runoff coefficient.
- Computing runoff by using infiltration capacity curve.
- Computing runoff by using infiltration indices
- Computing peak rate of runoff by rational formula.
- Computing runoff hydrograph by using unit hydrograph theory.

Conceptual models are widely used for determination of instantaneous unit hydrograph. Various investigators have proposed various methods for the derivation of IUH. The approaches by Nash and Clark are more practical and widely used models. Only Clark model is discussed in this paper.

5.6 Estimation of Flood Flow

A flood may be defined as an overflow coming from some river or from some other body of water. A river may get flooded due to excessive rainfall or excessive melting of snow or due to some other form of ice obstruction in the form of jams.

Verious methods are used for determining flood flow, which are classified into the following four classes.

5.6.1 Determination by means for Empirical formulae:

Many formulas have been derived for the purpose of estimating flood flows. Some important empirical formulas named are given below.

5.6.1.1 The formulae involving drainage area only

- Dickens formula.
- Ryve's formula.
- Inglis' formula.
- Nawab Jung Bahadur formula.
- W.P. Creager's formula.
- Jarvis formula.
- Modified Myer's formula.

5.6.1.2 Formula Involving Drainage Area and its Shape.

Dredge or Burge's formula.

Pettis formula.

5.6.1.3 Formulae Involving Total Runoff and Drainage Area.

Boston Society of Civil Engineers formula.

5.6.1.4 Formula Involving Rainfall Intessity and Drainage Area.

Rational formula.

5.6.1.5 Formula Involving Drainage Area and Flood Frequency.

fullers formula.

- Determination by Envelope curves;
- Determination by Statistical or Probability methods; and
- Determination by Unit hydrograph method:

Unit Hydrograph method is very useful and reliable method for the determination of flood hydrograph for the small and medium size basin, say up to 5000sq km. For larger basin,

basin has to be subdivided in to smaller sub basins (stream wise) to compute unit hydrograph and flood hydrograph. All the flood hydrograph of the sub basin will then have to be routed upo to the project site by “river routing techniques”. If reservoir will also happen to exist on the travel path, then the flood hydrograph will also have to be routed through them by using “reservoir routing techniques”. The cumulative impact of all the design flood hydrographs will finally by computed at the project site to determine the design flood for such large basins. Such long calculation makes this method unattractive and imprecise for large basins.

To estimate the design flood hydrograph by unit hydrograph method, evaluate the effective design storm (i.e. hyetograph of excess rain), which can be obtained by subtracting the initial loss and infiltration from the design storm. The design storm may be (i) the storm of any selected design frequency or (ii) the probable maximum storm (iii) the slandered project storm.

In order to compute the design storm of the given frequency, the study of developing of I D F curve (Intensity-Duration –frequency curve) for this design frequency is necessary. Such a curve will indicate the maximum rainfall depths. DAD curves have to be developed, when the design frequency is not considered and the flood hydrograph is to be compute for the probable maximum precipitation (PMPs). DAD curves of the basin shall usually be considered to obtain rainfall depth for the “Standard Project Storm”.

5.6.2 Clark’s Model:

In 1945 Clark showed that the IUH may be obtained by routing the rainfall excess over a drainage area by considering the linear channel in series with a linear reservoir. Clark’s has introduced the following two critical processes in the transformation of excess precipitation to runoff.

5.6.2.1 Translation:

Every water particles has to travel certain distance before it reaches to the gauging station, so the peak of DRH occurs after ERH. This is known as translation.

5.6.2.2 Attenuation:

As the quantities of water from different parts of the basin pass through the channel, the channel storage rises, so the depth of highest ERH block is always higher then the depth of peak DR

Magnitude of discharge is reducing as the rainfall excess is stored throughout the watershed, so the depth of highest ERH block is always higher then the depth of peak DRH. The effect is called attenuation.

This means that the flood peak is translated to the to the basin outlet which is the effect of time. Attenuation is achieved due to the storage effect of the catchments. In Clark's model, the translation is first achieved by channel travel time of the time area histogram and the attenuation by routing the output through a linear reservoir at watershed outlet.

Short-term storage of water throughout a watershed—in the soil, on the surface,

and in the channels—plays an important role in the transformation of precipitation excess to runoff. The linear reservoir model is a common representation of the effects of this storage.

Time-Area Histogram:

The general continuity equation of flow is given as

Inflow – Outflow = change in storage

Or $\frac{I_1+I_2}{2}\Delta Tt - \frac{Q_1+Q_2}{2}\Delta Tt = S_2 - S_1$ ……………………………….. (5.3)

Taking $S2 = KQ_2$ and $S1 = KQ_1$ equation (3.5) can be written as

$\Rightarrow$ $0.5 X (I_1 + I_2) \Delta T_t - 0.5 X (Q_1 + Q_2) \Delta T_t = K (Q2 - Q_1)$ …………… (5.4)

Where ΔT_t is the time of travel of water from the end of one isochrones to the other, Q1 and Q2 are the out flows at the beginning and end of ΔT_t, I_1 and I_2 are the time area histograms at the beginning and end of the time interval and K is the storage coefficient. From equation (5.4) we can derive Q_2 as

$Q_2 = Q_0 I_1 + C_1 I_2 + QC_2 Q_1$ ………………………. (5.5)

Where

$C_0 = \frac{0.5\Delta T_t}{K + 0.5\Delta T_t}$ …………………………………… (5.6)

$C_0 = \frac{0.5\Delta T_t}{K + 0.5\Delta T_t}$

And, $C_2 = \frac{K - 0.5\Delta T_t}{K + 0.5\Delta T_t}$ …………………………… (5.7)

The routed outflow from equation (5.5) of the time area histogram gives the required IUH for the basin; I_1 and I2 are the inflow hydrograph ordinates. For routing time-area-histogram $C_0$is taken as C_1as the inflow ΔT_t interval is taken as the block of time area histogram of same travel time ΔT_t in hours, the values of I_1 and I_2 can be taken as equal. The inflow rate due to the inter- isochrones with area in sq. km and 1 cm rainfall excess during time interval ΔT_t is given as

$$I = \frac{A_\gamma X 10^4}{3600 \Delta T_\gamma} = \frac{2.78 A_\gamma}{\Delta T_\gamma} \quad \text{..............................} (5.8)$$

Therefore $Q_2 = 2\ C_1\ I_1 + C_2\ Q_1$ …………….. (5.9)

And $C_0 + C_1 + C_2 = 1.0$ …………………... (5.10)

With Clark's model, the linear reservoir represents the aggregated impacts of all watershed storage. Thus, conceptually, the reservoir may be considered to be located at the watershed outlet.

In addition to this lumped model of storage, the Clark model accounts for the time required for water to move to the watershed outlet. It does that with a linear channel model, in which water is "routed" from remote points to the linear reservoir at the outlet with delay (translation), but without attenuation. This delay is represented implicitly with a so-called time-area histogram. That specifies the watershed area contributing to flow at the outlet as a function of time. If the area is multiplied by unit depth and divided by Δt, the computation time step, the result is inflow, It, to the linear reservoir.

5.6.2.3 Determination of Clark’s UH Model parameters

The required parameters for the Clark’s UH Model are

- Time of Concentration (T_c)
- Storage Coefficient (K)

Properties of the time-area • histogram

The time of concentration defines the maximum travel time in the sub basin. It is used in the development of the translation hydrograph.

The storage coefficient is used in the linear reservoir that accounts for storage affects. Many studies have found that the storage coefficient, divided by the sum of time of concentration and storage coefficient, is reasonably constant over a region i.e.

$$\frac{R}{T_c \, \Gamma R} \mathrm{X} \text{constant over a region} \quad \text{………………………} (5.11)$$

The recession limb of the DRH is expressed as

$$Q_t = Q_0\, e^{-t/k} \text{……………………………………..} (5.12)$$

Where Qt is out flow at any other time t, Q0 is the out flow at the beginning and K is the storage constant. Taking logarithm of the equation (5.12)

$$\ln Q_1 = \frac{-t}{K} Q_0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5.13)$$

Or
$$K = -t \frac{\ln Q_0}{\ln Q_1} = t \frac{\ln Q_t}{\ln Q_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.14)$$

Or
$$K = t \ln \left(\frac{Q_0}{Q_t}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.15)$$

Taking any two points in the recession limb (t1, Q_1) and (t2, $Q_{2)}$, Two equations of (5.15) are formed. Subtracting one from the other, the only unknown Q_0 is computed. Resubstituting the values we get K in hours.

