APPLICABILITY OF RATIONAL FORMULA IN HYDROLOGICAL ANALYSIS OF HIGHWAY CROSS DRAINAGE STRUCTURES

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Applicability of Rational Formula in Hydrological Analysis of Highway Cross Drainage Structures

Abstract

The peak flow estimation at Highway –Waterway intersects has substantial effects on Hydraulic design aspects of culverts and bridges. Fair and accurate estimation of peak flow would be the basis in deciding the size of cross drainage structures to ensure proper transfer of runoff collected at inlet towards the downstream.

The history of hydrology modelling varies from well-known Rational Formula to sophisticated computer aided models. Rational Formula has been used for over 150 years and still remains as the most widely used method due to its simplicity in approach. The present study considered five numbers of flood estimation techniques; Rational Formula, Fuller Formula, Snyder's Method, Flood transportation and HEC-HMS for catchments located in four road segments where area varies from 9 – 6663 hectares (ha). All catchments are ungauged and prediction of flood flows for ungauged basins is extensively discussed in past decades and still remains a question due to accuracy and validity of assumptions made in the analysis.

The study focused on different methods of time of concentration, runoff coefficient and design discharge estimations. Three empirical relationships along with Irrigation Department guideline (1984) were considered for the computation of Time of Concentration. Time of concentration results of Kirpich equation was substantially lower than other methods while UK Flood Studies Report equation was identified as the highest. Only the Bransby – William equation showed fair agreement with Irrigation Department Guideline.

Peak flow estimations of flood transportation technique is highly sensitive for the drainage area ratio and relatively low drainage area ratios correspond to culvert and bridge sites caused significant deviation from other methods. Fuller formula estimations were also considerably deviated from other methods.

The difference in peak flow estimation methods was not significant up to catchment area of 100 ha. Peak flow estimations of cross drainage structures in studied road segments revealed that Rational formula can be applied up to 770 ha. As a comparative assessment catchments larger than 770 ha to be modeled using Rational formula and alternative flood estimation methods.

Key Words: Time of Concentration, Rational Formula, HEC-HMS, Fuller Formula, Flood Transportation

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LIST OF ABBREVIATIONS

Abbreviation	Description
A, F	Area
AMC	Antecedent Moisture Condition
ASTER	Advanced Spaceborne Thermal Emission and Reflection
BPR	Bureau of Public Roads
C	Runoff Coefficient
CAg	Catchment Area of gauged site
CAu	Catchment Area of ungauged site
CN	Curve Number
Cp	Peak Parameter
Ct	Time Parameter
d	Depth of rainfall
D	Duration of Unit Hydrograph
D’	Storm Duration
DDF	Rainfall Depth Duration Frequency
DEM	Digital Elevation Model
DRH	Direct Runoff Hydrograph
ESDAC	European Soil Data Centre
FAO	Food and Agriculture Organization of the United Nations
f_c	Final/Equilibrium infiltration capacity
FR	Ferralsols
GIS	Geographic Information System
GPS	Global Positioning System
GTOPO	Global 30 arc-second Elevation
ha	hectares
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
hr	Hour
HSG	Hydrologic Soil Group
HydroSHEDS	Shuttle Elevation Derivatives at multiple Scales
I	Rainfall Intensity
Ia	Initial Abstraction
ID	Irrigation Department ,Sri Lanka
IDF	Rainfall Intensity Duration Frequency

IL+ULS	Initial loss plus Uniform loss rate
IWMI	International Water Management Institute
K	Frequency factor
km	kilometer
km^2	Square kilometer
L	Length
Lca	Center of Gravity of a Catchment Length
LV	Luvisols
mi	Mile
NRCS	U.S. National Resources Conservation Services
P	Excess Rainfall
Q	Peak Flow
q_{pi}	Peak runoff of unit hydrograph
Qpi	Flood hydrograph peak
RBE	Reddish Brown Earth
S	Slope
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
T	Return Period
Tb	Time base
tc	Time of Concentration
tp	Time lag/Basin time lag
TR	Technical Release
UH	Unit Hydrograph
USGS	United States Geological Survey
V	Velocity
W_{50}	Width in hrs of unit hydrograph for 50% of q_{pi}
W_{75}	Width in hrs of unit hydrograph for 75% of q_{pi}
X	Mean
Yr/YR	Year
y_T	Reduced variate
σ	Standard Deviation

LIST OF APPENDICES

1. INTRODUCTION

1.1. Background

Hydrological design would be a crucial consideration in design and rehabilitation stage of highways as several locations of highway intersects major or minor watercourses, where it acts as a barrier against the free movement of water which used to occur prior to its construction that creates necessity to make cross drainage structures to transfer water collected at inlet towards the downstream of the structure. Provision for adequate drainage is paramount importance in highway designs and cannot be underemphasized as inadequate aperture of culverts/bridges lead to inundation of upstream areas, waterlogging areas, erosion at downstream, weakening structural integrity of the road pavement, road embankment failures, loss of accessibility and adding environmental hazards. In stationary catchments with sufficiently long stream gauge records, the design discharge can be evaluated using statistical frequency analysis. The major issue pertaining to the hydrological designs of culverts and bridges is many stream crossings intersecting highways associated with ungauged basins, catchment heterogeneity and lack of stream gauge records or so often no records are available.

In the absence of ephemeral stream discharge measurements, various methods have been developed for the estimation of magnitude of flood using empirical equations, regional regression equations and other analytical approaches derived through catchment area and slope, rainfall patterns, land use and other relevant physical and climatic characteristics.

The hydrologist has to make fair engineering judgment on watershed area, runoff coefficient and time of concentration, design recurrence interval, design rainfall intensity in the determination of design discharge and to propose adequate opening size for culvert/bridge.

Most drainage facility designs require determination of peak flow rate while others concern on runoff volume generated by runoff hydrographs. However peak flow rates are the most often used parameter in design of culverts, bridges, side drains etc.

Therefore it is important to consider the applicability of different methodologies established for the determination of time of concentration, runoff coefficient and peak discharge. It is good practice to determine the design flood of major bridges using more than one method and if historical runoff data are available it should be analyzed as well. Results obtained from different methods can be compared to arrive at most optimum solution.

The history of hydrological modelling ranges from the well-known Rational Formula to recently distributed physically – meaningful models (Todini, 2007). The Rational Formula was developed by Mulvaney (1850), but Kuichling (1889) presented more comprehensive treatment on the method. However this only computes the flood peak and is sensitive to the design rainfall intensity and runoff coefficient, which is based on the user experience and availability of data. This method assumes that peak discharge occurs when the duration of particular rainfall event is equal to the time of concentration and rainfall intensity does not vary and is distributed uniformly over the catchment (Smithers, 2012). For small catchments, this assumption may hold true however in the case of a large catchment it stands a high probability that rainfall intensity varies over the area. It is possible to result incorrect estimation of peak runoff for large catchments if rational formula is adopted (Chu, 2010). Most of the federal guidelines stated that Rational Method can be used for drainage areas up to 80 ha. However this limit really depends on the watershed complexity and it is the analyst’s responsibility to determine whether the method is applicable or not and justify the application of the method based on professional judgment (Thompson, 2006).

The predictions in ungauged basins can be arrived through three methodological categories; “Borrowing”,” Substituting”, and “Generating”. The flood transportation can be referred as “borrowing” and widely used method to transfer flood information of data rich gauged catchments to adjacent ungauged basins with similar configurations.

There are several computer aided models; either event or continuous models available in rainfall-runoff simulation. Event model typically estimates runoff from an individual storm event while continuous simulation model operates for a sustained period which includes both rainfall events and inter storm events. The HEC-HMS developed by US army Corps of Engineers is one of the popular and most widely used tool and readily available for public domain.

1.2. Objectives

The overall objective concerns on the applicability of Rational formula to estimate runoff for the design of cross drainage structures in selected four roads in Sri Lanka. The relative performance of Rational Method is compared with more contemporary approaches for simulating surface runoff.

The specific objectives of the study are,

- To compare runoff characteristics in terms of time of concentration and runoff coefficient estimated by different methods.
- To compare peak flow derived from Rational Formula and other hydrologic design methods over a wide range of catchment areas.

1.3. Scope and Limitations of the Study

In general two types of design flows are applied in flood simulation for cross drainage structures.

- Structural design flows to evaluate the structural integrity of culverts and bridges.
- Bed design flows to evaluate the stability of particles intended to be permanent inside a drainage structure.

The acceptable risk factor associated with two design flows is different and the design peak flow defined in the present study refers to the structural design flows of cross drainage structures.

Wijesekera (2000) stated the following.

> Peak flow of a watershed varies from the peak flow corresponding to a specific return period, to Estimated Limiting Value (ELV) which is the largest magnitude of flow possible at a given location. Therefore it is a prerequisite to establish the acceptable risk levels or the desired return periods prior to

estimating the peak flows. Due to the varying nature of design levels depending on the importance of the locality and the involved resources it is necessary to study peak flow corresponding to a few design return periods providing the flexibility for requisite decision making. (p.4)

The Storm event corresponds to the design return periods of 25, 50 and 100 years is used as input to generate alternative rainfall-runoff models. Flood magnitude computations are made using Rational and Fuller formula, Snyder's Method, Flood Transportation techniques and HEC-HMS software. HEC-HMS Model input parameters are verified with the findings of previous studies in same or similar nature watersheds due to non-availability of observed flood data for calibration and validation purposes.

The watershed physical parameters limited to area, land cover, length of longest watercourse and slope whereas effects of watershed shape, its form factor, compactness coefficient and surface roughness are excluded.

1.4. Outline of the Thesis

The thesis begins with a discussion on application of various hydrologic procedures and their limitations prevailed in the estimation of peak flows. This further extends to study of different methods used in evaluation of time of concentration and runoff coefficient. The approach, methodology and tools applicable in determination of physical characteristics of catchments are presented in detail. The above factors are elaborated in the literature review. Furthermore applicability of some of the frequently used empirical relationships and hydrological design procedures for Sri Lankan conditions is discussed with its limitations.

Development of data base, data acquisition procedures, tools and techniques used are explained under the methodology. Results, comparison and identified relationships pertaining to the study are given in the latter part, where the factors that have contributed to such results are also discussed in detail. The identified future research needs and extension to the present study are also presented.

2. LITERATURE REVIEW

Peak discharge is the most useful parameter in calculation of cross sectional area required to convey flood and to determine the backwater effect of any structures that influences the normal flow conditions (South African National Roads Agency SOC Ltd, 2013).

The literature review component focused on different data extraction methods and tools, data processing and analysis techniques, study of different empirical relationships in the assessment of time of concentration and finally comprehensive review of methods used for the determination of peak flow for highway cross drainage structures.

The modeling of hydrological process requires acquiring in depth knowledge about the suitability of different hydrological design methodologies for a particular geographical and hydrological zone. Geographic Information Systems (GIS) has many applications in extracting information from satellite images and digital database. Available Digital Elevation Models (DEM) can be used to derive topographic attributes and terrain information. In combination with other spatial data DEMs are an important database for topography related analyses.

2.1. Time of Concentration (tc) Estimation Methods

Daniil, Michas and Lazaridis found that Kirpich and Giandotti formulas are the most popular equations in Greece for the determination of time of concentration. Seven numbers of tc estimation equations; Chow Method, Espey Rural Equation, SCS Average Velocity Method, SCS Lag Equation, Ramser Equation, Kirpich Equation and NDOR Nomograph were compared by Hotchkiss and Mccallum (1995) for small, ungauged, agricultural watersheds for the design of roadway culverts. The SCS lag equation showed poor results on all sites regardless of the method used for the evaluation of curve number. The modified version of Kirpich equation and SCS average velocity method made adequate estimation as compared with other methods.

Wijesekera (2000) applied Kirpich method, UK flood studies Report and Department of Irrigation guideline to determine time of concentration of eight urban sub catchments ranges from 9.4 to 33.8 hectares (ha) draining to Port of Colombo. The inlet time was considered as 15 and 5 minutes for large and small watersheds respectively. Direct computation of tc also made based on the actual drainage paths due to the significant variations observed in tc results. The UK flood studies Report equation gave the highest time of concentration. tc obtained from direct computations were much lesser than that of empirical equations. The irrigation department guideline resulted the second lowest.

The same author studied 122 km^2 drainage basin, a tributary of Bentota Ganga at its intersection with Southern Expressway at Welipenna in 2011 and Kirpich equation, Irrigation Department guideline and Bransby-William equation were used for the calculation of time of concentration. The lowest value of tc was from Kirpich equation and ID guidelines gave the highest values. The study reveals that the method of time of concentration estimation is more important in the case of large catchments.

The hydrological study of Proposed Expressway Hambanthota Seaport to Mattala Airport (2014) also used Irrigation Department guideline for the determination of tc for cross culverts. The same study did separate hydrologic analysis for Malala Ara Bridge where tc estimation was presented as an average of Kirpich Formula, Formula from "Design of Small Dams and Kirkpatric Formula. The variation in tc among three methods were found to be minimal. However tc determined as per ID guidelines was approximately 127% higher than the average.

Batuwitage (1985) compared peak flow analysis of 16 numbers of catchments range from 17.5 – 565 $mile^2$. Findings indicated satisfactory results for Rational Method with tc from Irrigation Department guideline. It was further stated that the method chosen for the determination of time of concentration is vital, and has considerable effect on the design flood. The same Irrigation department guideline was referred for tc calculations made for the lower order cross drainage structures of Colombo – Kandy expressway (Ranatunga, 2001).

2.2. Runoff Coefficient (C)

Wijesinghe and Wijesekera (2011) considered three alternative approaches in the assessment of runoff coefficient for the catchment at the intersection of Southern Expressway and Bentota Ganga. Alternative runoff coefficient estimations were based on three criteria; slope, land use and slope, land use, slope and hydrologic soil type and it was found that Irrigation Department guideline (slope) showed higher peak flows as compared with other alternatives. The coefficient, C established on multiple parameters (Slope, Land use Soil type) is considered as the most accurate method.

Runoff coefficient values stipulated in “Applied Hydrology, V.T.Chow (1988)” was the reference to the Hydrological study of Southern Expressway Hambanthota Seaport to Mattala Airport (2014). The land use patterns in the catchments were extracted from the 1:50,000 topographic maps published by the Department of Surveying.

2.3. Rainfall Intensity Duration Frequency (IDF) Curves

Ranatunga (2001) analyzed 26 numbers of meteorological stations with a density about 2500 km^2 per instrument to develop IDF curves for return periods of 2,5,10,25,50,100 and 200 years. A given single IDF equation can be adopted for a small drainage area at or near (meaning hydrometeorologic similarity) any of the 26 stations mentioned in the study. The author suggested developing set of Iso intensity curves for the entire island in the future. The above reference is widely applied in local context for the rainfall intensity estimations. The hydrological computations of Proposed Expressway from Hambanthota Seaport to Mattala Airport (2014) also referred to IDF curves published by Ranatunga (2001).

2.4. Peak Flow Estimation Methods

Hydrologic modeling has a long history and it has evolved alongside with the development of more powerful computational tools. Rational Formula, Snyder’s

Method, Soil Conservation Service (SCS) method, Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS), Regional Regression equations and Statistical Analysis are some of the most widely used methods.

Hagen studied hydrologic procedures adopted for urban watersheds with area less than 30 $mile^2$ (7770 ha) through questionnaire circulated among the hydrological model users. Results showed that more than 86% of users relied on, Technical Release – 55 (TR-55) computer method (51%), Rational method (20%), TR-20 by Soil Conservation Service (SCS) (9%) and rural regression equations by the U.S. Geological Survey (6%). It was further revealed that less data involved methods are quite popular and practitioners may not be fully aware on some of the effective methods available for analyzing small urban watershed flood flows. Calibrated rainfall runoff models (TR-20 and HEC-1) constitute to a small percentage (12%) of the models adopted.

Smithers (2012) made detailed analysis on Design Flood Estimation methods in South Africa. It was found that lack of hydrological data and suitable guidelines are the main problem associated with hydrological analysis of small catchments (<100 km^2) in South Africa. Rational Method is the most commonly used method and the use of Time Area, SCS and Kinematic procedures are significant in small basins. In the availability of stream flow data for a specific area a choice has to be made between flood frequency analysis and rainfall based methods. The rainfall based methods are widely used as better quality longer rainfall records are available at more sites compared to stream flow records. Also areal extrapolation of rainfall records can be achieved more easily than runoff records. Errors encountered in measurement of stream flows and inconsistencies in the data and non-homogeneous stream flows make the data unsatisfactory for direct frequency analysis. Similarly, non-stationary stream flow records due to changes occurred in catchment conditions can render stream flow record unsatisfactory for direct frequency analysis. Rainfall – runoff models can incorporate historical, present and expected future conditions of catchment physical characteristics in terms of variations in land cover, sub soil conditions and rainfall in predicting the runoff for a specified time. Unit hydrographs are described for catchments range from 15 to 5000 km^2. SCS method is widely applied for small agricultural catchments less than 8 km^2.

Study on 19 km long highway associated with 180 km^2 drainage area by Daniil et al. found that 50 year return period discharge of rational method approximately 25% higher than that of HEC-HMS model. Fuller equation which is a usual choice in flood flow analysis for highways/railways – water crossings used in parallel to rational method and HEC-HMS. It is further explained that rational method should not be used for areas larger than 2.5 km^2 without subdividing the overall catchment.

Hotchkiss and McCallum (1995) applied Potter Method, Fletcher Method, Beckman Method, USGS Regression Equations, Rational Method and TR-55 for hydrological designs of roadway culverts in state of Nebraska. Rational method found as the best estimate for return periods of up to 5 years. This method did not perform well when estimating 25 year flood. The Beckman and USGS regression methods provided the closest estimates for the 25 year flood.

Mcenroe (2007) reviewed methods and criteria in sizing highway culverts and bridges in United States. During the early stage of highway construction, culverts and bridges were sized by empirical methods derived from past experiences during the flood events. Most of these methods were introduced for the railroads which no particular recurrence intervals were defined in the designs. The most popular hydrologic design methodologies used prior to 1950 were Dun's table, Myers and Talbot formula and the Burkli-Ziegler formula. The recently developed hydrological modeling is based on the frequency analysis of stream flow and/or rainfall data. In addition, Rational method, SCS method, Bureau of Public Roads (BPR) method and regional regression equations are widely employed in peak flow determination.

Guidelines for Road Drainage Design by Road Engineering Association of Malaysia (2004) suggested flood estimation procedures applicable for gauged and ungauged catchments. Rational formula, Regional Flood frequency methods, Synthetic Unit Hydrograph methods and runoff routing methods can be used for the data poor ungauged catchments. In contrastingly flood frequency analysis, unit hydrograph methods and runoff routing methods are defined for the data rich gauged catchments. The design recurrence intervals for culverts are defined as 25 or 50 years and that of bridges are 25, 50 or 100 years depending on the scale of the structure categorized as minor, medium or major. Even though the travel time from individual elements to the out let is less, the recommended minimum time of concentration for road inlet and small areas(< 0.4 ha) is given as 5 and 10 minutes respectively.

Wijesekera (2000) modeled eight numbers of urban sub catchments (9.4- 33.8 ha) draining to Port of Colombo with Rational Formula, HEC-HMS, SCS and Snyder's unit hydrograph. Rational Formula was applied for catchments less than 4 ha as the method of peak flow estimation is less sensitive in small drainage areas. Variations in different peak flow estimations are significant in the case of large catchments. Approximately Rational and SCS methods were of similar values and closer to the lower ends. It is noted that Rational Formula estimations deviated from other models in larger watersheds.

The hydrological evaluation of bridge at intersection of Southern Expressway and Welipenna Ganga done by Wijesinghe and Wijesekera (2009) found that peak flows of Snyder's method and SCS method were nearly 7% and 0.8% of Rational formula estimations. Rational method and SCS method resulted extreme end peak flows. Snyder's method only showed fair agreement with field observations. The Runoff coefficients and curve numbers used in rational and SCS methods are extracted from literature due to the absence of site specific values, thereby causing disparity in results. Time and peak parameters of Snyder's Method were extracted from Irrigation Department guideline which is a clear reflection of actual conditions prevailing in the watershed.

Batuwitage (1985) compared flood estimations of sixteen numbers of catchments range from 17.5 – 565 mile^2 using Rational Formula, Snyder's Technique, US Soil Conservation Service Method (SCS) and Statistical methods. Rational formula showed satisfactory results for the time of concentration followed by the Irrigation Department guideline. SCS method resulted highest peak flows with the increase in catchment size.

Skills International (2014) used HEC-HMS software to generate flood simulation model of Malala Ara Bridge of Extension of Southern Expressway project. SCS Unit Hydrograph was used as the transform model with a curve number of 60 (AMC III). Approximately HEC-HMS design flood flow was 53% higher than that of Rational Method for a drainage area of 278.8 km^2.

2.5. Flood Frequency Estimates

Statistical methods involve use of historical data to determine flood for a given return period. Their use is thus limited to catchments with suitable previous flow records. Where accurate records for longer period are available, statistical methods are the best and recommended method to determine the flood peak especially for longer return periods (Drainage Manual, 2013).

Road Engineering Association of Malaysia (2004) specifies two parameter log normal distribution, Gumbel or extreme value type I distribution and generalized extreme value (GEV) or extreme value III distribution, Log-Gumbel distribution and Log-Pearson Type III distribution as most useful distributions for the flood frequency studies.

Transformation of flood flow from gauged site to ungauged site on the same stream or nearby stream can be made by weighting the gauge data with sufficient length of records (more than 10 years) by a ratio of drainage area as follows;

$$Q_{ungauged} = Q_{gauged} \times (A_{ungauged}/A_{gauged})^{x}$$

Where Q : Discharge

A : Basin area at gauge site and project site

x : Slope exponent of the curve (power function) relating Q to A for suitable gauges in the hydro-physiographic province

The same can be applied for an ungauged site in vicinity of gauged site subjected to the fact that the basin area is within 0.5 to 1.5 times that of the gauged site. The accuracy and validity of the flow estimates are related to the similarity of aspects relating to precipitation, drainage area and shape, orographic expression, vegetation, lithology/geology of gauged and ungauged sites.

Gamage (2006) analyzed probability distribution of annual maximum, mean and minimum stream flows of 46 numbers of gauging catchments in Sri Lanka. The gauging sites with minimum ten years of recorded flood flows were selected for the study. It was found that annual maximum, annual minimum and average annual flows can be well approximated by Generalized Extreme Value (GEV), GEV and Pearson Type III (PE3) distributions respectively.

Abeynayake (2000) also applied flood transportation technique to generate annual maximum flood peaks of gauged river basins in wet zone of Sri Lanka, with data series range from 23 to 43 years. The ratio of drainage area varied from 0.06 to 1.00. The relationship of this type of situation is presented in the form of $Q= CA^n$, where n is an exponent. It is concluded that annual peak flow can be proportioned to its watershed area raised to power of 0.8. Also results showed best accurate estimation as compared to other methods. Error in estimated peak flow with exponent n equals to 0.8 showed an average error of 35 % for similar catchments within the same river basin and 55% for any other catchments from the wet zone.

2.6. Applicability of Rational Formula

As stated in many literature Rational Formula is appropriate for small catchments. However the definition of small catchment is not consistent across practitioners. Most of guidelines suggest a limit of 80 ha for the successful application of Rational method. This limit is relaxed in some references and extends even up to 500 ha. Ponrajah (1984) recommends to apply Rational Formula for area less than 5000 ha. Similarly some of the international findings also state that Rational Method can be employed for catchments up to 25 km^2 subjected to further check with more detailed procedures when the area is 10 km^2 or more.

Road Engineering Association of Malaysia (2004) specifies Rational formula for culverts, small to medium bridges and causeways falls in the category of small to medium size catchments. FSU Programme (2012) demonstrates limits of catchment area for the application of Rational Formula as tabulated in Table 2-1 and 2-2.

Table 2-1 Size of catchment where Rational Method is applied according to some countries

Region/Countries where Rational Method is widely applied		Catchment size (km^2)
Australia	Urban	5.00
	Rural	25.00
Canada		25.00
USA	Washington State	0.40
	Maine State	2.60
	Florida	2.43
	New York	0.08
US Dept. of Transportation		0.80
Hong Kong		1.50
Malaysia		0.80
UK		2.00 – 4.00
New Zealand		0.50

Source: Table 2.1, FSU Programme (2012)

Table 2-2 Size of Catchment where Rational Method is applied according to literatures

Literature	Catchment size (km^2)	Remarks
Debo and Reese,1995,Municipal Storm Water Management,p.209	0.08	
Wanielista,Kersten and Eaglin, Hydrology, Water Quantity and Quality Control,2nd edition,1997	0.20 to 0.40	
Chow,V.T., Handbook of Applied Hydrology,Chow,1964,p.25	0.40 to 0.80	
Design and Construction of urban Storm water Management Systems(ASCE Manuals and Reports of Engineering Practice No.77), ASCE,1992,p.90	0.40 to 0.80	
Singh,V.P.,1992,Elementary Hydrology,p.599	0.40 to 0.96	

Literature	Catchment size (km^2)	Remarks
ASCE(1996), Urban Hydrology, Chapter 9 in Hydrology Handbook, Manuals and Reports on Engineering Practice,No.28,p.580	1.00	urban
Ponce,V.M.,1989,Engineering Hydrology,p.119	1.30 to 2.50	
Gray,D.M.,(ed.) 1970, Handbook on the principles of Hydrology,1970,p.8.2	2.56	
Viessman, W. and Lewis, G.L. (1996). Introduction to Hydrology, fourth edition,p.318	2.56	
Gupta,R.S.(1989),Hydrology and Hydraulic Systems,p.621	10.00	rural

Source : Table 2.2, FSU Programme (2012)

Majidi, Moradi and Vagharfard (2012) compared flood magnitude estimates of Rational Method and Synthetic Unit Hydrograph (SCS) for ungauged catchment of 8362 ha in Iran. The entire catchment was divided into homogeneous sub basins where area ranges from 288 – 1016 ha. The results showed that SCS method was more accurate estimate than rational method and error in flood hydrographs were relatively less as compared with the rational method.

Peak flows of Rational Method compared with SCS method based on curve number concept for catchments in Saudi Arabiya by Dawod, Mirza and Ghamdi (2011). Results indicated 44% difference in both methods and authors stated that the difference is mainly due to the invalidity of assumptions made in Rational formula for large size catchments. Hydrological study of 90 km long Ramadi-Nukhaib highway in Iraq by Sulaiman, Shujairi, Madhloom and Hashimi (2016) considered rational formula up to drainage area of 2.5 km^2 while basins larger than 2.5 km^2 were modeled using SCS method.

3. METHODOLOGY

3.1. Study Area

The present study was conducted for 46 numbers of catchments associated with cross drainage structures located in four road segments; Bodagma - Hambegamuwa – Kaltota (B528) road, Naula - Elahera - Pallegama – Hettipola (B312) road, Kandy – Jaffna (A009) road and Paranthan - Kachchai – Mullaitivu (A035) road as shown in Figure 3-1 to 3-4.

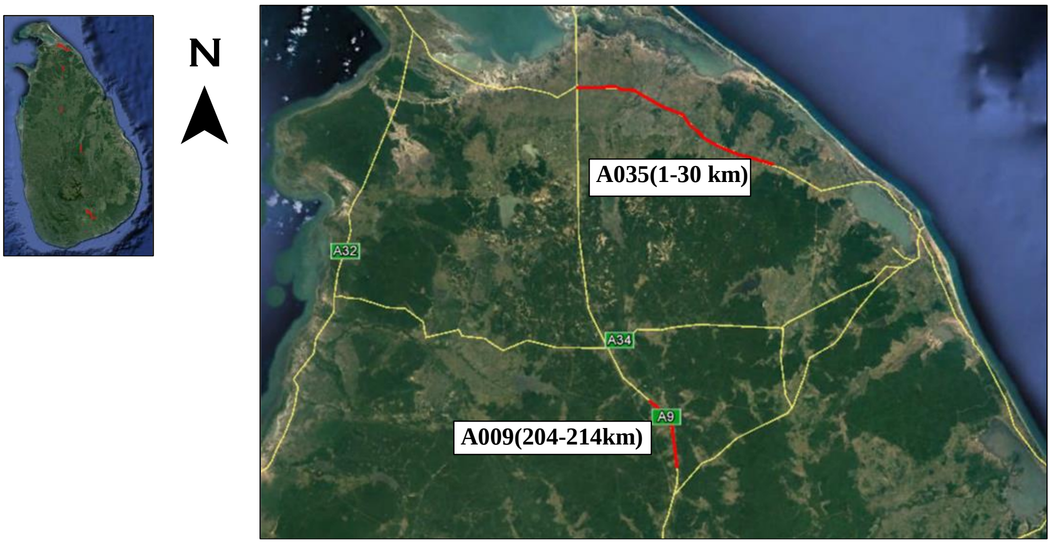


Figure 3-1 Location Map of A009 and A035 Roads

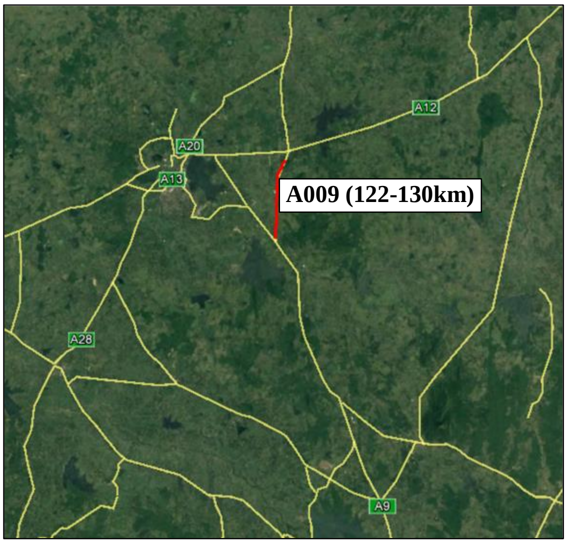


Figure 3-2 Location Map of A009 Road

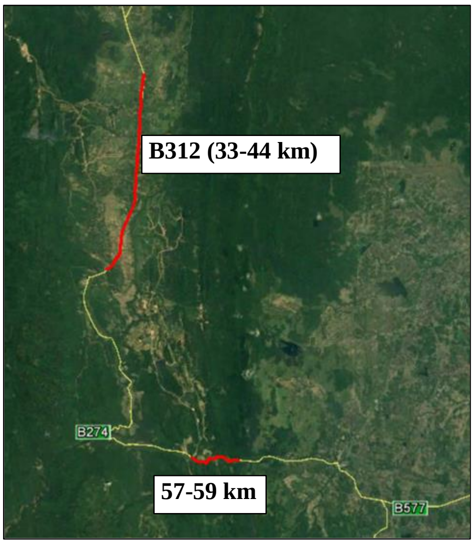


Figure 3-3 Location Map of B312 Road

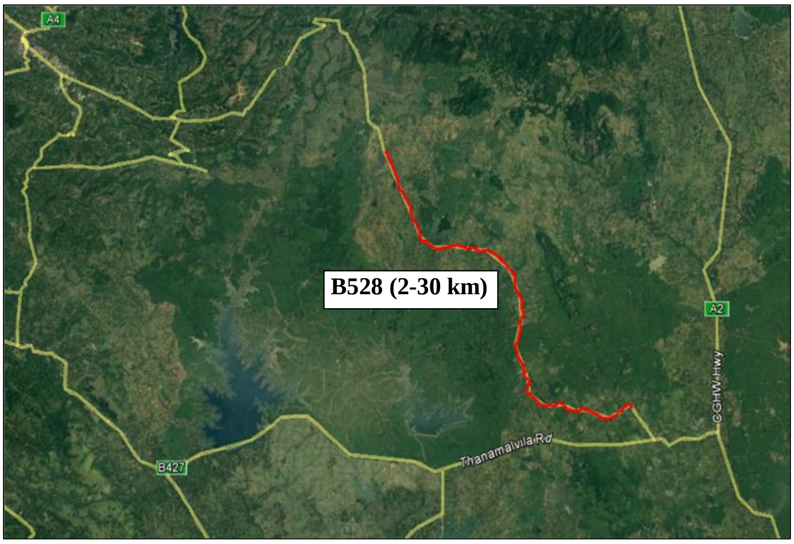


Figure 3-4 Location Map of B528 Road

The selected road segments cross tributaries of main streams or minor streams at several locations, thus culverts/minor bridges/major bridges/causeways are provided to discharge stream flow from upstream to downstream. Sub basins located in the same road with similar nature characteristics were omitted, finally total numbers of 46 catchments range from 9.080 to 6662.610 hectares (ha) were analyzed.

3.2. Methodology and Approach

The methodology and approach was formulated to achieve the study objectives in a systematic manner. Hydrological response of a catchment depends on different source data like topography, soil, land use etc. The assimilated data in the form of topography, soil type and land cover etc. were processed to extract physical attributes of an area then further refined with open source data published by different authorities/agencies prior to estimation of time of concentration, runoff coefficient, curve numbers and peak flow. Hydrological analysis was made under several options and finally results of Rational Formula and other peak flow alternatives were compared. Schematic diagram of overall methodology and approach is depicted in Figure 3-5.

