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RAINFALL RUNOFF MODELING BETWEEN TR-55 HYDROLOGIC WATERSHED MODEL AND OVERLAND TIME OF CONCENTRATION MODEL

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ABSTRACT

The rainfall-runoff process in a catchment is a complex and complicated phenomenon governed by large number of known and unknown physiographic factors that vary both in space and time. Application of mathematical modeling techniques to the constituent processes involved in the physical processes of runoff generation has led to better understanding of the processes and their interaction. Conventional hydrological models for the prediction of runoff particularly over a basin require considerable hydrological and meteorological data. Collection of these data is expensive, time consuming and difficult process. Remote Sensing technology and Geographical Information Systems (GIS) can augment the conventional methods to a great extent in rainfall runoff studies.

In the present study a small agricultural watershed rainfall-runoff model was chosen. The advantage of formulating this model for the watershed is that it enables to generate the runoff. Once the model is formulated, calibrated and validated, the same can be applied to any watershed to estimate the runoff, even if the sub catchment is ungauged.

Keeping these points in view, the rainfall-runoff model, Overland Time of Concentration Model has been formulated and developed. It contains three modules namely Time of Concentration, Rainfall and Soil Moisture module for the estimation of daily runoff. Pamena – I Watershed, Chevella Mandal, Rangareddy District, Andhra Pradesh, India has been considered for the study. It is concluded that the developed OTC model is a fairly good model and it is comparable with the standard model considered in the present study i.e. TR-55 Model.

Key words: Technical Release – 55, Overland time of concentration, soil moisture module, remote sensing, Geographical Information Systems (GIS)

INTRODUCTION

Watershed modeling is a comprehensive program to determine runoffs using standard techniques. Model flood control structures such as detention basins with various outlet structures, use actual or synthetic rainfall distributions. Watershed modeling includes rainfall maps for the entire area to calculate intensity duration frequency relationships. [1] The rainfall-runoff process in a watershed is a complex and complicated phenomenon governed by large number of known and unknown physiographic factors that vary both in space and time. The rain falling on a catchment undergoes number of transformations and abstractions through various component processes such as interception, detention, transpiration, overland flow, infiltration, interflow, percolation, sub-base flow, base flow etc., and emerges as runoff at the catchment outlet. [12] Application of mathematical modeling techniques to the constituent processes involved in the physical processes of runoff generation has led to better understanding of the processes and their interaction.

In strict mathematical sense, the word ‘Model’ describes a system of assumptions, equations and procedures intended to describe the performance of a physical phenomenon. [2] The distribution of the hydrologic system shows that it is complex and can not easily be described by a simple model. Some models attempt to describe the actual physical processes of the hydrologic cycle so as to simulate actual hydrological events such as the transformation of a series of rainfall inputs to the resulting stream flow hydrograph. [7]

Broadly speaking, a mathematical model is a combination of two basic components viz., deterministic and stochastic. Deterministic component enables the knowledge concerning the physical phenomenon, whereas the stochastic component, expresses in statistical terms which can not be explained by means of physical representation (Clarke, 1973).

A classification of mathematical models describing physical phenomenon connected with the hydrological cycle may be advanced, based on the following four classes namely purely stochastic, Lumped integral, Distributed integral and Distributed differential (Todini, 1988).

Lumped integral models, where the available information is set in integral form in terms of a response function (for instance the Unit Hydrograph), and where simple physical information is set either in terms of constraints, or more specifically as the full shape of the response function, may be derived by integrating the basic differential equations or the Gamma response function. [8]

RAINFALL – RUNOFF MODEL:

Hydrologists are concerned with the amount of surface runoff generated in a watershed for a given rainfall pattern and attempts have been made to analyze historical rainfall, infiltration, evaporation and stream flow data to develop predictive relationships. [4] Both statistical and theoretical approaches have been used to develop predictive tools for the analysis of both small and large watershed areas. [5] Variations in factors such as antecedent rainfall, soil moisture, infiltration rate, volume and seasonal runoff response have made development of the relationship between them difficult.

When rainfall occurs water begins to accumulate as surface storage in small depressions governed by surface topography. As depression storage begins to fill, overland flow or sheet flow may begin to occur in portions of a watershed, and the flow quickly converges into small rivulets or channels which then flow into larger streams. [6] Contributions to a stream can also come from the shallow subsurface via interflow or base flow (from bank storage), and contribute to the overall discharge hydrograph from a rainfall event. [9]

STUDY AREA

Pamena – I Watershed which is the part of Pamena village falls under the agro-climatic zone V of Andhra Pradesh which is designated as North Telangana agro climatic zone. The village is 6 km away from Chevella located on Shabad road and in the southern part of Ranga Reddy district.(Source: Action plan for Watershed Development Program in Pamena – I Watershed, Chevella Mandal, Ranga Reddy District, A.P.). The village lies between longitudes 78º 06' – 78º 09' and latitudes 17º 15'30'' – 17º 17'30'' falling in Survey of India toposheet no.56 K/3. Pamena-I Watershed has a geographical area of 500 ha.. The study area with watershed drainage, village site and roads is shown in Figure 1. The study area on satellite imagery of Indian Remote Sensing (IRS) - 1D, Linear Imaging Self-scanning Sensor (LISS)-III & PAN (Panchromatic) merged map is shown in Figure 2. The distribution of rainfall is unequal and major part of annual rainfall occurs in a few months due to South West monsoon. Early withdrawal of monsoon results in crop failures and makes agriculture a gamble.

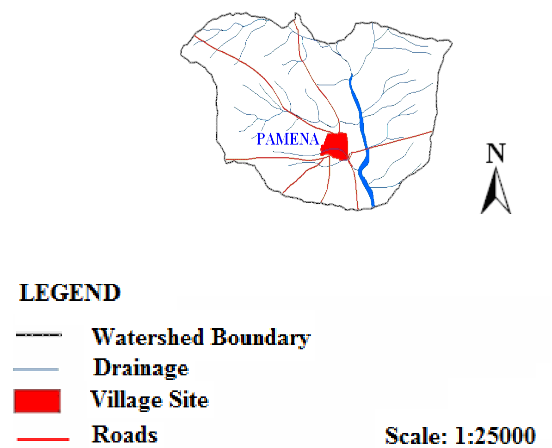

Figure 1. LOCATION MAP OF PAMENA - 1 WATERSHED

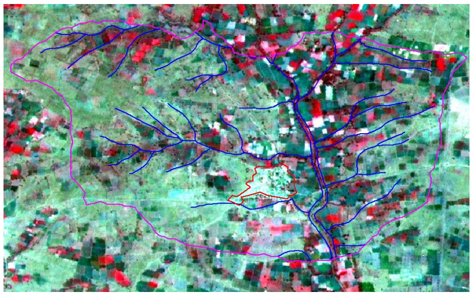

Figure 2. STUDY AREA ON SATELLITE IMAGERY

OBJECTIVES OF THE PRESENT STUDY

Rainfall - Runoff models form the basis for most hydrological simulation applications, including flood forecasting, yield assessment and water quality modeling. There has been a growing recognition that the accuracy of the output parameters even for a single objective function, is limited, and that this leads to uncertainty in the derived parameter values identified through optimization. This uncertainty has severely restricted the rainfall - runoff modeling applications. The implications of coupled models, for example of watershed modeling, are only now being explored. Stochastic methods are available to explore model structure and parameter uncertainty, and a trade-off between model complexity and performance can be made. The accuracy of the hydrological parameters can be increased by the use of multiple objectives, which in turn provide further insight into model structures and performance.