T_t is determined from the plot of the observed DRH and ERH. It is the distance along X axis between the end of ERH and the point of contra flexure (inflection) of recession limb of DRH.

5.7 Estimation of base flow:

HEC-HMS program provides three models (constant monthly model, exponential recession model and linear reservoir model).to represent watershed base flow.

5.7.1 Exponential Recession Model:

The program includes a exponential recession model to represent watershed baseflow (Chow, Maidment, and Mays, 1988). The recession model has been used often to explain the drainage from natural storage in a watershed (Linsley et al, 1982). It defines the relationship of Q_t, the base flow at any time *t*, to an initial value as:

$$Q_t = Q_0 K^t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5.16)$$

Where Q_0 = initial base flow (at time zero); and k = an exponential decay constant. The base flow thus computed is illustrated in figure (5.1). The shaded region represents base flow in this figure; the contribution decays exponentially from the starting flow. Total flow is the sum of the base flow and the direct surface runoff.

As implemented in the program, k is defined as the ratio of the base flow at time t to the base flow one day earlier. The starting base flow value, Q_0, is an initial condition of the model.

It may be specified as a flow rate (m^3/s or cfs), or it may be specified as a flow per unit area ($m^3/s/km^2$ or cfs/sq mi).

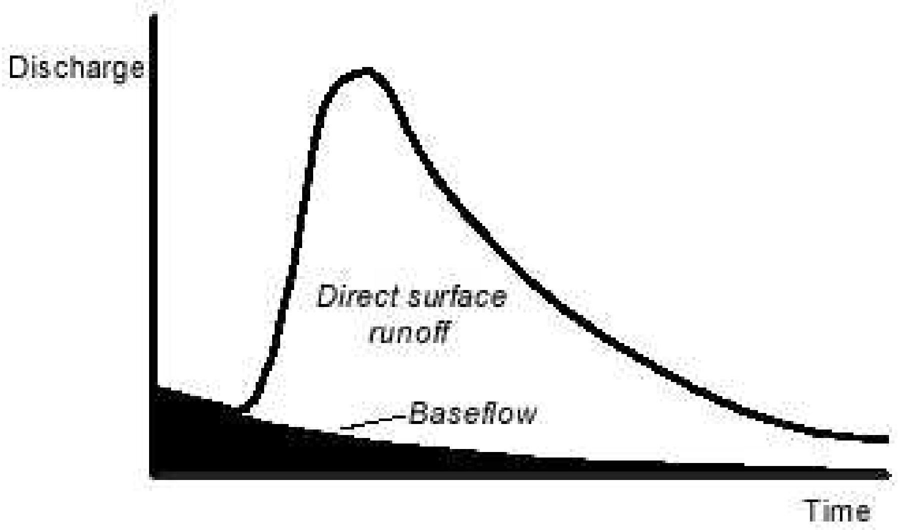

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Figure 5-1:- Initial base flow recession

The recession base flow model is applied both at the start of simulation of a storm event, and later in the event as the delayed subsurface flow reaches the watershed channels, as illustrated in figure(5.2). User -specified threshold flow defines when recession model governs total flow.

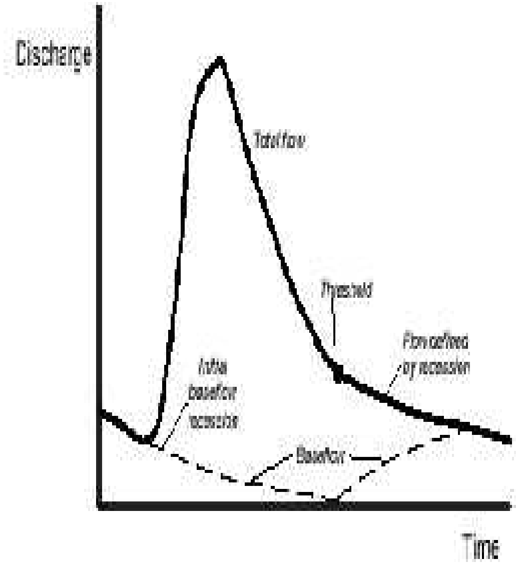

Figure 5-2:- Base flow model illustration

5.8 Shakya B (2002) Formula

In Nepal, 24 hour rainfall data is only published, in such situation a relation between 24 hour rainfall and rainfall less than 24 hours duration is necessary to have rainfall of required duration. Such relationship was derived by Shakya B (2002).

$$\frac{P_t}{P_{24}} \mathrm{X}\sin \frac{\text{®} \,|\, t}{48}^{0.4727} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5.17)$$

Where, t is duration in hours and P_{24} is one day rainfall and sine of angle is in radian.

5.9 Alternating Block Method

This method is used to develop design hyetograph by using an intensity-duration-frequency curve. The design hyetograph produced by this method specifies the precipitation depth occurring in ‘n’ successive time intervals of duration $T_d = n\Delta t$.

6 ANALYSIS

6. 1 Analysis:

From the data of 10 July 1992 one of the biggest events of the isolated rainfall storm (Appendix I) was used to calibrate the rainfall runoff process parameters of Jhikhu Khola watershed. For this half hourly rainfall data was used along with the same interval runoff data to optimize the basin parameters using HEC-HMS version 2.2.2. Thus the optimized values for the following parameters were obtained.

Table 6-1 Unit Hydrograph Parameters for Jhikhu Kholo watershed

Parameter	Unit	Initial Value	Constraints		Optimized value	Objective Function (Sensitivity)
			Maximum	Minimum		
Initial loss	mm	5.000	0.00100	5000	5.000	0.000
Constant loss rate	mm/hr	69.378	0.00100	3000	69.3780	-14.77
Clark storage coefficient	hr	1.481	0.01000	1000	1.471	-0.08
Initial base flow	m^3/s	3.92	0.00100	100000	4.969	-0.04
Recession constant	n/a	0.00135	0.00001	1	0.000267	0.02
Recession threshold flow	m^3/s	18.2	0.00100	100000	17.100	-0.03
Time of concentration	hr	1.16	0.10000	10000	1.129	-0.07

These optimized values were used for the validation of the model for the rainfall events as given in the table.

Table 6-2 Major Rainfall events data used for model validation.

Date	**Daily Rainfall (mm)**
15-May-1998	46.00
26-May-1998	33.00
21-Jun-1998	35.80
26-Jun-1998	37.50
8-Jul-1998	42.00
21-Jul-1998	40.40
19-Aug-1998	24.00
21-Aug-1998	46.50
27-Aug-1998	28.40
5-Sep-1998	28.00
6-Sep-1998	69.00

From the rainfall of the dates mentioned the runoff hydrograph was computed for the given periods.

For the purpose of the calibration and validation, of the rainfall-runoff process three model components were prepared. First is the basin model. In the basin model, Clark unit hydrograph was used for the direct runoff (Unit Hydrograph), exponential recession method was for the base flow, and Initial and constant-rate was used for the runoff volume computation. Second component was meteorological model. For this component user specified hyetograph was used. Thirdly the control specification was prepared which provides the time duration for the hydrograph generation.

RESULT AND DISCUSSION

7.1 Model calibration:

The trial and error method was utilized during optimization process so as to decide appropriate values of basin model parameters. The obtained parameters are given in Table 6.2 which is as follows; the initial loss was optimized as 5 mm, 69.378 mm/hr was the constant loss rate, Clark storage coefficient was computed as 1.471 hr, time of concentration was 1.129 hr, initial base flow was 4.962 m3/s, recession constant was 0.000267 and Recession threshold flow was 17.1 m^3/s, mention Adhikari Tirtha (2008). The Clark's unit hydrograph of the event in 10 Jul 1992 in Jhikhu Khola watershed as shown in Figure (7.1) and the Optimized hydrograph along with observed hydrograph for 10th July 1992 as shown in figure (7.2).