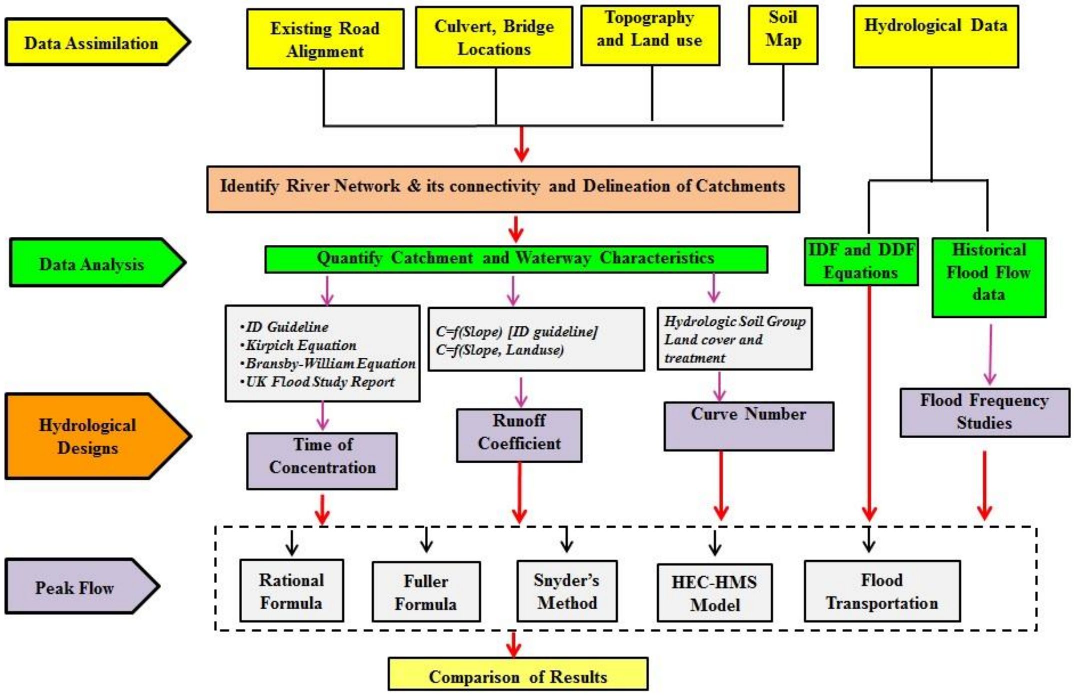


Figure 3-5 Methodology and Approach

Table 3-1 below indicates summary of input parameters and physical characteristics referred in each flood estimation method.

Table 3-1 Input Parameters required in Different Flood Estimation Methods

Flood Estimation Method	Input Parameters
Rational Formula	Catchment Area Rainfall Intensity → Time of Concentration, Design Return Period, IDF Curves Runoff Coefficient → Slope, Land Coverage
Fuller Formula	Catchment Area and Design Return Period
Snyder's Method	Catchment Area DDF curves → Rainfall Depths, Deign Return Period Length of river, Length from point of interest to the pint on the stream closest to the centroid of the watershed, Catchment coefficients

Flood Estimation Method	Input Parameters
HEC-HMS Model	Catchment Area Runoff curve Number → Soil and land cover Rainfall Depth → Design return period, IDF curves Lag Time→ Time of Concentration
Flood Transportation	Catchment Area Historical Peak Flood data

3.3. Data Assimilation

Data assembly consists of all necessary topographical, physical, soil and hydrological attributes required in the hydrological designs. The data collection process was commenced with the identification of sample of drainage points; which refers to inlets of existing culverts and bridges located along the roads. Once the catchment area relevant to such inlet was demarcated, parameters which influencing the runoff potential of such area were quantified in terms of catchment area (A), longest watercourse length (L), stream slope (S), center of gravity of catchment Length (Lca), time of concentration (tc), land cover and soil type etc.

3.3.1. Field Data Collection

The existing culverts and bridges along the selected road segments were initially identified with the aid of site reconnaissance surveys, field visits and available topographic maps and survey data. This further enhanced with Global Positioning System (GPS) survey to capture coordinates of road alignment and culverts/bridges. The GPS data base was regularly updated with additional points/locations obtained during the field surveys. Separate field surveys were carried out to collect information pertaining to prevailing drainage patterns, drainage directions across and along the road, land use patterns etc. to verify the validity of data obtained from other sources. Most recent topographic survey done during the road rehabilitation and improvement stage was also collected from the relevant authority. This includes plan and profile of road, existing culvert/bridge locations, cross sections at existing culverts and bridges etc.

3.3.2. Topographic Maps and Satellite Images

Topographic maps published by Survey Department, Sri Lanka in the scale of 1:10,000 and 1:50,000 were used as the primary topographic information. Shuttle Radar Topography Mission (SRTM) /GTOPO30/ASTER Global raster digital elevation model (DEM) files were used in image processing and GIS applications to derive flow accumulation, flow direction, slope grid and watershed boundaries and to check the compatibility of data collected from other sources. Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales (HydroSHEDS) developed by USGS also provide hydrographic information in regional and global context that offers geo-referenced data sets in vector and raster format including river networks, watershed boundaries, drainage directions, flow accumulation and river topology. International Water Management Institute (IWMI) provides open access web based water information of Sri Lanka which consist of river basins, stream flow and rainfall stations, soil profile, geology, paddy areas and evaporation stations in the format of shapefile feature class (point/line/polygon) with reference to WGS84 coordinate system.

3.3.3. Hydrological, Topographical and Soil data from Publications

Database consisting of topographical, hydrological and soil characteristics were established based on the findings of previous studies. This is mainly consisting of watershed boundaries, watershed areas of main river basins and river gauge stations, flood frequency analysis for different return periods, IDF equations, Rainfall Depth Duration Frequency (DDF) curves, land use maps, soil maps, annual flood peaks at river gauge stations etc. which used for gap filling and data verification. A summary of data used in the study as outlined in section 3.3.1, 3.3.2 and 3.3.3 is given in Table 3-2 below.

Table 3-2 Reports and Data Availability

Item	Data	Description	Source of Data/Reference
1.0	Topographical Data	Topographic Map/Base Map	• Survey Department 1:10,000 & 1:50,000 maps • Detailed Topographical Survey done for the road rehabilitation work
		Land use, slope	• Survey Department 1:10,000 & 1:50,000 maps • Google Maps • Site Reconnaissance survey
		Digital Elevation Model	• SRTM/GTOPO30 • ASTER Global DEM
2.0	Hydrological Data	Physical Characteristics of river Basins	• HydroSHEDS • Water Information-Sri Lanka(IWMI) • Master Plan for Electricity Supply Sri Lanka,1987 • Field Surveys
		Historical stream Discharge	• Master Plan for Electricity Supply Sri Lanka,1987 • Water Information-Sri Lanka(IWMI)
		IDF curves	• Ranatunga, 2001
		DDF curves	• Vanniasingam R. Baghirathan and Elizabeth M. Shaw,1977 • Technical Guidelines for Irrigation Works", A.J.P.Ponrajh, 1988
		Runoff Coefficient	• Applied Hydrology, Ven TeChow,David R. Maidment, Larry W.Mays and other international publications • Irrigation Department Guideline, A.J.P.Ponrajah (1984)
		Runoff Curve Number	• Hydrologic Modeling System HEC-HMS: Technical Reference Manual
3.0	Geographical Data	Soil Map	• Water Information-Sri Lanka(IWMI) • Harmonized World Soil Database Viewer-Food and Agriculture Organization of the United Nations • European Soil Data Centre (ESDAC)

Item	Data	Description	Source of Data/Reference
4.0	Road Network and Existing culverts and bridges	GPS data of road alignment and cross drainage structures	• Survey Department 1:10,000 & 1:50,000 maps • Google Maps • Topographical Survey • Site Reconnaissance survey
5.0		Software Applications	• ArcMap • HEC-HMS • AutoCAD • Google Earth

3.3.4. Gap Filling of Collected Data

All digital format maps were georeferenced to SLD Kandawala datum in ArcMap platform. This enabled to import field collected GPS data into the same data frame for further analysis and processing. Shapefile layers consist of topographic, land use, river network, soil data, road traces and existing culvert/bridge locations were imported into the ArcMap. This was compared with data obtained from different sources in order to verify its consistency and accuracy. The missing data were then collected from field visits or surveys or assumed reasonable values.

3.4. Design Inputs derived through Mapping Process

All hydrological design methods listed in section 3.2 require physical catchment parameters to simulate flood flow for a given return period. The first step is to delineate catchment areas which can either done by manually, or with the aid of software applications. Given the known boundaries of a catchment, enables the user to quantify other required catchment characteristics by appropriate means.

Electronic versions of topographic maps published by Survey Department, Sri Lanka in the scale of 1:10,000 or 1:50,000 were imported into ArcMap. Whereas in some areas Survey Department provides electronic versions of topographic maps in the format of shapefiles with reference to the national grid. The other images except shapefiles can be georeferenced manually once it is imported to the ArcMap. GPS coordinates of existing culverts and bridges entered in the excel sheet was also imported to the same ArcMap interface. The catchment areas of cross drainage structures were demarcated in the same file and relevant attributes inside the already drawn polygons (catchment areas and coordinates of the centroid of the catchments) were obtained. Combined catchment areas were identified where individual basin areas could not be delineated due to topography and closed proximity of culverts. The effective water course length of each sub basin was determined in the same manner. Drainage directions, catchment slopes and types and areas of different land use patterns were also extracted from ArcMAp. The open access soil profile shapefiles of Sri Lanka provided by IWMI was imported to the same data frame and respective soil type was identified. This was compared with the Soil Maps published by other sources for further verification. All shapefiles were then exported as KML format to support in Google Earth map as a separate layer. Those exported layers shown as an overlay on Google Earth map used for further verification on slopes and drainage directions and other physical parameters.

DEMs published by SRTM/GTOPO30/ASTER has opened to public domain and ArcMap includes several tools to work on DEMs and to derive design inputs for Hydrological Designs. Elevation raster files were used to generate flow direction raster which graphically represents the flow direction for a cell by comparing its elevation to those of its neighbors. The generated flow direction raster was used to locate sinks and pre identified sinks were filled to correct the cells having lower elevations. The watershed raster developed by basin tool in hydrology toolset mainly used to demarcate watersheds for the whole area. Resulted river basins of major streams in the study area were compared with main river basin shapefiles published by HydroSHEDS, IWMI and other printed maps. The other tool available in Hydrology toolset; “Watershed” was used to generate watersheds for each pour points which refer to inlet of culverts and bridges. Catchment areas correspond to cross drainage structures of B312 Road are depicted in Figure 3-6 through 3-10. Individual and combine catchments identified for the rest of the structures are shown in Appendix B.

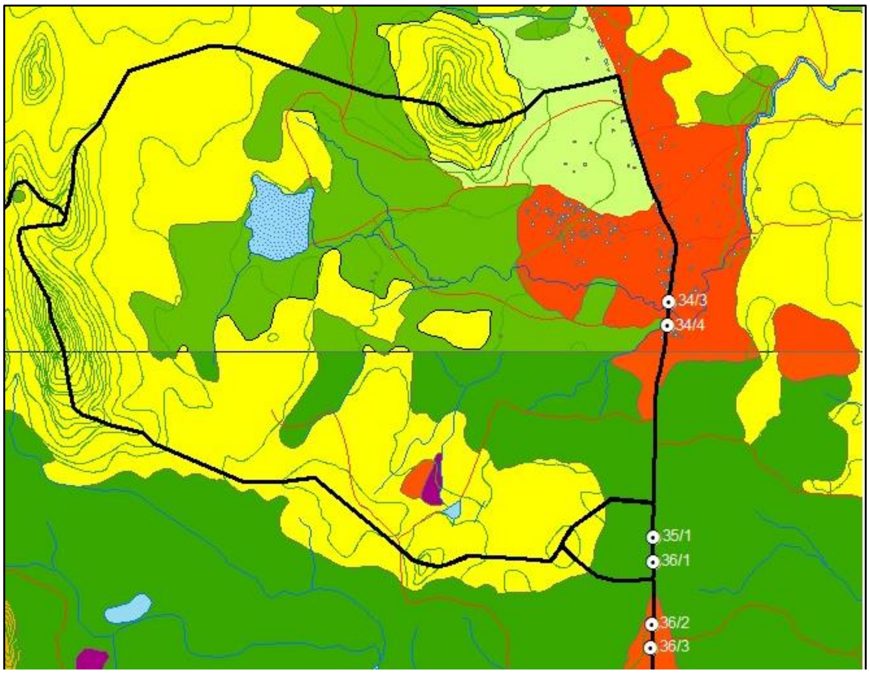


Figure 3-6 Catchment Area B312 Road [34/3 to 36/1]

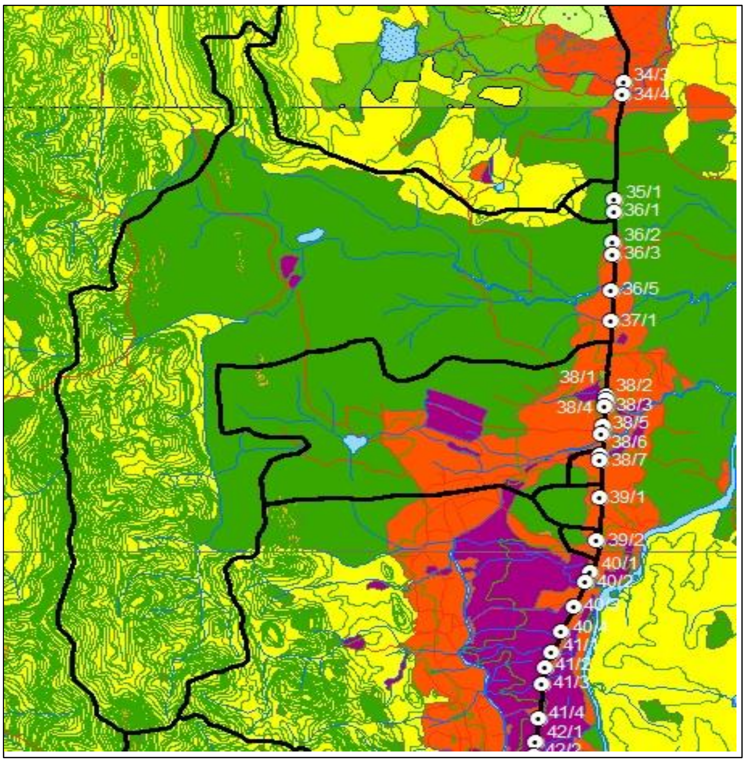


Figure 3-7 Catchment Area B312 Road [36/2 to 39/2]

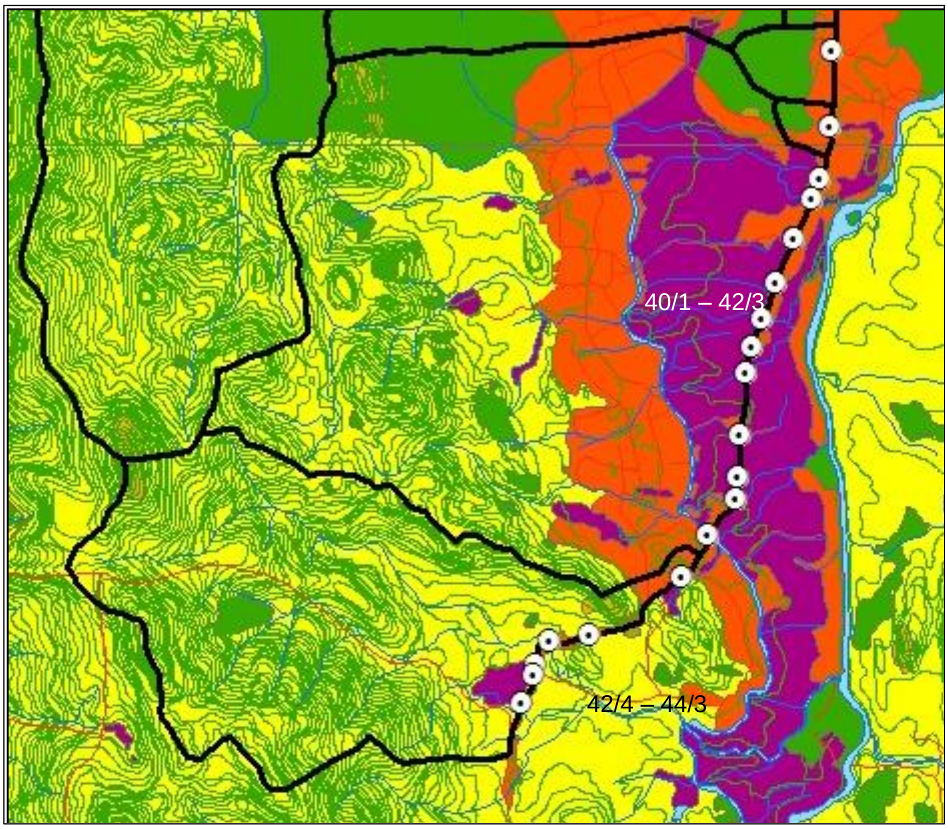


Figure 3-8 Catchment Area B312 Road [40/1 to 44/3]

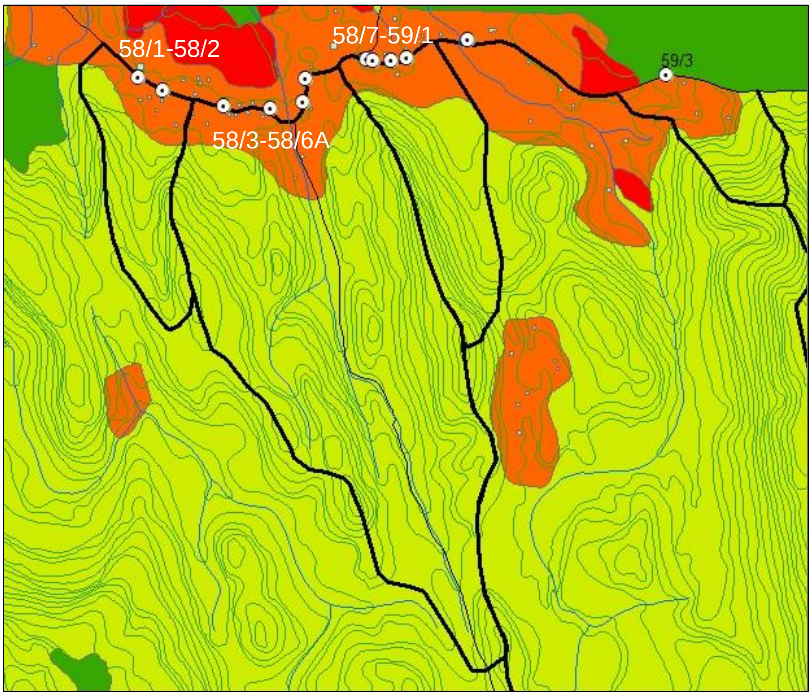


Figure 3-9 Catchment Area B312 Road [58/1 to 59/1 & 59/3]

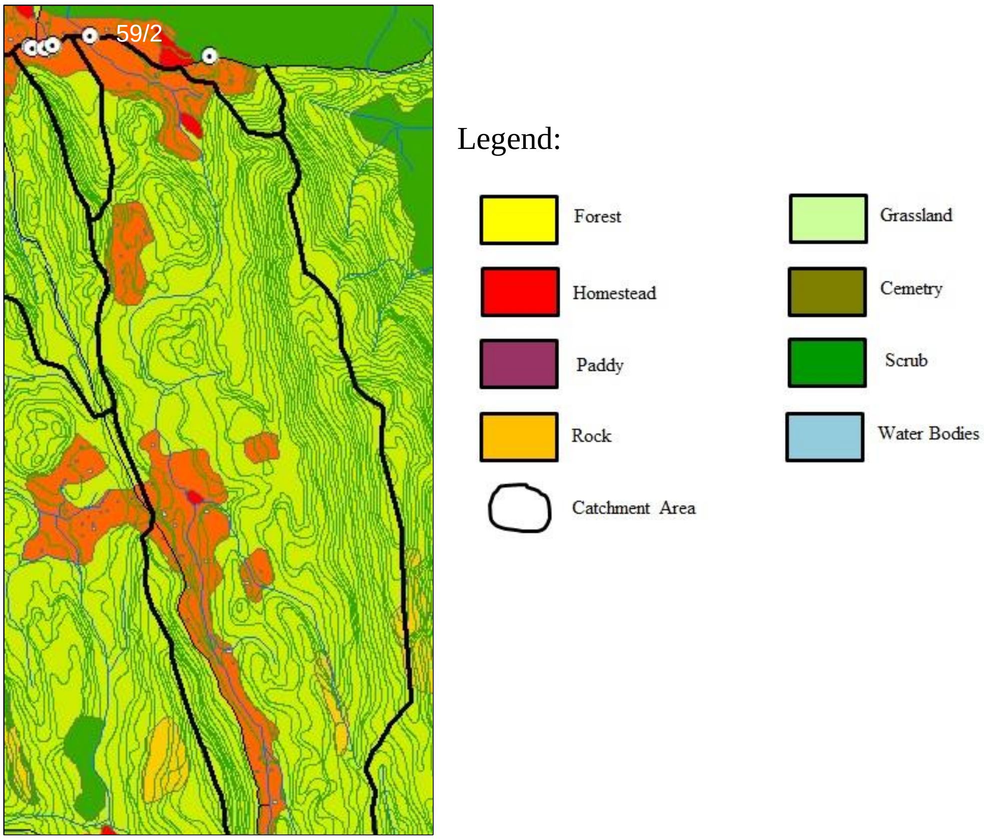


Figure 3-10 Catchment Area B312 Road [59/2]

3.5. Quantify Catchment Characteristics

3.5.1. Stream Slope (S)

The stream slope was calculated by dividing the elevation difference at the highest point of the watercourse and point of interest by the length of the watercourse. The stream slope was computed considering the entire water length as a single unit since variation among average of segmental slopes along the watercourse is insignificant.

3.5.2. Longest Watercourse Length (L)

The path of longest watercourse was identified using ArcMap software. The corresponding length was obtained from the attribute table of generated flow paths. This was verified with the findings of field visits.

3.5.3. Center of Gravity of catchment Length (Lca)

The center of gravity of a catchment length is the distance measured from the drainage point to a point on the longest watercourse opposite the center of gravity of the catchment area. The center of gravity was determined with the aid of ArcMap and CAD applications.

3.5.4. Time of Concentration (tc)

The origin of the rational formula is rooted in the design of culverts and conveyance systems, where time of concentration is simply defined as the time taken to travel for a particle of water from the most hydraulically remote point in the watershed to the outlet, which means the inlet of culvert/bridge. The time of concentration plays an important role in developing the peak discharge of a watershed and is one of the critical factors in runoff estimation methods.

There are several methods available for the estimation of time of concentration which may differ from country to country as some countries developed their own guidelines/equations in appropriate for the regional flow path characteristics. The method of estimation can be classified as "lumped" which is designed and calibrated for the entire watershed (eg: SCS lag equation). The other most commonly used method is based on the principal flow path and velocity of flow along the particular segment in calculating the time of concentration. The direct computations based on the observed data of a flow path/watershed would be an important factor to arrive at reliable estimation. The present study considered following empirical relationships in the assessment of time of concentration.

3.5.4.1. Irrigation Department (ID) Method, Design of Irrigation Headworks for Small Catchments (Ponrajah A.J.P., 1984)

The following equation is originally developed for Sri Lankan conditions.

tc = [L/(Vx 60)] + 15 minutes

Where tc : Time of Concentration (min)

L : Length of longest water course (m)

V : Velocity of Flow (ms^{-1}), Table 3-3 demonstrates flow velocities correspond to average stream gradient.

Table 3-3 Flow Velocity

Average Gradient of the Stream %	Velocity (m/sec)
0 to < 1	0.4572
1 to < 2	0.6096
2 to < 4	0.9144
4 to < 6	1.2192
≥6	1.5240

Source: Table 4.2.6 Ponrajah A.J.P. (1984)

3.5.4.2. Kirpich Equation (KIR)

In 1940, Kirpich developed following equation from SCS data of 7 rural basins in Tennessee with well-defined channel and steep slopes (3% to 10%) where land use pattern is less than 56% of timber coverage. Kirpich found that tc depends on length of travel and slope. Many later references indicated an adjustment factor for the type of land cover which is not appeared in the original equation. A factor of 0.40 is introduced for the overland flow on concrete/asphalt surface, while that is 0.20 for concrete channels. No adjustment is proposed for the overland flow on bare soil or flow in roadside ditches.

$$tc = 0.0078\ L^{0.77}\ S^{-0.385}$$

Where tc : Time of Concentration (min)

L : Length of Channel (ft)

S : Slope of Total Length (ft/ft)

3.5.4.3. Bransby - Williams Equation (B-W)

The Bransby-Williams formula dates from 1922 when George Bransby William published a paper on "Flood discharge and dimensions of spillways in India". The equation is originally defined for the rural catchments.

$$tc = 58.5\ L/[(A^{0.5})(S^{0.2})]$$

Where tc : Time of Concentration (min)

L : Longest Stream Length (km)

A : Watershed Area (km^2)

S : Watershed Slope (m/km)

3.5.4.4. UK Flood Studies Report (UK)

The following equation is recommended in UK Flood Studies Report (1975).

$$t_c = 2.8 \left(\frac{L}{\sqrt{S}}\right)^{0.47}$$

Where tc : Time of Concentration (hrs)

L : Main Stream Length (km)

S : Main Stream Slope (m/km)

3.5.5. Runoff Coefficient (C)

Runoff coefficient is the proportion of precipitation rate which contributes to the peak runoff rate, is a dimensionless coefficient less than unity. The coefficient of runoff for a given watershed is a major source of uncertainty in application of Rational formula. C accounts for initial losses due to depression storage as well as infiltration during runoff process. It implicitly accounts for the hydrodynamics of the runoff process whereby runoff throughout the catchment flows down to the mouth where the discharge to be computed. The antecedent moisture condition in the catchment, storm duration and hydrograph shape are disregarded in C. Most of the guidelines suggest a multiplication factor based on the recurrence interval adopted in the hydrological design.

The runoff coefficient can be established on runoff affecting parameters like slope, land use and cover, soil type etc. Accordingly two numbers of approaches were adopted in the present study as discussed below.

a) Guideline 1 : C based on Slope of the Catchment

Guideline 1 was established referring to "Design of Irrigation Headworks for Small Catchments (Ponrajah, 1984)". However this does not include multiplication factor to account for the effects of different recurrence intervals. Table 3-4 below shows runoff coefficient for different slope classes.

Table 3-4 Runoff Coefficient for Various Catchment Slopes

*Catchment Slope in %	Runoff Coefficient (C)
0 to < 2	0.3
2 to < 4	0.4
≥ 4	0.5

Source: Table 4.2.4 Ponrajah (1984)

*The slope is defined as the difference in level between the highest point in the longest watercourse and the point of interest divided by the length of the longest watercourse.

b) Guideline 2 : Guideline 2 was based on slope and land use as specified in Applied Hydrology, Ven Te Chow, David R. Maidment, Larry W. Mays ,which is reproduced in Table 3-5. In the absence of C value for surface characters other than what is specified below, values stipulated in literature were used with the frequency factors suggested in Table 3-6.

Table 3-5 Runoff Coefficients for Rational Formula

Character of Surface	Return Periods (years)						
	2	5	10	25	50	100	500
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	080	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor Condition (grass cover less than 50% of the area)							
Flat, 0-2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2-7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair Condition (grass cover on 50% to 75% of the area)							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60

Character of Surface	Return Periods (years)						
	2	5	10	25	50	100	500
Good Condition (grass cover larger than 75% of the area)							
Flat, 0-2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2-7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0-2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2-7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0-2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2-7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0-2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2-7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Source: Table 15.1.1, Applied Hydrology, Ven Te Chow, David R. Maidment, Larry W. Mays

Table 3-6 Frequency Factor for Different Recurrence Intervals

Recurrence Interval	Multiplier
2-10 years	1.00
25 years	1.10
50 years	1.20
100 years	1.25

Source: Table 3.1, Storm water Hydrology and Drainage, D.J. Stephenson

Runoff coefficient for paddy cultivation was assigned as 0.33, 0.70 and 0.90 for 25, 50 and 100 year return periods (Food and Agriculture Organization of the United Nations and Irrigation Department of Ceylon, 1968). Following formula is suggested to estimate the weighted average runoff coefficient for drainage areas with different uses of land classes.

$$C_{\text{weighted}} = \left(\frac{\sum_{i=1}^{n} (A_i \times C_i)}{\sum_{i=1}^{n} A_i} \right)$$

Where	C weighted	: Weighted average runoff coefficient of drainage area
	Ai	: Area of sub basin i
	Ci	: Runoff coefficient of sub basin i

3.5.6. Design Return Period

Establishment of suitable return period is an important consideration in drainage designs. The return periods to be employed for major and minor classes of roads which are subjected to the limitations on the excess flow that can be tolerated in the system. This is due to the fact that damage to adjacent property, embankment, road pavement and loss of accessibility are less important in some roads whilst in other roads the necessity of safe and accessibility are considered as critical. As all roads considered in the study are categorized as major highways of class “A” or “B”, return periods of 50 and 100 years for culverts and bridges are fairly reasonable. However these conditions can be relaxed subjected to budgetary constraints prevailed in the rehabilitation stage. For the comparison purpose, all catchments were modeled for 25, 50 and 100 year return periods.

3.5.7. Rainfall Intensity

Rainfall intensity can be treated as the most influencing hydrological parameter in application of Rational and Unit Hydrograph methods. The determination of rainfall intensity is usually done by employing Rainfall Intensity Duration Frequency (IDF) curves for a given return period. The research article entitled “Towards More Efficient Hydraulic and Hydrological Design of Cross Drainage Structures Using New Developed Intensity Duration Frequency Equations by D.G.L. Ranatunga (2001)” was referred for the IDF curves related to the project area. This provides IDF curves for many localities throughout the country where pluviograph rainfall data are presented. These IDF curves served as secondary data derived from primary rainfall data obtained from the Department of Meteorology and Department of Irrigation, etc. Therefore there is no necessity to obtain additional daily rainfall records for this purpose. Respective rain gauge stations for the selected road segments are tabulated in Table 3-7.

Table 3-7 IDF Curve Stations

Road	Section	Respective Rainfall Station
B312	33+000 km – 59+000 km	Polonnaruwa
B528	2+000 km – 30+000 km	Hambantota
A009	122+000 km – 130+000 km	Anuradhapura
A009	204+000 km – 214+000 km	Vavniya
A035	1+000 km – 30+000 km	Vavniya

The IDF curve equations for the aforesaid rainfall stations are depicted in Figure 3-11 through 3-14.