Objectives of the present study:

1. To study and estimate Time of Concentration in the Pamena-I watershed, using the standard equations in popular usage.
2. To calculate daily runoff using TR-55 (Technical Release – 55) model.
3. To compare and correlate calculated runoff using TR-55 model with the estimated runoff using OTC (Overland Time of Concentration) runoff model.

METHODOLOGY

Technical Release - 55 (TR – 55) Model

The model structure, input parameters required for the estimation of daily runoff viz., define the area, specify the flow of runoff to a reach (water path), rain fall data, runoff curve**,** time of concentration and procedure for the estimation of daily runoff were explained in the following sub sections.

Model Structure

Technical Release-55 (TR-55) presents simplified procedures for estimating runoff and peak discharges in small watersheds. In selecting the appropriate procedure, consider the scope and complexity of the problem, the available data, and the acceptable level of error. While this TR -55 gives special emphasis to urban and urbanizing watersheds, the procedures apply to any small watershed in which certain limitations are met. [3] The TR – 55 Model is a Hydrologic model for small watersheds specifically for rainfall – runoff. (USDA, Urban Hydrology for Small Watersheds Natural Resources Conservation Service, Conservation Engineering Division, Technical Release– 55, June1986). TR-55 creates a theoretic rain storm in the computer and assesses how much water runs into the river.

The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in a watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development as well as design and implement measures that will minimize its adverse effects. TR – 55 determines the amount of runoff from smaller watersheds evaluates the size of structure needed to contain runoff and also determines the amount of runoff accumulated from several sub watersheds into an outlet or containment structure.

Time of Concentration

Time of concentration is a fundamental watershed parameter. It is used to compute the peak discharge for a watershed. The peak discharge is a function of the rainfall intensity, which is based on the time of concentration. Time of concentration is the longest time required for a drop of water to travel from the watershed divide to the watershed outlet.

The Time of Concentration thus calculated using the following equation is taken as input to TR-55 model along with rainfall.

$$t_c = \frac{0.93 L^{0.6} N^{0.6}}{i^{0.4} S^{0.3}} \quad \text{--------------------} \; (1)$$

Where t_c = Time of Concentration, i = Rainfall intensity, L = Overland flow distance, S = Slope,

N = Manning's coefficient

One critical parameter in this model is Time of Concentration (t_c), which is the time, it takes for runoff to travel to a point of interest from the hydraulically most distant point. Normally rainfall duration equal to or greater than t_c is used. Therefore, the rainfall distributions were designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

PARAMETERS REQUIRED IN TR-55 MODEL: Rainfall and Time of Concentration are the major inputs; in addition there are three parameters namely the area, overland flow and runoff curve number, required as inputs to the model. These three parameters are required for use in TR-55 model to estimate daily runoff from daily rainfall. The concept and description of all these five parameters have been outlined in the following subsections.

OVERLAND TIME OF CONCENTRATION – RUNOFF MODEL

Despite the importance of overland time of concentration on the design discharge, the assessment covers nine formulas published between 1946 and 1993, which are intended for overland flow only that is subjected to uniform rain. The assessment compares the estimation from the formulas with experimental values that are derived under the same conditions for two surfaces: concrete and grass. The assessment shows that formulas which do not account for the rainfall intensity are only valid for a limited range of rainfall intensities. The formulas that account for the rainfall intensity generally show better agreement with the experimental data. Finally, the assessment gives two rankings of the formulas for the two surfaces in accordance to their accuracy as compared to the experimental data. The formula that has the best accuracy for both surfaces is the Chen and Wong formula. In the overland time of concentration calculation, we require inputs for the longest watercourse length in the watershed (L), the average slope of that watercourse (S), and a coefficient representing the type of groundcover. Usually L and S can be obtained from topographic maps. The coefficient is determined from photographs of the watershed or field reconnaissance. The calculation computes the time of concentration and average velocity in the longest watercourse. Once the model is validated at a watershed level, it can be applied to ungauged sub basins to calculate runoff.

Keeping these points in view, Overland Time of Concentration (OTC) Runoff Model has been formulated and developed. It contains five modules namely Rainfall, Time of Concentration (t_c), Wilting Point, Accumulated Potential Water Loss (APWL) and Soil Moisture for the estimation of daily runoff.

RAINFALL : Daily rainfall data which constitutes one of the major inputs to the model was collected from Agricultural Research Institute (ARI) Hyderabad for a period of 1996 to 2005 for the Pamena – I watershed and was processed.

ESTIMATION OF TIME OF CONCENTRATION (t_c): Time of concentration is a fundamental watershed parameter. It is used to compute the peak discharge for a watershed. The peak discharge is a function of the rainfall intensity which is based on the time of concentration. Time of concentration is the longest time required for a drop of water to travel from the watershed divide to the watershed outlet. Daily meteorological parameters viz. maximum temperature, minimum temperature in degrees centigrade, maximum relative humidity, minimum relative humidity in percentage, wind velocity in kmph, Sunshine Hours per day and evaporation in mm per day are collected for a period of 1996 to 2005 from meteorological station located at ARI, Ranga Reddy District, Andhra Pradesh. This data was processed, and gaps were filled with the average of previous and subsequent day. For the present study, Time of concentration was calculated from Kinematic Wave Formula. Daily Time of concentration was estimated from the following equation.

$$t_c = \frac{0.93 L^{0.6} N^{0.6}}{i^{0.4} S^{0.3}} \quad \text{--------------------} \; (2)$$

Thus the daily Time of Concentration calculated is given as an input to Overland Time of

Concentration Runoff Model. Predominant crop coverage in study area in both the seasons was identified from the land utilization data collected from hand book of Statistics, Ranga Reddy District, Andhra Pradesh.

WILTING POINT: Wilting Point is the minimal point of soil moisture the plant requires not to wilt. If moisture decreases to this or any lower point a plant wilts, and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. The wilting point is physically expressed as the water content at −1500 J/kg (or −15 bars) of suction pressure, or negative hydraulic head.

However, it is noted that the WP values under field conditions are not constant for any given soil, but are determined by the integrated effects of plant, soil and atmospheric conditions.

ACCUMULATED POTENTIAL WATER LOSS (APWL): Accumulated potential water loss is the potential deficiency of soil moisture associated with moisture contents below the water-holding capacity of a soil. Thus, an associated accumulated potential water loss is there for each soil moisture content. Accumulated potential water loss is increased during dry seasons because of an insufficient supply of water (i.e., maximum percolation) to meet the demands of PET, reduced during wet seasons due to the recharge of soil moisture, and equals zero when soil moisture storage equals the water-holding capacity of the soil.

Accumulated potential water loss is never equal to the actual water loss, because as the soil moisture declines during a dry season, it becomes increasingly difficult to extract additional water from the soil. This causes AET to be less than PET during the dry season. The accumulated potential water loss for a given month of the dry season is the sum of the absolute value of potential percolation for that month and the accumulated potential water loss of the previous month. This new accumulated potential water loss is then used to calculate soil moisture for the given month. For any given month of the wet season, soil moisture is calculated as the sum of the potential percolation for that month and the soil moisture of the previous month.