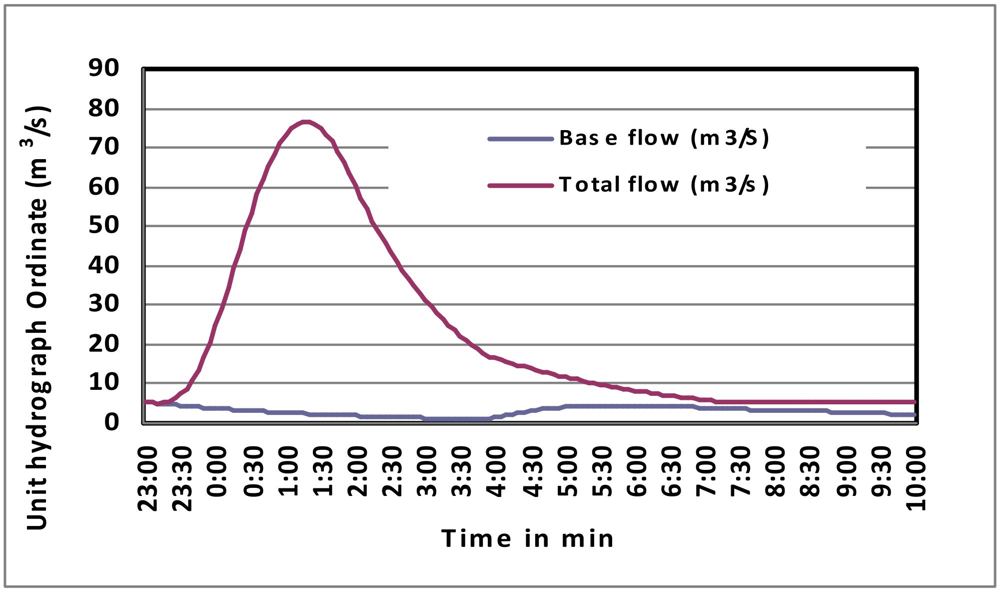

Figure 7-1 Clark's Unit Hydrograph of the event in 10 July 1992

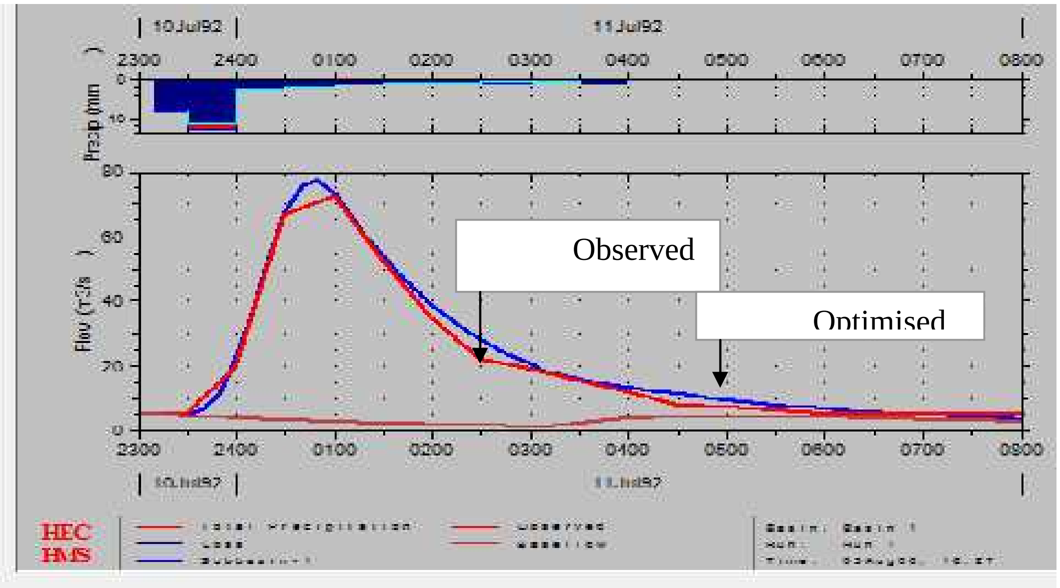

Figure 7-2:- Optimized hydrograph along with observed hydrograph for 10th July 1992

7.2 Model validation

From the obtained values of the basin model from table (6.1) the basin model was used to generate the output hydrograph of the rainfall for the events mentioned in table (6.2)

The results of the computation from the model for the discharge hydrograph of the above mentioned dates are given in table 7.1

Table 7-1 Computed values obtained using the simulation model.

Date	Peak Discharge (m^3/s)	Total loss (mm)	Total Direct Runoff (mm)	Total base flow (mm)	Total Excess (mm)	Discharge (mm)
15-May-98	39.66	40.30	2.63	1.06	2.63	3.69
26-May-98	27.45	29.05	1.75	1.07	1.75	2.82
21-Jun-98	98.01	23.33	7.45	0.87	7.47	8.83
26-Jun-98	56.63	30.87	4.16	0.94	4.16	5.10
8-Jul-98	62.43	34.62	4.16	0.97	4.61	5.59
21-Jul-98	57.53	35.32	4.11	1.19	4.12	5.30
19-Aug-98	85.31	16.05	6.34	1.64	6.35	7.97
21-Aug-98	188.95	28.33	15.07	1.63	15.1	16.70
27-Aug-98	53.65	22.56	3.97	0.86	3.97	4.83
5-Sep-98	88.31	19.26	6.88	1.06	6.88	7.94
6-Sep-98	96.09	57.43	6.99	1.49	6.99	8.48

From the obtained hydrograph the rainfall event with maximum peak was in 21st Aug 1998 and it was 188.95 m^3/s. Minimum discharge was obtained in 26-May-1998, it was 27.45 m3/s. The generated flow from 24 hours rainfall data converted 10 minutes discharge from HEC-HMS model presented in Appendix III. The computed flow hydrograph of biggest event is also present in Figure A-1.

The hydrograph obtained from the model for the major rainfall events in different dates are as given in appendix (IV).

7.3 Relationship between rainfall and base flow:

Regression equation of the rainfall and base flow was carried out, it shows a linear relation ship of the equation y=.007x+0.877 with the reliability value R^2 is 0.051, fig (7.15) this shows there is less reliability in the relation ship and the correlation of these rainfalls and runoff is not strong.

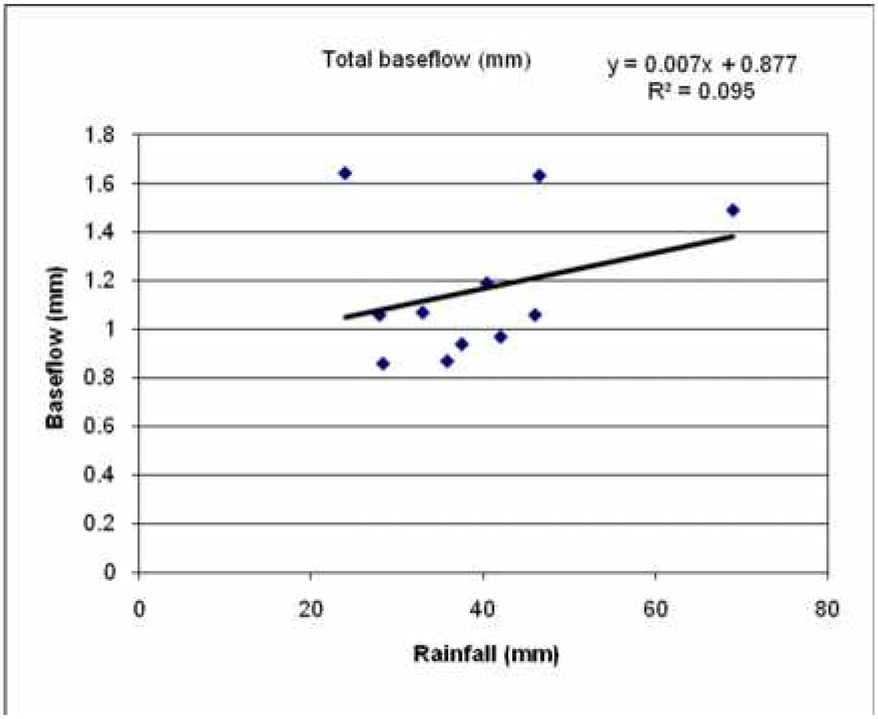

Figure 7- 3 The relationship between rainfall and base flow.

7.4 Relationship between rainfall and total excess

A plot of total rainfall vs. total excess has been represented with linear equation as, Y= 0.064X + 3.302. The computed reliability R^2 is 0.048 which shows the relationship between rainfall and total excess is not strong.