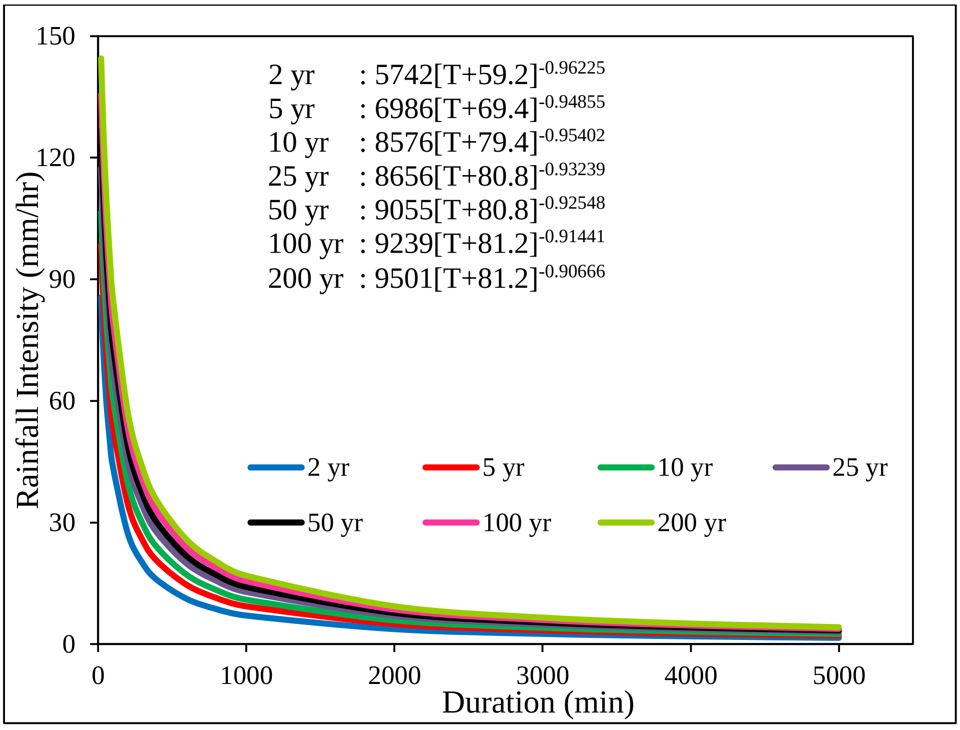


Figure 3-11 IDF Curves for Station Polonnaruwa

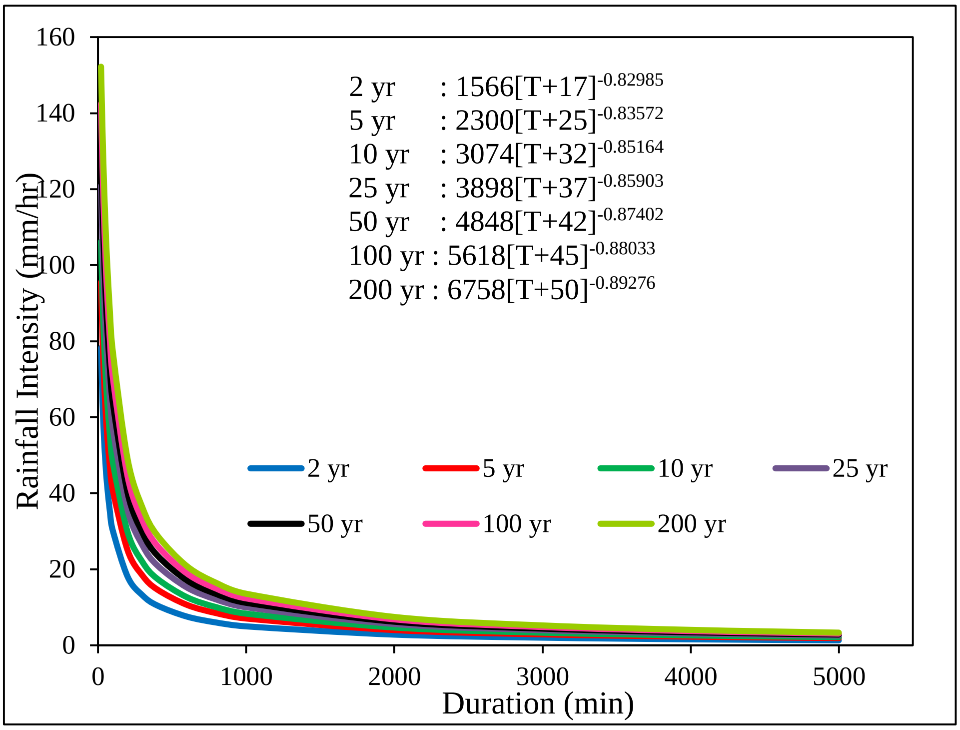


Figure 3-12 IDF Curves for Station Hambantota

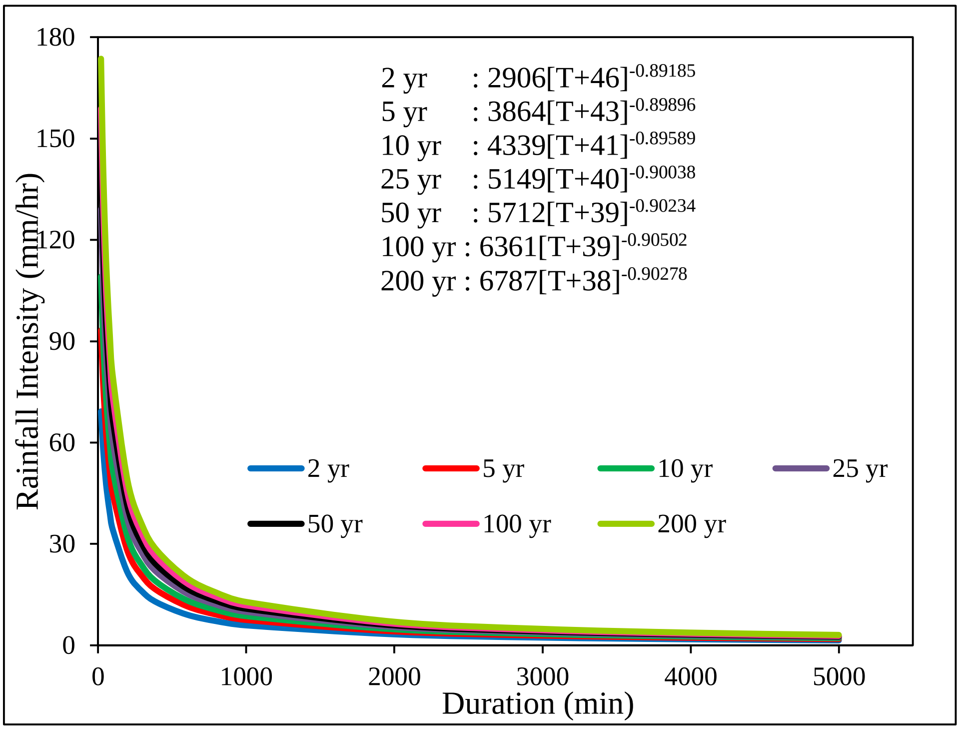


Figure 3-13 IDF Curves for Station Anuradhapura

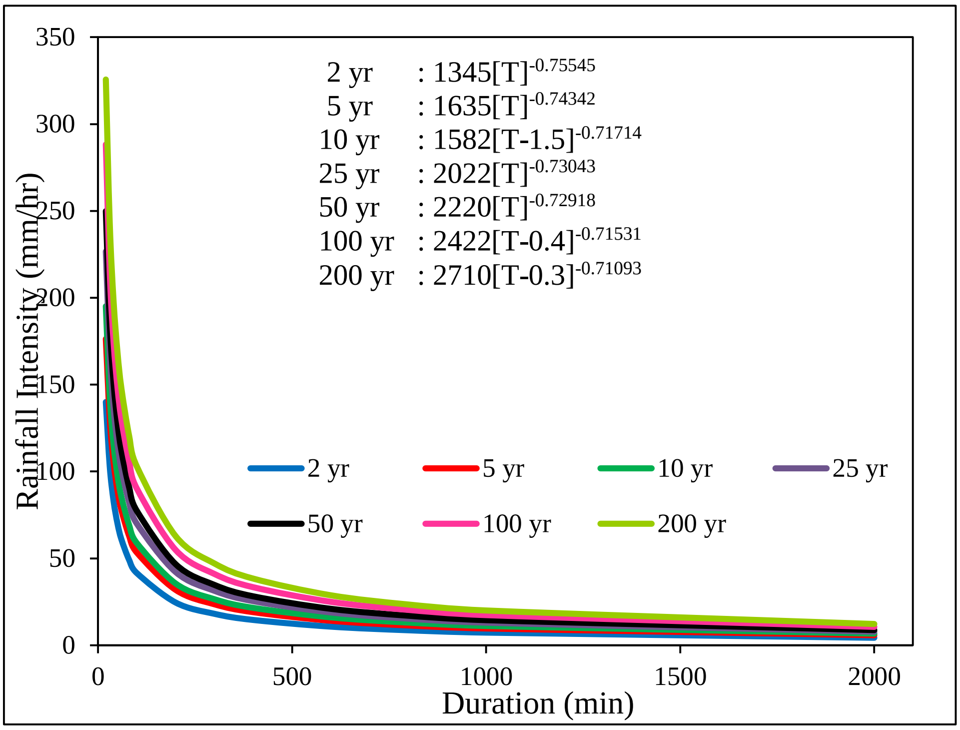


Figure 3-14 IDF Curves for Station Vavniya

3.5.8. Rainfall Depth Duration Estimates

Limited number of studies are made for rainfall depth duration frequency relationships in local context. The design rainfall depth duration relationships published by Baghirathan and Shaw (1977) and Ponrajah (1988) are the main prelude to the present study. The publication made in 1977 analyzed historical rainfall data over 19 numbers of stations and presents individual station wise DDF estimations up to return period of 50 years due to the inadequate coverage of island wide data and relatively short duration of records. This was prompted to develop Regional DDF equations by dividing country into for six numbers of hydrological zones enabling widen the scope of the DDF estimations even for longer return periods. The later study made in 1988 provides regional DDF estimations for six numbers of hydrological zones up to 100 year return period. The differences in rainfall depths in both references are insignificant, therefore DDF relationships given in the most recent study was referred. The appropriate hydrological zone for the each road segment and design rainfall depth in inches for different return periods are tabulated in Table 3-8 and 3-9. Six numbers of hydrological zones defined by Ponrajah (1988) is shown in Figure 3-15.

Table 3-8 Corresponding Hydrological Zones

Road	Reference Hydrological zone
B312	Zone 5
A035	Zone 1
A009 (122-130 km)	Zone 2
A009 (204-214 km)	Zone 1
B528	Zone 5

Figure 3-15 General locality of stations and Hydrological Zones
Source: Annex 6.1, Ponrajah (1988)

Table 3-9 Depth of Rainfall (inches)

Hours	2	4	6	8	10	12	14	16	18	20	22	24
100 year storm												
Zone1	8.2	9.5	9.8	10.2	10.5	10.8	11.2	11.5	11.9	12.2	12.6	12.9
Zone 2	7.6	8.5	8.9	9.4	9.8	10.3	10.7	11.1	11.6	12.0	12.4	12.9
Zone 5	4.3	5.4	6.2	6.9	7.5	8.0	8.5	8.9	9.3	9.7	9.8	10.2
50 year storm												
Zone1	7.3	8.4	8.7	9.1	9.4	9.7	9.9	10.2	10.5	10.8	11.1	11.4
Zone 2	6.6	7.5	7.9	8.3	8.7	9.2	9.6	10.0	10.4	10.8	11.2	11.6
Zone 5	3.8	4.9	5.6	6.2	6.7	7.1	7.5	7.9	8.3	8.6	9.0	9.3
25 year storm												
Zone1	6.4	7.3	7.6	7.9	8.1	8.4	8.7	9.0	9.2	9.5	9.8	10.0
Zone 2	5.9	6.8	7.1	7.4	7.8	8.1	8.4	8.7	9.1	9.4	9.7	10.1
Zone 5	3.5	4.4	5.0	5.5	5.9	6.3	6.6	6.9	7.2	7.5	7.8	8.1

Source: Ponrajah (1988), p.59

3.5.9. Land Use/Land Cover and Soil Profile

Different land use patterns and coverage were identified through digital mapping process. Equivalent land coverage areas were then combined together in assigning respective surface parameters. The soil characteristics and land-use of the area formed the rationale for curve number derivation according to US Soil Conservation Service (SCS). Table 3-10 to 3-13 indicates composition of land cover types prevailed in each catchment.

Table 3-10 Percentage of Land Coverage of Sub Catchments in B312 Road

Culvert ID.	Catchment Area (A-km^2)	% of Land Cover							
		Homestead	Scrub	Paddy	Forest	Rock	Cemetery	Tank	Grassland
34/3- 34/4	7.685	8	37	0	47	0	0	2	6
35/1- 36/1	0.178	0	75	0	25	0	0	0	0
36/2- 37/1	17.091	2	51	0	45	2	0	0	0
38/1- 38/5	5.092	31	61	7	0	1	0	1	0
38/6- 38/7	0.114	65	32	2	0	0	0	0	0
39/1	0.271	28	72	0	0	0	0	0	0
39/2	0.103	61	39	0	0	0	0	0	0
40/1- 42/3	9.782	25	10	20	42	1	1	0	0
42/4- 44/3	4.916	2	2	2	93	1	0	0	0
58/1- 58/2	0.183	23	0	0	77	0	0	0	0
58/3-58/6A	1.020	10	0	0	90	0	0	0	0
58/7- 59/1	0.228	21	0	0	79	0	0	0	0
59/2	5.439	14	0	0	84	1	0	0	0
59/3	0.122	42	0	0	58	0	0	0	0

Table 3-11 Percentage of Land Coverage of Sub Catchments in A035 Road

Culvert ID.	Catchment Area (A-km^2)	% of Land Cover				
		Homestead	Scrub	Paddy	Forest	Tank
2/1-2/2	0.708	0	0	100	0	0
2/3-2/4	0.456	0	0	100	0	0
4/2-5/1	1.533	15	0	85	0	0
16/1	0.091	100	0	0	0	0
21/1	48.111	17	13	2	64	5
22/1 - 22/2	5.455	43	37	0	20	0
24/1 - 26/1	66.626	4	4	6	79	7
28/1-28/4	22.688	6	14	4	75	1
30/2	0.175	68	0	0	0	32

Table 3-12 Percentage of Land Coverage of Sub Catchments in A009 Road

Culvert ID.	Catchment Area (A-km^2)	% of Land Cover					
		Homestead	Scrub	Paddy	Forest	Tank	Chena
123/3-123/4	3.030	5	25	11	56	3	0
125/1	0.674	13	70	0	17	0	0
126/1	4.868	13	39	6	13	8	22
127/2	1.144	4	43	0	10	3	39
128/1	0.125	91	0	0	0	0	9
129/2	0.259	44	0	0	0	0	56
130/1-130/2	0.401	19	32	0	0	0	50
131/1	0.682	42	31	0	0	0	28
205/2-206/1	7.937	10	0	4	79	8	0
206/3	0.348	74	0	0	26	0	0
207/1-207/2	6.065	17	0	4	75	4	0
209/2	0.202	0	0	100	0	0	0
210/2-210/6	0.413	18	57	0	0	8	17
212/1-213/1	3.846	7	25	4	31	13	20
215/1	0.107	0	35	0	65	0	0

Table 3-13 Percentage of Land Coverage of Sub Catchments in B528 Road

Culvert ID.	Catchment Area (A-km^2)	% of Land Cover					
		Homestead	Scrub	Paddy	Forest	Tank	Chena
3/1 - 3/3	1.289	0	27	0	54	0	19
4/1-5/4	7.388	2	40	3	43	4	7
7/1-7/2	30.266	0	39	0	44	3	14
11/2-11/3	1.852	20	30	5	43	2	0
12/3-13/2	8.895	3	31	0	52	5	8
16/3-17/2	10.126	0	26	0	50	6	18
20/1	5.803	1	26	0	54	9	11
31/3	4.279	2	44	5	8	3	38

Figure 3-16 below indicates great soil groups in Sri Lanka and it was compared with web based soil database and apparently soil profiles indicated in both references are same. Majority of soil type found in catchments are in the form of Reddish Brown Earth (RBE) where additional soil type ‘Solodised Solonetz and Solonchalks’ is exist in catchments of A035 road. The web referenced soil database HWSD shows dominant soil group of all catchments as Luvisols (LV) as per FAO categorization where slight variations of loamy soil texture can be seen with the change of geographical locations. The dominant soil group exists in A035 road catchments is Ferralsols (FR) which soil texture varies from loam to sandy clay loam.

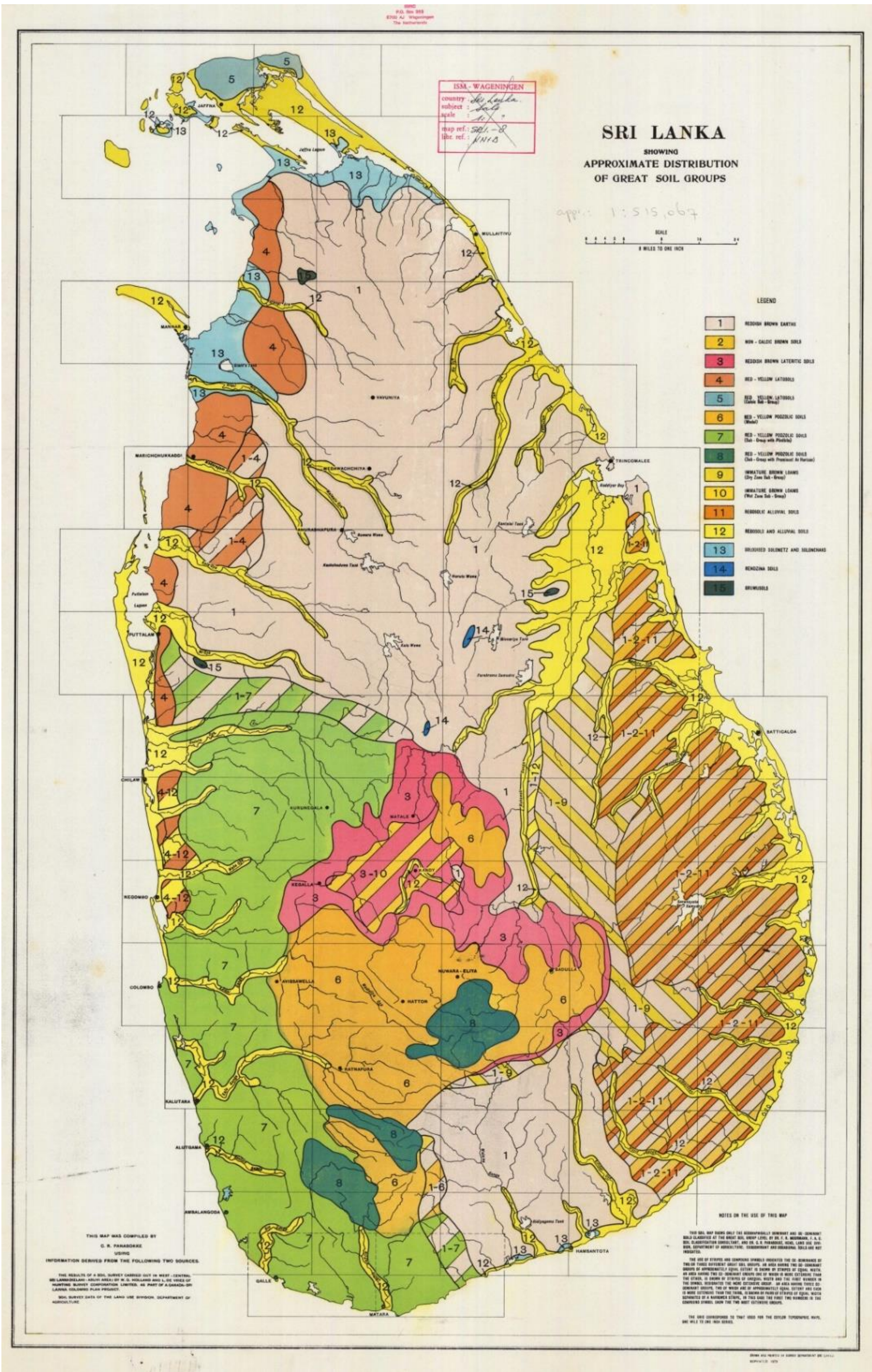


Figure 3-16 Soil Map of Sri Lanka
Source: Survey Department, Sri Lanka

3.6. Hydrological Design

The continuous repetition of interaction between precipitation and land is termed as the Hydrologic Cycle where storm water runoff is one of the forms that water may takes as indicated in Figure 3-17. Evaporation, Transpiration, Interception and Infiltration are the process occurred in the hydrologic cycle other than runoff.

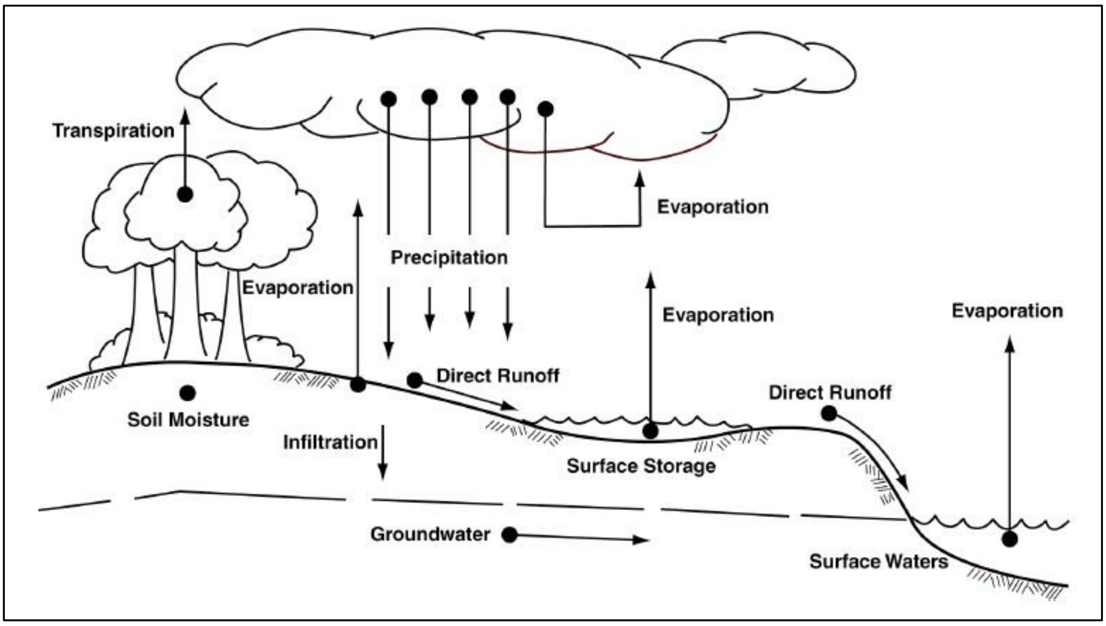


Figure 3-17 Hydrologic Cycle
Source: Fundamentals of Urban Runoff Management

All rainfall runoff computation methods can be treated as expression of Hydrologic Cycle to a certain extent by utilizing several mathematical approximations to transform excess precipitation to surface runoff. The procedures adopted in determination of peak flow at inlet of culvert/bridge for different return periods are elaborated below with theoretical introduction.

3.6.1. Rational Formula

The well-known Rational Formula was initially proposed in 1850 by an Irish Engineer Mulvaney. Later on in 1889 Emil Kuichling introduced more detailed treatment in Rational Method, still it is received wide spread applications in Hydrological Designs irrespective of frequent criticism for its simplistic approach.

The basis of the relationship is the law of the conservation of mass and the hypothesis that the flow rate is directly proportional to the size of the contributing area, rainfall intensity and runoff coefficient as shown in following relationship.

$$Q = CIA/360$$

Where Q : Peak Flow (m^3/s)

C : Runoff Coefficient (dimensionless)

I : Rainfall Intensity (mm/hr)

A : Catchment Area (ha)

The application of rational formula is subjective and inherent to assumptions listed below.

- Peak flow occurs when the entire watershed is contributing to the flow.
- Rainfall intensity is uniform over the entire drainage area.
- Rainfall intensity is uniform over time duration equal to the time of concentration.
- Frequency of the computed peak flow is the same as that of the rainfall intensity.
- The runoff coefficient remains constant throughout the duration of the storm and is determined solely by basin surface conditions. Characteristics of drainage basin are fairly homogeneous.

The above conditions dictate the limit of catchment size in the application of Rational formula. The size of the watershed should be small enough to maintain homogeneous soil type, land use, land cover etc. As many literature indicated the method is more meaningful up to 80 ha and some variations are also noticed as mentioned in section 2.6.

3.6.2. Fuller Formula

Fuller formula is another empirical method introduced in 1914 by Fuller W.E., can be treated as the first flood frequency formula and widely used method in estimating discharge at highway waterway crossings. Fuller sought that regional variations in empirical coefficient 0.8 is not significant except for semi-arid areas. He suggests this equation for flood estimations in longer return periods like 1000 years.

$$Q_T = Q_1(1 + 0.8 \log T)\left(1 + \frac{2.66}{F^{0.30}}\right)$$

$$Q_1 = 1.80F^{0.80}$$

Where Q_T : T year return period discharge (m^3/s)

Q_1 : Mean daily discharge of the 1 year flood (m^3/s)

T : Return period in years

F : Drainage area in km^2

It is specified that Q_1 to be determined based on the observed flood data. In the absence of historical flood flow data it can be computed from the relationship in the form of $Q_1=CF^a$. However, $Q_1=1.80F^{0.80}$ relationship is usually adopted in highway projects without further investigations (Daniil et al.). Due to the lack of previous flood flow data, the present study also considered the same equation in determining Q_1.

3.6.3. Snyder's Unit Hydrograph

Synthetic Unit Hydrographs are introduced for the ungauged basins with inadequate data or concurrent observations of precipitation and stream flow and subjected to the following constraints.

- Excess rainfall is uniformly distributed over the basin area.
- Rainfall intensity is constant throughout the selected rainfall duration.
- The runoff rate at any time within the runoff hydrograph duration is directly proportional to the total volume of excess rainfall.
- The unit hydrograph is invariant from storm to storm and during the storm which it is applied.
- For any volume of excess rainfall occurring within the specified duration, the resulting runoff hydrograph has the same duration.
- Basins with similar physiographic characteristics located in the same area will have similar values of Ct and Cp. Therefore, for ungauged basins, it is preferred that the basin be near or similar to gauged basins for which these coefficients can be determined.

Following empirical relationships were developed by Snyder in 1938 to provide sufficient flexibility for simulating flood discharge deriving two parameters, namely time parameter (Ct) and peak parameter (Cp) after analyzing large number of hydrographs from drainage basins of areas from 25 to 25000 km^2.

Lag time/Basin time lag (hrs): $t_p = 0.75C_t(LL_{ca})^{0.3}$

Duration of Unit Hydrograph (hrs): $D = {t_p}/{5.5}$

Corresponding basin lag for Duration D'(hrs): $t_{pi} = t_p + 0.25(D' - D)$

Time base of Unit Hydrograph (days) : $T_b = 3 + \left(\frac{t_{pi}}{8}\right)$

The time base formula is defined for the larger watersheds. This produces excessive results for the smaller areas. Therefore the time base for the small and medium watersheds shall be 3 to 5 times the basin lag ($T_b = 4t_p$ is adopted in lack of better knowledge).

Peak runoff per unit rainfall excess (m^3/s/cm):$q_{pi} = 2.78C_pA/t_{pi}$

Flood hydrograph peak (m^3/s):$Q_{Pi} = d \times q_{pi}$

The sketching of unit hydrograph is further assisted by following relationships.

$$W_{50} = \frac{2.14}{\left(\frac{Q_{Pi}}{A}\right)^{1.08}} \qquad W_{75} = \frac{1.22}{\left(\frac{Q_{Pi}}{A}\right)^{1.08}}$$

Where,

t_p : Lag time from midpoint of effective rainfall duration to peak of a unit hydrograph (hr)

L : Basin length measured along the water course from the basin divide to the gauging station (km)

Lca : Distance along the main water course from the gauging station to a point opposite the watershed centroid (km)

Ct : a regional constant representing lag factor

Cp : a regional constant representing peak flow factor

A : catchment Area (km^2)

d : Depth of rainfall (mm)

T_b : Time base of unit hydrograph

W_{50} : Width in hrs of unit hydrograph for 50% of q_{pi}

W_{75} : Width in hrs of unit hydrograph for 75% of q_{pi}

Figure 3-18 and 3-19 illustrate watershed physical parameters and derivations of Snyder's Unit Hydrograph.

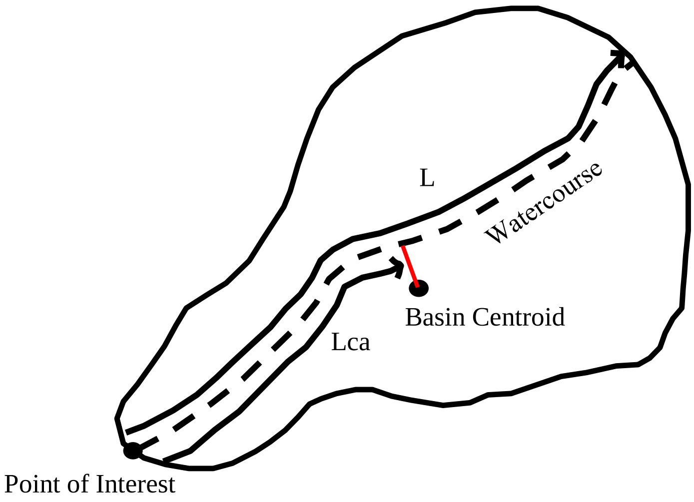


Figure 3-18 Watershed Physical parameters used in Snyder's UH Method

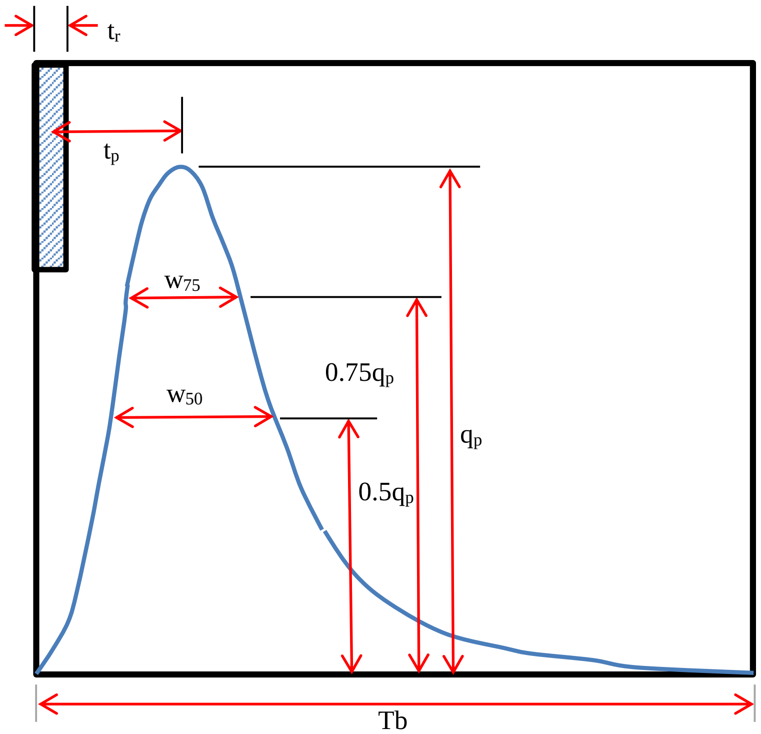


Figure 3-19 Snyder's Unit Hydrograph

The coefficients of Ct and Cp relevant to the study area were extracted from Ponrajah (1988) are given in Table 3-14.

Table 3-14 Ct, Cp Values for Snyder's Methods

Road	Hydrological Station	Ct	Cp
B312	Elahera	2.22	1.00
A035	Kappachchi	4.42	0.87
A009 (122-130 km)	Kappachchi	4.42	0.87
A009 (204-214 km)	Kappachchi	4.42	0.87
B528	Lunugamwehera	1.13	1.07

Source: Ponrajah (1988)

Design Rainfall depths and catchment physical parameters were evaluated following the procedures outlined in section 3.4 – 3.5.

3.6.3.1. Effective Rainfall Depth

The runoff reduction due to losses is the main concern in transforming rainfall hyetograph into a runoff hydrograph. The losses can be occurred mainly as two types; Initial losses and Continuing losses.

<u>Initial Losses</u>

The initial losses are less important and so often neglected in the case of highly urbanized areas.

- Interception & Wetting Losses

  Some amount of precipitation is captured by flora. However this lasts only for an initial period, thereafter rainfall will flow over/through the foliage to reach the soil.

- Depression Storage

  This accounts for the precipitation trapped in small depressions on the catchment surface preventing the water from running off. This will be influenced by; surface type, surface slope and rainfall return period. Depression storage is normally expressed as a depth across the whole catchment.

Continuing Losses

Continuing losses are sustained throughout the rainfall event.

- Evapotranspiration

  The water withdrawn from land area by evaporation from water surfaces and plant transpiration is termed as 'Evapotranspiration' and can be neglected as it quantifies few millimeters per day.

- Infiltration

  Infiltration is a significant component of hydrologic cycle. Different soil types have varying infiltration capacities which influenced by soil type, degree of saturation, and nature of ground cover. In addition, activities that has happened in soil surface will also change or alter it properties which have a modifying effect on the infiltration capacity. When the rainfall intensity is less than the infiltration capacity, all the precipitation reaching the ground can infiltrate. Once the rainfall intensity exceeds the subsoil infiltration capacity, infiltration will occur only up to the infiltration capacity of the soil strata, and water in excess will be stored in depressions, become surface runoff, or evaporate. As the soil becomes saturated with the continuation of precipitation, the infiltration rate diminishes to a relatively constant rate. Several loss rate methodologies have been derived to apply in the Snyder's Unit Hydrograph method.

  - Initial loss plus Uniform loss rate (IL+ULS)
  - Holtan Infiltration Equation
  - SCS Curve Number
  - Green and Ampt Infiltration Equation
  - Exponential loss rate

The Holtan infiltration equation is an exponential decay type of equation which rainfall loss rate asymptotically diminishes to the minimum infiltration rate (fc). The exponential loss rate method is a four parameter method that is not extensively used, but method most preferred by U.S. Army Corps of Engineers. The SCS CN method has wide acceptance among many agencies. The Green and Ampt infiltration equation is a physically based model that has been in existence since 1911, and incorporated in HEC-HMS too.

The simplified rainfall loss method so often used is IL+ULS and generally accepted for flood hydrology. In applying the simplified method it is assumed that initially all rainfall is lost until the accumulated rainfall is equal to the initial loss, once the initial loss is satisfied, a portion of all future rainfall is receded at a uniform rate. The uniform loss rate represents the long term equilibrium infiltration capacity of soil. Initial loss and Uniform Loss Rates published for different HSG are indicated in Table 3-15 and 3-16 below.

Table 3-15 Published values for Initial Loss

Hydrologic Soil Group (HSG)	Initial Loss (in)		
	Dry	Normal	Saturated
A	0.6	0.5	0
B	0.5	0.3	0
C	0.5	0.3	0
D	0.4	0.2	0

Dry: Non irrigated lands such as deserts and rangeland, Normal: Irrigated lawn, turf and permanent pasture, Saturated: Irrigated agricultural lands
Source: Hydrological Design Manual, Maricopa Country, Arizona

Table 3-16 Published values for Uniform Loss Rates

Hydrologic soil Group (HSG)	Uniform Loss Rate (in/hr)
A	> 0.3 in/hr (. 7.6 mm/hr)
B	0.15 – 0.30 in/hr (3.8 -7.6 mm/hr)
C	0.05 – 0.15 in/hr (1.3 – 7.6 mm/hr)
D	0.00 – 0.15 in/hr (0.0 – 1.3 mm/hr)

Source: TR-55, Appendix A & HEC-HMS Technical Reference Manual

The effective rainfall depth after losses is applied in the unit hydrograph ordinates to estimate the peak flow of storm hydrograph which can be expressed by the following matrix.

$$[Q] = [P]\,[U]$$

Where, P : Excess rainfall (cm)

U : Unit Hydrograph ordinate (m^3/s/cm)

Q : Discharge (m^3/s)

3.6.4. Flood Transportation

The flood transportation technique is established on the basis of transferring peak flow of one watershed to another with same climatic, topographic and geological characteristics. This method can be applied for predicting peak flows of ungauged basins in vicinity of gauged site which is not necessary in the same watershed preferably with similar nature hydrogeological characteristics. The gauging site should be a clear representative of the ungauged basin in concern, with basin area ratio of 0.5 to 1.5 and adequate size of past flood records. A record of minimum 10 years is considered as the minimum size of the database whilst 20 years is generally required without comparison with other methods. The slope exponent factor applies on drainage basin ratio shall vary from basin to basin. There are no specific values established in Sri Lanka for slope exponent factors, thus parameters used in previous study by Abeynayake (2000) was considered. The above study used 0.8 as the slope exponent where drainage area ratio varied from 0.06 – 1.00.

Culverts and bridges analyzed in the present study are of relatively less basin areas as compared with that of the gauge site. Hence basin area ratios of all cases are less than 0.5, which the lower margin suggested in international references. The condition on drainage area ratio between gauged and subjective site was relaxed in the analysis as applied in previous study by Abeynayake (2000). The gauge transfer equation used for the determination of peak flow at culvert/bridge is given below.

$$Q_{(ungauged)} = Q_{(gauged)} \times \left(\frac{A_{(ungauged)}}{A_{(gauged)}}\right)^{x}$$

Where, $Q_{(ungauged)}$: Peak flow at ungauged site (culvert/bridge site)

$Q_{(gauged)}$: Peak flow at gauged site

$A_{(ungauged)}$: Drainage area of ungauged site (culvert/bridge site)

$A_{(gauged)}$: Drainage area of gauged site

x : Slope exponent (0.8)

Peak flow transferring can be accomplished by applying appropriate statistical distribution over a set of stream gauge records of the same watershed or adjacent similar nature watershed. The lower margin of recorded length is specified as 10 years. Historical annual maximum flood flow data were obtained from Master Plan for Electricity Supply of Sri Lanka (1987). Only three numbers of road segments were analyzed due to the non-availability of sufficient length of records for A035 and A009 (204-214 km) roads. The statistical analysis of annual peak flow was followed by Gumbel's Distribution. Flood frequency estimates at gauging stations given in Table 3-17 were transferred to ungauged basins where its locality is a subset of the gauge basin or in closed proximity to the gauge basin.