ESTIMATION OF SOIL MOISTURE: The soil map pertaining to the study area was extracted in GIS environment. [11] Boundaries of different soil textures were digitized in ARC/INFO and the polygons representing soil classes were assigned different colours for reorganization of hydrologic soil groups.

The table 1 gives the type of soil, soil group (group B) as per USDA classification. Predominant soil (black loamy) type was identified and listed in Table 2. Accordingly Field capacity (FC) and Wilting Point (WP) values were adopted in the model.

Soil moisture estimation can be done in situ and/or through water budgeting. The soil moisture estimated through budgeting can be validated with in situ estimation. Several research studies proved that there has been good correlation between these two methods. [10] Soil moisture is the amount of moisture per meter of soil depth and is obtained by using parameters such as amount of daily rainfall, Time of Concentration, crop coefficient, root zone depth, field capacity and wilting point. Rainfall is the major source of soil moisture in this study area.

The difference between the daily rainfall and the water flows as runoff in the time of concentration results in either water surplus or deficit. Soil moisture retention depends on the type of the soil, soil texture and soil structure and hence it is determined by field capacity and wilting point. The parameters field capacity, wilting point and readily available soil moisture, are taken from the different soil types and the same were used for water budgeting depending on the predominant type of soil in the study area.

However these values cannot be used universally, as in the field the soil composition, texture, structure and size vary due to man’s influence. Further, the soil depth for water budgeting is limited only to root zone depth of the major crops, since there is continuous variation in the root development especially from initial period to maturity stage of the crop.

This variation in the root development is taken into account in this model. Depending on the root zone development for different crops, the varying soil depths were considered for each day of the growing period of the crop. The soil water parameters such as wilting point, filed capacity and water holding capacity were accordingly estimated based on the daily crop root zone depth under consideration for each day.

Difference between rainfall amount and the water flows as runoff in the time of concentration was calculated for each day. If the difference is negative, then there will be a potential water loss.

And as long as differences are negative in the subsequent days, potential water loss accumulates and is known as Accumulated Potential Water Loss (APWL). Initial soil moisture level is assumed to be at wilting point as the water budgeting is commenced after summer season i.e. at the beginning of Kharif season. For the subsequent days, soil moisture is obtained by adding previous soil moisture values to the positive differences of precipitation and runoff of Time of Concentration. However, for the negative differences, previous soil moisture is added to the rainfall amount and then modified by an exponential factor depending on accumulated potential water loss using the following equation.

$$SMi = SM(i-1)EXP^{[APWL(i-1)/[SM(i-1)]}$$

As only that part of soil moisture between wilting point and field capacity is utilized for crop growth, soil moisture is always limited to either to a minimum of wilting point or a maximum of field capacity.

REPRESENTATION OF ISOCHRONES:

One of the most efficient overland flow routing methods is Time-Area method. In this method, with omitting the storage effects, watershed is divided into some subareas. This is performed by constructing isochrones. An isochrone is actually a contour which passes through points of the same travel time to the outlet of the basin. Histogram of subareas, named Time-Area Histogram (TAH) is the base of the Time-Area method as a Rainfall-Runoff model.

Time to equilibrium is actually the time of wave translation. All of the area behind the wave front is in equilibrium state which in hydraulics of surface flow means the considered area is in steady state. For a long duration rainfall, time to equilibrium at outlet is equal to time of concentration. The latter is familiar to hydrologists. Time of concentration according to definition is the time which a drop of water needs to reach to the outlet from farthest point of watershed. For constructing TAH, time to equilibrium must be divided into some equal parts, say Δt. This Δt will be used as the time difference between isochrones. Figure 3 is represented the representation of Isochrones from a Pamena – I watershed

Researches on isochrones delineation methods are very limited. Hence forth almost all of the available isochrones mapping methods are empirical, approximate and without a well defined hydraulic basis. This issue introduces errors in hydrograph calculation, which are not clear in origin and magnitude.

In the present research the Time-Area method was investigated. Shokoohi and Saghafian had performed a research on precision of isochrone mapping methods. They showed that all of the methods define travel time (time to equilibrium for any desired point; t_e) as a function of travel Length (L) at a power ($t_e \approx L^{\beta}$). For kinematic wave, β was obtained as 5/3 and for all of the other methods the power was in a range as 0.5 to 1.5. Quoted from Shokoohi and Saghafian, Time-Area method could give results as precise as analytical method if $\beta = 1.5$. In this research isochrones arranged from upstream to downstream. These conclusions have a conflict with that of kinematic wave theory. The achieved results confirmed new concept of reordering isochrones and then finding a robust hydraulic based method for isochrone mapping. A noticeable outcome of the present study was the point that the best result was achieved by application a value of β which comes from kinematic wave theory.

Actually, Time-Area method is the most efficient semi-distributed model which has been developed in 1940`s. This method is known as a hydrologic watershed rainfall-runoff model. After developing and applying in Clarke conceptual model, it was used by specialists in very limited area. The main cause of this limitation was shortcoming of isochrone deriving methods. Paying attention to its power and capabilities were commenced after fast development of computer science and GIS (Geographical Information System) software. One of the most important advantages of Time-Area method is including two important geomorphologic properties of watershed; shape and drainage pattern of basin in its simulation. Time-Area method uses these two watershed properties in determining shape and peak discharge of flood hydrograph. It must state that Time-Area method success in rainfall-runoff simulation is mainly dependent on precision of isochrone mapping. According to available reports, nowadays in 40 to 60% of Corp of Engineers (USA) projects, Time-Area method is used as rainfall-runoff model.

Table 1. SOIL CLASSIFICATION USING GIS

Name of the area	Soil Group type B, area in Sq. km	Soil Group type C, area in Sq. km	Soil Group type D, area in Sq. km	Total area in Sq. km
Pamena – I Watershed	2.4	2.2	0.4	5.0

Table 2. PREDOMINANT TYPES OF SOIL, KHARIF AND RABI CROP FOR THE STUDY AREA

Name of the study area	Soil	Kharif Crop	Rabi Crop
Pamena- I watershed	Black Loamy	Green gram	Jowar