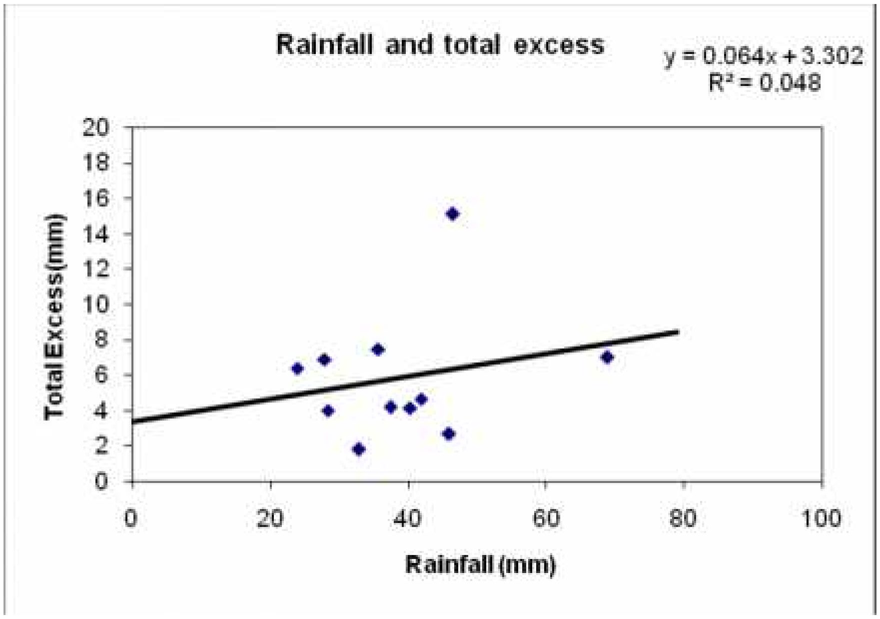

Figure 7-4 The relationship between rainfall and total losses

7.5 Relationship between rainfall and total loss:

The average infiltration and unit hydrograph parameters including the establishment of the relationship between infiltration loss and rainfall has been represented by equation Y= 0.876X -3.663 Adhikari (2008). The result shows the high degree of reliability in the relationship between rainfall and total losses.

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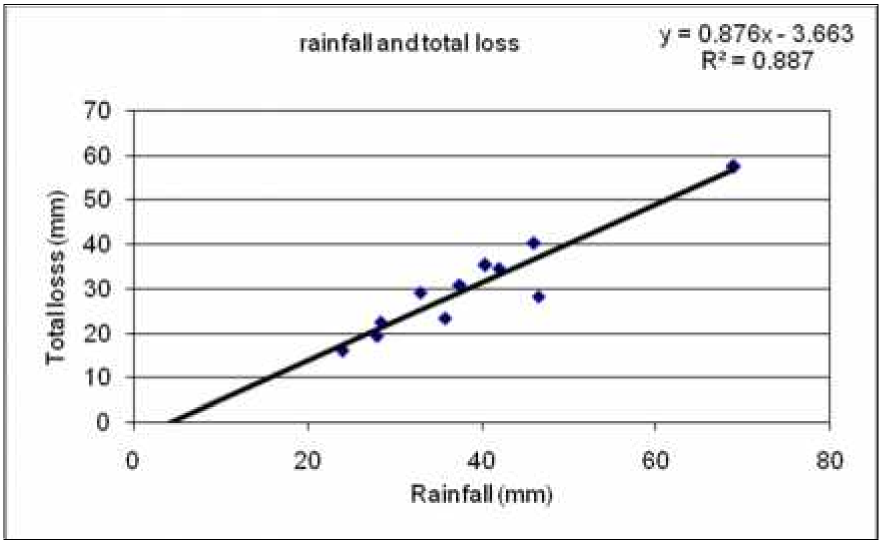

Figure 7-5 The relationship between rainfall and total loss.

7.6 Relationship Between Rainfall and Direct Runoff:

A plot of rainfall vs. direct runoff has been represented with linear equation as, Y= 0.063X -3.288. The reliability so obtained R^2 is 0.047 which shows the low degree of reliability in the relationship between rainfall and total losses.

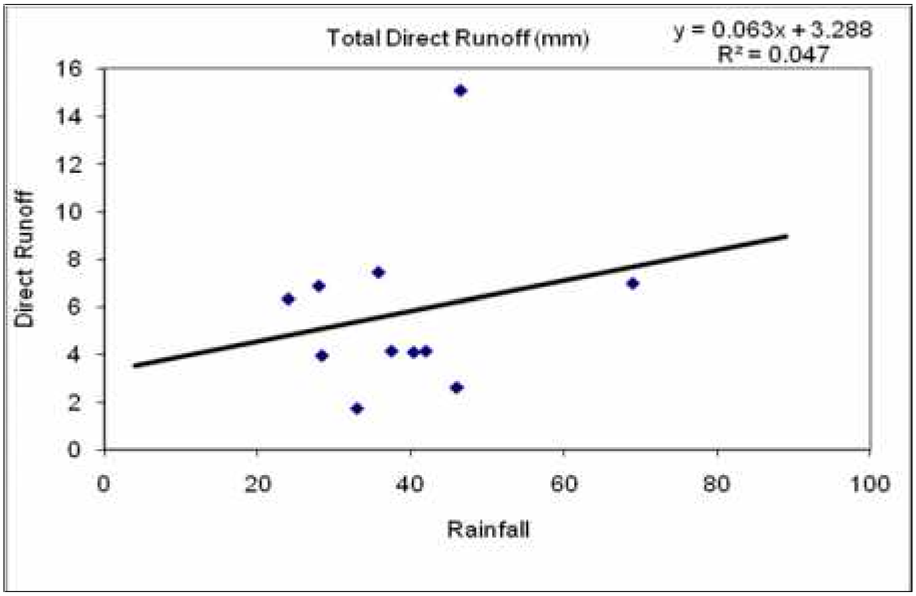

Figure 7-6 The relationship between rainfall and direct runoff.

7.7 Relationship between rainfall and constant rate of infiltration:

A plot of constant rate of infiltration and rainfall has been represented with linear equation as, Y= 0.578X - 4.610. The reliability of the obtained linear co-relation equation R^2 is 0.819, which shows the high degree of reliability in the relationship between constant rate of infiltration and to rainfall.

Table 7-2 Constant rate of infiltration of selected rainfall events.

Date	Rainfall (mm)	Constant rate of Infiltration (mm)
15-May-98	46	25.6
26-May-98	33	18.5
21-Jun-98	35.8	12.5
26-Jun-98	37.5	18.7
8-Jul-98	42	21.1
21-Jul-98	40.40	20.5
19-Aug-98	24	8
21-Aug-98	46.5	15
27-Aug-98	28.4	13
5-Sep-98	28	10
6-Sep-98	69	35.2

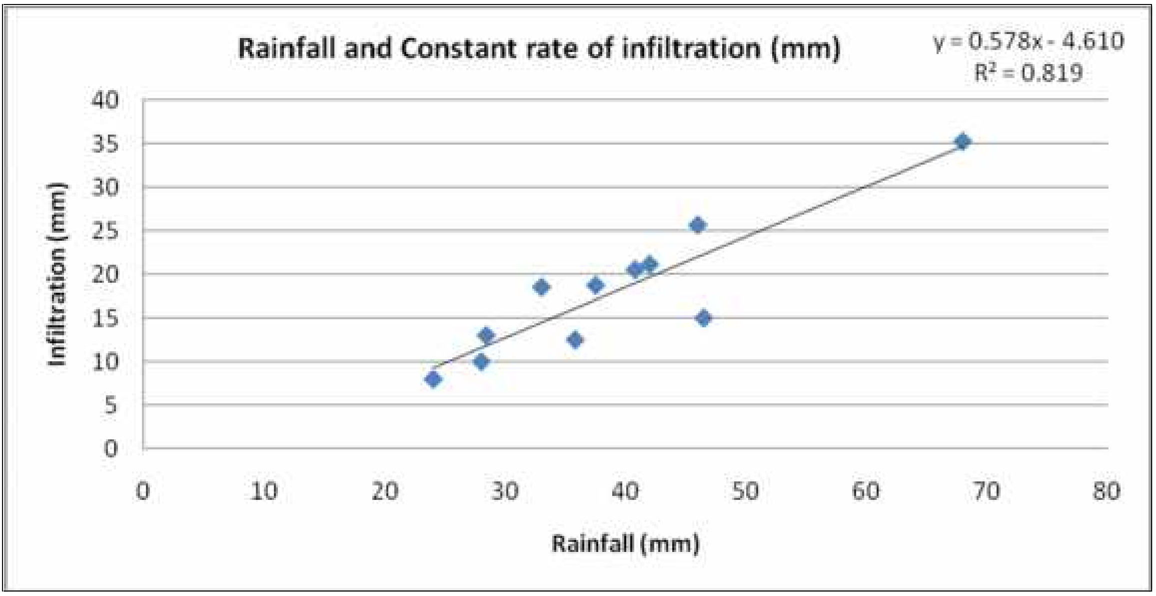

Figure 7-7 The relationship between rainfall and constant rate of infiltration

7.8 Comparison of observed, simulated discharge and constant loss of selected rainfall events.

The comparison of observed and simulated discharge values are shown in Table 7-3. A good relation having average of about ±0.4% was observed between them. However there are some exceptionally high differences of +5.029% in 21 July 1998, because the rainfall was received on previous 3 days regularly in the entire whole watershed. So, the calculated peak is found to be lower than observed peak. Similarly, the difference of -3.917% in 26 Jun 1998 occurs, because of no rainfall received up to 3 days as the soil was drier and so hydrograph characteristics of calculated peak is found to be higher than observed peak. The relative difference is found to be ±0.399 (Table 7.3) from observed and calculated discharge. As there is no such variation found, HEC-HMS model can be used to estimate peak discharge from daily rainfall data.