Table 3-17 Corresponding River Gauge Stations

Ungauged basin	Gauge Basin
Culvert/Bridge Catchments of B 312 road	Amban Ganga at Elahera (774 km^2)
Culvert/Bridge Catchments of A 009 road (122-130 km)	Malwathu Oya at Kappachchi (2117 km^2)
Culvert/Bridge Catchments of B 528 road	Walawe Ganga at Embilipitiya (1580 km^2)

The equation for fitting the Gumbel distribution to observed series of flood flows at different return period T is,

$$X_T = X + K\sigma_{n-1}$$

$$y_T = -(\ln . \ln . (T/T - 1))$$

$$K = (y_T - y_n)/\sigma_n$$

Where,

X_T : Magnitude of the T year flood event

K : Frequency factor

X : mean of the maximum instantaneous flows

σ_{n-1} : Standard deviation of the maximum instantaneous flows

y_T : Reduced variate

y_n & σ_n : from standard tables as given in Table 3-18

Table 3-18 Values of y_n and σ_n in Gumbel Distribution

N (Number of years)	y_n	σ_n	N (Number of years)	y_n	σ_n
10	0.4952	0.9497	65	0.5536	1.1803
15	0.5128	1.0206	70	0.5548	1.1854
20	0.5236	1.0620	75	0.5559	1.1898
25	0.5309	1.0915	80	0.5569	1.1938
30	0.5362	1.1124	85	0.5578	1.1973
35	0.5403	1.1285	90	0.5589	1.2007
40	0.5436	1.1413	95	0.5593	1.2038
45	0.5463	1.1518	100	0.5600	1.2065
50	0.5465	1.1607	200	0.5672	1.2359
55	0.5504	1.1681	500	0.5724	1.2588
60	0.5521	1.1747	1000	0.5745	1.2685

3.6.5. HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System)

HEC-HMS programme was developed by U.S. Army Corps of Engineers (USACE) to simulate rainfall runoff of dendritic watershed systems. The inherent assumption made in this programme is that, the hydrologic processes of an area can be represented by parameters that reflect the average physical conditions within a basin. The computer aided hydrological model is developed by separating hydrological cycle into sub components and applying boundary conditions over the watershed in concern. Any mass or energy flux in the hydrological cycle is represented with mathematical model where multiple model choices are provided with user define parameters. More general representation of watershed runoff is indicated in Figure 3-20 where minor components associated in developing runoff is omitted or lumped to major components.

HEC-HMS is equipped with several hydrological design applications including runoff computations, flood frequency studies, flood loss reduction studies, reservoir design studies, surface erosion and sediment routing studies etc. As mentioned above, HEC-HMS facilitates very diverse and extensive uses and complete discussion on its application and limitations would be lengthy and excluded in the content of this study.

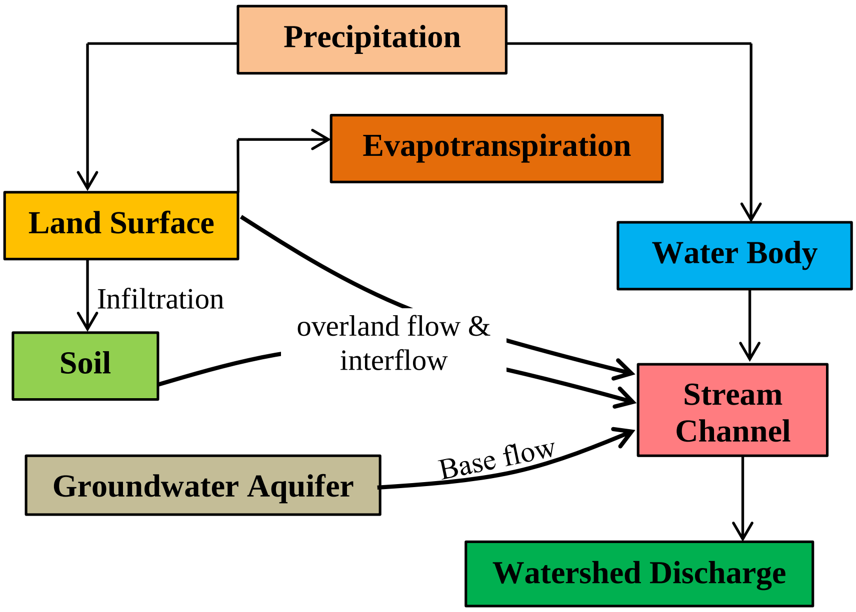


Figure 3-20 Watershed Runoff Process
Source: HEC-HMS, Technical Reference Manual

3.6.5.1. HEC-HMS Model Structure

HEC-HMS model structure mainly consists of four components;

- Meteorological Model

  The meteorological model describes the climatological conditions over the watershed in terms of precipitation, snow melt and potential evapotranspiration.

- Basin Model

  The physical description of the watershed is explained in the basin model.

- Control Specifications

  The hydrological elements are interconnected in control specification to represent the watershed behavior. Even though this model does not contain much parameters it will control when to commence and end the simulation process and time interval to be used in the simulation.

- Input data (time series, paired data and gridded data)

3.6.5.2. Loss Model and Transform Model

The precipitation falls on the pervious surface subjected to losses due to interception, depression, evaporation etc. The software provides several alternative approaches to account for those losses. The transform model converts excess precipitation remains after losses into direct runoff. Similar to loss model, transform model too facilitates with several options. The model choices used in the study were SCS Curve Number (CN) and SCS unit hydrograph for loss and transform functions as those two options are widely applied in Sri Lanka in rainfall runoff modeling.

3.6.5.2.1. Soil Properties

Physical and chemical properties of soil exist in the watershed have a high influence on rainfall runoff rate. The single most important soil property used is the minimum rate of infiltration obtained for bare soil after prolong wetting; used to classify four numbers of hydrologic soil groups as tabulated in Table 3-19 below.

Table 3-19 Classification Criteria for HSG

HSG	Classification Criteria
A	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission (greater than 0.30 in/hr)
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15- 0.30 in/hr)
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission (0.05-0.15 in/hr)
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or, near the surface and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission (0-0.05 in/hr)

Source: TR-55

3.6.5.2.2. Runoff Curve Number

This is more frequently applied in ungauged catchments to evaluate effects on surface runoff due to changes taken place in land use and treatment. The combination of hydrologic soil group, land use and treatment class is termed as hydrologic soil-cover complex and presents as curve number values published for wet, dry and normal soil moisture conditions which refer to Antecedent Moisture Condition (AMC) I (dry), II (normal), and III (wet). The AMC is related to the amount of rainfall in five days previous to the design storm. AMC-I has the lowest runoff potential and represents dry watershed soils. AMC-III has the highest runoff potential as it represents soils that are practically saturated from antecedent rainfall. Table 3-20 below shows the classification criteria for different AMC conditions.

Table 3-20 Classification for AMC Condition

AMC Group	Soil Characteristics	Total 5 day Antecedent rainfall (mm)	
		Dormant Season	Growing Season
I	Soils are dry not to wilting point, cultivation has taken place	< 13	< 36
II	Average Condition	13-28	36-53
III	Heavy or light rainfall and low temperatures have occurred within the last 5 days; saturated soils	> 28	> 53

Source: TR-55

When estimating the peak discharge for an annual percent chance storm, such as 1% annual chance storm, it is standard practice to assume AMC-II conditions. Other AMC conditions may be assumed when estimating the peak flow for an actual event, based on the observed rainfall before the event (Richard and Sorrell, 2010). The equivalent runoff curve number value for AMC-I and AMC-III conditions can be approximated using following equations.

$$\mathrm{RCN(I)} = \frac{4.2 \times \mathrm{RCN(II)}}{10 - 0.058 \times \mathrm{RCN(II)}}$$

$$\mathrm{RCN(III)} = \frac{23 \times \mathrm{RCN(II)}}{10 + 0.13 \times \mathrm{RCN(II)}}$$

Land cover types were decided based on field reconnaissance surveys, aerial photographs, and topographic maps. Treatment is a cover type modifier which describes the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced or no tillage. Description on land use and treatment types are presented in Appendix C.

3.6.5.2.3. Initial Abstraction (Ia)

Initial abstraction is all losses occurred prior to commencement of runoff. It includes water retained in surface depressions, water intercepted by vegetation, evaporation and infiltration. Ia is highly variable but generally correlated with soil and land cover parameters. Through the study of many small agricultural watersheds, Ia is approximated by the following empirical equation (TR-55, 1986) where all losses are generalized to 0.2S.

$$Ia = 0.2\ S$$

Where S : Potential maximum retention after runoff begins

3.6.5.2.4. SCS Curve Number Loss Model

SCS CN loss model calculates rainfall runoff based on precipitation, land use/land cover, and antecedent moisture condition. The initial abstraction represents the precipitation depth prior to occurrence of excess precipitation. The CN is a combination of the different land use/land cover and soil groups prevailed in the area. Watershed runoff potential is mainly influenced by the hydrologic characteristics of prevailing soil strata. The loss model is defined by following mathematical relationships.

$$Pe = (P-Ia)^2/(P-Ia+S) \qquad Ia = 0.2\ S \qquad Pe = (P-0.2\ S)^2/(P+0.8S)$$

$$S = (1000-10CN)/CN \text{ (foot-pound system)} \qquad S = (25400-254CN)/CN \text{ (SI units)}$$

$$CN_{composite} = \sum AiCNi / \sum Ai$$

Where,

Pe : Accumulated precipitation excess at time t

P : Accumulated rainfall depth at time t

Ia : Initial abstraction (Initial loss)

S : Potential maximum retention after runoff begins

CN : Curve Number, value ranges from 100 (water bodies) to 30 (permeable soils with high infiltration rates)

$CN_{composite}$: weighted average CN for watershed consists of several soil types and land use

Ai : Area of sub basin i

CN_i : Curve Number of sub basin i

The dominant soil group prevailed in sub catchments can be categorized as 'Luvisols' where the corresponding HSG is 'B'. For sub basins of A035 road, the dominant soil group is 'Ferralsols' which falls to the same HSG 'B'. As unique land cover and treatment cannot be observed in most areas, composite CN was considered based on the extent of particular cover type and treatment. The land cover types identified from the topographical maps were reclassified into six categories; pasture/grassland, scrub, wood, paddy areas, other cultivations and water bodies and relevant curve numbers were assigned as published in SCS TR-55 CN tables (Refer Appendix C).

Model	Method	Parameters
Loss	SCS Curve Number	Initial abstraction, Curve Number, Imperviousness (%)

3.6.5.2.5. SCS Unit Hydrograph Method

The basic parameter requires to define in the transform model with SCS unit hydrograph method is the lag time (also termed as basin lag), which is the time from center of mass of excess rainfall to the hydrograph peak, can be taken as 60% of time of concentration. The time of concentration determined from ID guideline was used in computation of basin lag as this equation is originally developed for the Sri Lankan watersheds.

Model	Method	Parameters
Transform	SCS Unit Hydrograph	Lag Time (min)

3.6.5.3. Design Hyetographs

Design Hyetographs were developed using respective IDF curve and alternative block method. Storm durations were set equivalent to the time of concentration of individual/ combine catchments as tabulated in Table 3-21. Design Hyetographs adopted for B312 road for storm duration of 3.5 hours are shown in Figure 3-21 to 3-23.

Table 3-21 Selected Storm Durations for Design Hyetographs

Road	Storm Duration (hrs)	Rain gauge Station
B312	3.5	Polonnaruwa
B312 (36/2-37/1)	6.0	Polonnaruwa
A035	3.0	Vavniya
A035 (21/1 & 24/1-26/1)	18.0	Vavniya
A035 (22/1-22/2 & 28/1-28/4)	12.0	Vavniya
A009 (122-130 km)	2.0	Anuradhapura
A009 (122-130 km) (126/1)	4.0	Anuradhapura
A009 (204-214 km)	3.0	Vavniya
A009 (204-214 km) (205/2-206/1)	4.0	Vavniya
B528	3.5	Hambantota
B528 (4/1-5/4 & 7/1-7/2)	6.0	Hambantota

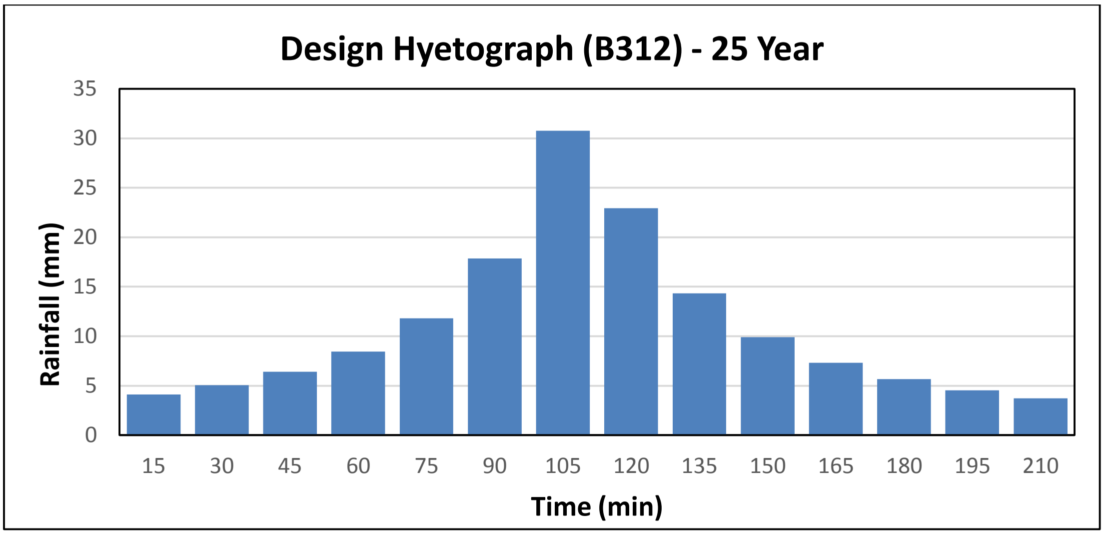


Figure 3-21 Design Hyetograph for Catchments in B312 Road

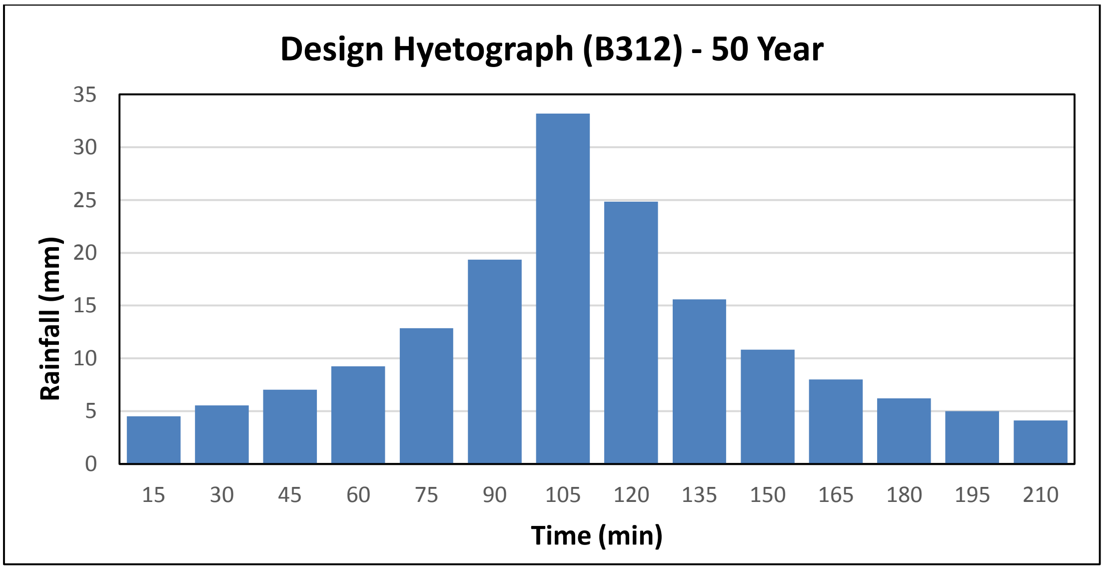


Figure 3-22 Design Hyetograph for Catchments in B312 Road

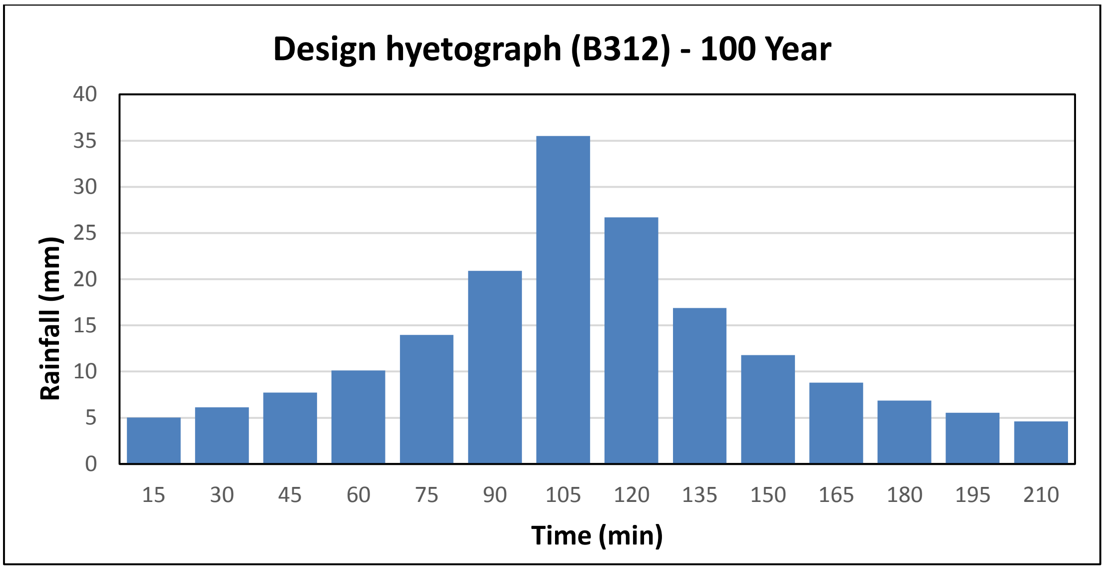


Figure 3-23 Design Hyetograph for Catchments in B312 Road

3.6.5.4. Model Verification

The user has to define certain parameter values in each model. Appropriateness of user specified parameters need to be verified. The calibration and validation process are to find the optimal parameter values and to confirm the validity of the same. However calibration and validation of hydrologic simulation model of ungauged watershed still remains a question due to lack/ non-availability of measured data. As an alternative approach adjacent similar nature gauged watershed can be modeled and optimized parameter values can be found through calibration and validation. However there are no similar nature gauge sites in vicinity of catchments considered in the present study. The size of watersheds of highway culverts and bridges are relatively small and type of land cover is not consistent over the entire area. Therefore present study carefully identified different land cover types with the aid of topographical maps which was verified with field observations and curve numbers were assigned for the respective area of each land cover type to estimate weighted average curve number for the individual basin. This was compared with HEC-HMS model parameter values published in previous studies for the same project areas/adjacent to the project area. The Hydrological Study Report on Extension of Southern Expressway Project-Section 4 (From Mattala – Hambantota) presented HEC-HMS model analysis for Malala Ara Oya Bridge, where catchment curve number is assigned as 60. The curve number values of calibrated HEC-HMS model of Rakwana oya catchment; a tributary of Walawe Ganga basin is given as 39 - 60 by Weragala and Smakthin (2004). The selected road section of B528 road traverses in both Malala Oya and Walawe Ganga basins. The Environmental Assessment Report on Accelerated Mahaweli Development Program (1980) presents curve numbers for the forest lands and rice paddy areas in the project area as;

Land Cover	Runoff Curve Number			
	HSG A	HSG B	HSG C	HSG D
Forest Land	36	60	70	76
Paddy Land	62	71	78	81

Accordingly CN values of individual catchments of B528 and B312 roads were compared with findings of previous studies. Neither stream gauge records nor published curve number values are available for the watersheds in vicinity of balance road sections.

4. RESULTS AND DISCUSSION

4.1. Catchment Physical Parameters

Catchment physical parameters are tabulated in Table 4-1.

Table 4-1 Catchment Physical Parameters

Catchment ID	L (m)	Lca (m)	Highest Level (m)	Lowest Level (m)	Slope (%)	Catchment Area (ha)	Catchment Area (km^2)
B 312 Road							
34/3 - 34/4	3317	1800	161	119	1.27	768.5286	7.6852856
35/1 - 36/1	505	207	153	130	4.55	17.7511	0.1775110
36/2 - 37/1	9935	4727	435	120	3.17	1709.1110	17.0911100
38/1 - 38/5	3937	2050	280	128	3.86	509.2448	5.0924480
38/6 - 38/7	380	211	135	130	1.32	11.3763	0.1137630
39/1	693	302	153	135	2.60	27.1074	0.2710740
39/2	421	167	143	128	3.56	10.2593	0.1025930
40/1 - 42/3	4760	1789	400	131	5.65	978.1636	9.7816360
42/4 - 44/3	3743	1672	505	150	9.48	491.6382	4.9163820
58/1 - 58/2	771	300	281	193	11.41	18.2918	0.1829180
58/3 - 58/6A	1876	690	291	190	5.38	102.0480	1.0204800
58/7 - 59/1	981	389	290	181	11.11	22.7579	0.2275790
59/2	5189	3079	310	174	2.62	543.8840	5.4388400
59/3	635	316	320	190	20.47	12.1606	0.1216060
A035 Road							
2/1-2/2	1264	514	14	11	0.24	70.7800	0.7078
2/3-2/4	1162	552	15	13	0.17	45.6400	0.4564
4/2-5/1	2053	1209	16	11	0.24	153.3170	1.5332
16/1	267	93	21	19	0.75	9.0800	0.0908
21/1	14600	7878	63	20	0.29	4811.0600	48.1106
22/1 - 22/2	3690	2144	42	26	0.43	545.5000	5.4550
24/1 - 26/1	15400	9159	69	20	0.32	6662.6100	66.6261
28/1-28/4	9170	4993	55	19	0.39	2268.8400	22.6884
30/2	756	318	27	23	0.53	17.5200	0.1752
A009 Road							
123/3-123/4	2920	1731	243	116	4.35	303.0000	3.0300
125/1	978	605	134	118	1.64	67.4210	0.6742
126/1	2735	1586	124	110	0.51	486.7990	4.8680

Catchment ID	L (m)	Lca (m)	Highest Level (m)	Lowest Level (m)	Slope (%)	Catchment Area (ha)	Catchment Area (km^2)
127/2	1261	614	135	115	1.59	114.4310	1.1443
128/1	450	267	124	118	1.33	12.5070	0.1251
129/2	543	383	122	117	0.92	25.8840	0.2588
130/1-130/2	538	498	123	116	1.30	40.0680	0.4007
131/1	1130	689	132	117	1.33	68.2420	0.6824
205/2-206/1	4198	2699	102	72	0.71	793.6700	7.9367
206/3	1180	555	77	68	0.76	34.8430	0.3484
207/1-207/2	2550	1275	86	66	0.78	606.4920	6.0649
209/2	363	182	70	63	1.93	20.2220	0.2022
210/2-210/6	888	397	67	61	0.68	41.3080	0.4131
212/1-213/1	2443	1162	76	63	0.53	384.6240	3.8462
215/1	373	169	66	62	1.07	10.7070	0.1071
B528 Road							
3/1 - 3/3	1649	707	123	109	0.85	128.9200	1.2892
4/1-5/4	5180	2626	127	101	0.50	738.7500	7.3875
7/1-7/2	6986	4541	184	97	1.25	3026.6124	30.2661
11/2-11/3	1833	897	127	100	1.47	185.1921	1.8519
12/3-13/2	5260	3012	232	108	2.36	889.4600	8.8946
16/3-17/2	3070	1341	215	117	3.19	1012.5800	10.1258
20/1	3130	1724	266	129	4.38	580.3100	5.8031
31/3	2576	916	210	140	2.72	427.9100	4.2791

4.2. Time of Concentration

The lager the catchment, the longer it takes runoff to reach the extreme point in the watershed. However combine effect of length and slope should be considered as sloppy watershed results greater runoff velocities and time to peak will be less. The input parameters of tc formulas can be separated as Length of watercourse (L), Slope (S) and Area (A) as indicated below;

Irrigation Department Guideline → tc = *f* (L, S)

Kirpich Equation → tc = *f* (L, S)

Bransby-Williams Equation → tc = *f* (L, A, S)

UK Flood Studies Report → tc = *f* (L, S)

The slope of the watershed reflects the momentum of flood runoff. The watershed length is more often used as its size factor. The important of each of these inputs varies with the type of analysis being made. For better comparison direct computation of tc is much useful as it reflects the actual conditions prevailed in a watershed. In general time taken to reach the extreme point of the watershed is increased with the magnitude of catchment and vice versa. Table 4-2 below demonstrates results of different tc equations. Graphical representation of same is shown in Figure 4-1 to 4-4.

Table 4-2 Time of Concentration

Catchment ID	L (m)	Slope (%)	Catchment Area (ha)	Catchment Area (km^2)	Time of Concentration (minutes)			
					ID	KIR	B-W	UK
B 312 Road								
34/3 - 34/4	3317	1.27	768.5286	7.6852856	105.69	53.82	95.19	162.54
35/1 - 36/1	505	4.55	17.7511	0.1775110	21.90	7.72	16.37	49.67
36/2 - 37/1	9935	3.17	1709.1110	17.0911100	196.08	87.96	219.20	219.39
38/1 - 38/5	3937	3.86	509.2448	5.0924480	86.76	39.98	94.26	135.57
38/6 - 38/7	380	1.32	11.3763	0.1137630	25.39	10.00	16.49	58.18
39/1	693	2.60	27.1074	0.2710740	27.63	12.22	24.08	65.77
39/2	421	3.56	10.2593	0.1025930	22.67	7.37	15.14	48.31
40/1 - 42/3	4760	5.65	978.1636	9.7816360	80.07	39.96	98.93	135.53
42/4 - 44/3	3743	9.48	491.6382	4.9163820	55.93	27.20	75.14	107.18
58/1 - 58/2	771	11.41	18.2918	0.1829180	23.43	7.50	20.73	48.83
58/3 - 58/6A	1876	5.38	102.0480	1.0204800	40.65	19.88	49.36	88.50
58/7 - 59/1	981	11.11	22.7579	0.2275790	25.73	9.13	25.94	55.04
59/2	5189	2.62	543.8840	5.4388400	109.58	57.40	133.36	169.07
59/3	635	20.47	12.1606	0.1216060	21.94	5.16	15.82	38.86
A035 Road								
2/1-2/2	1264	0.24	70.7800	0.7078	61.08	48.57	64.25	152.68
2/3-2/4	1162	0.17	45.6400	0.4564	57.36	51.99	66.12	159.15
4/2-5/1	2053	0.24	153.3170	1.5332	89.84	70.56	96.59	191.77
16/1	267	0.75	9.0800	0.0908	24.73	9.46	13.27	56.25
21/1	14600	0.29	4811.0600	48.1106	547.23	297.12	468.60	461.20
22/1 - 22/2	3690	0.43	545.5000	5.4550	149.51	88.54	136.08	220.27
24/1 - 26/1	15400	0.32	6662.6100	66.6261	576.39	298.07	469.12	462.10
28/1-28/4	9170	0.39	2268.8400	22.6884	349.28	185.30	299.04	345.72
30/2	756	0.53	17.5200	0.1752	42.56	24.10	37.71	99.54
A009 Road								
123/3-123/4	2920	4.35	303.0000	3.0300	54.92	30.33	71.89	114.55
125/1	978	1.64	67.4210	0.6742	41.74	19.02	34.01	86.15
126/1	2735	0.51	486.7990	4.8680	114.70	65.83	98.60	183.82
127/2	1261	1.59	114.4310	1.1443	49.48	23.41	41.85	97.80
128/1	450	1.33	12.5070	0.1251	27.30	11.34	19.31	62.84
129/2	543	0.92	25.8840	0.2588	34.79	15.11	23.33	74.85
130/1-130/2	538	1.30	40.0680	0.4007	29.71	13.13	20.65	68.71
131/1	1130	1.33	68.2420	0.6824	45.89	23.05	40.93	96.86
205/2-206/1	4198	0.71	793.6700	7.9367	168.03	80.61	134.89	208.01

Catchment ID	L (m)	Slope (%)	Catchment Area (ha)	Catchment Area (km^2)	Time of Concentration (minutes)			
					ID	KIR	B-W	UK
206/3	1180	0.76	34.8430	0.3484	58.02	29.56	51.13	112.75
207/1-207/2	2550	0.78	606.4920	6.0649	107.96	52.96	82.60	160.97
209/2	363	1.93	20.2220	0.2022	24.92	8.33	13.78	52.04
210/2-210/6	888	0.68	41.3080	0.4131	47.37	24.78	38.68	101.26
212/1-213/1	2443	0.53	384.6240	3.8462	104.06	59.46	89.48	172.75
215/1	373	1.07	10.7070	0.1071	25.20	10.67	16.98	60.55
B528 Road								
3/1 - 3/3	1649	0.85	128.9200	1.2892	75.11	36.63	61.30	128.53
4/1-5/4	5180	0.50	738.7500	7.3875	203.83	108.48	179.82	249.34
7/1-7/2	6986	1.25	3026.6124	30.2661	206.00	95.97	175.35	231.38
11/2-11/3	1833	1.47	185.1921	1.8519	65.11	32.18	58.90	118.76
12/3-13/2	5260	2.36	889.4600	8.8946	110.87	60.39	131.42	174.40
16/3-17/2	3070	3.19	1012.5800	10.1258	70.96	35.53	71.28	126.15
20/1	3130	4.38	580.3100	5.8031	57.79	31.92	72.12	118.16
31/3	2576	2.72	427.9100	4.2791	61.95	33.00	67.31	120.60

ID: Irrigation Department Guideline, KIR: Kirpich Equation, B-W: Bransby –Williams Equation, UK: UK Flood Studies Report

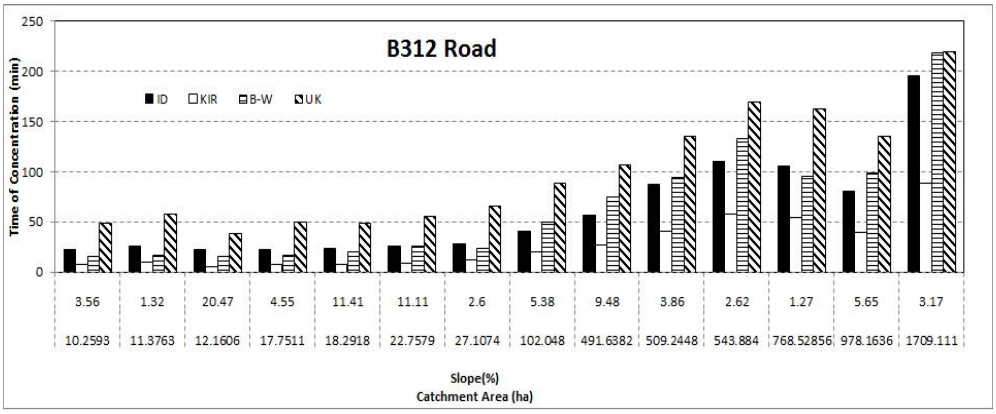


Figure 4-1 Catchment Physical Parameters vs. Time of Concentration graph of B312 Road

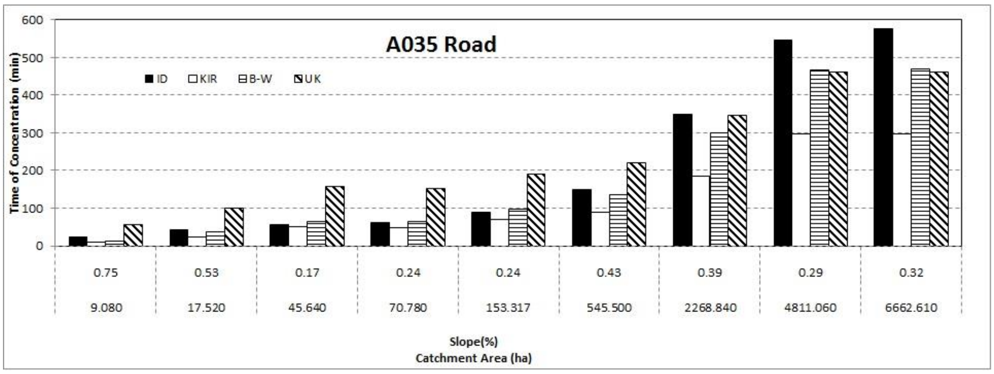


Figure 4-2 Catchment Physical Parameters vs. Time of Concentration graph of A035 Road

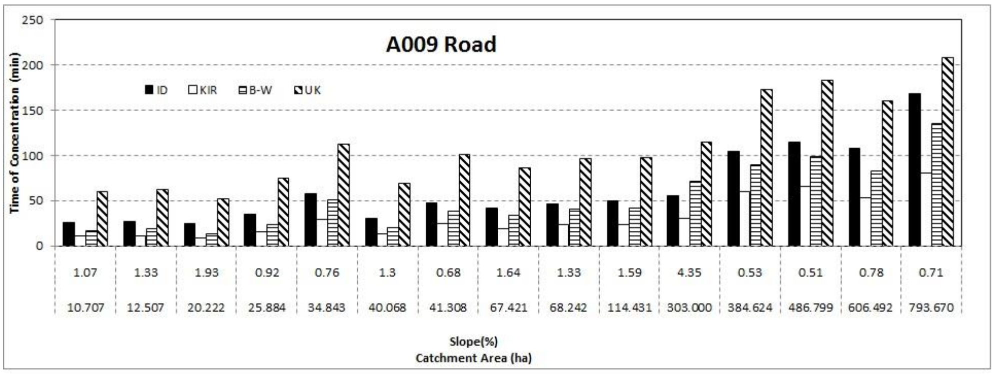


Figure 4-3 Catchment Physical Parameters vs. Time of Concentration graph of A009 Road

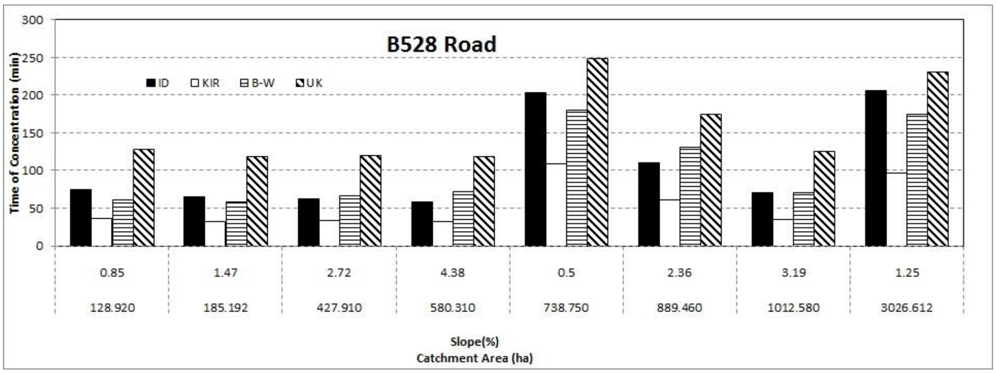


Figure 4-4 Catchment Physical Parameters vs. Time of Concentration graph of B528 Road

Time of concentration obtained from UK Flood Studies equation was the highest and Kirpich equation gave the lowest results. Bransby-Williams equation only showed fair agreement with ID guideline. However percentage difference in tc over ID guideline tends to decrease with the increase in catchment size.