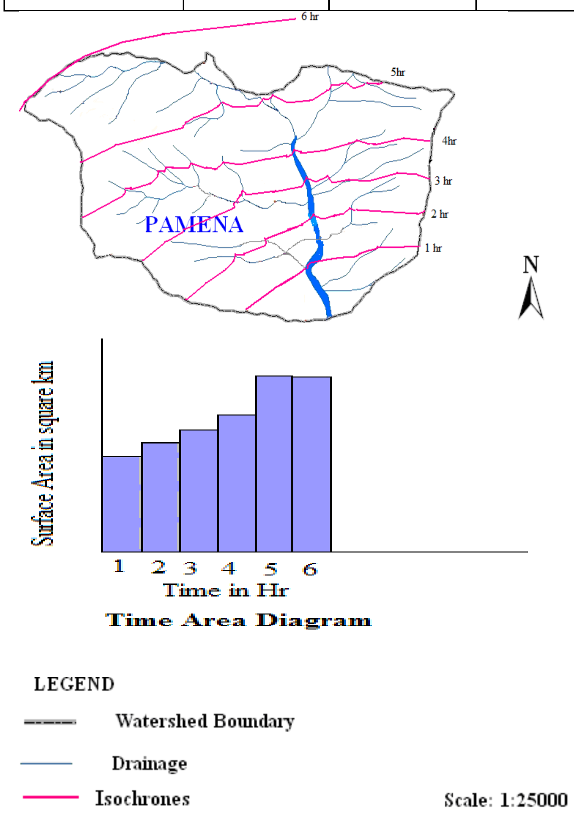

Figure 3 Representation of Isochrones from a Pamena – I watershed

ANALYSIS AND INTERPRETATION

Analysis of Rainfall and Comparison of estimated runoff from TR-55 model with

Observed runoff: Comparison of daily, monthly and yearly variation of rainfall and the corresponding daily, monthly and yearly runoff values were estimated from TR-55 model for the period from 1996 to 2005. Table 4 shows the variation of daily rainfall with daily runoff for the month of August 2001, and also compared with the daily observed runoff. On the dates of 3rd,7th and on 9th August the observed runoff values are slightly higher than the TR-55 model. Similarly calculations have been carried out for the other periods i.e. from 1996 to 2005. Variation of the same was represented graphically in Figure 4. Now daily values of rainfall and runoff were converted into monthly values which were given in Table 5. Graphical representation of the monthly variation of rainfall and runoff values for the year 2001 was shown in Figure 5. From the entire study area and the entire duration of 1996 to 2005, it is found that a minimum monthly runoff of 33% of rainfall was observed in the year 1997 and maximum monthly runoff of 60 % of rainfall was observed in the year 2003. The above minimum runoff took place because the rainfall (741 mm) in that year was less and also, the same was distributed in five months i.e. June, July, August, September and October. Similarly, the above maximum runoff took place because half of the yearly rainfall occurred just in one month i.e. in July 2003.

Maximum and minimum monthly runoff was calculated in different years for Pamena –I watershed and analyzed. In 1996 the maximum runoff was found in the month of September i.e. 62.47 %. . In 1997 the maximum runoff was found in the month of July i.e. 53.22 %. In 1998 the maximum runoff was found in the month of August i.e. 70.20 %. In the year 1999, maximum runoff was found in the month of July i.e. 61.86 %. In the year 2000, the maximum runoff was found in the month of August i.e. 76.7 %. In the year 2001, the maximum runoff was found in the month of October i.e. 59.35 %. In the year 2002, maximum runoff was found in the month of October i.e. 53.66 %. In the year 2003, the maximum runoff was found in the month of July i.e. 76.35 %. In the year 2004, the maximum runoff was found in the month of July i.e. 65.6 %. In the year 2005, the maximum runoff was found in the month of July i.e. 65.6 %. Table 6 shows the comparison of monthly estimated runoff using TR-55 method and monthly observed runoff in mm.

In table 4, the remaining dates from 21 to 31 st , the data is zero including the observed runoff.

Monthly rainfall and runoff were then converted into yearly rainfall and runoff. These values were given in Table 7 and also given the yearly observed runoff values for comparison with estimated runoff of TR-55 method. The yearly observed runoff values are less than the estimated runoff values of TR-55 model. Highest runoff through TR-55 method is 624 in the year 2003 i.e. 624 mm, in the same year the highest observed runoff is recorded i.e. 589 mm. Almost equal runoffs are observed in the year 2002, those respective runoffs are 253 mm through TR-55 model and 251 mm in observed runoff. The graphical representation for comparison of yearly rainfall and estimated yearly runoff using TR- 55 model is shown in Figure 6. Also the graphical representation of comparison of yearly estimated runoff using TR-55 method with yearly observed flow is shown in Figure 7. The maximum runoff occurred in the year 2003 as 624 mm against the rainfall of 1042 mm. This is because the maximum rainfall occurred in two months namely July and August only, where as in the year 1998, the maximum rainfall was distributed in four months July, August, September and October.

Correlation coefficients of the daily, monthly and yearly estimated runoff of TR- 55 method and the corresponding daily, monthly and yearly observed runoff for this study area were computed and given in Table 8. Considering as a whole, monthly correlation coefficients exhibited a good fit between rainfall and runoff, followed by yearly and daily correlation. The daily, monthly and yearly correlation coefficients (R^2) for the study area are found to be 0.98, 0.95 and 0.97 respectively.

Runoffs estimated from TR-55 method for all the years are 51, 33, 59, 46, 57, 55, 39, 60, 47 and 56 percentages of rainfall for the years 1996 to 2005 respectively. Average runoff of this study area for the duration of 1996 to 2005 was estimated as 51.5% of rainfall.

TABLE 4. COMPARISON OF DAILY RAINFALL, DAILY ESTIMATED RUNOFF USING TR-55 METHOD AND DAILY OBSERVED RUNOFF IN MM FOR THE MONTH OF AUGUST 2001

Date	Rainfall	Estimated TR-55 Runoff	Observed Runoff
1	0.00	0.00	0.00
2	0.60	0.00	0.00
3	52.00	33.13	36.54
4	15.00	9.84	8.24
5	4.60	1.27	0.00
6	0.20	0.00	0.00
7	31.00	19.34	17.89
8	0.00	0.00	0.00
9	59.60	38.11	42.52
10	1.00	0.00	0.00
11	0.60	0.00	0.00
12	0.80	0.00	0.00
13	10.40	5.15	1.14
14	2.20	0.00	0.00
15	8.20	2.45	0.98
16	0.00	0.00	0.00
17	0.00	0.00	0.00
18	0.60	0.00	0.00
19	0.00	0.00	0.00
20	1.40	0.00	0.00

TABLE 7 COMPARISON OF YEARLY RAINFALL, YEARLY ESTIMATED TR – 55 RUNOFF AND YEARLY OBSERVED RUNOFF IN MM

Year	Rainfall	TR-55 Runoff	Observed Runoff
1996	877	448	385
1997	741	244	205
1998	1050	615	576
1999	678	309	279
2000	869	498	461
2001	840	463	376
2002	643	253	251
2003	1042	624	589
2004	768	358	321
2005	1041	585	538

TABLE 8 R^2 VALUE BETWEEN ESTIMATED RUNOFF USING TR-55 MODEL AND OBSERVED RUNOFF

TR-55	R^2
Daily	0.98
Monthly	0.95
Yearly	0.97

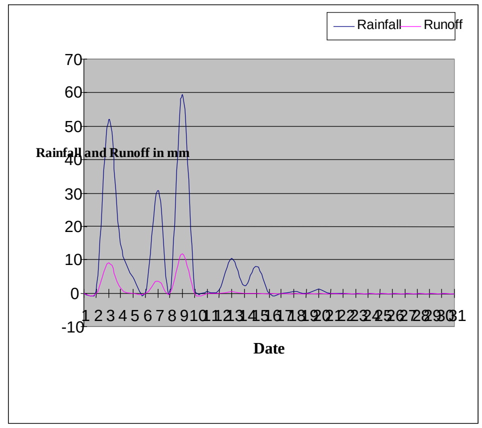

Figure 4 Variation of daily Rainfall and estimated Runoff for the month of August 2001 using TR-55 method