Table 7-3 Comparison of observed, simulated discharge and constant loss of selected rainfall events.

Date	Constant loss rate (mm/hr)	Comparison of discharge		
		Observed (Q)	Simulated (Q)	Relative different (%)
15-May-98	25.6	6.012	6.12	-1.796
26-May-98	25.0	5.809	5.91	-1.739
21-Jun-98	11.409	8.284	8.36	-0.917
26-Jun-98	18.72	12.279	12.76	-3.917
8-Jul-98	69.378	18.174	18.27	-0.528
21-Jul-98	20.5	13.741	13.05	5.029
19-Aug-98	12.0	12.495	12.49	0.040
21-Aug-98	15.0	16.572	16.96	-2.341
27-Aug-98	13.0	11.185	11.01	1.565
5-Sep-98	10.0	9.392	9.38	0.128
6-Sep-98	35.2	27.044	27.02	0.089

±0.399

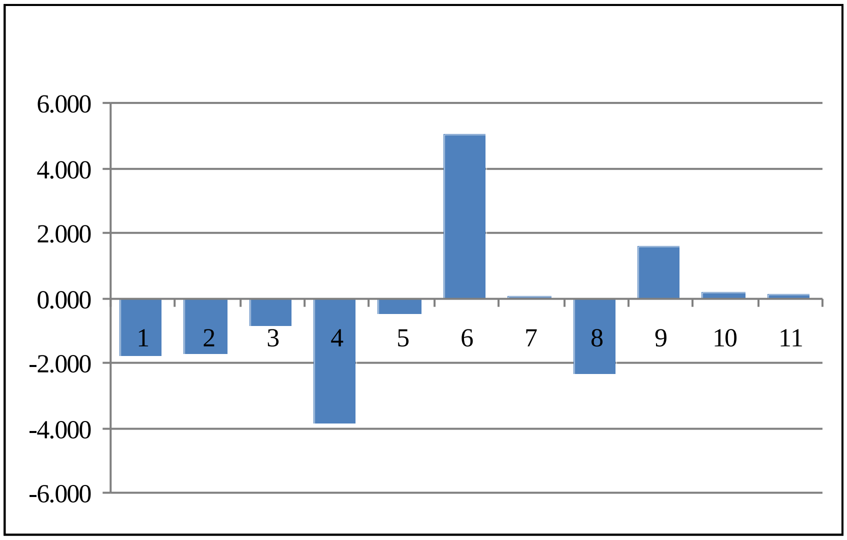

Figure 7-8 Relative different of measured and observed hydrograph characteristics.

8 CONCLUSION

8.1 Conclusion:

Result of the optimization of the hydrological parameters can be stated to have Clark's storage coefficient (R) of 1.4714 hr and time of concentration (Tc) of 1.129 hr have for rainfall event in 10th July 1992. On the basis of this unit hydrograph peak discharge and the direct runoff for different dates are calculated. The highest peak flood has been found as 188.95 m^3/s in 21 Aug 1998 and lowest peak flood as 27.45 m^3/s in 26 May 1998. The regression equation has been developed from the data. A plot of rainfall vs. total loss has been represented with linear equation as, Y= 0.876X -3.663. The reliability so obtained R^2 is 0.887. A plot of rainfall vs. constant rate of infiltration has been represented with linear equation as, Y= 0.578X - 4.610. The reliability so obtained R^2 is 0.819. The regression analysis between rainfall and base flow; rainfall and total excess; Rainfall and Direct Runoff shows weak relation between rainfall vs. baseflow, total excess and direct runoff. A Constant loss rate value is higher in pre monsoon than in the mid to the end of monsoon.

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Appendix (I)

Table A-1: Cumulated Rainfall and Observed Discharge in 10 July 1992

Date	Time (hrs)	Time (min)	Cumulated Rainfall(mm)	Observed Dischargem^{3}s	Remarks
10th july1992	3.00	00	0	5.3	
	3.30	30	24.62	5.3	
	0.00	60	64.40	19.2	
	0.30	90	71.03	66.5	
	1.00	120	77.18	72.4	
	1.30	150	80.02	52.2	
	2.00	180	81.92	34.5	
	2.30	210	84.28	22.2	
	3.00	240	85.65	18.9	
	3.30	270	86.65	15.6	
	4.00	300	90.44	12.0	
	4.30	330		8.0	
	5.00	360		7.2	
	5.30	390		6.2	
	6.00	420		5.4	
	6.30	450		5.3	
	7.00	480		5.3	

Appendix: (II)

Table A-2: One day rainfall and discharge of major events in 1998

Data	1day Rainfall(24hrs mm)	1day discharge (24hrs m^3s)	Previous data	1day Rainfall(24hrs mm)	1 day discharge (24 hrs m^3s)
15 may 1998	46.0	6.012	14 may 1998	0.0	9.293
26 may 1998	33.0	5.809	25 may 1998	0.0	6.326
21 June 1998	35.8	8.284	20 June 1998	0:0	4.662
26June 1998	37.5	12.279	25 June 1998	0:0	4.841
8 July 1998	42.0	18.174	7 July 1998	0:0	4.757
21 July1 998	40.2	13.741	20 July 1998	11:4	17.597
19 Aug 1998	24.0	12.459	18 Aug 1998	28.2	17.087
21 Aug 1998	46.5	16.572	20 Aug 1998	0:0	16.725
5 Sep 1998	28.0	9.392	4 Sep 1998	0.0	4.737
6 Sep 1998	69.0	27.044	5 Sep 1998	28:0	9.392

Lowest discharge in 21 May 1998 =3.624 and highest discharge in 14 May = 9.293

Lowest discharge in 7 Jun 1998 =3.660 and highest discharge in 26Jun = 12.279

Lowest discharge in 5 July 1998 =4.546 and highest discharge in 8 July =18.174

Lowest discharge in 29 Aug 1998 =5.758 and highest discharge in 18 Aug =17.087

Lowest discharge in 28 Sep 1998 =1.022 and highest discharge in 6 Sep =27.044

Appendix (III)

Table A-1 : 24 hours rainfall data converted 10 minutes discharge from HEC-HMS model.