Comparison of tc with respect to catchment physical parameters (slope (%) and area (ha)) are shown in Figure 4-5. Results of percentage difference in tc with respect to ID guideline are arranged in the ascending order of area and shown in Figure 4-6 and Table 4-3.

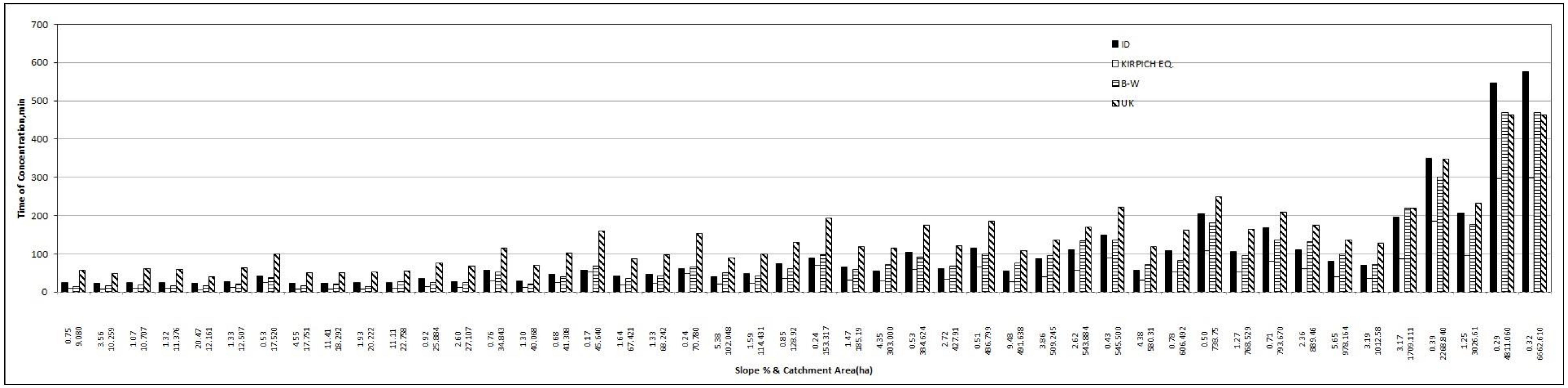


Figure 4-5 Catchment Physical Parameters vs. Time of Concentration

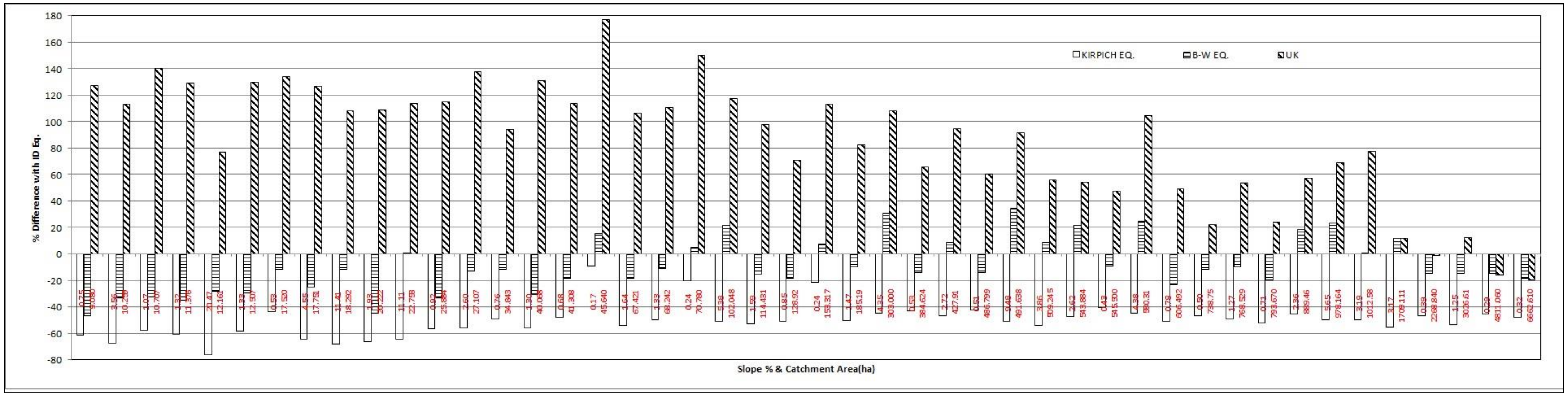


Figure 4-6 Catchment Physical Parameters vs. % difference in Time of Concentration with ID guideline

Table 4-3 Variation in tc with respect to ID Guideline

Road	Catchment ID	Catchment Area (ha)	Slope (%)	% Difference tc with ID		
				KIR	B-W	UK
A035	16/1	9.0800	0.75	-61.75	-46.35	127.43
B312	39/2	10.2593	3.56	-67.48	-33.24	113.07
A009	215/1	10.7070	1.07	-57.64	-32.60	140.29
B312	38/6 - 38/7	11.3763	1.32	-60.62	-35.05	129.16
B312	59/3	12.1606	20.47	-76.48	-27.91	77.08
A009	128/1	12.5070	1.33	-58.46	-29.26	130.14
A035	30/2	17.5200	0.53	-43.37	-11.39	133.89
B312	35/1 - 36/1	17.7511	4.55	-64.77	-25.28	126.78
B312	58/1 - 58/2	18.2918	11.41	-67.97	-11.54	108.41
A009	209/2	20.2220	1.93	-66.58	-44.70	108.80
B312	58/7 - 59/1	22.7579	11.11	-64.52	0.82	113.91
A009	129/2	25.8840	0.92	-56.59	-32.95	115.11
B312	39/1	27.1074	2.6	-55.76	-12.87	138.03
A009	206/3	34.8430	0.76	-49.06	-11.87	94.34
A009	130/1-130/2	40.0680	1.3	-55.81	-30.50	131.27
A009	210/2-210/6	41.3080	0.68	-47.68	-18.35	113.75
A035	2/3-2/4	45.6400	0.17	-9.37	15.27	177.46
A009	125/1	67.4210	1.64	-54.43	-18.51	106.41
A009	131/1	68.2420	1.33	-49.79	-10.81	111.05
A035	2/1-2/2	70.7800	0.24	-20.48	5.19	149.98
B312	58/3 - 58/6A	102.0480	5.38	-51.10	21.43	117.73
A009	127/2	114.4310	1.59	-52.68	-15.41	97.66
B528	3/1 - 3/3	128.9200	0.85	-51.23	-18.39	71.11
A035	4/2-5/1	153.3170	0.24	-21.46	7.52	113.46
B528	11/2-11/3	185.1921	1.47	-50.58	-9.55	82.39
A009	123/3-123/4	303.0000	4.35	-44.76	30.92	108.59
A009	212/1-213/1	384.6240	0.53	-42.85	-14.01	66.02
B528	31/3	427.9100	2.72	-46.73	8.64	94.66
A009	126/1	486.7990	0.51	-42.60	-14.04	60.26
B312	42/4 - 44/3	491.6382	9.48	-51.36	34.33	91.62
B312	38/1 - 38/5	509.2448	3.86	-53.92	8.64	56.26
B312	59/2	543.8840	2.62	-47.62	21.70	54.29
A035	22/1 - 22/2	545.5000	0.43	-40.78	-8.98	47.32
B528	20/1	580.3100	4.38	-44.77	24.80	104.47
A009	207/1-207/2	606.4920	0.78	-50.94	-23.49	49.10
B528	4/1-5/4	738.7500	0.5	-46.78	-11.78	22.33
B312	34/3 - 34/4	768.5286	1.27	-49.08	-9.94	53.80

Road	Catchment ID	Catchment Area (ha)	Slope (%)	% Difference tc with ID		
				KIR	B-W	UK
A009	205/2-206/1	793.6700	0.71	-52.02	-19.72	23.79
B528	12/3-13/2	889.4600	2.36	-45.53	18.53	57.29
B312	40/1 - 42/3	978.1636	5.65	-50.10	23.55	69.26
B528	16/3-17/2	1012.5800	3.19	-49.93	0.46	77.78
B312	36/2 - 37/1	1709.1110	3.17	-55.14	11.79	11.88
A035	28/1-28/4	2268.8400	0.39	-46.95	-14.38	-1.02
B528	7/1-7/2	3026.6124	1.25	-53.41	-14.88	12.32
A035	21/1	4811.0600	0.29	-45.70	-14.37	-15.72
A035	24/1 - 26/1	6662.6100	0.32	-48.29	-18.61	-19.83

4.3. Runoff Coefficient

The difference in runoff coefficient based on two guidelines is significant in flat lands (approximately slope < 4%). Guideline 1 estimations were higher than that of Guideline 2. This showed fair agreement with the previous study made by Wijesinghe and Wijesekera (2011). It can be seen that runoff coefficient is significantly varied with different land cover types. Therefore runoff coefficient obtained from guideline 2 can be considered as the most accurate estimation. Significant difference in runoff coefficients was noticed for lower return periods. In the case of paddy cultivated areas, guideline 1 underestimates runoff coefficient and this is critical for catchments with more than 85% of paddy areas. Considering above, C values based on Guideline 2 were used in the Rational Formula.

Runoff coefficients and percentage difference in runoff coefficient with respect to guideline 2 are indicated in Table 4-4. Graphical illustration of different runoff coefficient estimations are depicted in Figure 4 -7 to 4 -10.

Table 4-4 Comparison of Runoff Coefficient as per Guideline 1 and 2

Road	Catchment ID	Slope (%)	Catchment Area (ha)	Runoff Coefficient, C				% Difference in C from Guideline 2			% of Land Cover			
				Guideline 1	Guideline 2 :*f* [Slope, Landuse]						Vegetation	Water Bodies	Paddy	Cultivation
				25,50,100 Yrs	25 Yrs	50 Yrs	100 Yrs	25 Yrs	50 Yrs	100 Yrs				
B312	39/2	3.57	10.2593	0.40	0.21	0.24	0.25	89	67	60	100	0	0	0
B312	38/6 - 38/7	1.22	11.3763	0.30	0.14	0.17	0.18	109	75	65	98	0	2	0
B312	59/3	20.48	12.1606	0.50	0.40	0.43	0.46	25	16	9	100	0	0	0
B312	35/1 - 36/1	4.73	17.7511	0.50	0.25	0.29	0.31	100	74	64	100	0	0	0
B312	58/1 - 58/2	11.43	18.2918	0.50	0.42	0.45	0.49	18	11	3	100	0	0	0
B312	58/7 - 59/1	11.12	22.7579	0.50	0.42	0.45	0.49	18	10	2	100	0	0	0
B312	39/1	2.66	27.1074	0.40	0.21	0.24	0.25	95	67	60	100	0	0	0
B312	58/3 - 58/6A	5.36	102.0480	0.50	0.38	0.41	0.45	31	22	12	100	0	0	0
B312	42/4 - 44/3	9.48	491.6382	0.50	0.45	0.48	0.52	12	3	-5	98	0	2	0
B312	38/1 - 38/5	3.71	509.2448	0.40	0.23	0.28	0.31	76	41	31	93	1	7	0
B312	59/2	2.63	543.8840	0.40	0.38	0.41	0.45	5	-2	-10	100	0	0	0
B312	34/3 - 34/4	1.26	768.5286	0.31	0.27	0.30	0.33	16	2	-6	98	2	0	0
B312	40/1 - 42/3	5.65	978.1636	0.50	0.33	0.43	0.49	51	17	2	80	0	20	0
B312	36/2 - 37/1	3.18	1709.1110	0.40	0.31	0.34	0.37	30	17	9	100	0	0	0
A035	16/1	0.75	9.0800	0.30	0.11	0.12	0.13	173	150	140	100	0	0	0
A035	30/2	0.53	17.5200	0.52	0.39	0.40	0.40	33	31	30	68	32	0	0
A035	2/3-2/4	0.17	45.6400	0.30	0.33	0.70	0.90	-9	-57	-67	0	0	100	0
A035	2/1-2/2	0.24	70.7800	0.30	0.33	0.70	0.90	-9	-57	-67	0	0	100	0
A035	4/2-5/1	0.24	153.3170	0.30	0.30	0.61	0.78	1	-51	-62	15	0	85	0
A035	22/1 - 22/2	0.43	545.5000	0.30	0.18	0.21	0.22	64	43	34	100	0	0	0

Road	Catchment ID	Slope (%)	Catchment Area (ha)	Runoff Coefficient, C				% Difference in C from Guideline 2			% of Land Cover			
				Guideline 1 25,50,100 Yrs	Guideline 2 :*f* [Slope, Landuse]						Vegetation	Water Bodies	Paddy	Cultivation
					25 Yrs	50 Yrs	100 Yrs	25 Yrs	50 Yrs	100 Yrs				
A035	28/1-28/4	0.39	2268.8400	0.31	0.29	0.34	0.38	7	-9	-18	95	1	4	0
A035	21/1	0.29	4811.0600	0.33	0.30	0.33	0.36	12	-1	-10	94	5	2	0
A035	24/1 - 26/1	0.32	6662.6100	0.35	0.34	0.40	0.44	2	-13	-21	87	7	6	0
A009	215/1	1.07	10.7070	0.30	0.27	0.31	0.34	11	-4	-12	100	0	0	0
A009	128/1	1.33	12.5070	0.30	0.14	0.15	0.15	122	104	94	91	0	0	9
A009	209/2	1.93	20.2220	0.30	0.33	0.70	0.90	-9	-57	-67	0	0	100	0
A009	129/2	0.92	25.8840	0.30	0.27	0.29	0.32	10	2	-6	44	0	0	56
A009	206/3	0.76	34.8430	0.30	0.16	0.18	0.19	86	68	55	100	0	0	0
A009	130/1-130/2	1.30	40.0680	0.30	0.28	0.31	0.34	6	-4	-11	50	0	0	50
A009	210/2-210/6	0.68	41.3080	0.36	0.28	0.31	0.32	28	16	11	75	8	0	17
A009	125/1	1.64	67.4210	0.30	0.21	0.24	0.26	45	23	17	100	0	0	0
A009	131/1	1.33	68.2420	0.30	0.22	0.24	0.26	38	24	16	72	0	0	28
A009	127/2	1.59	114.4310	0.32	0.31	0.34	0.37	3	-7	-13	58	3	0	39
A009	123/3-123/4	4.35	303.0000	0.52	0.35	0.42	0.47	47	23	11	86	3	11	0
A009	212/1-213/1	0.53	384.6240	0.39	0.38	0.42	0.45	3	-8	-14	63	13	4	20
A009	126/1	0.51	486.7990	0.35	0.31	0.36	0.40	11	-4	-11	65	8	6	22
A009	207/1-207/2	0.78	606.4920	0.33	0.30	0.35	0.39	8	-6	-15	92	4	4	0
A009	205/2-206/1	0.71	793.6700	0.35	0.34	0.39	0.43	2	-10	-19	88	8	4	0
B528	3/1 - 3/3	0.85	128.9200	0.30	0.30	0.34	0.37	1	-11	-18	81	0	0	19
B528	11/2-11/3	1.47	185.1921	0.31	0.25	0.30	0.33	24	3	-6	93	2	5	0
B528	31/3	2.72	427.9100	0.42	0.34	0.39	0.42	24	6	-1	54	3	5	38

Road	Catchment ID	Slope (%)	Catchment Area (ha)	Runoff Coefficient, C				% Difference in C from Guideline 2			% of Land Cover			
				Guideline 1 25,50,100 Yrs	Guideline 2 :*f* [Slope, Landuse]						Vegetation	Water Bodies	Paddy	Cultivation
					25 Yrs	50 Yrs	100 Yrs	25 Yrs	50 Yrs	100 Yrs				
B528	20/1	4.38	580.3100	0.54	0.40	0.43	0.46	34	24	17	81	9	0	11
B528	4/1-5/4	0.50	738.7500	0.33	0.30	0.35	0.38	10	-5	-12	85	4	3	7
B528	12/3-13/2	2.36	889.4600	0.43	0.36	0.40	0.42	18	9	2	87	5	0	8
B528	16/3-17/2	3.19	1012.5800	0.44	0.39	0.42	0.45	12	4	-3	76	6	0	18
B528	7/1-7/2	1.25	3026.6124	0.32	0.30	0.34	0.36	8	-4	-12	83	3	0	14

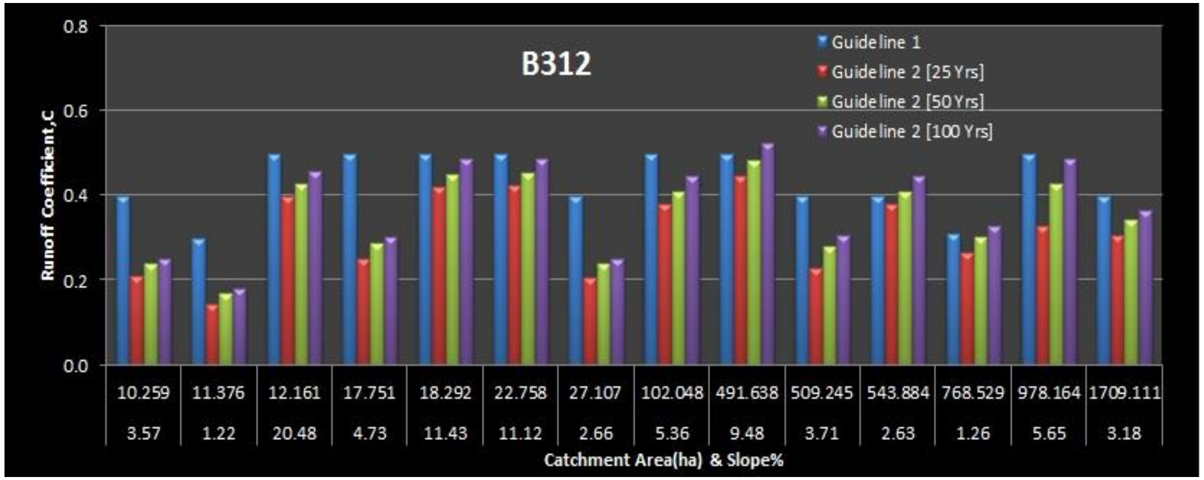


Figure 4-7 Comparison of Runoff Coefficient of B 312 Road

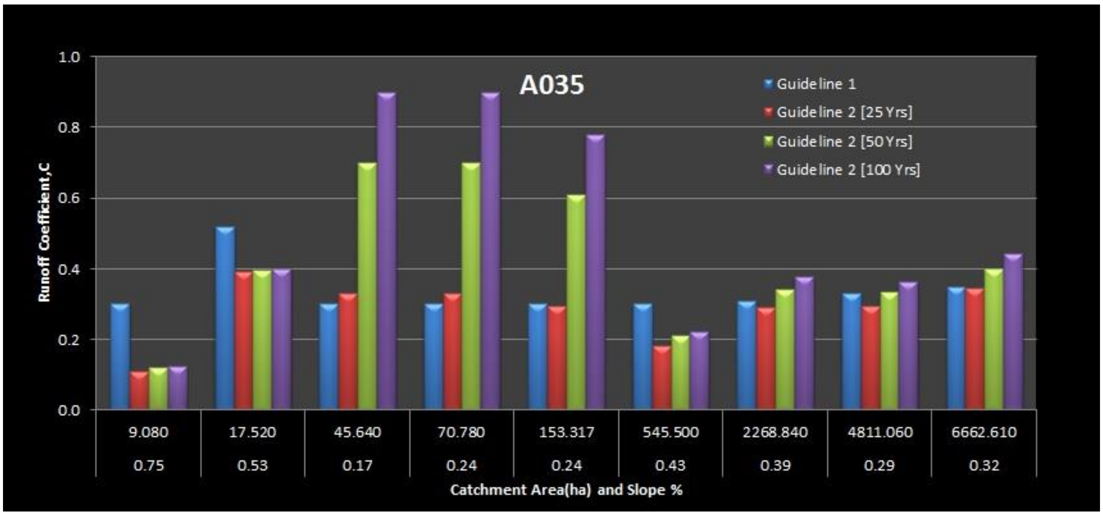


Figure 4-8 Comparison of Runoff Coefficient A 035 Road

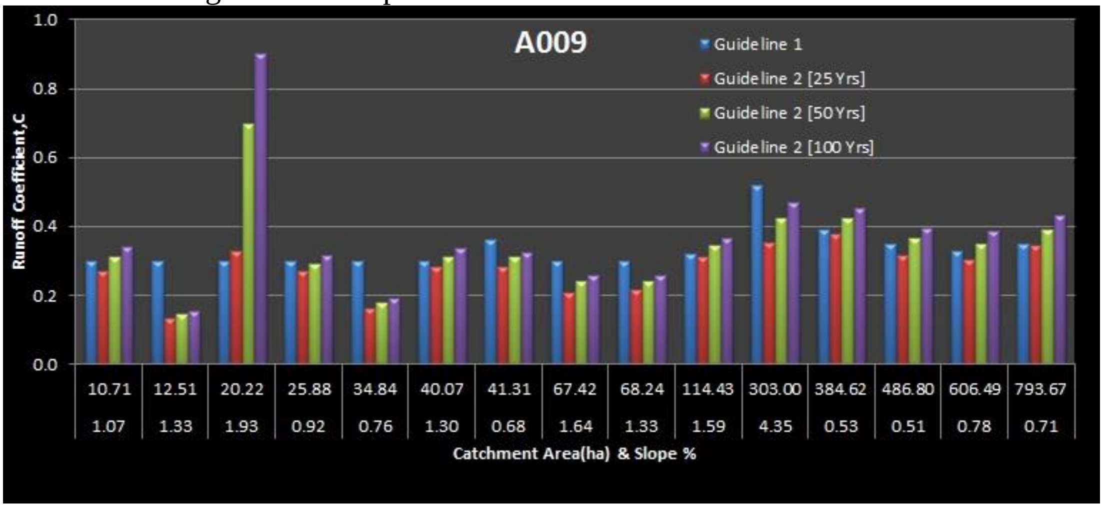


Figure 4-9 Comparison of Runoff Coefficient A 009 Road

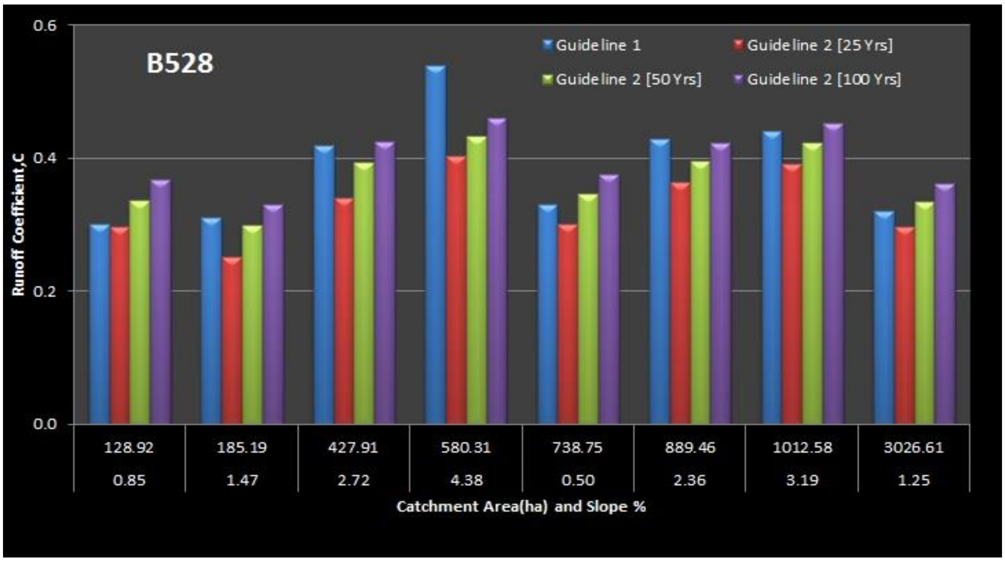


Figure 4-10 Comparison of Runoff Coefficient B 528 Road

4.4. Design Rainfall Intensity

Shorter period storm duration leads to higher rainfall intensities. Storm duration equals to tc from ID guideline was set as the baseline for the comparison of other options. For a given tc formula, the percentage difference did not vary with the magnitude of rainfall event falls in a watershed. Design rainfall intensities for 25 year return periods are depicted in Figures 4-11 to 4-14.

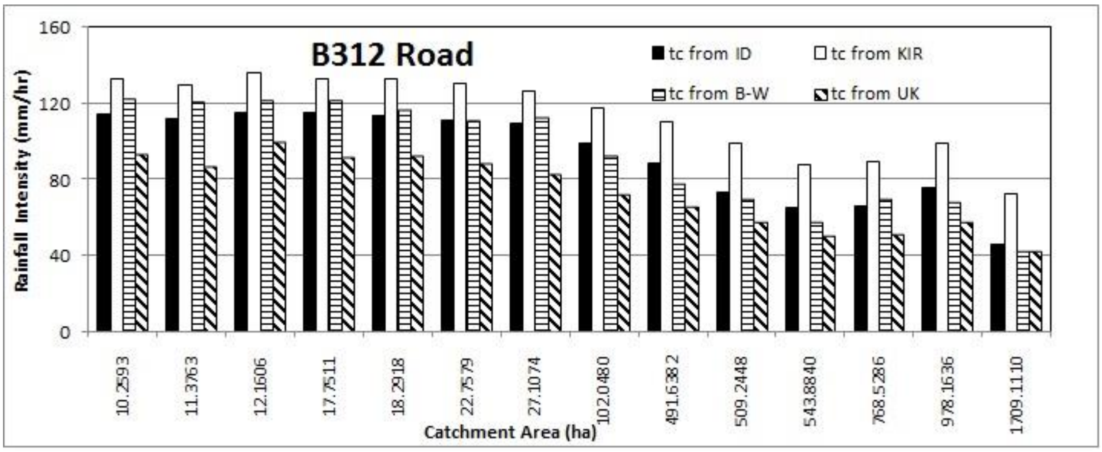


Figure 4-11 Rainfall Intensity for 25 Years Return Period for B 312 Road

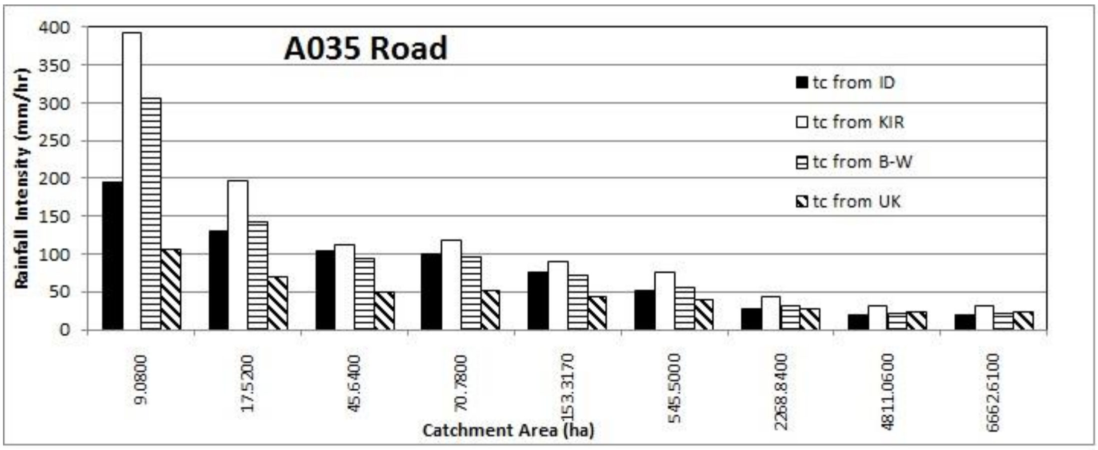


Figure 4-12 Rainfall Intensity for 25 Years Return Period for A 035 Road

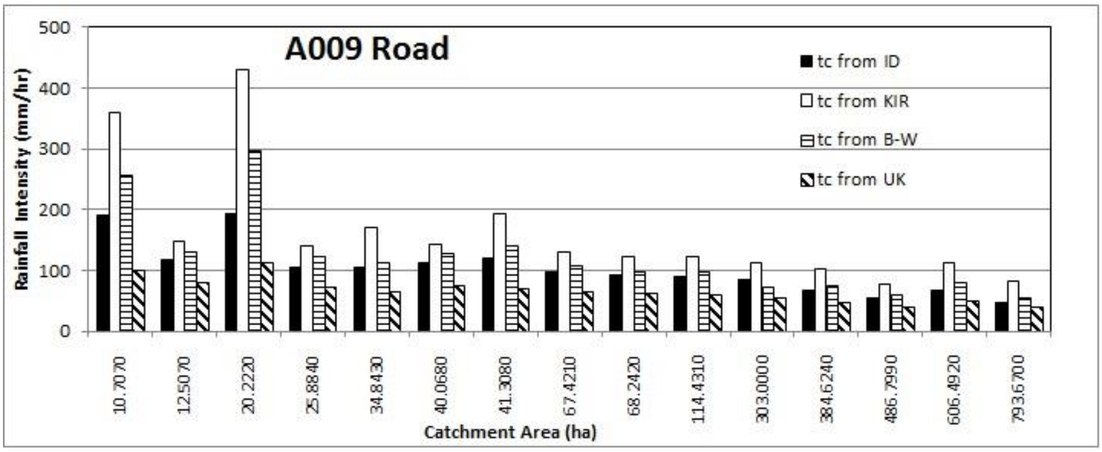


Figure 4-13 Rainfall Intensity for 25 Years Return Period for A 009 Road

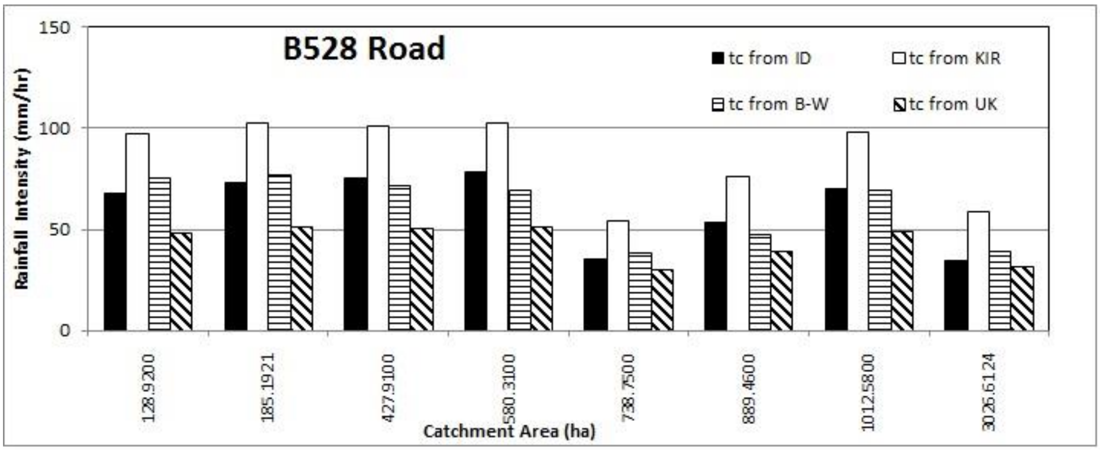


Figure 4-14 Rainfall Intensity for 25 Years Return Period for B 528 Road

4.5. Statistical Analysis of Flood Peak Data

Annual maximum flood peak records were arranged in the descending order and expected flood flows were predicted for return periods 25, 50 and 100 years. The values of yn and σn to be applied in Gumbel distribution for a recorded time period are given in Table 3-18. Flood frequency analysis made for the river gauge station at Embilipitiya of Walawe Ganga is shown in Table 4-5 and 4-6. It is necessary to confirm the applicability of Gumbel distribution for a given set of observed flood measurements. This can be verified with the plot of reduced variate and magnitude of flood and if an eye fits to this plot suggested a straight line (as shown in Figure 4-15, 4-16 and 4-17), then it is reasonable to conclude that Gumbel's distribution is a good fit for the observed records. The results of statistical analysis made for the balance road segments are given in Table 4-7 through 4-10.