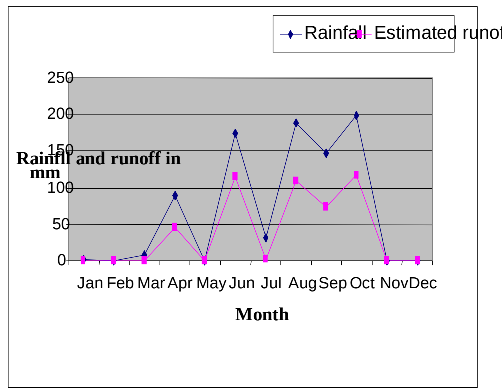

Figure 5 Monthly variation of rainfall and estimated runoff using TR-55 model for the year 2001

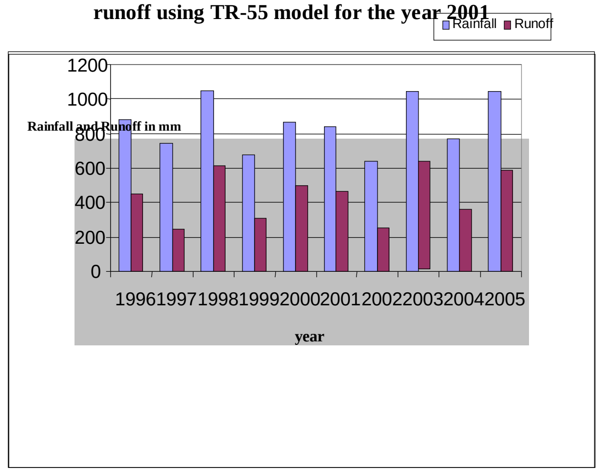

Figure 6 Comparison of Yearly Rainfall and estimated yearly Runoff using TR- 55 model

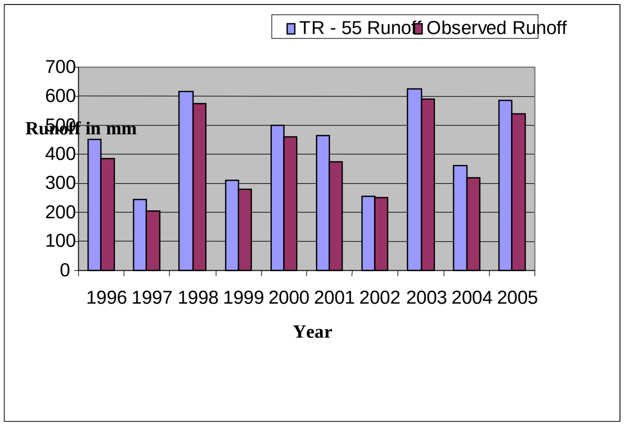

Figure 7 Comparison of yearly estimated TR-55 runoff with yearly observed runoff

ANALYSIS OF RAINFALL AND COMPARISON OF ESTIMATED RUNOFF FROM OTC - RUNOFF MODEL WITH OBSERVED RUNOFF:

Comparison of daily, monthly and yearly variation of rainfall and runoff was carried out for the period from 1996 to 2005. Table 9 shows the same for a sample month of August 2001 with observed runoff values for the Pamena–I watershed area. On the dates of 4th, 5th, 7th,13th, and on 15th August the observed runoff values are less compared to estimated OTC method runoff. Variation of daily rainfall and daily runoff were represented graphically in Figure 8. Daily values of rainfall and runoff were converted into monthly values which were given in Table 10. Graphical representation of the monthly variation of rainfall and estimated runoff is shown in Figure 9**.** From the entire study area and the entire duration of 1996 to 2005, it is found that a minimum monthly runoff of 41% was observed in the year 2002 and maximum monthly runoff of 67 % was observed in the year 2003. The above minimum runoff took place because the rainfall (643 mm) in that year was very less and also, the same was distributed in five months i.e. May, June, July, August and October. Similarly, the above maximum runoff took place because half of the yearly rainfall occurred just in two months i.e. in July and August 2003.

Maximum and minimum monthly runoff was calculated in different years for Pamena –I watershed and analyzed. In the year 1996, the maximum runoff was found in the month of September i.e. 64.09 %. In the year 1997, the maximum runoff was found in the month of September i.e. 55.65 %. In the year 1998, the maximum runoff was found in the month of October i.e. 73.30 %. In the year 1999, the maximum runoff was found in the month of August i.e. 76.69 %. In the year 2000, the maximum runoff was found in the month of August i.e. 78.12%. In the year 2001, the maximum runoff was found in the month of October i.e. 66.63%. In the year 2002, maximum runoff was found in the month of October i.e. 51.09 %. In the year 2003, the maximum runoff was found in the month of July i.e. 81.44%. In the year 2004, the maximum runoff was found in the month of July i.e. 70.08 %. In the year 2005, the maximum runoff was found in the month of July i.e. 73.98 %.

Comparison of monthly estimated runoff using OTC method and monthly observed runoff in mm is shown in Table 11. Monthly rainfall and runoff were then converted into yearly rainfall and runoff shown in Table 12**.** Observed runoff values are also given in Table 12 and the highest estimated runoff is in the year 2003 i.e .697 mm through OTC method and the highest observed runoff is 589 mm in the same year. Lowest estimated runoff is 264 mm through OTC method in the year 2002 and the lowest observed runoff is 205 mm in year 1997. But in all the years from 1996 to 2005 the yearly observed runoff values are less than the estimated runoff values of OTC method. Comparison of yearly rainfall and estimated runoff by OTC method were graphically represented in Figure 10. The maximum runoff occurred in the year 2003 as 697 mm against the rainfall of 1042 mm. This is because the maximum rainfall was distributed in two months namely July and August only, where as in the year 1998, the maximum rainfall was distributed uniformly in four months namely July, August, September and October.

Comparison of estimated yearly OTC runoff with yearly observed runoff is shown in Figure 11. Correlation coefficients of the daily, monthly and yearly estimated OTC method and the corresponding daily, monthly and yearly observed runoff for this study area were computed and given in Table 13. Considering as a whole, correlation coefficients of daily runoff exhibited a good fit between estimated runoff and observed runoff, followed by monthly and yearly correlation. The correlation coefficients of daily, monthly and yearly runoffs (R^2) for the study area are found to be 0.98, 0.98 and 0.93 respectively.

Average runoff estimated from OTC method for all the years as 48.80, 36.84, 55.23, 57.22, 58.68, 54.52, 41.05, 66.89, 48.56 and 54.85 percentages of rainfall for the years 1996 to 2005 respectively.

Average runoff of this study area for the duration of 1996 to 2005 was estimated as 53.19% of rainfall.