Time	5-Sep	6-Sep	27-Aug	21-Aug	19-Aug	8-Jul	21-Jul	26-Jun	21-Jun	26-May	15-May	10-Jul
0	5	10	4	15	14	5	5	5	5	6	6.01	5.3
0.1	4.722	9.445	3.778	14.167	13.222	4.722	4.722	4.722	4.722	5.667	5.676	5.006
0.2	4.465	8.932	3.573	13.388	12.492	4.467	4.466	4.466	4.466	5.358	5.369	4.743
0.3	4.235	8.481	3.393	12.842	11.814	4.247	4.24	4.243	4.24	5.082	5.101	4.539
0.4	4.719	9.55	3.726	14.794	11.54	4.991	5.111	4.885	5.111	5.238	5.552	5.672
0.5	7.557	14.63	5.723	22.814	12.989	8.295	9.119	7.834	9.119	6.583	7.879	10.32
0.6	14.285	25.28	10.453	39.085	17.772	15.15	17.757	13.998	17.757	9.666	12.8	19.84
0.7	25.254	41	17.998	63.597	26.426	25.28	31.175	23.138	31.175	14.257	19.914	33.47
0.8	39.529	59.12	27.427	93.754	38.399	37.05	47.974	33.769	47.974	19.35	27.677	48.3
0.9	55.452	76.51	37.407	125.78	52.4	48.51	66.037	44.114	66.037	23.851	34.441	61.25
1	70.351	89.68	46.081	154.48	66.121	57.41	82.183	52.145	82.183	26.739	38.699	69.47
1.1	81.376	96.09	51.686	175	76.936	62.03	93.192	56.299	93.192	27.453	39.657	71.47
1.2	87.264	96	53.65	186.19	83.341	62.43	98.013	56.631	98.013	26.278	37.855	68.27
1.3	88.306	91.47	52.57	188.95	85.307	59.83	97.333	54.252	97.333	24.096	34.633	62.39
1.4	85.606	84.8	49.567	184.76	83.699	55.67	92.646	50.461	92.646	21.794	31.254	56.2
1.5	80.298	77.29	45.488	175.28	79.45	50.8	85.428	46.046	85.428	19.697	28.183	50.57
1.6	73.542	69.62	40.994	162.36	73.553	45.74	77.113	41.468	77.113	17.784	25.387	45.45
1.7	66.539	62.44	36.716	148.11	67.102	40.99	69.081	37.17	69.081	16.474	22.844	40.79
1.8	59.843	55.98	32.873	133.77	60.682	36.71	61.831	33.303	61.831	15.559	20.536	36.57
1.9	53.596	50.17	29.426	119.98	54.547	32.87	55.308	29.83	55.308	14.695	18.451	32.76
2	47.938	44.97	26.341	107.38	48.944	29.44	49.466	26.719	49.466	13.879	16.83	29.34
2.1	42.881	40.31	23.583	96.117	43.928	26.36	44.246	23.937	44.246	13.108	15.895	26.28
2.2	38.362	36.15	21.118	86.047	39.436	23.62	39.58	21.449	39.58	12.38	15.012	23.55
2.3	34.323	32.42	18.913	77.043	35.415	21.16	35.411	19.223	35.411	11.692	14.178	21.1
2.4	30.713	29.08	16.971	68.992	31.813	18.96	31.684	17.232	31.684	11.043	13.391	18.91
2.5	27.486	24.9	16.028	61.793	28.586	16.76	28.353	16.176	28.353	10.43	12.647	16.98
2.6	24.602	24.8	15.138	55.355	25.695	16.76	25.376	15.277	25.376	9.85	11.945	16.03
2.7	22.023	24.7	14.297	49.596	23.104	16.76	22.714	14.429	22.714	9.303	11.281	15.14
2.8	19.717	24.6	13.503	44.445	20.782	16.76	20.334	13.627	20.334	8.787	10.655	14.3
2.9	17.656	24.5	12.753	39.837	18.7	16.76	18.207	12.871	18.207	8.299	10.063	13.51
3	16.431	24.5	12.045	35.714	16.914	16.76	16.648	12.156	16.648	7.838	9.504	12.76
3.1	15.518	24.5	11.376	32.025	15.974	16.76	15.724	11.481	15.724	7.402	8.976	12.05
3.2	14.656	24.5	10.744	28.724	15.087	16.76	14.85	10.843	14.85	6.991	8.478	11.38
3.3	13.842	24.5	10.147	25.769	14.249	16.76	14.026	10.843	14.026	6.603	8.007	10.75
3.4	13.074	24.5	9.584	23.124	13.458	16.76	13.247	10.843	13.247	6.236	7.562	10.15
3.5	12.348	24.5	9.052	20.757	12.71	16.76	12.511	10.843	12.511	5.89	7.142	9.587
3.6	11.662	24.5	9.052	18.636	12.004	16.76	11.816	10.843	11.816	5.563	6.746	9.055
3.7	11.014	24.5	9.052	16.866	11.338	16.76	11.16	10.843	11.16	5.254	6.371	8.552
3.8	10.402	24.5	9.052	15.93	10.708	16.76	10.54	10.843	10.54	4.962	6.017	8.077
3.9	9.825	24.5	9.052	15.045	10.113	16.76	9.955	10.843	9.955	4.686	5.683	7.628
4	9.279	24.5	9.052	14.209	9.552	16.76	9.402	10.843	9.402	4.426	5.367	7.205
4.1	8.764	24.5	9.052	13.42	9.021	16.76	8.88	10.843	8.88	4.18	5.069	7.205

4.2	8.277	24.5	9.052	12.675	8.52	16.76	8.387	10.843	8.387	3.948	4.788	7.205
4.3	7.817	24.5	9.052	11.971	8.047	16.76	7.921	10.843	7.921	3.729	4.522	7.205
4.4	7.383	24.5	9.052	11.306	8.047	16.76	7.481	10.843	7.481	3.729	4.271	7.205
4.5	6.973	24.5	9.052	10.678	8.047	16.76	7.065	10.843	7.065	3.729	4.271	7.205
4.6	6.586	24.5	9.052	10.085	8.047	16.76	6.673	10.843	6.673	3.729	4.271	7.205
4.7	6.22	24.5	9.052	9.525	8.047	16.76	6.302	10.843	6.302	3.729	4.271	7.205
4.8	5.875	24.5	9.052	8.996	8.047	16.76	5.952	10.843	5.952	3.729	4.271	7.205
4.9	5.548	24.5	9.052	8.496	8.047	16.76	5.622	10.843	5.622	3.729	4.271	7.205
5	5.24	24.5	9.052	8.024	8.047	16.76	5.31	10.843	5.31	3.729	4.271	7.205
5.1	4.949	24.5	9.052	7.579	8.047	16.76	5.015	10.843	5.015	3.729	4.271	7.205
5.2	4.674	24.5	9.052	7.158	8.047	16.76	5.015	10.843	5.015	3.729	4.271	7.205
5.3	4.415	24.5	9.052	6.76	8.047	16.76	5.015	10.843	5.015	3.729	4.271	7.205
5.4	4.415	24.5	9.052	6.385	8.047	16.76	5.015	10.843	5.015	3.729	4.271	7.205
5.5	4.395	24.5	9.052	6.01	8.047	16.76	5.015	10.843	5.015	3.729	4.271	7.205
5.6	4.395	24.5	9.052	5.635	8.047	16.76	5.015	10.843	5.015	3.729	4.271	7.205
5.7	4.395	24.5	9.052	5.635	8.047	16.76	4.814	10.843	4.814	3.729	4.271	7.205
5.8	4.395	24.5	9.052	5.635	8.047	16.76	4.55	10.843	4.55	3.729	4.271	7.205
5.9	4.395	24.5	9.052	5.244	8.047	16.76	4.286	10.843	4.286	3.729	4.271	7.205
6	4.395	24.5	9.052	5.244	8.047	16.76	4.022	10.843	4.022	3.729	4.271	7.205
6.1	4.395	24.5	9.052	5.244	8.047	16.76	3.758	10.843	3.758	3.729	4.271	7.205
6.2	4.395	24.5	9.052	5.244	8.047	16.76	3.494	10.843	3.494	3.729	4.271	7.205
6.3	4.395	24.5	9.052	5.244	8.047	16.76	3.23	10.843	3.23	3.729	4.271	7.205
6.4	4.395	24.5	9.052	5.244	8.047	16.76	2.966	10.843	2.966	3.729	4.271	7.205
6.5	4.395	24.5	9.052	5.244	8.047	16.76	2.702	10.843	2.702	3.729	4.271	7.205
6.6	4.395	24.5	9.052	5.244	8.047	16.76	2.438	10.843	2.438	3.729	4.271	7.205
6.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
6.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
6.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
7.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
8.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205

9.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
9.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
10.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
11.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
12.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
13.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205

14	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
14.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
15.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
16.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
17.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
18	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
18.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
18.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
18.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
18.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
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18.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
18.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205

18.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
19.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
20	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
20.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
20.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
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20.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
21	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
21.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
21.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
21.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
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21.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
21.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
22.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.1	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.2	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.3	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.4	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.5	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.6	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.7	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205

23.8	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
23.9	4.395	24.5	9.052	5.244	8.047	16.76	2.174	10.843	2.174	3.729	4.271	7.205
24	**4.395**	24.5	9.052	**5.244**	**8.047**	16.76	2.174	10.843	2.174	**3.729**	4.271	7.205
	9.3788	**27.02**	**11.012**	**16.962**	**12.494**	**18.27**	**8.2041**	**12.757**	**8.2041**	**5.11499**	**6.2051**	**10.27**