Table 4-5 Statistical Analysis of Historical Flood Peak of Walawe Ganga
(River: Walawe Ganga, Station: Embiliptiya, Location: Lat. 06-20-40 N, Long. 80-53-55 E, Area: 1580 km^2, Length: 35.5 km)

Year	Flood Peak (m^3/s)	Order (m)	$Sx^2 = (n-X)^2$	Return Period, Tr =(n+1)/m	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))
1946	2251	1	1812572.647	23	3.1134
1962	1869	2	929909.5558	12	2.3972
1957	1558	3	426824.6467	8	1.9678
1950	1416	4	261446.2831	6	1.6552
1961	1161	5	65699.01033	5	1.4060
1945	1133	6	52129.19215	4	1.1964
1956	1133	7	52129.19215	3	1.0136
1951	1062	8	24749.01033	3	0.8499
1944	935	9	919.1921488	3	0.7003
1942	787	10	13849.01033	2	0.5612
1963	708	11	38683.7376	2	0.4299
1960	680	12	50481.91942	2	0.3044
1943	665	13	57447.37397	2	0.1828
1948	637	14	71653.55579	2	0.0637
1954	623	15	79344.64669	2	-0.0545
1958	600	16	92831.01033	1	-0.1736
1949	538	17	134455.5558	1	-0.2955
1952	538	18	134455.5558	1	-0.4227
1953	521	19	147211.7376	1	-0.5592
1959	510	20	155773.7376	1	-0.7114
1955	323	21	338353.7376	1	-0.8930
1947	255	22	422086.4649	1	-1.1428

Sum:19903, Average: 904.6818, Standard deviation: 505.3526

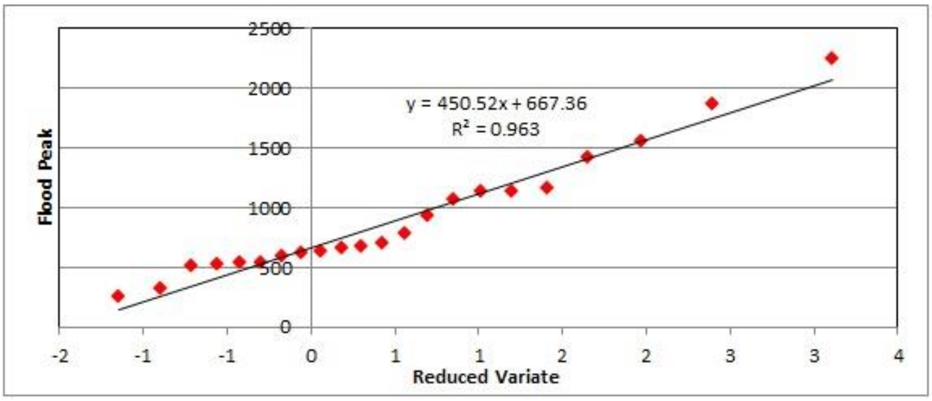


Figure 4-15 Reduced variate vs. Flood Peak for Station Embilipitiya

Table 4-6 Expected Flood for different Return Periods at Walawe Ganga (Station-Embilipitiya)

Return Period(Tr)	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))	Frequency Factor, KT=(Yt-Yn)/σn	Expected Flood XT=ẋ+KT.Sx
2	0.366512921	-0.1490	829
5	1.499939987	0.9065	1363
10	2.250367327	1.6054	1716
25	3.198534261	2.4884	**2162**
50	3.901938658	3.1435	**2493**
100	4.600149227	3.7937	**2822**
200	5.295812143	4.4415	3149
400	5.990213243	5.0882	3476

Table 4-7 Statistical Analysis of Historical Flood Peak of Amban Ganga
(River: Amban Ganga, Station: Elahera, Location: Lat. 07-40-45 N, Long. 80-45-25 E, Area: 774 km^2, Length: 50.5 km)

Year	Flood Peak (m^3/s)	Order (m)	$Sx^2 = (n-X)^2$	Return Period, Tr =(n+1)/m	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))
1979	1605	1	1376361.192	39	3.6506
1983	929	2	247192.1392	20	2.9442
1974	923	3	241261.9287	13	2.5252
1964	833	4	160948.7708	10	2.2236
1960	667	5	55311.61288	8	1.9863
1961	661	6	52525.40235	7	1.7894
1980	624	7	36934.77078	6	1.6204

Year	Flood Peak (m^3/s)	Order (m)	$Sx^2 = (n-X)^2$	Return Period, Tr =(n+1)/m	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))
1981	599	8	27950.56025	5	1.4715
1984	522	9	8133.191828	4	1.3380
1972	505	10	5355.92867	4	1.2165
1947	474	11	1779.507618	4	1.1046
1973	455	12	537.5076177	3	1.0004
1978	434	13	4.770775623	3	0.9027
1970	431	14	0.665512465	3	0.8104
1968	422	15	96.34972299	3	0.7226
1976	421	16	116.9813019	2	0.6385
1963	420	17	139.6128809	2	0.5577
1975	411	18	433.2970914	2	0.4796
1969	393	19	1506.665512	2	0.4037
1952	382	20	2481.612881	2	0.3297
1971	359	21	5302.139197	2	0.2572
1967	343	22	7888.24446	2	0.1859
1962	307	23	15578.9813	2	0.1154
1965	300	24	17375.40235	2	0.0455
1957	279	25	23352.66551	2	-0.0242
1966	267	26	27164.24446	2	-0.0940
1985	265	27	27827.50762	1	-0.1644
1948	261	28	29178.03393	1	-0.2356
1955	251	29	32694.34972	1	-0.3082
1977	251	30	32694.34972	1	-0.3828
1951	249	31	33421.61288	1	-0.4600
1950	212	32	48318.9813	1	-0.5410
1953	209	33	49646.87604	1	-0.6269
1954	202	34	52815.29709	1	-0.7198
1949	189	35	58959.50762	1	-0.8230
1959	147	36	81120.03393	1	-0.9419
1982	126	37	93523.29709	1	-1.0887
1956	81	38	123071.7181	1	-1.2984

Sum:16409, Average: 431.8158, Standard deviation: 283.7493

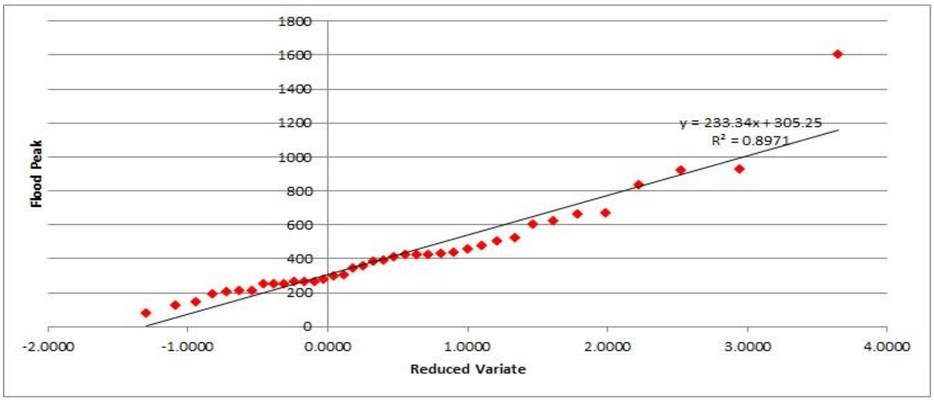


Figure 4-16 Reduced variate vs. Flood Peak for Station Elahera

Table 4-8 Expected Flood for different Return Periods at Amban Ganga (Station-Elahera)

Return Period(T) in years	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))	Frequency Factor, KT=(Yt-Yn)/σn	Expected Flood XT=ẋ+KT.Sx
2	0.366512921	-0.1547	388
5	1.499939987	0.8428	671
10	2.250367327	1.5033	858
25	3.198534261	2.3378	**1095**
50	3.901938658	2.9569	**1271**
100	4.600149227	3.5714	**1445**
200	5.295812143	4.1837	1619
400	5.990213243	4.7949	1792

Table 4-9 Statistical Analysis of Historical Flood Peak of Malwathu Oya (River: Malwathu Oya, Station: Kapachchi, Location: Lat. 08-35-55 N, Long. 81-16-20 E, Area: 2117 km^2)

Year	Flood Peak (m^3/s)	Order (m)	$Sx^2 = (n-X)^2$	Return Period, Tr =(n+1)/m	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))
1948	2494	1	4434032.653	36	3.5695
1967	1578	2	1415420.082	18	2.8619
1963	1021	3	400327.3673	12	2.4417
1966	1019	4	397800.5102	9	2.1389
1965	934	5	297804.0816	7	1.9002
1962	865	6	227256.5102	6	1.7020
1960	811	7	178687.3673	5	1.5314

Year	Flood Peak (m^3/s)	Order (m)	$Sx^2 = (n-X)^2$	Return Period, Tr =(n+1)/m	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))
1954	469	8	6514.795918	5	1.3811
1973	391	9	7.367346939	4	1.2459
1969	366	10	496.6530612	4	1.1226
1951	362	11	690.9387755	3	1.0088
1964	350	12	1465.795918	3	0.9027
1980	281	13	11510.22449	3	0.8029
1961	274	14	13061.22449	3	0.7083
1979	231	15	24738.79592	2	0.6180
1953	198	16	36208.65306	2	0.5314
1972	187	17	40515.93878	2	0.4477
1971	182	18	42553.79592	2	0.3665
1978	182	19	42553.79592	2	0.2873
1970	145	20	59187.93878	2	0.2096
1959	125	21	69319.36735	2	0.1330
1977	110	22	77442.93878	2	0.0571
1949	108	23	78560.08163	2	-0.0184
1981	108	24	78560.08163	2	-0.0940
1955	104	25	80818.36735	1	-0.1703
1984	102	26	81959.5102	1	-0.2476
1952	97	27	84847.36735	1	-0.3266
1958	96	28	85430.93878	1	-0.4082
1950	95	29	86016.5102	1	-0.4932
1956	93	30	87193.65306	1	-0.5832
1982	93	31	87193.65306	1	-0.6801
1976	39	32	122000.5102	1	-0.7872
1968	35	33	124810.7959	1	-0.9102
1975	26	34	131250.9388	1	-1.0614
1974	19	35	136371.9388	1	-1.2763

Sum:13590, Average: 388.2857, Standard deviation: 515.7123

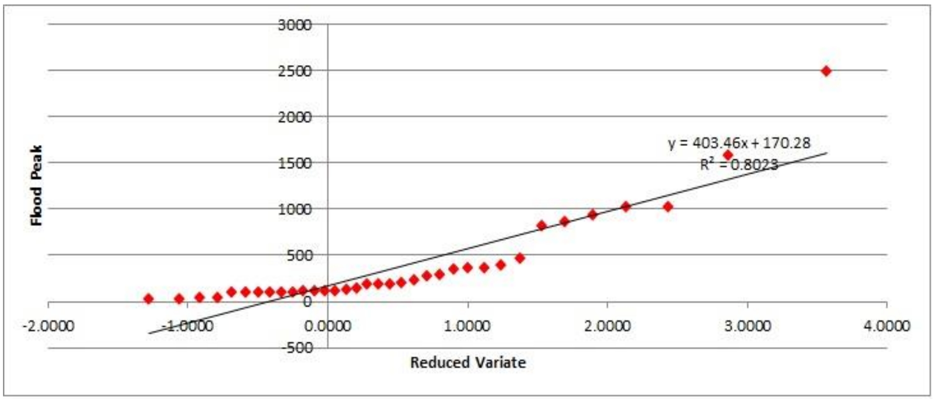


Figure 4-17 Reduced variate vs. Flood Peak for Station Kapachchi

Table 4-10 Expected Flood for different Return Periods at Malwathu Oya (Station-Kapachchi)

Return Period in Years	Reduced Variate, Y =-ln.ln(Tr/(Tr-1))	Frequency Factor, KT=(Yt-Yn)/σn	Expected Flood XT=ẋ+KT.Sx
2	0.366512921	-0.1540	309
5	1.499939987	0.8504	827
10	2.250367327	1.5153	1170
25	3.198534261	2.3555	**1603**
50	3.901938658	2.9789	**1925**
100	4.600149227	3.5976	**2244**
200	5.295812143	4.2140	2562
400	5.990213243	4.8293	2879

Table 4-11 below shows results of flood frequency analysis of gauged catchments.

Table 4-11 Results of Flood Frequency Analysis

Gauge Catchment/Area	Discharge (m^3/s)			Target Ungauged Catchments
	25 Years	50 Years	100 Years	
Amban Ganga at Elahera/774 km^2	1095	1271	1445	B 312 Road
Malwathu Oya at Kappachchi/2117 km^2	1603	1925	2244	A 009 Road (122-130 km)
Walawe Ganga at Embilipitiya/1580 km^2	2162	2493	2822	B 528 Road

4.6. Hydrological Design

4.6.1. Peak Flow Estimation using Rational Formula

Even though prevailing hydrological design concerns stated that Rational Formula is not meaningful in larger size watersheds, almost all watersheds were modeled with Rational Method to understand its behavior over a wide range of area. Rational Method peak flow computations were expressed as four options based on different time of concentration equations. Tabular and graphical presentation of results for 25, 50 and 100 year return periods are attached to Appendix F.

Peak flow based on storm duration equals to tc from UK Flood Studies Report showed the lowest, while Kirpich equation resulted the highest magnitude of flood flow.

4.6.2. Peak Flow Estimation using Fuller Formula

Despite the fact that frequent applications of fuller formula in global context, no previous studies are available on its applicability for Sri Lankan conditions. The equation was applied without modifying its constants as such drainage area is the only dependent parameter.

4.6.3. Peak Flow Estimation using Snyder's Method

Successful application of Snyder synthetic unit hydrograph formulas depend on the determination of coefficients Ct and Cp. The study absorbed those coefficients as stipulated in ID Guideline (1988). Direct Runoff Hydrograph (DRH) calculations are presented in Appendix E.

4.6.4. Peak Flow Estimation using Flood Transportation

Since there are no stream gauges exist in the catchments considered in the study, the weighted gauge data of same stream at a location outside the catchment or adjacent similar nature watershed were used. The watershed similarity are expressed in terms of precipitation, drainage area and shape, orographic characters, land cover and lithology/geology. The compatibility of gauge and ungauged sites were decided based on visual observation on hydrological zone, soil type and land use patterns.

Slope exponent factor of 0.8 was adopted, as no values are published for stream gauge locations in Sri Lanka. Further no substantial findings are available on drainage area ratios applicable for Sri Lanka. Transferred peak flow values for ungauged sites are given in Table 4-12.

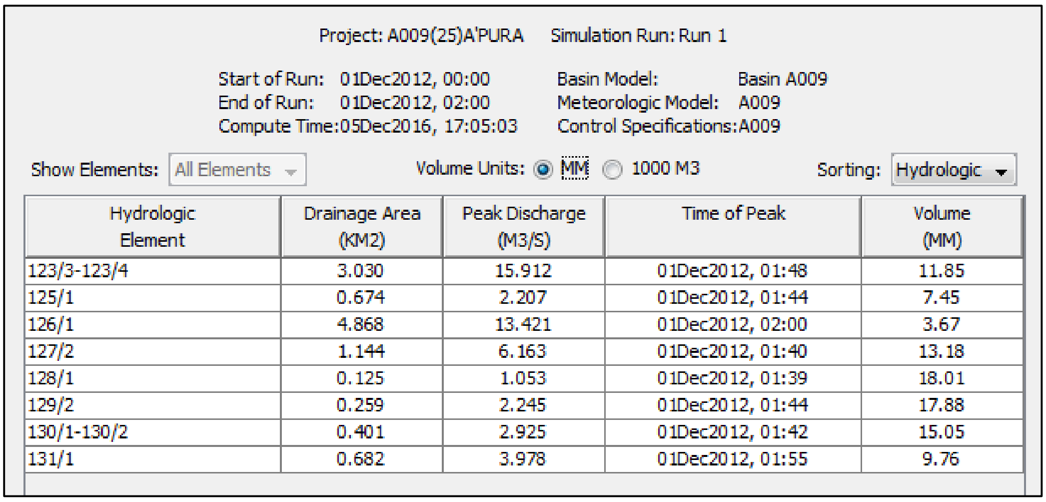
Table 4-12 Peak Flow Estimation using Flood Transportation

Catchment ID	Catchment Area km^2		CA_u/CA_g	Peak Flow (m^3/s) Ungauged		
	CAu	CAg		25	50	100
B 312 Road						
34/3 - 34/4	7.685	774	0.0099	27.354	31.741	36.096
35/1 - 36/1	0.178	774	0.0002	1.342	1.558	1.771
36/2 - 37/1	17.091	774	0.0221	51.845	60.161	68.415
38/1 - 38/5	5.092	774	0.0066	19.680	22.837	25.970
38/6 - 38/7	0.114	774	0.0001	0.940	1.091	1.241
39/1	0.271	774	0.0004	1.883	2.186	2.485
39/2	0.103	774	0.0001	0.866	1.005	1.142
40/1 - 42/3	9.782	774	0.0126	33.176	38.497	43.779
42/4 - 44/3	4.916	774	0.0064	19.134	22.203	25.250
58/1 - 58/2	0.183	774	0.0002	1.375	1.596	1.814
58/3 - 58/6A	1.020	774	0.0013	5.439	6.312	7.178
58/7 - 59/1	0.228	774	0.0003	1.638	1.900	2.161
59/2	5.439	774	0.0070	20.744	24.071	27.374
59/3	0.122	774	0.0002	0.992	1.151	1.309
A 009 Road						
123/3-123/4	3.030	2117	0.0014	8.502	10.207	11.899
125/1	0.674	2117	0.0003	2.555	3.067	3.576
126/1	4.868	2117	0.0023	12.424	14.915	17.388
127/2	1.144	2117	0.0005	3.901	4.684	5.460
128/1	0.125	2117	0.0001	0.664	0.797	0.929
129/2	0.259	2117	0.0001	1.188	1.426	1.663
130/1-130/2	0.401	2117	0.0002	1.685	2.023	2.358
131/1	0.682	2117	0.0003	2.580	3.097	3.611
B 528 Road						
3/1 - 3/3	1.289	1580	0.0008	7.315	8.435	9.547
4/1-5/4	7.388	1580	0.0047	29.564	34.091	38.584
7/1-7/2	30.266	1580	0.0192	91.356	105.342	119.226
11/2-11/3	1.852	1580	0.0012	9.774	11.270	12.756
12/3-13/2	8.895	1580	0.0056	34.298	39.549	44.762
16/3-17/2	10.126	1580	0.0064	38.046	43.871	49.653

Catchment ID	Catchment Area km²		CA_u/CA_g	Peak Flow (m³/s) Ungauged		
	CAu	CAg		25	50	100
20/1	5.803	1580	0.0037	24.372	28.104	31.808
31/3	4.279	1580	0.0027	19.101	22.025	24.928

4.6.5. Peak Flow Estimation using HEC-HMS

HEC-HMS models were made assuming that there is no sustained runoff due to temporary storage of prior precipitation and delayed subsurface runoff. HEC-HMS provides results in tabular and graphical form including global results table or results of individual elements within the model as depicted in Figure 4-18 to 4-20. Results of HEC-HMS analysis are shown in Table 4-13.


Project: A009(25)A'PURA Simulation Run: Run 1

Start of Run: 01Dec2012, 00:00 Basin Model: Basin A009
End of Run: 01Dec2012, 02:00 Meteorologic Model: A009
Compute Time: 05Dec2016, 17:05:03 Control Specifications: A009

Show Elements: All Elements Volume Units: MM 1000 M3 Sorting: Hydrologic

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
123/3-123/4	3.030	15.912	01Dec2012, 01:48	11.85
125/1	0.674	2.207	01Dec2012, 01:44	7.45
126/1	4.868	13.421	01Dec2012, 02:00	3.67
127/2	1.144	6.163	01Dec2012, 01:40	13.18
128/1	0.125	1.053	01Dec2012, 01:39	18.01
129/2	0.259	2.245	01Dec2012, 01:44	17.88
130/1-130/2	0.401	2.925	01Dec2012, 01:42	15.05
131/1	0.682	3.978	01Dec2012, 01:55	9.76

Figure 4-18 Summary of Peak Flow Estimation for Return Period 25 Years

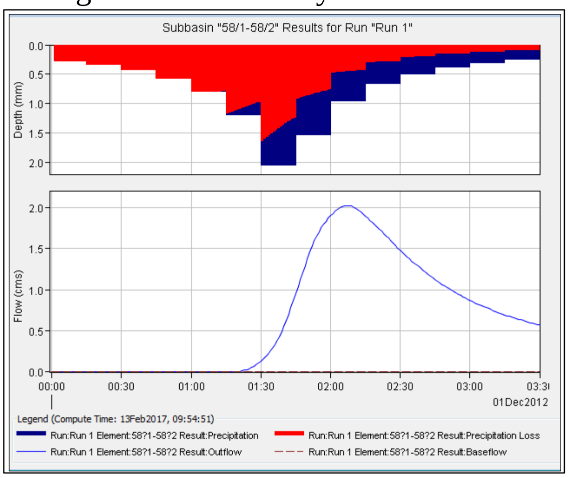


Figure 4-19Hydrograph and Hyetograph

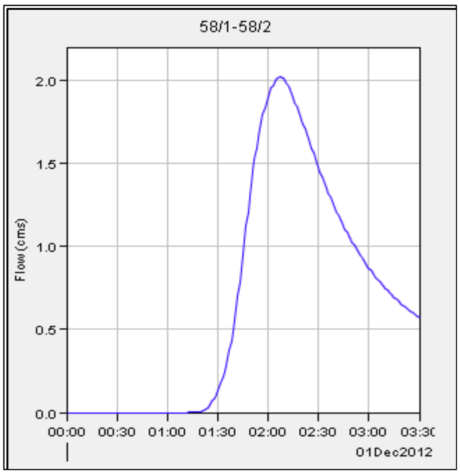


Figure 4-20 Runoff Hydrograph of Catchment 58/1-58/2

Table 4-13 Peak Flow Estimation using HEC-HMS

Catchment ID	Catchment Area (km^2)	Basin Lag Time (min)	CN	Peak Flow (m^3/s)		
				25 Years	50 Years	100 Years
B 312 Road						
34/3 - 34/4	7.685	63.41	56	41.815	50.049	58.981
35/1 - 36/1	0.178	13.14	51	1.231	1.514	1.818
36/2 - 37/1	17.091	117.65	54	69.697	83.476	98.860
38/1 - 38/5	5.092	52.06	54	27.439	33.140	39.336
38/6 - 38/7	0.114	15.23	57	1.074	1.282	1.500
39/1	0.271	16.58	52	1.896	2.318	2.772
39/2	0.103	13.60	56	0.945	1.131	1.326
40/1 - 42/3	9.782	48.04	61	76.389	89.855	104.150
42/4 - 44/3	4.916	33.56	60	42.568	50.254	58.373
58/1 - 58/2	0.183	14.06	60	2.019	2.378	2.750
58/3 - 58/6A	1.020	24.39	60	9.821	11.600	13.466
58/7 - 59/1	0.228	15.44	60	2.469	2.912	3.370
59/2	5.439	65.75	60	34.934	41.212	47.949
59/3	0.122	13.17	60	1.362	1.602	1.851
A035 Road						
2/1-2/2	0.708	36.65	71	9.938	11.855	15.364
2/3-2/4	0.456	34.42	71	6.691	7.985	10.345
4/2-5/1	1.533	53.90	69	15.023	18.026	23.600
16/1	0.091	14.84	61	1.441	1.803	2.493
21/1	48.111	328.34	61	142.759	170.281	227.925
22/1 - 22/2	5.455	89.71	56	30.034	36.925	50.937
24/1 - 26/1	66.626	345.83	63	202.402	239.997	318.385
28/1-28/4	22.688	209.57	59	78.363	94.785	128.675
30/2	0.175	25.54	73	3.412	4.046	5.189
A009 Road						
123/3-123/4	3.030	32.95	60	15.912	20.291	25.179
125/1	0.674	25.04	52	2.207	2.998	3.915
126/1	4.868	68.82	61	22.920	28.320	34.331
127/2	1.144	29.69	59	6.163	7.931	9.914
128/1	0.125	16.38	62	1.053	1.227	1.511
129/2	0.259	20.88	64	2.245	2.596	3.172
130/1-130/2	0.401	17.83	60	2.925	3.429	4.270
131/1	0.682	27.54	59	3.978	4.666	5.831
205/2-206/1	7.937	100.82	64	43.368	52.577	70.388
206/3	0.348	34.81	61	3.202	3.984	5.476

Catchment ID	Catchment Area (km^2)	Basin Lag Time (min)	CN	Peak Flow (m^3/s)		
				25 Years	50 Years	100 Years
207/1-207/2	6.065	64.77	62	38.173	47.005	63.932
209/2	0.202	14.95	71	5.144	6.142	7.953
210/2-210/6	0.413	28.42	58	3.670	4.649	6.537
212/1-213/1	3.846	62.43	64	27.303	33.354	44.847
215/1	0.107	15.12	56	1.229	1.588	2.289
B528 Road						
3/1 - 3/3	1.289	45.07	58	5.604	7.414	9.285
4/1-5/4	7.388	122.30	58	20.457	26.600	32.983
7/1-7/2	30.266	123.60	57	78.830	103.106	128.421
11/2-11/3	1.852	39.07	58	8.644	11.435	14.320
12/3-13/2	8.895	66.52	59	33.139	43.497	54.181
16/3-17/2	10.126	42.57	60	51.119	66.668	82.618
20/1	5.803	34.67	60	32.361	42.171	52.230
31/3	4.279	37.17	59	21.759	28.567	35.576

4.7. Comparison of Peak Flow Estimation Methods

Different peak flow estimation methods were employed in hydrological analysis of highway cross drainage structures. Rational Method (tc from ID guideline) was used as the baseline in comparison of other methods.

Runoff coefficients and curve number values were abstracted from literature. Parameters correspond to time to peak and peak flow of Snyder's method were extracted from Irrigation Department Guideline where Cp and Ct values are presented at gauging stations located in major river basins of Sri Lanka. Peak flow results are summarized in Table 4-14 to 4-16. Graphical presentation of same is shown in Figure 4-21 and 4-22.

Table 4-14 Summary of Peak Flow Estimation for 25 Year Return Period

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				25 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
B 312	34/3 - 34/4	768.529	1.27	38.098	51.628	40.214	29.727	47.607	40.771	27.354	41.815
B 312	35/1 - 36/1	17.751	4.55	1.421	1.632	1.496	1.137	5.230	2.037	1.342	1.231
B 312	36/2 - 37/1	1709.111	3.17	67.293	106.774	62.446	62.410	78.870	59.261	51.845	69.697
B 312	38/1 - 38/5	509.245	3.86	23.762	32.244	22.811	18.722	36.910	25.223	19.680	27.439
B 312	38/6 - 38/7	11.376	1.32	0.494	0.572	0.536	0.385	4.091	1.346	0.940	1.074
B 312	39/1	27.107	2.60	1.733	1.999	1.788	1.308	6.623	2.872	1.883	1.896
B 312	39/2	10.259	3.56	0.685	0.795	0.735	0.557	3.866	1.232	0.866	0.945
B 312	40/1 - 42/3	978.164	5.65	68.021	88.877	61.343	51.606	55.359	48.013	33.176	76.389
B 312	42/4 - 44/3	491.638	9.48	54.250	67.595	47.994	40.319	36.122	25.780	19.134	42.568
B 312	58/1 - 58/2	18.292	11.41	2.426	2.832	2.487	1.980	5.318	1.891	1.375	2.019
B 312	58/3 - 58/6A	102.048	5.38	10.621	12.650	9.956	7.792	14.121	7.748	5.439	9.821
B 312	58/7 - 59/1	22.758	11.11	2.958	3.464	2.953	2.358	6.005	2.110	1.638	2.469
B 312	59/2	543.884	2.62	37.223	50.178	33.354	28.887	38.434	22.676	20.744	34.934
B 312	59/3	12.161	20.47	1.557	1.839	1.649	1.351	4.244	1.302	0.992	1.362
A 035	2/1-2/2	70.780	0.24	6.508	7.694	6.272	3.333	11.425	5.956	N/A	9.938
A 035	2/3-2/4	45.640	0.17	4.393	4.721	3.960	2.085	8.888	3.858	N/A	6.691
A 035	4/2-5/1	153.317	0.24	9.668	11.533	9.169	5.556	17.926	9.225	N/A	15.023
A 035	16/1	9.080	0.75	0.539	1.087	0.849	0.296	3.616	0.945	N/A	1.441
A 035	21/1	4811.060	0.29	81.059	126.630	90.783	91.845	154.892	98.759	N/A	142.759
A 035	22/1 - 22/2	545.500	0.43	14.226	20.860	15.239	10.720	38.504	21.185	N/A	30.034
A 035	24/1 - 26/1	6662.610	0.32	122.488	198.285	142.370	143.946	192.484	129.477	N/A	202.402

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				25 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
A 035	28/1-28/4	2268.840	0.39	51.294	81.501	57.456	51.680	94.647	62.204	N/A	78.363
A 035	30/2	17.520	0.53	2.479	3.755	2.708	1.333	5.192	1.087	N/A	3.412
A 009	123/3-123/4	303.000	4.35	25.152	32.944	21.688	16.216	26.911	13.586	8.502	15.912
A 009	125/1	67.421	1.64	3.842	5.151	4.201	2.599	11.110	5.355	2.555	2.207
A 009	126/1	486.799	0.51	23.055	32.449	25.453	16.532	35.904	23.076	12.424	22.920
A 009	127/2	114.431	1.59	8.873	12.097	9.613	6.015	15.097	8.298	3.901	6.163
A 009	128/1	12.507	1.33	0.566	0.722	0.634	0.386	4.310	1.424	0.664	1.053
A 009	129/2	25.884	0.92	2.054	2.704	2.386	1.396	6.454	2.636	1.188	2.245
A 009	130/1-130/2	40.068	1.3	3.513	4.487	3.983	2.355	8.255	3.768	1.685	2.925
A 009	131/1	68.242	1.33	3.896	5.147	4.110	2.561	11.187	4.939	2.580	3.978
A 009	205/2-206/1	793.670	0.71	35.901	61.390	42.150	30.718	48.572	31.800	N/A	43.368
A 009	206/3	34.843	0.76	1.613	2.639	1.769	0.993	7.627	2.849	N/A	3.202
A 009	207/1-207/2	606.492	0.78	33.441	56.257	40.663	24.978	41.105	33.944	N/A	38.173
A 009	209/2	20.222	1.93	3.578	7.969	5.516	2.090	5.623	2.650	N/A	5.144
A 009	210/2-210/6	41.308	0.68	3.880	6.228	4.499	2.228	8.399	3.964	N/A	3.670
A 009	212/1-213/1	384.624	0.53	27.595	41.527	30.811	19.055	31.094	22.020	N/A	27.303
A 009	215/1	10.707	1.07	1.538	2.880	2.051	0.811	3.957	1.412	N/A	1.229
B 528	3/1 - 3/3	128.920	0.85	7.266	10.426	8.134	5.199	16.189	15.907	7.315	5.604
B 528	4/1-5/4	738.750	0.5	21.587	33.286	23.625	18.605	46.451	59.321	29.564	20.457
B 528	7/1-7/2	3026.612	1.25	87.763	147.313	98.539	80.584	114.149	199.876	91.356	78.830
B 528	11/2-11/3	185.192	1.47	9.424	13.167	9.947	6.557	20.045	21.747	9.774	8.644
B 528	12/3-13/2	889.460	2.36	47.421	67.883	42.407	34.885	52.156	67.763	34.298	33.139
B 528	16/3-17/2	1012.580	3.19	76.632	107.849	76.433	53.748	56.575	101.171	38.046	51.119

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m³/sec							
				25 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
B 528	20/1	580.310	4.38	50.370	66.235	44.632	32.985	40.000	54.029	24.372	32.361
B 528	31/3	427.910	2.72	30.426	40.961	29.079	20.399	33.181	48.842	19.101	21.759

N/A: Not Available

Table 4-15 Summary of Peak Flow Estimation for 50 Year Return Period

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m³/sec							
				50 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
B 312	34/3 - 34/4	768.529	1.27	45.912	62.077	48.442	35.890	53.019	45.251	31.741	50.049
B 312	35/1 - 36/1	17.751	4.55	1.780	2.043	1.874	1.427	5.824	2.261	1.558	1.514
B 312	36/2 - 37/1	1709.111	3.17	80.267	126.924	74.527	74.483	87.837	65.836	60.161	83.476
B 312	38/1 - 38/5	509.245	3.86	31.351	42.446	30.106	24.745	41.107	28.019	22.837	33.140
B 312	38/6 - 38/7	11.376	1.32	0.649	0.750	0.703	0.506	4.556	1.494	1.091	1.282
B 312	39/1	27.107	2.60	2.140	2.466	2.207	1.619	7.376	3.188	2.186	2.318
B 312	39/2	10.259	3.56	0.846	0.981	0.907	0.689	4.305	1.368	1.005	1.131
B 312	40/1 - 42/3	978.164	5.65	96.032	125.228	86.670	73.007	61.653	53.335	38.497	89.855
B 312	42/4 - 44/3	491.638	9.48	62.627	77.905	55.455	46.647	40.229	28.611	22.203	50.254
B 312	58/1 - 58/2	18.292	11.41	2.808	3.274	2.877	2.295	5.922	2.098	1.596	2.378
B 312	58/3 - 58/6A	102.048	5.38	12.391	14.740	11.622	9.112	15.727	8.605	6.312	11.600
B 312	58/7 - 59/1	22.758	11.11	3.424	4.005	3.418	2.734	6.688	2.340	1.900	2.912