TABLE 9 COMPARISON OF DAILY RAINFALL, DAILY ESTIMATEDOTC RUNOFF AND DAILY OBSERVED RUNOFF IN MM FOR THE MONTH OF AUGUST 2001

Date	Rainfall	Estimated OTC Runoff	Observed Runoff
1	0.0	0	0.00
2	0.6	0	0.00
3	52.0	36.27	36.54
4	15.0	10.46	8.24
5	4.6	3.20	0.00
6	0.2	0	0.00
7	31.0	21.62	17.89
8	0.0	0	0.00
9	59.6	41.57	42.52
10	1.0	0	0.00
11	0.6	0	0.00
12	0.8	0	0.00
13	10.4	6.41	1.14
14	2.2	0	0.00
15	8.2	4.87	0.98
16	0.0	0	0.00
17	0.0	0	0.00
18	0.6	0	0.00
19	0.0	0	0.00
20	1.4	0	0.00
21	0.0	0	0.00
22	0.0	0	0.00
23	0.0	0	0.00
24	0.0	0	0.00
25	0.0	0	0.00
26	0.0	0	0.00
27	0.0	0	0.00
28	0.0	0	0.00
29	0.0	0	0.00
30	0.0	0	0.00
31	0.0	0	0.00

TABLE 12 COMPARISON OF YEARLY RAINFALL, YEARLY ESTIMATED RUNOFF USING OTC METHOD AND YEARLY OBSERVED RUNOFF IN MM

TABLE 13 R^2 VALUE BETWEEN ESTIMATED RUNOFF USING OTC METHOD

Year	Rainfall	OTC Runoff	Observed Runoff
1996	877	428	385
1997	741	273	205
1998	1050	580	576
1999	678	388	279
2000	869	510	461
2001	840	458	376
2002	643	264	251
2003	1042	697	589
2004	768	373	321
2005	1041	571	538

AND OBSERVED RUNOFF

OTC	R^2
Daily	0.98
Monthly	0.98
Yearly	0.93

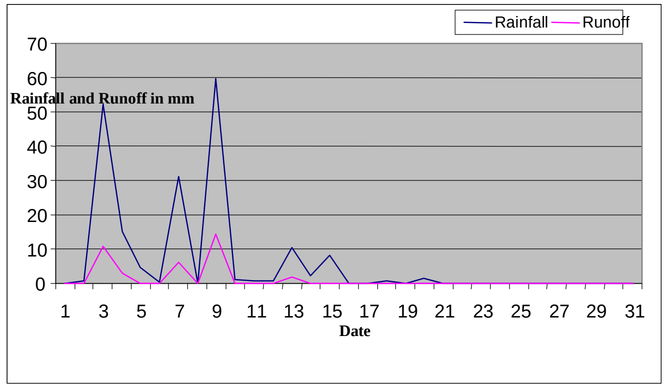

Figure 8 Variation of daily Rainfall and estimated Runoff using OTC model for the month of August 2001

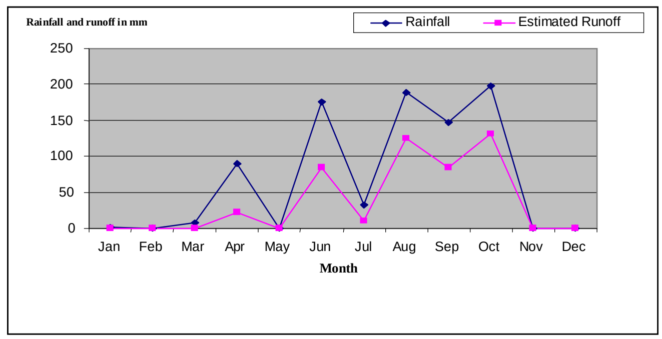

Figure 9 Monthly variation of rainfall and estimated runoff of OTC method for the year 2001

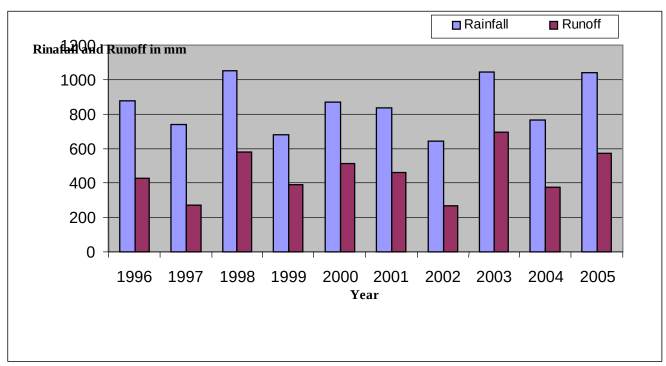

Figure 10 Comparison of yearly rainfall and estimated runoff using OTC - runoff model

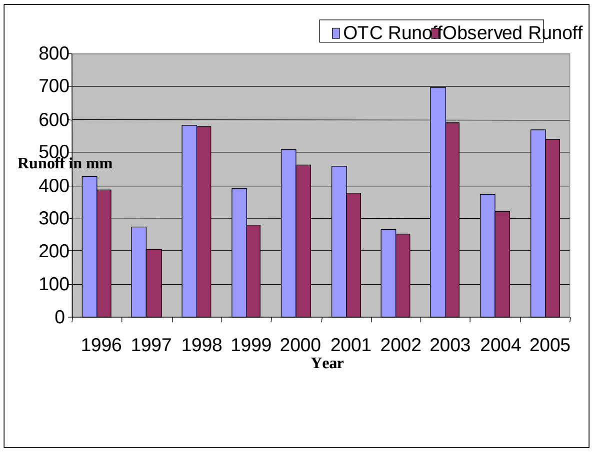

Figure 11 Comparison of estimated yearly OTC runoff with yearly Observed Runoff

COMPARISON OF RUNOFF ESTIMATED FROM OTC MODEL WITH TR-55 MODEL

Monthly runoff values estimated from OTC model have been compared with those from TR-55 model. Yearly runoff values estimated from OTC model have been compared with those from TR-55 model and were presented in Table 14**.** Comparison of yearly runoff values from OTC method and from TR-55 model with respect to rainfall were represented graphically in Figure 12. In the TR-55 model, highest runoff occurred in the year 2003 i.e. 624 mm and where as in OTC model highest runoff occurred in the same year i.e. 697 mm against the rainfall of 1042 mm. The average runoff was high as in TR-55 model in the years of 1996, 1998, 2001 and in 2005 when compared to OTC model and it is represented in the Figure 13.

Minimum runoff occurred in the year 1997 i.e. 244 mm against the rainfall of 741 mm in TR-55 model, where as in OTC method the runoff was minimum in 2002 i.e. 264 mm against the rainfall of 643 mm, this least rainfall occurred in the10 year duration. According to OTC model minimum runoff occurred when the minimum rainfall was recorded.

The average runoff, estimated for the study area over a period of 10 years, has been determined as 51.43 % and 53.19 % of rainfall from TR-55 model and OTC model respectively. It indicates that TR-55 model under estimated the average yearly runoff by 1.76% compared to OTC model. Correlation coefficients for the daily, monthly and yearly runoff estimated from TR-55 model and OTC model were calculated and were enumerated in Table 15. Comparison of estimated yearly TR-55 Runoff and OTC Runoff with yearly Observed Runoff was graphically represented in Figure 13.

Correlation coefficient for the daily runoff estimated from TR-55 model and the estimated daily runoff from OTC method was 0.98. Correlation coefficient for the monthly runoff estimated from TR-55 model and the estimated monthly runoff from OTC method was 0.98 and correlation coefficient for the yearly runoff estimated from TR-55 model and the estimated yearly runoff from OTC method was 0.93.