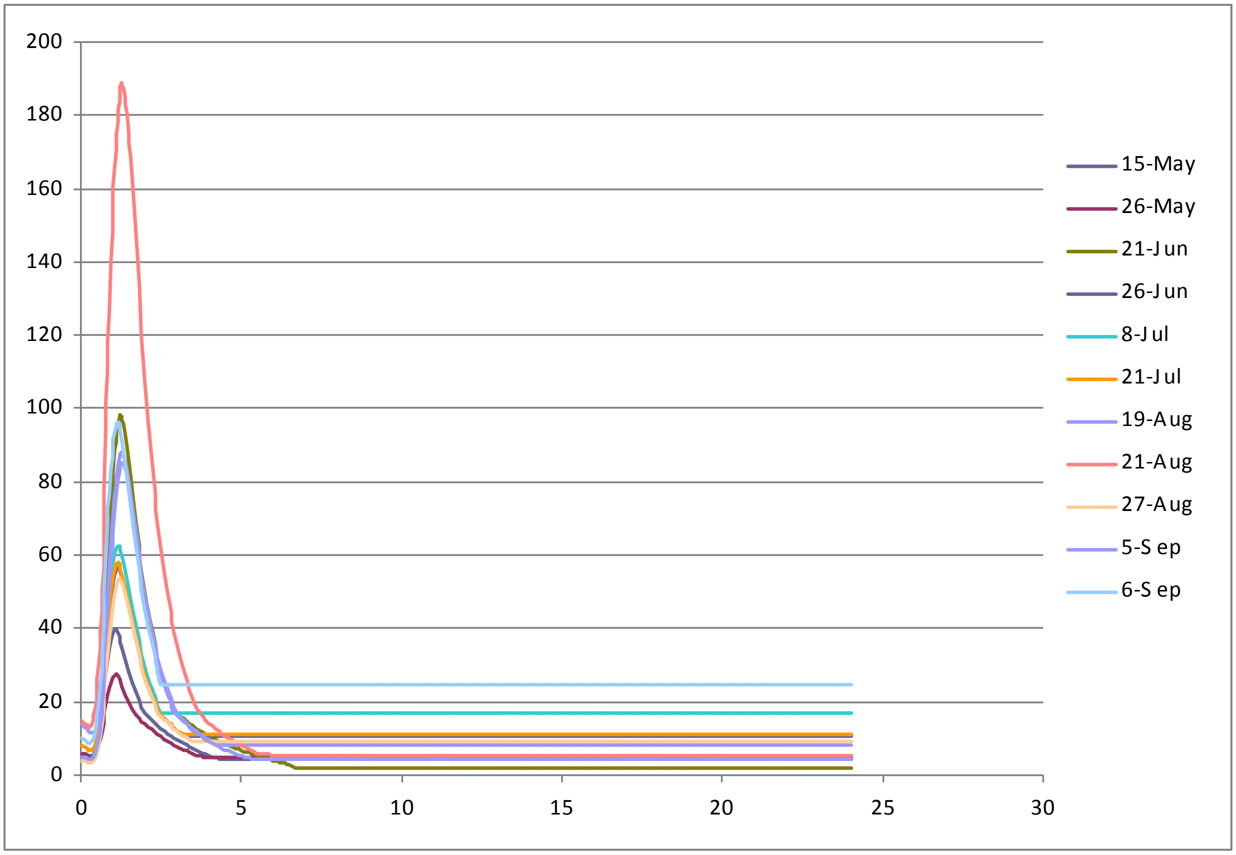
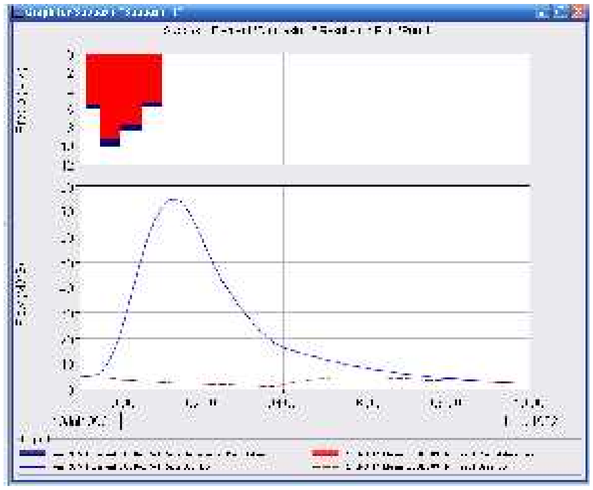


Figure A-1: Hydrograph of major rainfall event in 1998

Appendix (IV)