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				50 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
B 312	59/2	543.884	2.62	43.565	58.597	39.068	33.872	42.803	25.190	24.071	41.212
B 312	59/3	12.161	20.47	1.808	2.132	1.914	1.570	4.726	1.445	1.151	1.602
A 035	2/1-2/2	70.780	0.24	15.235	18.005	14.682	7.811	12.724	6.801	N/A	11.855
A 035	2/3-2/4	45.640	0.17	10.284	11.048	9.271	4.886	9.898	4.405	N/A	7.985
A 035	4/2-5/1	153.317	0.24	21.704	25.884	20.587	12.486	19.964	10.531	N/A	18.026
A 035	16/1	9.080	0.75	0.648	1.305	1.020	0.356	4.027	1.105	N/A	1.803
A 035	21/1	4811.060	0.29	98.671	154.026	110.486	111.776	172.500	115.265	N/A	170.281
A 035	22/1 - 22/2	545.500	0.43	18.337	26.869	19.640	13.824	42.882	24.702	N/A	36.925
A 035	24/1 - 26/1	6662.610	0.32	159.476	257.951	185.314	187.363	214.367	151.133	N/A	239.997
A 035	28/1-28/4	2268.840	0.39	66.512	105.597	74.487	67.011	105.407	71.996	N/A	94.785
A 035	30/2	17.520	0.53	2.804	4.245	3.063	1.509	5.782	1.270	N/A	4.046
A 009	123/3-123/4	303.000	4.35	33.504	44.057	28.839	21.500	29.971	15.306	10.207	20.291
A 009	125/1	67.421	1.64	4.883	6.579	5.347	3.288	12.373	6.036	3.067	2.998
A 009	126/1	486.799	0.51	29.581	41.779	32.688	21.158	39.985	26.008	14.915	28.320
A 009	127/2	114.431	1.59	10.810	14.811	11.725	7.295	16.813	9.347	4.684	7.931
A 009	128/1	12.507	1.33	0.676	0.867	0.759	0.459	4.800	1.606	0.797	1.227
A 009	129/2	25.884	0.92	2.457	3.250	2.861	1.661	7.187	2.972	1.426	2.596
A 009	130/1-130/2	40.068	1.3	4.335	5.562	4.926	2.890	9.193	4.244	2.023	3.429
A 009	131/1	68.242	1.33	4.723	6.268	4.987	3.090	12.459	5.563	3.097	4.666
A 009	205/2-206/1	793.670	0.71	45.503	77.739	53.409	38.945	54.094	36.869	N/A	52.577
A 009	206/3	34.843	0.76	2.002	3.274	2.195	1.233	8.495	3.302	N/A	3.984
A 009	207/1-207/2	606.492	0.78	43.086	72.419	52.373	32.198	45.778	39.305	N/A	47.005
A 009	209/2	20.222	1.93	8.367	18.608	12.887	4.891	6.262	3.060	N/A	6.142

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				50 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
A 009	210/2-210/6	41.308	0.68	4.739	7.601	5.494	2.724	9.353	4.584	N/A	4.649
A 009	212/1-213/1	384.624	0.53	33.681	50.650	37.599	23.273	34.629	25.531	N/A	33.354
A 009	215/1	10.707	1.07	1.946	3.641	2.595	1.027	4.407	1.631	N/A	1.588
B 528	3/1 - 3/3	128.920	0.85	9.185	13.010	10.249	6.613	18.029	17.529	8.435	7.414
B 528	4/1-5/4	738.750	0.5	28.338	43.519	31.001	24.428	51.731	66.409	34.091	26.600
B 528	7/1-7/2	3026.612	1.25	111.917	186.841	125.595	102.782	127.126	224.226	105.342	103.106
B 528	11/2-11/3	185.192	1.47	12.586	17.351	13.261	8.826	22.324	23.964	11.270	11.435
B 528	12/3-13/2	889.460	2.36	59.060	83.835	52.898	43.590	58.085	74.569	39.549	43.497
B 528	16/3-17/2	1012.580	3.19	91.971	127.799	91.739	64.960	63.007	111.286	43.871	66.668
B 528	20/1	580.310	4.38	60.139	78.176	53.484	39.771	44.547	59.348	28.104	42.171
B 528	31/3	427.910	2.72	38.808	51.622	37.142	26.250	36.953	53.792	22.025	28.567

N/A: Not Available

Table 4-16 Summary of Peak Flow Estimation for 100 Year Return Period

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				100 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
B 312	34/3 - 34/4	768.529	1.27	54.493	73.358	57.452	42.743	58.432	50.737	36.096	58.981
B 312	35/1 - 36/1	17.751	4.55	2.037	2.332	2.142	1.638	6.419	2.538	1.771	1.818
B 312	36/2 - 37/1	1709.111	3.17	94.724	148.839	88.037	87.986	96.803	73.766	68.415	98.860

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				100 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
B 312	38/1 - 38/5	509.245	3.86	37.399	50.409	35.935	29.617	45.303	31.403	25.970	39.336
B 312	38/6 - 38/7	11.376	1.32	0.735	0.848	0.796	0.575	5.021	1.677	1.241	1.500
B 312	39/1	27.107	2.60	2.387	2.745	2.461	1.814	8.129	3.578	2.485	2.772
B 312	39/2	10.259	3.56	0.943	1.091	1.010	0.771	4.744	1.535	1.142	1.326
B 312	40/1 - 42/3	978.164	5.65	117.848	153.073	106.514	89.938	67.946	59.776	43.779	104.150
B 312	42/4 - 44/3	491.638	9.48	72.903	90.387	64.670	54.532	44.335	32.078	25.250	58.373
B 312	58/1 - 58/2	18.292	11.41	3.273	3.807	3.353	2.683	6.527	2.355	1.814	2.750
B 312	58/3 - 58/6A	102.048	5.38	14.590	17.309	13.697	10.777	17.332	9.649	7.178	13.466
B 312	58/7 - 59/1	22.758	11.11	3.992	4.658	3.985	3.199	7.371	2.626	2.161	3.370
B 312	59/2	543.884	2.62	51.606	69.118	46.350	40.264	47.173	28.230	27.374	47.949
B 312	59/3	12.161	20.47	2.070	2.435	2.189	1.801	5.209	1.622	1.309	1.851
A 035	2/1-2/2	70.780	0.24	22.730	26.811	21.917	11.770	14.023	7.686	N/A	15.364
A 035	2/3-2/4	45.640	0.17	15.335	16.461	13.843	7.367	10.909	4.978	N/A	10.345
A 035	4/2-5/1	153.317	0.24	32.330	38.462	30.690	18.763	22.002	11.905	N/A	23.600
A 035	16/1	9.080	0.75	0.810	1.641	1.277	0.447	4.438	1.227	N/A	2.493
A 035	21/1	4811.060	0.29	128.234	198.573	143.294	144.936	190.109	131.313	N/A	227.925
A 035	22/1 - 22/2	545.500	0.43	22.509	32.787	24.081	17.050	47.259	28.126	N/A	50.937
A 035	24/1 - 26/1	6662.610	0.32	209.130	335.341	242.348	244.978	236.249	172.163	N/A	318.385
A 035	28/1-28/4	2268.840	0.39	88.035	138.644	98.392	88.684	116.167	82.165	N/A	128.675
A 035	30/2	17.520	0.53	3.245	4.899	3.541	1.760	6.372	1.411	N/A	5.189
A 009	123/3-123/4	303.000	4.35	41.247	54.284	35.488	26.434	33.030	17.699	11.899	25.179
A 009	125/1	67.421	1.64	5.822	7.851	6.376	3.915	13.636	6.978	3.576	3.915
A 009	126/1	486.799	0.51	36.112	51.055	39.916	25.804	44.067	30.069	17.388	34.331

Road	Catchment ID	Area (ha)	Slope %	Peak Flow-m^3/sec							
				100 Year							
				Rational Formula (tc-ID)	Rational Formula (tc-Kir.)	Rational Formula (tc-B-W)	Rational Formula (tc-UK)	Fuller Equation	Snyder's Method	Flood Transportation	HEC-HMS
A 009	127/2	114.431	1.59	12.943	17.751	14.043	8.725	18.530	10.808	5.460	9.914
A 009	128/1	12.507	1.33	0.745	0.955	0.836	0.505	5.290	1.856	0.929	1.511
A 009	129/2	25.884	0.92	2.984	3.952	3.477	2.016	7.921	3.435	1.663	3.172
A 009	130/1-130/2	40.068	1.3	5.236	6.722	5.950	3.486	10.132	4.908	2.358	4.270
A 009	131/1	68.242	1.33	5.631	7.478	5.946	3.679	13.731	6.433	3.611	5.831
A 009	205/2-206/1	793.670	0.71	58.867	99.736	68.914	50.515	59.616	41.732	N/A	70.388
A 009	206/3	34.843	0.76	2.451	3.990	2.685	1.520	9.362	3.737	N/A	5.476
A 009	207/1-207/2	606.492	0.78	56.041	93.526	67.924	42.076	50.450	44.516	N/A	63.932
A 009	209/2	20.222	1.93	12.415	27.843	19.146	7.288	6.901	3.468	N/A	7.953
A 009	210/2-210/6	41.308	0.68	5.665	9.054	6.558	3.279	10.308	5.193	N/A	6.537
A 009	212/1-213/1	384.624	0.53	42.106	62.961	46.927	29.268	38.164	28.893	N/A	44.847
A 009	215/1	10.707	1.07	2.464	4.627	3.285	1.307	4.857	1.848	N/A	2.289
B 528	3/1 - 3/3	128.920	0.85	10.992	15.443	12.240	7.951	19.869	19.851	9.547	9.285
B 528	4/1-5/4	738.750	0.5	34.070	52.134	37.253	29.387	57.012	74.464	38.584	32.983
B 528	7/1-7/2	3026.612	1.25	131.230	218.067	147.172	120.562	140.103	251.393	119.226	128.421
B 528	11/2-11/3	185.192	1.47	15.203	20.786	16.001	10.720	24.603	27.139	12.756	14.320
B 528	12/3-13/2	889.460	2.36	68.437	96.585	61.371	50.652	64.014	84.532	44.762	54.181
B 528	16/3-17/2	1012.580	3.19	108.308	149.304	108.039	76.881	69.439	126.191	49.653	82.618
B 528	20/1	580.310	4.38	70.555	91.071	62.897	46.975	49.095	67.364	31.808	52.230
B 528	31/3	427.910	2.72	45.869	60.563	43.939	31.217	40.725	60.942	24.928	35.576

N/A: Not Available

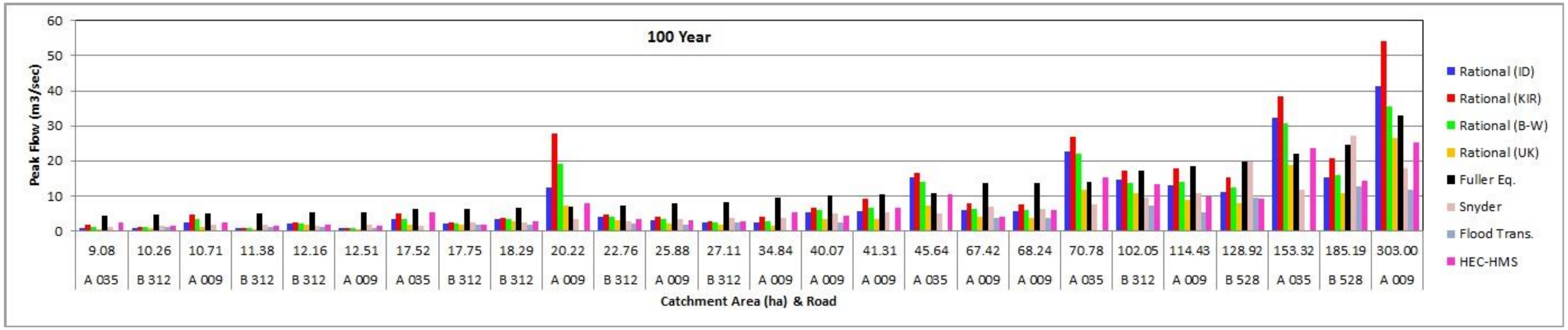


Figure 4-21 Peak Flow Estimations for 100 Year Return Period (Area: 9-303 ha)

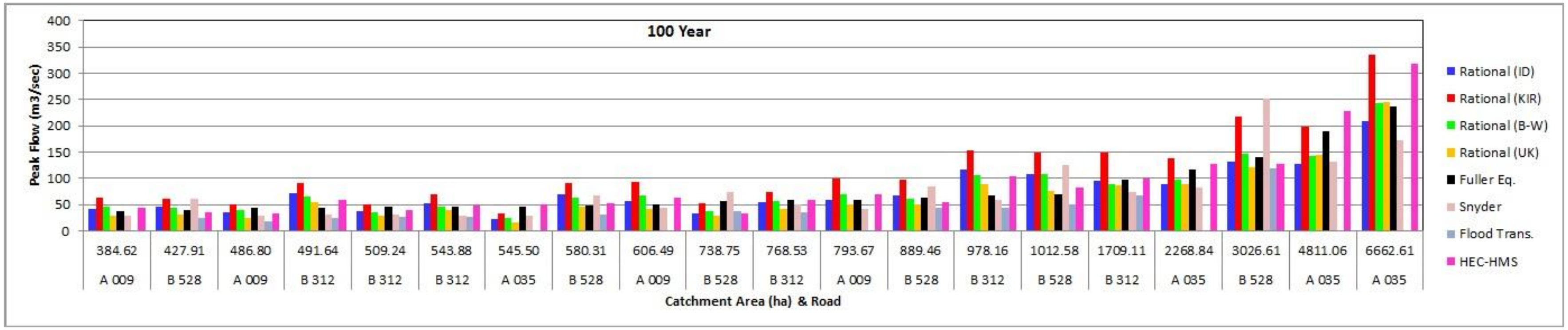


Figure 4-22 Peak Flow Estimations for 100 Year Return Period (Area: 384-6663 ha)

Scattered plot of catchment area (ha) and peak flow (m^3/s) was used to develop area-discharge relationship in the form $Q_n = aA^b$ (A: basin area (ha), a and b: coefficients, Qn: peak flow (m^3/s) for a return period of n years). Flood transportation technique was excluded due to the inadequate coverage in the study area. Accordingly trend line relationships shown in Table 4-17 were derived for different flood estimation methods. The given equations can be further optimized if additional catchments over and above 1000 ha are absorbed. Area and discharge curves for different return periods are given in Appendix F.

Table 4-17 Area vs. Discharge Relationship

Method	n = 25	n = 50	n = 100
Rational Formula (tc-ID)	$Q_{25}=0.1576A^{0.8164}$	$Q_{50}=0.214A^{0.809}$	$Q_{100}=0.2542A^{0.8147}$
	$R^2=0.9334$	$R^2=0.9125$	$R^2=0.9008$
Rational Formula (tc-Kir.)	$Q_{25}=0.1997A^{0.8361}$	$Q_{50}=0.2718A^{0.8279}$	$Q_{100}=0.3241A^{0.8322}$
	$R^2=0.9321$	$R^2=0.9121$	$R^2=0.8985$
Rational Formula (tc-B-W)	$Q_{25}=0.186A^{0.7951}$	$Q_{50}=0.2526A^{0.7878}$	$Q_{100}=0.3002A^{0.7933}$
	$R^2=0.9337$	$R^2=0.9157$	$R^2=0.9014$
Rational Formula (tc-UK)	$Q_{25}=0.0853A^{0.8739}$	$Q_{50}=0.1157A^{0.8669}$	$Q_{100}=0.1382A^{0.8721}$
	$R^2=0.9518$	$R^2=0.9421$	$R^2=0.9314$
Fuller Equation	$Q_{25}=0.9334A^{0.5936}$	$Q_{50}=1.0395A^{0.5936}$	$Q_{100}=1.1456A^{0.5936}$
	$R^2=0.9992$	$R^2=0.9992$	$R^2=0.9992$
Snyder's Method	$Q_{25}=0.1914A^{0.8025}$	$Q_{50}=0.2159A^{0.8026}$	$Q_{100}=0.244A^{0.803}$
	$R^2=0.9601$	$R^2=0.963$	$R^2=0.9631$
HEC-HMS	$Q_{25}=0.1945A^{0.7899}$	$Q_{50}=0.2333A^{0.7944}$	$Q_{100}=0.2897A^{0.7966}$
	$R^2=0.9500$	$R^2=0.9556$	$R^2=0.9524$

For further comparison methods which produced lower end and upper end results were omitted. Accordingly Rational Formula (tc: ID), Snyder’s method and HEC-HMS results were analyzed as shown below and Appendix F. Area - discharge curves developed for Rational Formula, Snyder’s method and HEC-HMS are depicted in Figure 4-23 to 4-25. In addition scatter plots between two methods are also presented in Figure 4-26 to 4-28. Table 4-18 below shows difference in peak flow alternatives with respect to Rational Formula. Column charts of peak flows arranged in the ascending order of catchment area are shown in Figure 4-29.

Table 4-18 Difference in Peak Flow of Snyder’s Method and HEC-HMS with Rational Formula

Road	Catchment ID	Area (ha)	Difference from Rational Formula (tc-ID)					
			100 Year		50 Year		25 Year	
			Snyder's Method	HEC-HMS	Snyder's Method	HEC-HMS	Snyder's Method	HEC-HMS
A 035	16/1	9.080	0.417	1.683	0.457	1.155	0.406	0.902
B 312	39/2	10.259	0.592	0.383	0.522	0.285	0.547	0.260
A 009	215/1	10.707	-0.616	-0.175	-0.315	-0.358	-0.126	-0.309
B 312	38/6 - 38/7	11.376	0.942	0.765	0.845	0.633	0.852	0.580
B 312	59/3	12.161	-0.448	-0.219	-0.363	-0.206	-0.255	-0.195
A 009	128/1	12.507	1.111	0.766	0.930	0.551	0.858	0.487
A 035	30/2	17.520	-1.834	1.944	-1.534	1.242	-1.392	0.933
B 312	35/1 - 36/1	17.751	0.501	-0.219	0.481	-0.266	0.616	-0.190
B 312	58/1 - 58/2	18.292	-0.918	-0.523	-0.710	-0.430	-0.535	-0.407
A 009	209/2	20.222	-8.947	-4.462	-5.307	-2.225	-0.928	1.566
B 312	58/7 - 59/1	22.758	-1.366	-0.622	-1.084	-0.512	-0.848	-0.489
A 009	129/2	25.884	0.451	0.188	0.515	0.139	0.582	0.191
B 312	39/1	27.107	1.191	0.385	1.048	0.178	1.139	0.163
A 009	206/3	34.843	1.286	3.025	1.300	1.982	1.236	1.589
A 009	130/1-130/2	40.068	-0.328	-0.966	-0.091	-0.906	0.255	-0.588
A 009	210/2-210/6	41.308	-0.472	0.872	-0.155	-0.090	0.084	-0.210
A 035	2/3-2/4	45.640	-10.357	-4.990	-5.879	-2.299	-0.535	2.298
A 009	125/1	67.421	1.156	-1.907	1.153	-1.885	1.513	-1.635
A 009	131/1	68.242	0.802	0.200	0.840	-0.057	1.043	0.082
A 035	2/1-2/2	70.780	-15.044	-7.366	-8.434	-3.380	-0.552	3.430
B 312	58/3 - 58/6A	102.048	-4.941	-1.124	-3.786	-0.791	-2.873	-0.800
A 009	127/2	114.431	-2.135	-3.029	-1.463	-2.879	-0.575	-2.710
B 528	3/1 - 3/3	128.920	8.859	-1.707	8.344	-1.771	8.641	-1.662
A 035	4/2-5/1	153.317	-20.425	-8.730	-11.173	-3.678	-0.443	5.355
B 528	11/2-11/3	185.192	11.936	-0.883	11.378	-1.151	12.323	-0.780
A 009	123/3-123/4	303.000	-23.548	-16.068	-18.198	-13.213	-11.566	-9.240
A 009	212/1-213/1	384.624	-13.213	2.741	-8.150	-0.327	-5.575	-0.292
B 528	31/3	427.910	15.073	-10.293	14.984	-10.241	18.416	-8.667
A 009	126/1	486.799	-6.043	-1.781	-3.573	-1.261	0.021	-0.135
B 312	42/4 - 44/3	491.638	-40.825	-14.530	-34.016	-12.373	-28.470	-11.682
B 312	38/1 - 38/5	509.245	-5.996	1.937	-3.332	1.789	1.461	3.677
B 312	59/2	543.884	-23.376	-3.657	-18.375	-2.353	-14.547	-2.289
A 035	22/1 - 22/2	545.500	5.617	28.428	6.365	18.588	6.959	15.808
B 528	20/1	580.310	-3.191	-18.325	-0.791	-17.968	3.659	-18.009
A 009	207/1-207/2	606.492	-11.525	7.891	-3.781	3.919	0.503	4.732

Road	Catchment ID	Area (ha)	Difference from Rational Formula (tc-ID)					
			100 Year		50 Year		25 Year	
			Snyder's Method	HEC-HMS	Snyder's Method	HEC-HMS	Snyder's Method	HEC-HMS
B 528	4/1-5/4	738.750	40.394	-1.087	38.071	-1.738	37.734	-1.130
B 312	34/3 - 34/4	768.529	-3.756	4.488	-0.661	4.137	2.673	3.717
A 009	205/2-206/1	793.670	-17.135	11.521	-8.634	7.074	-4.101	7.467
B 528	12/3-13/2	889.460	16.095	-14.256	15.509	-15.563	20.342	-14.282
B 312	40/1 - 42/3	978.164	-58.072	-13.698	-42.697	-6.177	-20.008	8.368
B 528	16/3-17/2	1012.580	17.883	-25.690	19.315	-25.303	24.539	-25.513
B 312	36/2 - 37/1	1709.111	-20.958	4.136	-14.431	3.209	-8.032	2.404
A 035	28/1-28/4	2268.840	-5.870	40.640	5.484	28.273	10.910	27.069
B 528	7/1-7/2	3026.612	120.163	-2.809	112.309	-8.811	112.113	-8.933
A 035	21/1	4811.060	3.079	99.691	16.594	71.610	17.700	61.700
A 035	24/1 - 26/1	6662.610	-36.967	109.255	-8.343	80.521	6.989	79.914

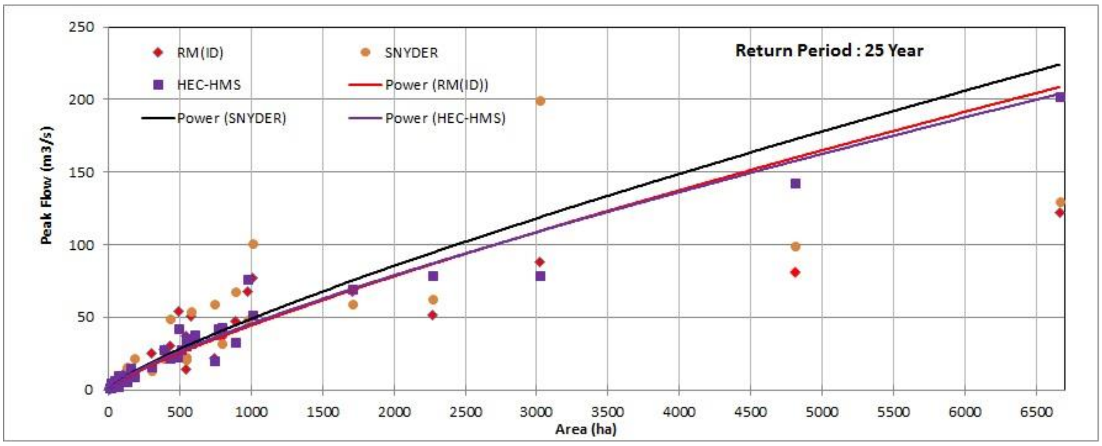


Figure 4-23 Area vs. Discharge Relationship 25 Year return period

Figure 4-24 Area vs. Discharge Relationship for 50 Year return period

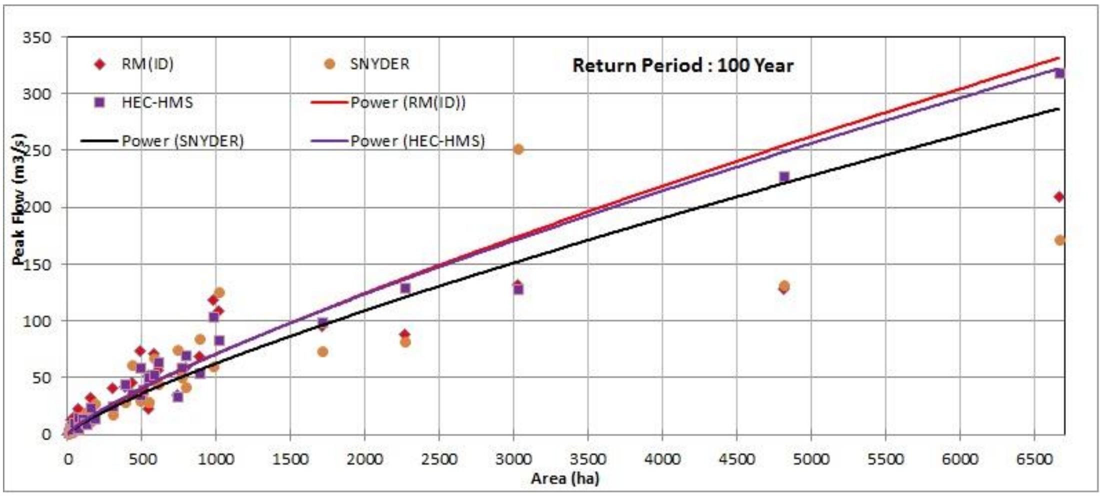


Figure 4-25 Area vs. Discharge Relationship 100 Year return period

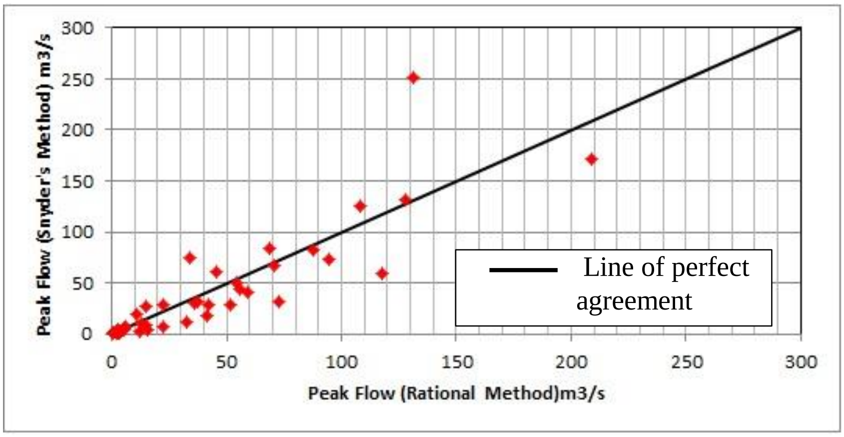


Figure 4-26 Rational and Snyder’s Method peak flow comparison (100 years)

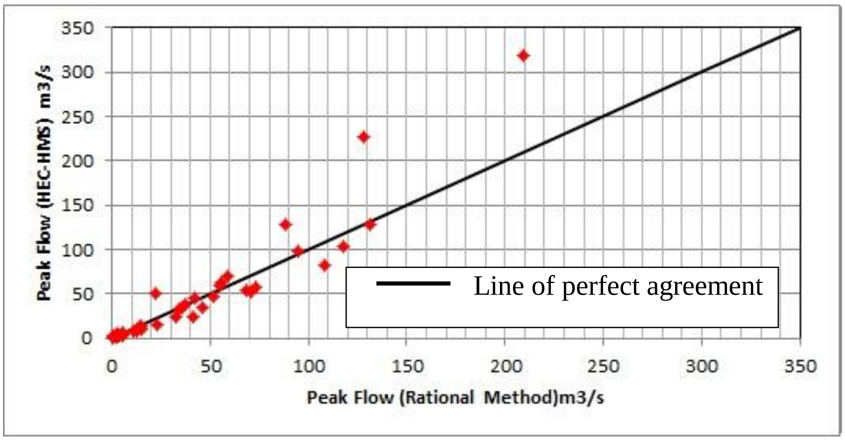


Figure 4-27 Rational Method and HEC-HMS peak flow comparison (100 years)

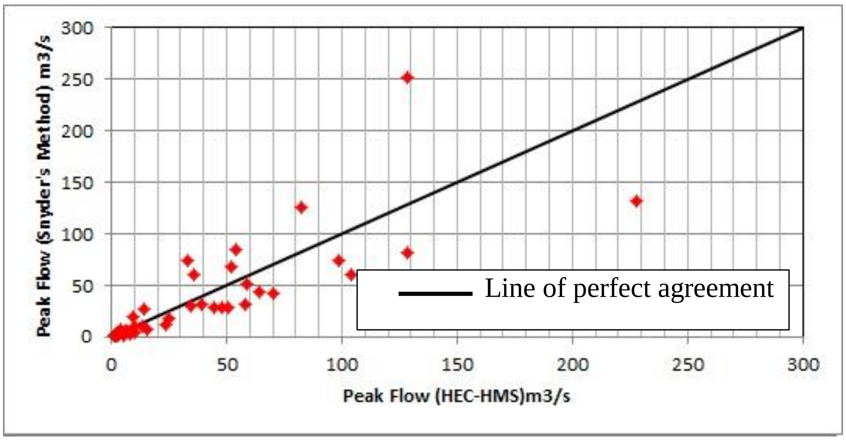
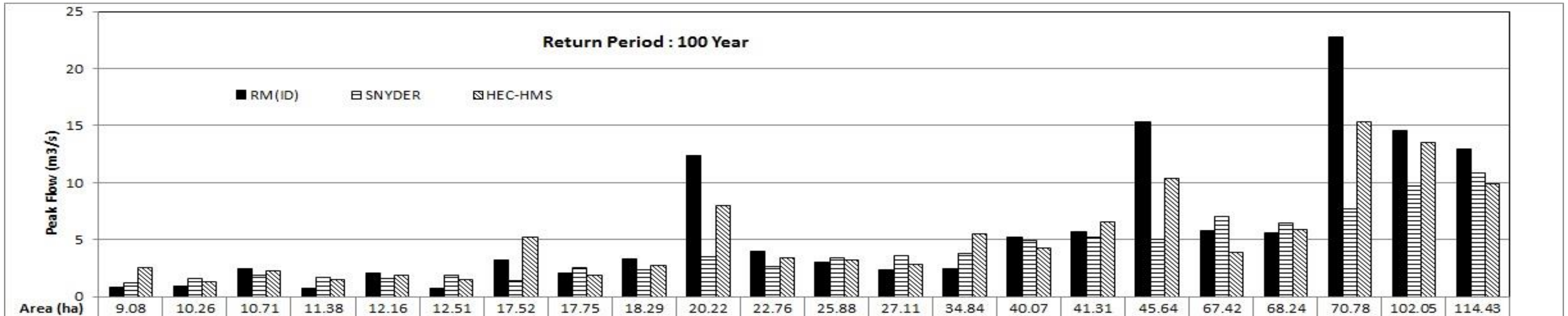
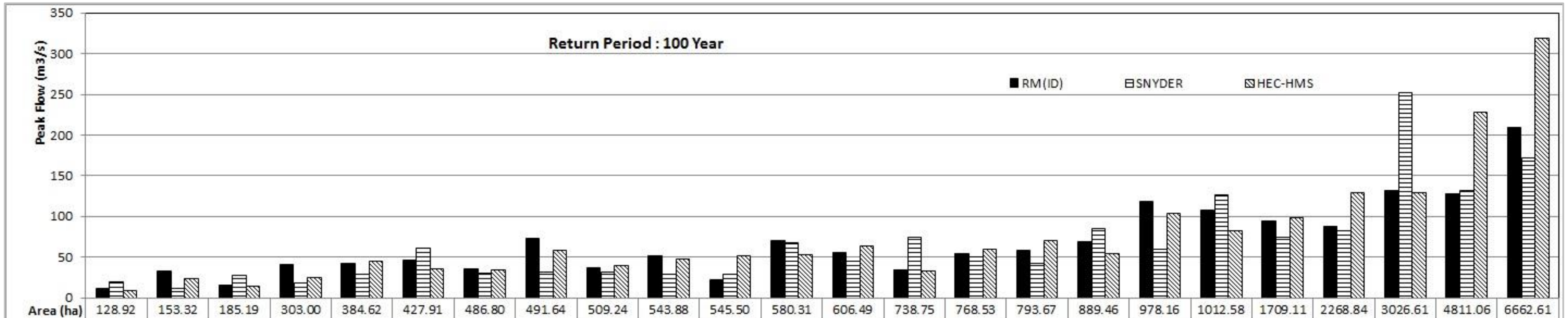


Figure 4-28 HEC-HMS and Snyder's Method peak flow comparison (100 years)



Area (ha)	9.08	10.26	10.71	11.38	12.16	12.51	17.52	17.75	18.29	20.22	22.76	25.88	27.11	34.84	40.07	41.31	45.64	67.42	68.24	70.78	102.05	114.43
RM(ID)	0.810	0.943	2.464	0.735	2.070	0.745	3.245	2.037	3.273	12.415	3.992	2.984	2.387	2.451	5.236	5.665	15.335	5.822	5.631	22.730	14.590	12.943
SNYDER	1.227	1.535	1.848	1.677	1.622	1.856	1.411	2.538	2.355	3.468	2.626	3.435	3.578	3.737	4.908	5.193	4.978	6.978	6.433	7.686	9.649	10.808
HEC-HMS	2.493	1.326	2.289	1.500	1.851	1.511	5.189	1.818	2.750	7.953	3.370	3.172	2.772	5.476	4.270	6.537	10.345	3.915	5.831	15.364	13.466	9.914



Area (ha)	128.92	153.32	185.19	303.00	384.62	427.91	486.80	491.64	509.24	543.88	545.50	580.31	606.49	738.75	768.53	793.67	889.46	978.16	1012.58	1709.11	2268.84	3026.61	4811.06	6662.61
RM(ID)	10.992	32.330	15.203	41.247	42.106	45.869	36.112	72.903	37.399	51.606	22.509	70.555	56.041	34.070	54.493	58.867	68.437	117.848	108.308	94.724	88.035	131.230	128.234	209.130
SNYDER	19.851	11.905	27.139	17.699	28.893	60.942	30.069	32.078	31.403	28.230	28.126	67.364	44.516	74.464	50.737	41.732	84.532	59.776	126.191	73.766	82.165	251.393	131.313	172.163
HEC-HMS	9.285	23.600	14.320	25.179	44.847	35.576	34.331	58.373	39.336	47.949	50.937	52.230	63.932	32.983	58.981	70.388	54.181	104.150	82.618	98.860	128.675	128.421	227.925	318.385

Figure 4-29 Comparison of Peak Flows for 100 Year Return Period

Accordingly noted that,

- Fuller Equation and Rational Formula (tc-Kirpich equation) indicated highest peak flows. Fuller Equation showed highest discharge approximately up to 360 ha, 225 ha and 155 ha for return periods 25, 50 and 100 years respectively. Significant variations in Fuller method estimates were noted as compared to other rainfall-runoff models.
- Lowest peak flows were obtained from Rational Formula (tc-UK) and flood transportation method. As most of the catchments at highway-waterway intersects are with low drainage area ratios, accuracy and validity of flood transportation estimates to be verified by comparing with other applicable methods.
- The percentage difference in peak flow derived from Rational Formula (tc: B-W) and Rational Formula (tc: ID) was in the range of -20% to +20%. This indicates fair agreement between Bransby-William formula and Irrigation Department guideline in estimation of time of concentration.
- Results of rainfall-runoff models show consistency in the case of smaller watersheds. Difference in peak flows is insignificant for catchments less than 100 ha.
- Rational Formula overestimates peak flows in the case of larger watersheds. Most of international references specify that Rational Formula is meaningful up to 80 ha. Ponrajah (1984) suggests to apply Rational Formula for catchments less than 5000 ha. Department of Transport and Main Roads, Queensland Government (2003) recommends to compare Rational Method results with more detailed procedures for catchments larger than 1000 ha. Results of Snyder's method and HEC-HMS revealed that at least one method was within ± 15% tolerance with Rational Formula estimates up to area of 770 ha. Therefore Rational Method can be used up to area of 770 ha.
- Comparatively HEC-HMS results were much closer to Rational Formula than Snyder's Method.