TABLE 14 COMPARISON OF YEARLY RAINFALL AND ESTIMATED YEARLY RUNOFF IN MM BETWEEN OTC AND TR-55 METHODS

Year	Rainfall	TR-55 Runoff	OTC Runoff
1996	877	448	428
1997	741	244	273
1998	1050	615	580
1999	678	309	388
2000	869	498	510
2001	840	463	458
2002	643	253	264
2003	1042	624	697
2004	768	358	373
2005	1041	585	571

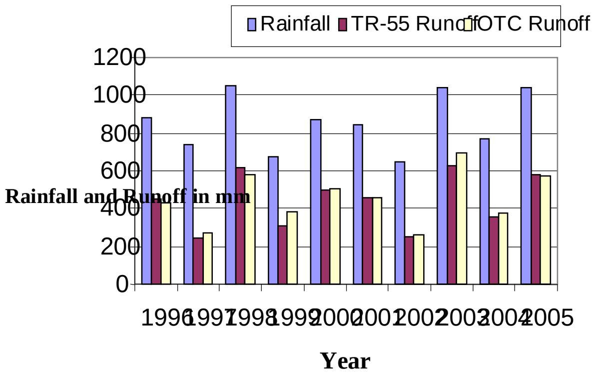

Fig. 12 Comparison of estimated yearly Runoff between TR-55 and OTC models with respect to yearly Rainfall

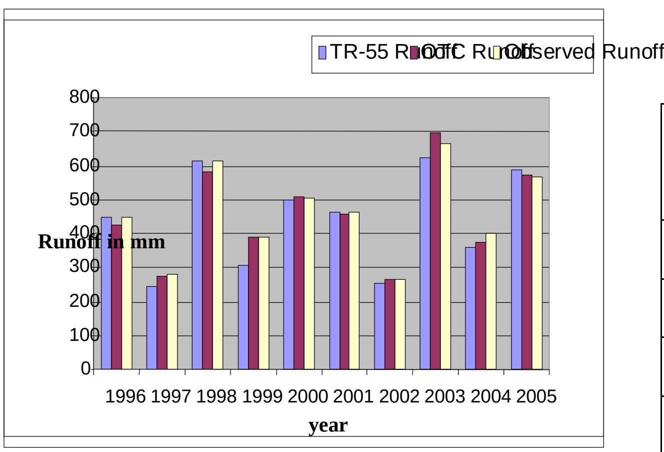

Fig. 13 Comparison of estimated yearly TR-55 Runoff and OTC Runoff with yearly Observed Runoff

TABLE 15 CORRELATION COEFFCIENT BETWEEN ESTIMATED RUNOFF USING TR-55 AND OTC METHODS

TR-55 & OTC	R^2
Daily	0.98
Monthly	0.98
Yearly	0.93

COMPARISON OF RUNOFF ESTIMATED USING TR-55 AND OTC MODEL

Yearly runoff estimated from the two models viz. TR-55 and OTC model have been compared and average yearly rainfall and runoff in mm over the Pamena–I watershed was estimated from TR-55 and OTC model were given in Table 16 and these values compared with yearly observed runoff in the same table. Monthly runoffs estimated from TR-55 and OTC model were quite close and some times OTC model over estimated, while TR-55 model under estimated.

Correlation coefficients for observed daily, monthly and annual runoff and the corresponding daily, monthly and annual runoff values estimated from TR-55 model and OTC model calculated, were listed in Table 17.

TABLE 16 COMPARISON OF YEARLY RAINFALL AND ESTIMATED YEARLY RUNOFF IN MM FROM TR-55 AND OTC METHODS WITH OBSERVED RUNOFF

Year	Rainf all	TR-55 Runoff	OTC Runoff	Observed Runoff
1996	877	448	428	385
1997	741	244	273	205
1998	1050	615	580	576
1999	678	309	388	279
2000	869	498	510	461
2001	840	463	458	376
2002	643	253	264	251
2003	1042	624	697	589
2004	768	358	373	321
2005	1041	585	571	538

TABLE 17 CORRELATION COEFFCIENT BETWEEN OBSERVED RUNOFF AND ESTIMATED RUNOFF USING TR-55 AND OTC MODELS

	TR-55	OTC
Daily	0.98	0.98
Monthly	0.95	0.98
Yearly	0.97	0.93

CONCLUSIONS

The following are the conclusions observed from the present study

1) In this OTC model, when rainfall exceeds the infiltration rate at the surface, excess water begins to accumulate as surface storage in small depressions governed by surface topography.

2) The average runoff, estimated for the study area over a period of 10 years, has been determined as 51.43% and 53.19% of rainfall from TR-55 model and OTC model respectively. It indicates that TR-55 model under estimated the average yearly runoff by 1.76 % compared to OTC model.

3) The combination of GIS and TR-55 model made the runoff estimation more accurate and fast. Therefore the runoff estimated using TR-55 model was found to be comparable with the observed runoff.
4) The runoff estimated using GIS and RS based OTC method was comparable with the observed runoff and is useful aid for better water management practices.

5) Validation of the results of the models viz. TR-55 and OTC showed good congruence with the observed data.

6) The Nash Coefficient of Efficiency (CE) indicated a value of 99 %. Hence, it is concluded that the OTC model is a very good model and it is comparable with standard model considered in the present study i.e. TR-55

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TABLE 5 MONTHLY RAINFALL AND MONTHLY ESTIMATED RUNOFF IN MM USING TR-55 MODEL

Year	**1996**		**1997**		**1998**		**1999**		**2000**	
Month	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff
Jan	0.00	0.00	38.00	2.81	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.80	0.00	2.70	0.08	25.20	2.18
Mar	0.00	0.00	52.40	13.16	1.20	0.00	0.00	0.00	0.00	0.00
Apr	35.60	4.28	45.60	7.42	3.50	0.07	0.00	0.00	12.40	0.84
May	3.40	0.06	2.80	0.00	52.20	13.23	141.70	67.86	74.50	28.00
Jun	129.20	62.60	71.00	17.36	50.50	9.68	69.40	17.85	257.50	162.05
Jul	137.30	72.47	131.00	69.72	198.10	121.39	183.50	113.52	97.30	42.86
Aug	225.00	126.56	116.60	48.48	283.40	198.94	157.00	83.19	329.50	252.77
Sep	212.10	132.50	125.10	63.44	197.30	124.75	55.50	10.43	49.80	8.37
Oct	109.00	47.32	73.10	10.64	241.20	145.69	68.60	15.88	21.20	0.91
Nov	26.00	2.07	49.10	7.36	21.90	1.46	0.00	0.00	1.40	0.01
Dec	0.00	0.00	36.40	3.73	0.00	0.00	0.00	0.00	0.60	0.00

Year	**2001**		**2002**		**2003**		**2004**		**2005**	
Month	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff
Jan	1.00	0.02	3.20	0.17	0.00	0.00	7.30	0.92	11.00	2.12
Feb	0.00	0.00	3.70	0.16	7.40	0.65	0.00	0.00	12.80	1.84
Mar	8.40	0.57	37.50	11.93	167.60	94.80	9.40	0.78	11.60	1.14
Apr	89.20	44.96	0.00	0.00	34.40	6.50	35.60	7.13	40.80	9.27
May	0.00	0.00	48.40	11.20	0.00	0.00	114.80	63.54	23.40	2.64
Jun	175.40	115.11	99.50	37.20	79.70	23.88	56.20	12.10	39.60	5.88
Jul	32.00	2.30	115.30	29.96	305.40	233.17	287.60	188.70	291.30	191.32
Aug	188.20	109.29	150.00	75.74	278.20	208.99	53.80	10.51	84.70	24.27
Sep	147.70	73.33	26.40	1.12	44.00	3.14	126.00	54.44	273.60	187.42
Oct	198.10	117.58	159.00	85.32	124.90	52.73	76.70	19.60	251.80	158.76
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 6 COMPARSION OF MONTHLY ESTIMATED TR - 55 RUNOFF AND OBSERVED RUNOFF IN MM