1.1.1. Figure A-2: Hydrograph of the event in 10 July 1992

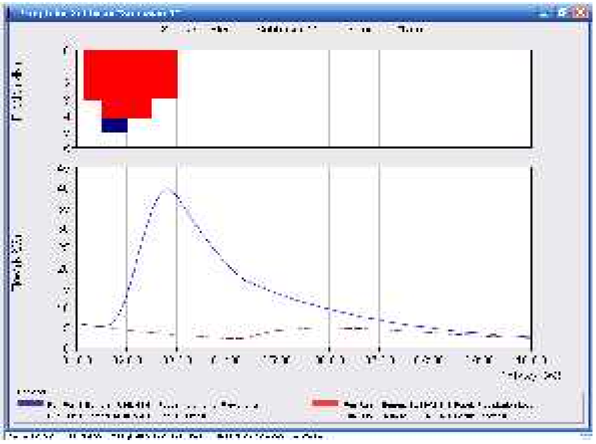


Figure A-3:- Hydrograph of the event in 15 May 1998

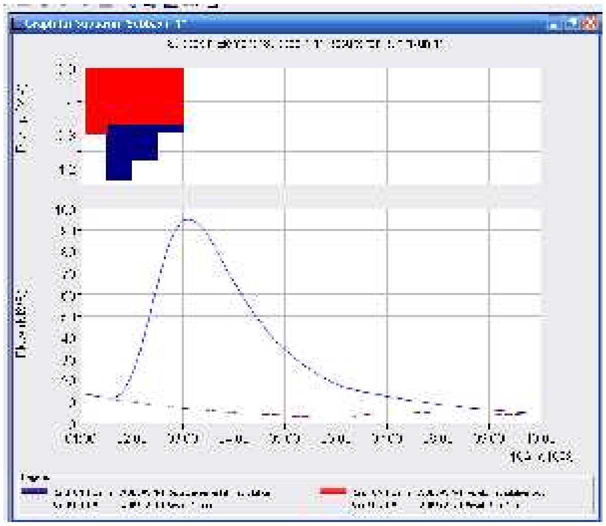


Figure A-4:- Hydrograph of the event in 19 Aug 1998

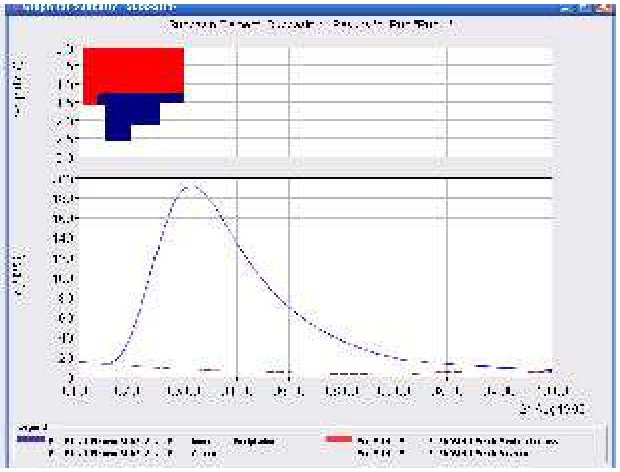


Figure A-5:- Hydrograph of the event in 21 Aug 98

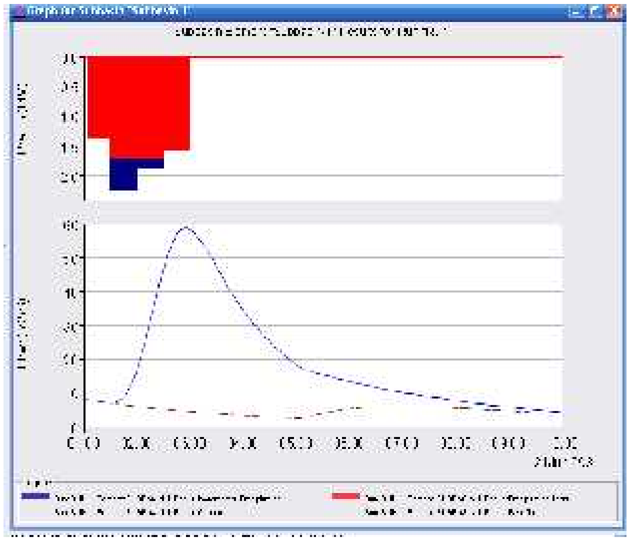


Figure A-6:- Hydrograph of the event in 21 July 98

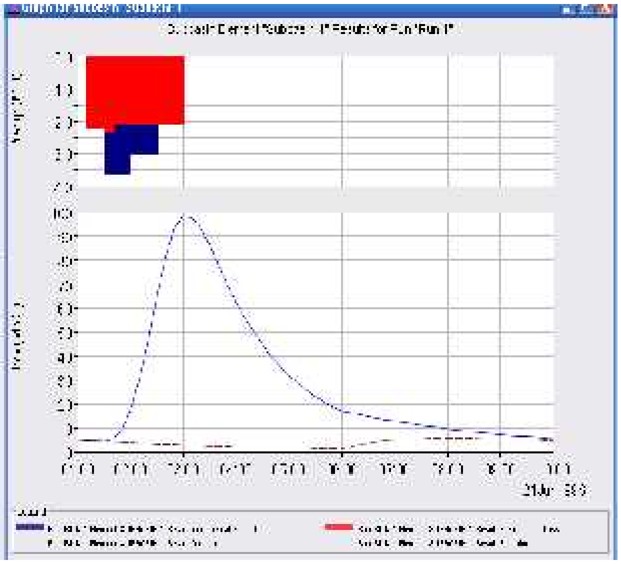


Figure A-7:- Hydrograph of the event in 21 Jun 98

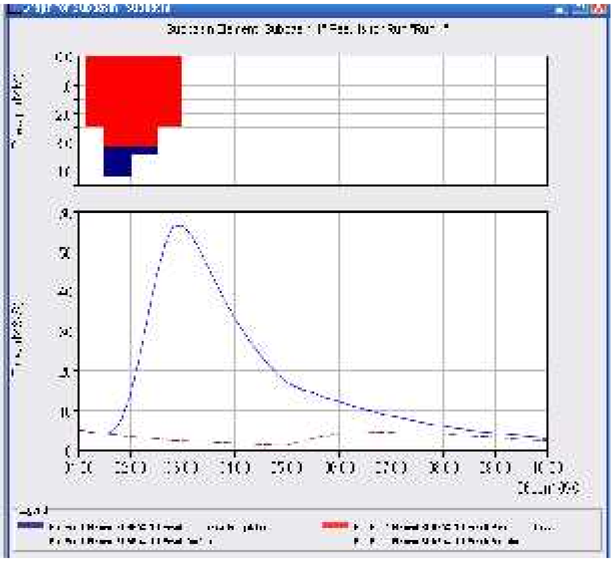


Figure A-8:- Hydrograph of the event in 26 Jun 98

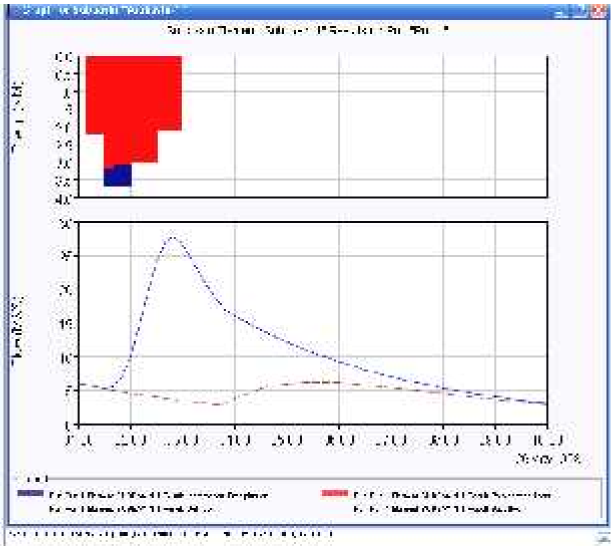


Figure A-9 :- Hydrograph of the event in 26 may 98

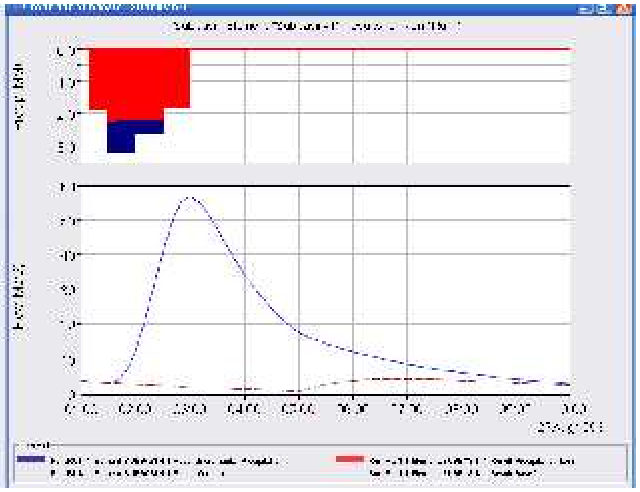


Figure A-10:- Hydrograph of the event in 27 August 1998

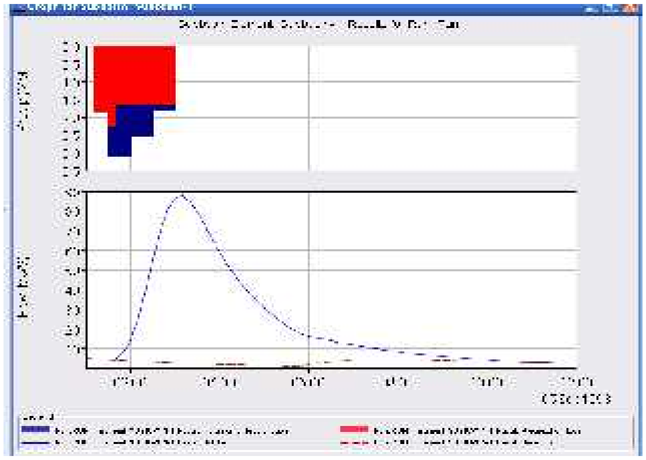


Figure A-11:- Hydrograph of the event in 5 September 1998

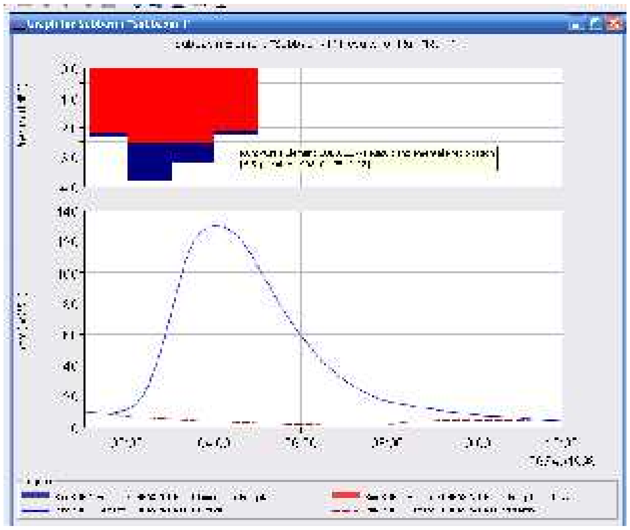


Figure A-12 :- Hydrograph of the event in 6 September 1998

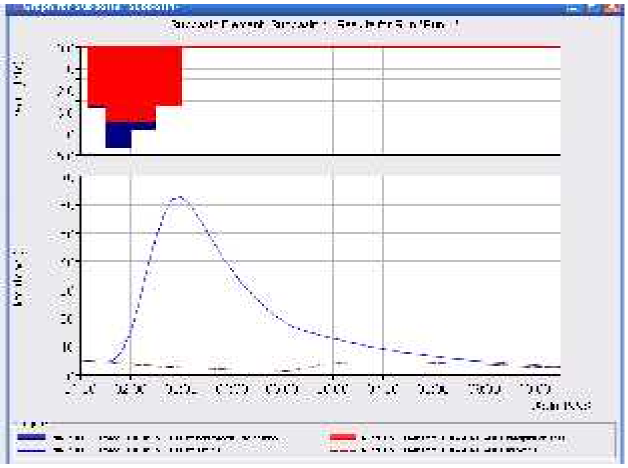


Figure A-13:- Hydrograph of the event in 8 July 1998