Year	1996		1997		1998		1999		2000	
Month	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff
Jan	0.00	0.00	2.81	2.58	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	2.18	0.01
Mar	0.00	0.00	13.16	7.80	0.00	0.00	0.00	0.00	0.00	0.00
Apr	4.28	1.82	7.42	4.76	0.07	0.00	0.00	0.00	0.84	0.00
May	0.06	0.00	0.00	0.00	13.23	6.25	67.86	59.54	28.00	19.78
Jun	62.60	41.08	17.36	16.43	9.68	7.08	17.85	17.28	162.05	165.70
Jul	72.47	69.60	69.72	57.48	121.39	103.67	113.52	101.33	42.86	32.02
Aug	126.56	106.04	48.48	39.40	198.94	196.65	83.19	77.12	252.77	238.82
Sep	132.50	125.40	63.44	49.08	124.75	109.2	10.43	7.19	8.37	5.03
Oct	47.32	41.0	10.64	19.75	145.69	153.16	15.88	16.13	0.91	0.00
Nov	2.07	0.30	7.36	5.01	1.46	0.00	0.00	0.00	0.01	0.00
Dec	0.00	0.00	3.73	2.36	0.00	0.00	0.00	0.00	0.00	0.00

Year	2001		2002		2003		2004		2005	
Month	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff
Jan	0.02	0.00	0.17	0.00	0.00	0.00	0.92	0.00	2.12	0.00
Feb	0.00	0.00	0.16	0.00	0.65	0.00	0.00	0.00	1.84	0.00
Mar	0.57	0.00	11.93	1.59	94.80	98.75	0.78	0.00	1.14	0.00
Apr	44.96	21.55	0.00	0.00	6.50	1.13	7.13	1.42	9.27	2.21
May	0.00	0.00	11.20	5.93	0.00	0.00	63.54	37.6	2.64	0.00
Jun	115.11	78.42	37.20	33.57	23.88	20.04	12.10	4.70	5.88	2.85
Jul	2.30	0.32	29.96	47.28	233.17	219.64	188.70	197.20	191.32	197.60
Aug	109.29	107.31	75.74	81.80	208.99	191.00	10.51	7.60	24.27	23.70
Sep	73.33	66.76	1.12	0.15	3.14	3.62	54.44	55.80	187.42	172.50
Oct	117.58	101.6	85.32	81.00	52.73	55.2	19.60	17.15	158.76	139.60
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 10 MONTHLY RAINFALL AND ESTIMATED MONTHLY RUNOFF IN MM USING OTC METHOD

Year	1996		1997		1998		1999		2000	
Month	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff
Jan	0.00	0.00	38.00	4.57	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.80	0.00	2.70	0.00	25.20	1.52
Mar	0.00	0.00	52.40	12.67	1.20	0.00	0.00	0.00	0.00	0.00

Apr	35.60	2.99	45.60	5.48	3.50	0.00	0.00	0.00	12.40	1.34
May	3.40	0.00	2.80	0	52.20	5.70	141.70	68.00	74.50	19.74
Jun	129.20	21.99	71.00	22.73	50.50	11.10	69.40	34.00	257.50	173.11
Jul	137.30	63.80	131.00	62.03	198.10	102.30	183.50	106.70	97.30	41.78
Aug	225.00	124.71	116.60	56.62	283.40	174.40	157.00	120.40	329.50	257.41
Sep	212.10	135.94	125.10	69.63	197.30	107.50	55.50	27.20	49.80	14.18
Oct	109.00	78.28	73.10	29.4	241.20	176.81	68.60	32.30	21.20	1.20
Nov	26.00	0.55	49.10	5.94	21.90	2.50	0.00	0.00	1.40	0.00
Dec	0.00	0.00	36.40	4.11	0.00	0.00	0.00	0.00	0.60	0.00

Year	**2001**		**2002**		**2003**		**2004**		**2005**	
Month	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff	Rainfall	Estimated Runoff
Jan	1.00	0.00	3.20	0.00	0.00	0.00	7.30	0.00	11.00	0.00
Feb	0.00	0.00	3.70	0.00	7.40	0.00	0.00	0.00	12.80	0.00
Mar	8.40	0.00	37.50	4.96	167.60	92.36	9.40	0.00	11.60	0.00
Apr	89.20	21.50	0.00	0.00	34.40	2.45	35.60	3.84	40.80	3.41
May	0.00	0.00	48.40	12.68	0.00	0.00	114.80	51.10	23.40	1.95
Jun	175.40	85.00	99.50	34.78	79.70	30.17	56.20	5.98	39.60	4.53
Jul	32.00	10.70	115.30	49.88	305.40	248.72	287.60	201.55	291.30	215.51
Aug	188.20	124.40	150.00	76.86	278.20	207.70	53.80	10.61	84.70	26.55
Sep	147.70	84.11	26.40	3.60	44.00	16.09	126.00	81.42	273.60	170.77
Oct	198.10	132.00	159.00	81.24	124.90	99.30	76.70	18.18	251.80	148.30
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 11 COMPARISON OF MONTHLY ESTIMATED RUNOFF USING OTC METHOD AND MONTHLY OBSERVED RUNOFF IN MM

Year	1996		1997		1998		1999		2000	
Month	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed runoff
Jan	0.00	0.00	4.57	2.58	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.01
Mar	0.00	0.00	12.67	7.80	0.00	0.00	0.00	0.00	0.00	0.00
Apr	2.99	1.82	5.48	4.76	0.00	0.00	0.00	0.00	1.34	0.00
May	0.00	0.00	0	0.00	5.70	6.25	68.00	59.54	19.74	19.78
Jun	21.99	41.08	22.73	16.43	11.10	7.08	34.00	17.28	173.11	165.70
Jul	63.80	69.60	62.03	57.48	102.30	103.67	106.70	101.33	41.78	32.02
Aug	124.71	106.04	56.62	39.40	174.40	196.65	120.40	77.12	257.41	238.82
Sep	135.94	125.40	69.63	49.08	107.50	109.2	27.20	7.19	14.18	5.03
Oct	78.28	41.0	29.4	19.75	176.81	153.16	32.30	16.13	1.20	0.00
Nov	0.55	0.30	5.94	5.01	2.50	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	4.11	2.36	0.00	0.00	0.00	0.00	0.00	0.00

Year	**2001**		**2002**		**2003**		**2004**		**2005**	
Month	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff	Estimated Runoff	Observed Runoff
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	4.96	1.59	92.36	98.75	0.00	0.00	0.00	0.00
Apr	21.50	21.55	0.00	0.00	2.47	1.13	3.84	1.42	3.41	2.21
May	0.00	0.00	12.68	5.93	0.00	0.00	51.10	37.6	1.95	0.00
Jun	85.00	78.42	34.78	33.57	30.17	20.04	5.98	4.70	4.53	2.85
Jul	10.70	0.32	49.88	47.28	248.72	219.64	201.55	197.20	215.51	197.60
Aug	124.40	107.31	76.86	81.80	207.70	191.00	10.61	7.60	26.55	23.70
Sep	84.11	66.76	3.60	0.15	16.09	3.62	81.42	55.80	170.77	172.50
Oct	132.00	101.6	81.24	81.00	99.30	55.2	18.18	17.15	148.30	139.60
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00