5. CONCLUSIONS AND RECOMMENDATIONS

The present study applied Rational Formula, Fuller Formula, Snyder's Method, HEC-HMS and Flood transportation technique to estimate peak flows of highway culverts and bridges. Accordingly following conclusions and recommendations are made.

- Data collection is one of the crucial consideration as most of the empirical equations, synthetic unit hydrographs and computer based flood simulation models are highly sensitive to the accuracy and validity of physical, hydrological and geological characteristics of drainage basin. The national and international sources referred in the study can be used to extract necessary parameters relevant to different flood estimation methods.
- The determination of time of concentration is critical even for a smaller size catchment. It was found that some of the formulas practiced in other countries did not suit for Sri Lankan conditions. Time of concentration calculated from Kirpich equation was substantially lower than that of Irrigation Department method. The results of tc equation given in UK Flood studies report showed higher values and it cannot be applied as it tends to underestimate the peak flows.
- Runoff coefficient based on slope and land use shows more accurate estimate than ID guideline. Runoff potential of a drainage area is significantly affected by the characteristics of prevailing soil layers. Therefore more accurate and optimized value of runoff coefficient can be obtained considering the combine effects of slope, land use and soil type.
- Reasonable peak flow estimation can be made for ungauged catchments at highway – waterway intersects by comparing different rainfall-runoff models derived on watershed physical, hydrological and geological parameters.
- Rational formula often serves as a quick check or validation for large drainage basins. Conversely other models do not have such inherent simplicity in their calculation of peak flows as those models have to absorb large/considerable variety of surface parameters to more closely represent the actual site conditions.

The variance between the methods are attributed to the many characteristics of a study area that are being incorporated into the model.

- Even though Fuller Method is widely applied in other countries due to its simplicity and quick approach, satisfactory results did not produce in the present study. This is mainly due to the fact that Fuller equation was applied without modifying its constants. Therefore it is necessary to modify the Fuller equation constants for Sri Lankan watersheds.
- Accuracy and validity of flood transportation estimates to be verified by comparing with other methods.
- The peak flow estimation methods used in the study showed that differences in peak flows are not significant up to catchment area of 100 ha.
- Rational Method can be applied in hydrological designs of cross drainage structures up to catchments of 770 ha. Alternative methods to be employed along with Rational formula for catchments larger than 770 ha. Due considerations to be made on the availability of design data and parameters relevant to such alternative approach. Synthetic unit hydrographs and HEC-HMS can be used for larger catchments however necessary input parameters shall be determined in complying with local conditions. This can be further supported with findings of previous studies pertaining to the same or similar nature area.
- The method used for the simulation of loss and transform model in HEC-HMS is also subjected to the availability of design inputs/ parameters specified in each model option. As most of the catchments associated with highway-waterway crossings are ungauged, alternative ways shall be considered to account for the calibration and validation of rainfall-runoff models.
- Design flood estimation may be performed by a frequency analysis of observed flood flows at a bridge site where these are available and are adequate in length and quality.

Identified Future Research Needs

- The present study covered hydrological design of culverts and bridges for four road sections. Physical parameters and characteristics of watershed will influence its runoff potential. The study can be further extended for highways located in different hydrogeological zones to identify the appropriate means of flood estimation methods.
- The Irrigation Department Guideline is the only local publication available for the estimation of time of concentration. The catchment response time has a direct impact on the estimation of design floods. Therefore most appropriate method of time of concentration estimate is still opened to further research due to the application of different empirical relationships and inconsistency remains among the methods used.
- Development of regional regression equations would be useful in predicting flood flows at selected recurrence intervals. This further facilitates comparison of different flood estimation models. However periodic updating of regression equations is an essential component upon its usage.
- Soil map of Sri Lanka can be reclassified based on the hydrologic soil groups. The overlay operation of hydrologic soil group map and land use map provides curve numbers of each unique land use-soil groups within the boundaries based on standard SCS curve numbers. The generated curve number map gives direct and ease access in assigning SCS curve numbers for a watershed. However continuous updating of curve number map is essential due to the varying nature of land cover and future development works.

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APPENDIX A. DETAILS OF EXISTING CROSS DRAINAGE STRUCTURES

Table A-1 Coordinates of Cross Drainage Structures

Road	Culvert ID	Easting (m)	Northing (m)	Longitude (decimal degrees)	Latitude (decimal degrees)
B312	34/3	206,921.6712	275,277.5437	80.834462	7.681257
B312	34/4	206,907.7880	275,141.9930	80.834336	7.680031
B312	35/1	206,830.9856	273,964.3578	80.833638	7.669381
B312	36/1	206,828.1837	273,826.1773	80.833613	7.668132
B312	36/2	206,820.6871	273,476.3390	80.833544	7.664968
B312	36/3	206,817.6253	273,346.1447	80.833516	7.663791
B312	36/5	206,803.8805	272,946.2371	80.833391	7.660174
B312	37/1	206,795.1165	272,596.0405	80.833311	7.657007
B312	38/1	206,748.7666	271,754.3565	80.832890	7.649395
B312	38/2	206,746.9854	271,720.9385	80.832874	7.649093
B312	38/3	206,738.6850	271,636.7119	80.832798	7.648331
B312	38/4	206,718.0581	271,413.1276	80.832611	7.646310
B312	38/5	206,709.4602	271,321.0000	80.832533	7.645476
B312	38/6	206,699.7610	271,094.6504	80.832445	7.643429
B312	38/7	206,697.6039	271,026.3685	80.832425	7.642812
B312	39/1	206,685.4937	270,605.1498	80.832315	7.639003
B312	39/2	206,669.2751	270,123.4080	80.832167	7.634646
B312	40/1	206,601.4694	269,782.0425	80.831552	7.631559
B312	40/2	206,552.8121	269,658.0140	80.831111	7.630437
B312	40/3	206,437.1103	269,390.7099	80.830062	7.628020
B312	40/4	206,322.5312	269,113.2458	80.829023	7.625511
B312	41/1	206,228.3347	268,879.1458	80.828169	7.623394
B312	41/2	206,161.6605	268,696.6426	80.827564	7.621744
B312	41/3	206,133.0418	268,525.3626	80.827305	7.620195
B312	41/4	206,096.6023	268,125.2215	80.826974	7.616576
B312	42/1	206,073.3779	267,861.4687	80.826763	7.614191
B312	42/2	206,059.2155	267,713.6864	80.826634	7.612854
B312	42/3	205,889.9369	267,487.9248	80.825100	7.610813
B312	42/4	205,711.9155	267,212.0850	80.823486	7.608319
B312	43/1	205,122.9738	266,835.3548	80.818147	7.604912
B312	43/2	204,861.2253	266,795.4831	80.815774	7.604552

Road	Culvert ID	Easting (m)	Northing (m)	Longitude (decimal degrees)	Latitude (decimal degrees)
B312	44/1	204,775.1944	266,638.4458	80.814995	7.603132
B312	44/2	204,759.1740	266,576.0184	80.814849	7.602567
B312	44/3	204,681.9661	266,398.0125	80.814149	7.600958
B312	58/1	209,382.2912	259,093.1048	80.856741	7.534889
B312	58/2	209,461.9624	259,052.1655	80.857463	7.534519
B312	58/3	209,654.4813	259,003.5117	80.859208	7.534079
B312	58/4	209,802.4604	258,992.1024	80.860549	7.533975
B312	58/5	209,908.6120	259,013.2743	80.861511	7.534166
B312	58/6	209,916.3605	259,086.5162	80.861581	7.534829
B312	58/6A	210,108.7970	259,148.0737	80.863325	7.535385
B312	58/7	210,128.7552	259,147.0752	80.863506	7.535376
B312	58/8	210,188.7438	259,145.9063	80.864050	7.535365
B312	59/1	210,236.9581	259,155.6788	80.864487	7.535454
B312	59/2	210,429.3049	259,209.7280	80.866230	7.535942
B312	59/3	211,059.2840	259,099.5060	80.871939	7.534944
A035	2/1	160,997.9337	469,359.6125	80.416376	9.437384
A035	2/2	161,185.6611	469,360.4330	80.418065	9.437331
A035	2/3	161,497.4789	469,362.3709	80.420968	9.437372
A035	2/4	161,586.9681	469,363.2978	80.421866	9.437443
A035	4/2	163,093.9022	469,363.7476	80.435173	9.437233
A035	4/3	163,610.3744	469,469.5254	80.439384	9.437854
A035	4/4	163,702.7642	469,488.9085	80.440139	9.438133
A035	5/1	163,825.3403	469,486.7276	80.440721	9.438386
A035	16/1	174,276.1531	464,917.0846	80.537250	9.397479
A035	21/1	177,333.2980	462,224.0390	80.565313	9.371778
A035	22/1	178,235.8770	461,697.3460	80.571595	9.368605
A035	22/2	178,296.0770	461,670.1660	80.572159	9.368350
A035	24/1	180,663.8540	460,641.1600	80.595648	9.357481
A035	24/2	180,723.9120	460,617.5100	80.596195	9.357267
A035	25/1	180,809.3690	460,583.9770	80.597119	9.356840
A035	25/2	180,888.4910	460,557.7030	80.597589	9.356686
A035	25/3	180,941.6490	460,542.4260	80.598157	9.356486
A035	25/4	180,981.6520	460,531.3690	80.598583	9.356365

Road	Culvert ID	Easting (m)	Northing (m)	Longitude (decimal degrees)	Latitude (decimal degrees)
A035	25/5	181,060.5170	460,510.9810	80.599260	9.356099
A035	25/6	181,281.3040	460,452.1420	80.601187	9.355588
A035	25/7	181,545.4250	460,382.1700	80.603676	9.354936
A035	26/1	181,975.5400	460,277.7920	80.607593	9.354201
A035	28/1	183,738.0826	459,734.4838	80.622955	9.349564
A035	28/2	183,829.0176	459,687.4829	80.624492	9.348891
A035	28/3	184,280.8046	459,620.3283	80.625480	9.348408
A035	28/4	184,581.5586	459,534.5717	80.631137	9.346869
A035	30/2	185,946.6418	459,029.6570	80.643588	9.343302
A009	123/3	169,884.9105	341,386.9009	80.497949	8.279013
A009	123/4	169,886.7777	341,481.1323	80.497965	8.279866
A009	125/1	169,910.5541	342,648.8897	80.498244	8.290426
A009	126/1	169,935.5144	343,894.6391	80.498623	8.301662
A009	127/2	169,964.3270	345,364.3541	80.498890	8.314983
A009	128/1	169,953.2272	346,198.2371	80.498887	8.322523
A009	129/2	169,973.8360	347,288.0153	80.498847	8.332367
A009	130/1	170,120.4882	347,931.3203	80.500758	8.338142
A009	131/1	170,436.7757	348,515.6898	80.503549	8.343462
A009	205/2	172,886.7645	420,303.1712	80.525580	8.992760
A009	205/3	172,847.9951	420,583.2259	80.525390	8.995293
A009	206/1	172,765.1619	421,404.8170	80.524588	9.002776
A009	206/3	172,726.1144	421,797.8735	80.524270	9.006232
A009	207/1	172,643.1776	422,471.7365	80.523650	9.012344
A009	207/2	172,615.9921	422,690.0986	80.523322	9.014358
A009	209/2	172,390.5620	424,420.8850	80.521118	9.029913
A009	210/2	172,260.5110	425,428.3680	80.519915	9.039079
A009	210/3	172,235.1660	425,496.3920	80.519565	9.039716
A009	210/4	172,194.6890	425,548.3530	80.519256	9.040206
A009	210/5	172,119.1240	425,636.4960	80.518926	9.041022
A009	210/6	172,078.7410	425,692.0150	80.518710	9.041656
A009	212/1	171,313.5630	427,010.0370	80.511550	9.053556
A009	212/3	171,209.1020	427,145.6030	80.510725	9.054843
A009	212/4	171,188.1040	427,173.0470	80.510324	9.055299

Road	Culvert ID	Easting (m)	Northing (m)	Longitude (decimal degrees)	Latitude (decimal degrees)
A009	212/5	171,072.2120	427,325.0610	80.509227	9.056590
A009	213/1	170,790.0440	427,596.8560	80.506428	9.058900
A009	215/1	168,846.7410	429,267.9100	80.488960	9.074005
B528	3/1	233,675.6231	138,861.3244	81.075058	6.446770
B528	3/2	233,658.7779	138,906.5243	81.074845	6.447098
B528	3/3	233,594.3509	139,073.9318	81.074263	6.447512
B528	4/1	233,260.4865	138,970.4623	81.072873	6.447127
B528	4/2	232,999.9267	138,724.5974	81.070760	6.445618
B528	5/1	232,529.4339	138,391.8746	81.066543	6.442741
B528	5/2	232,490.9697	138,368.8093	81.066333	6.442464
B528	5/3	232,029.9353	138,233.8065	81.061876	6.440168
B528	5/4	231,978.5411	138,228.1281	81.061423	6.440003
B528	7/1	230,518.2368	138,737.3551	81.047432	6.444347
B528	7/2	230,492.0379	138,747.6245	81.046896	6.444658
B528	11/2	227,151.7382	139,399.3661	81.016591	6.449913
B528	11/3	227,037.4919	139,472.2535	81.014914	6.451861
B528	12/3	226,740.0367	140,387.2236	81.012699	6.460717
B528	12/4	226,677.3869	140,554.9781	81.012097	6.461437
B528	12/5	226,603.7419	140,624.2976	81.011286	6.462117
B528	12/6	226,535.3350	140,668.6131	81.010322	6.462966
B528	13/1	226,457.2029	140,740.4027	81.010492	6.464491
B528	13/2	226,431.4206	141,121.6707	81.009873	6.467471
B528	16/3	226,250.3579	144,277.5783	81.008738	6.496034
B528	17/1	226,296.0902	144,361.8280	81.009010	6.497040
B528	17/2	226,352.6942	144,571.5248	81.009013	6.498794
B528	20/1	224,857.4550	147,844.4421	80.999006	6.524840
B528	24/2	221,332.5039	221,332.5039	80.964894	7.193364
B528	31/3	217,912.3317	152,157.1695	80.925400	6.588149

Figure A-1 Existing Culverts and Bridges on B312 Road

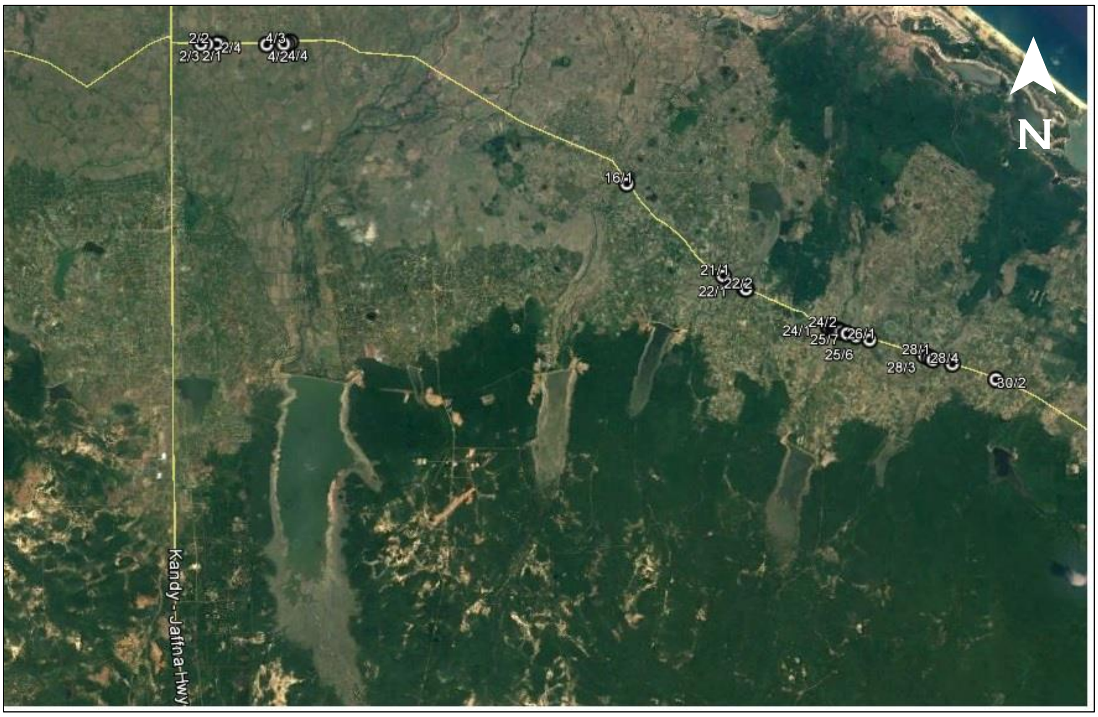


Figure A-2 Existing Culverts and Bridges on A035 Road

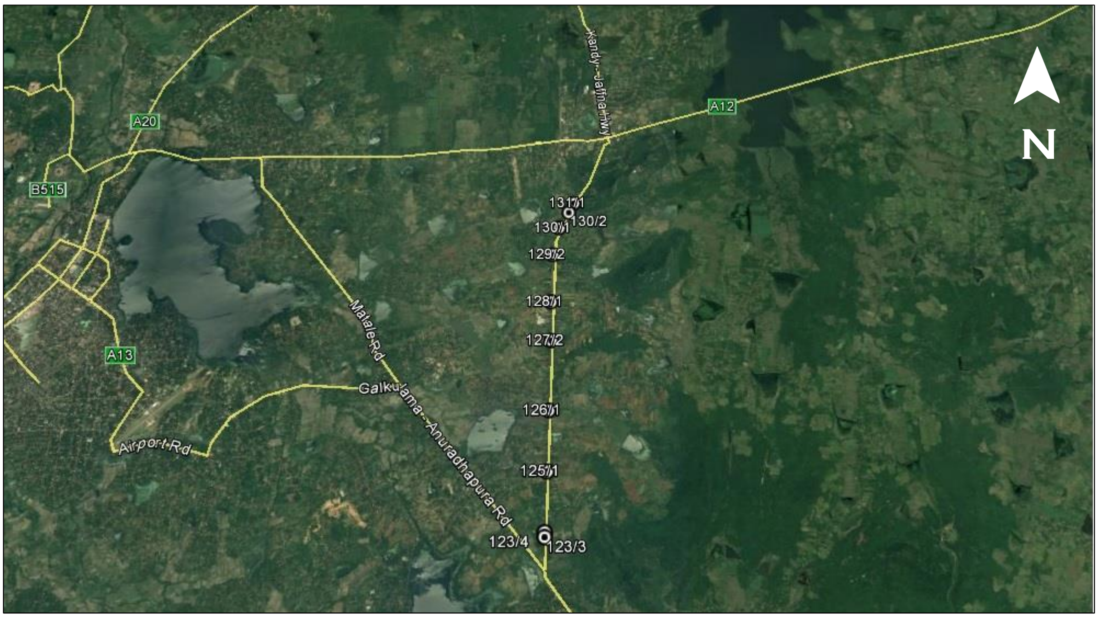


Figure A-3 Existing Culverts and Bridges on A009 Road

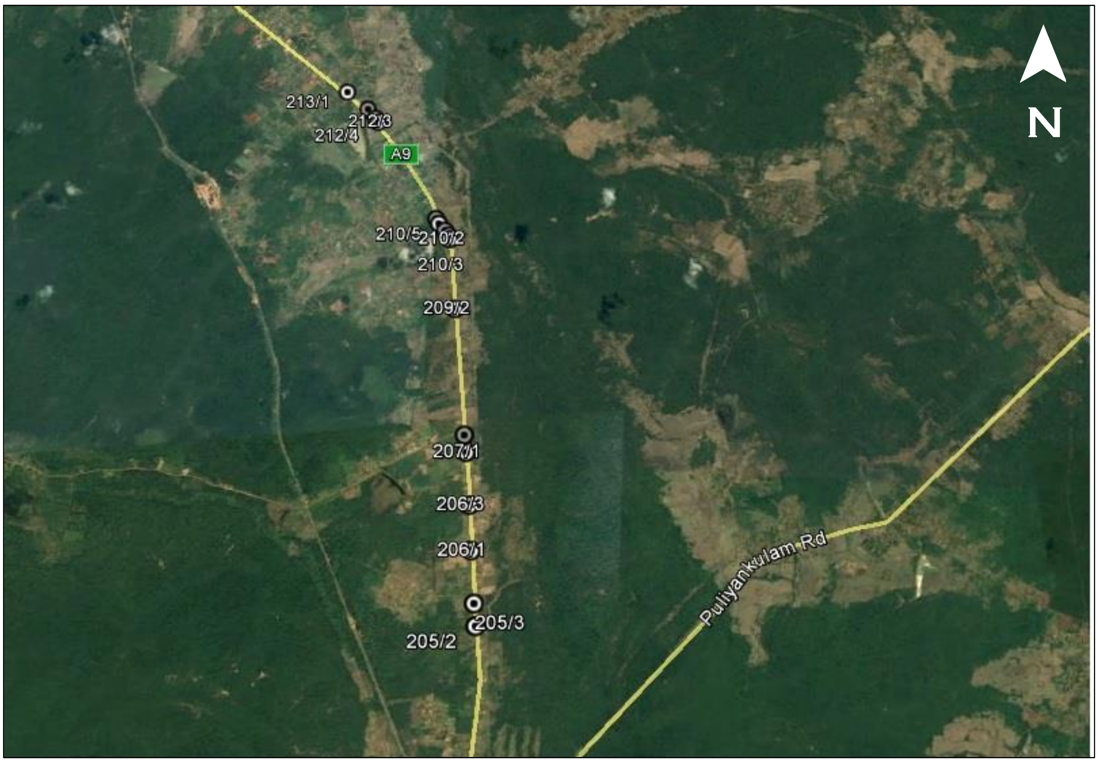


Figure A-4 Existing Culverts and Bridges on A009 Road

Figure A-5 Existing Culverts and Bridges on B528 Road

APPENDIX B. CATCHMENT AREAS

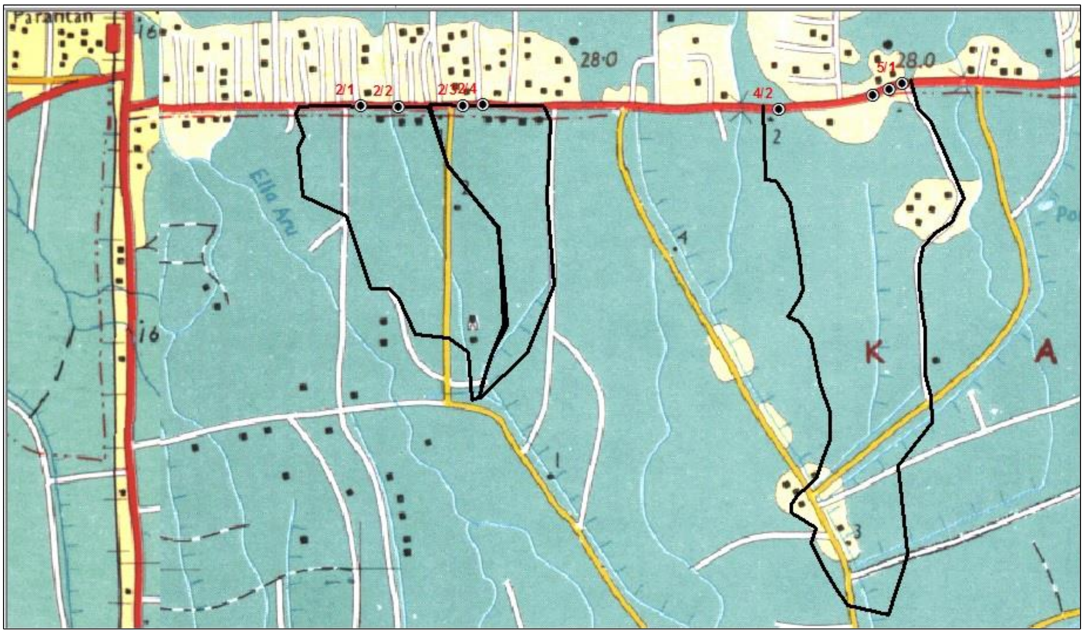


Figure B-1 Catchment Areas of A035 Road (2/1 to 5/1)

Legend

Paddy

Other Plantations/Garden

Scrub/Forest

Grassland/Chena

Marsh/Mangrove

Catchmanr Area

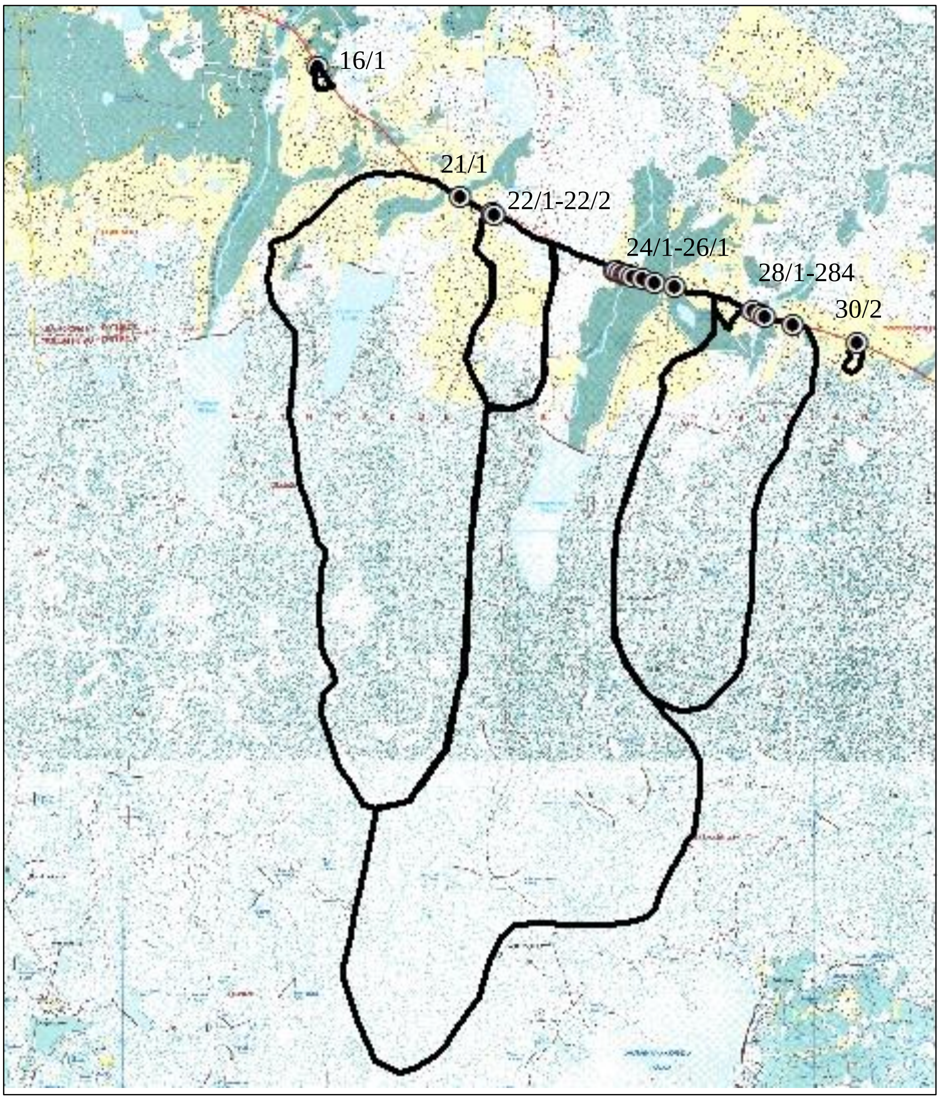


Figure B-2 Catchment Areas of A035 Road (16/1-30/2)

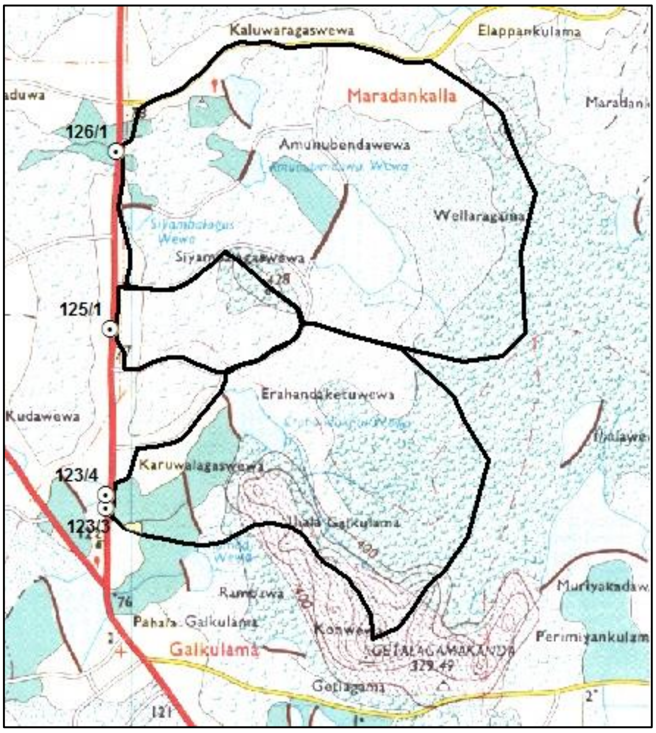


Figure B-3 Catchment Areas of A009 Road (123/3-126/1)

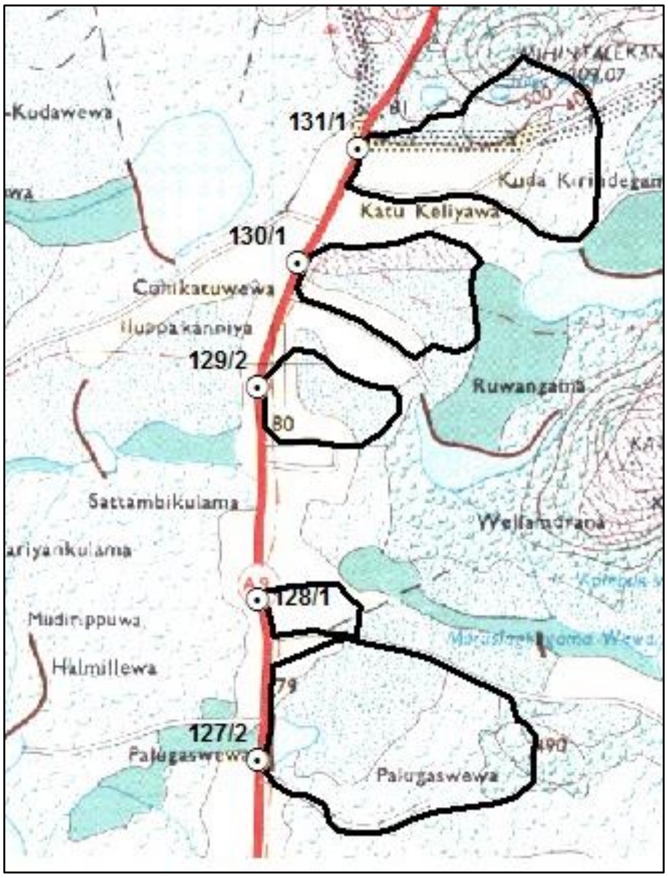


Figure B-4 Catchment Areas of A009 Road (127/2-131/1)

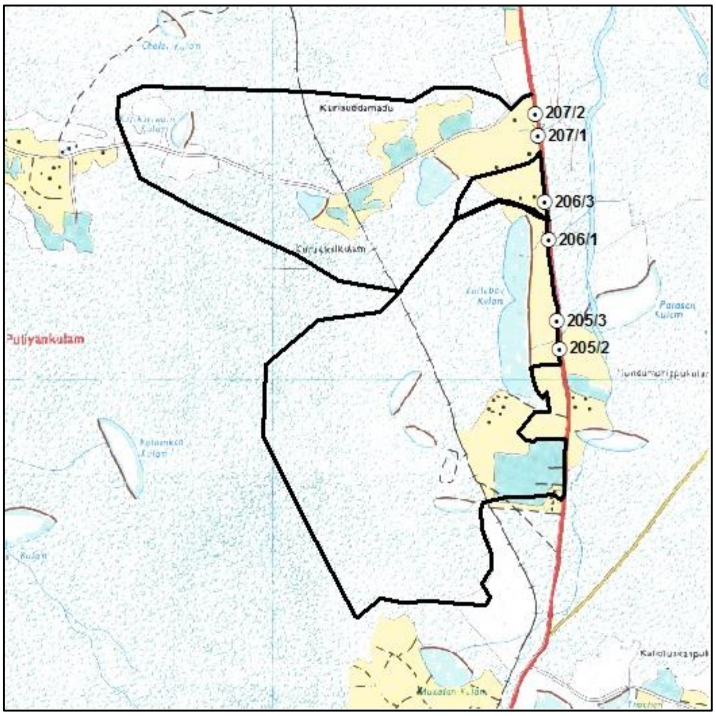


Figure B-5 Catchment Areas of A009 Road (205/2-207/2)

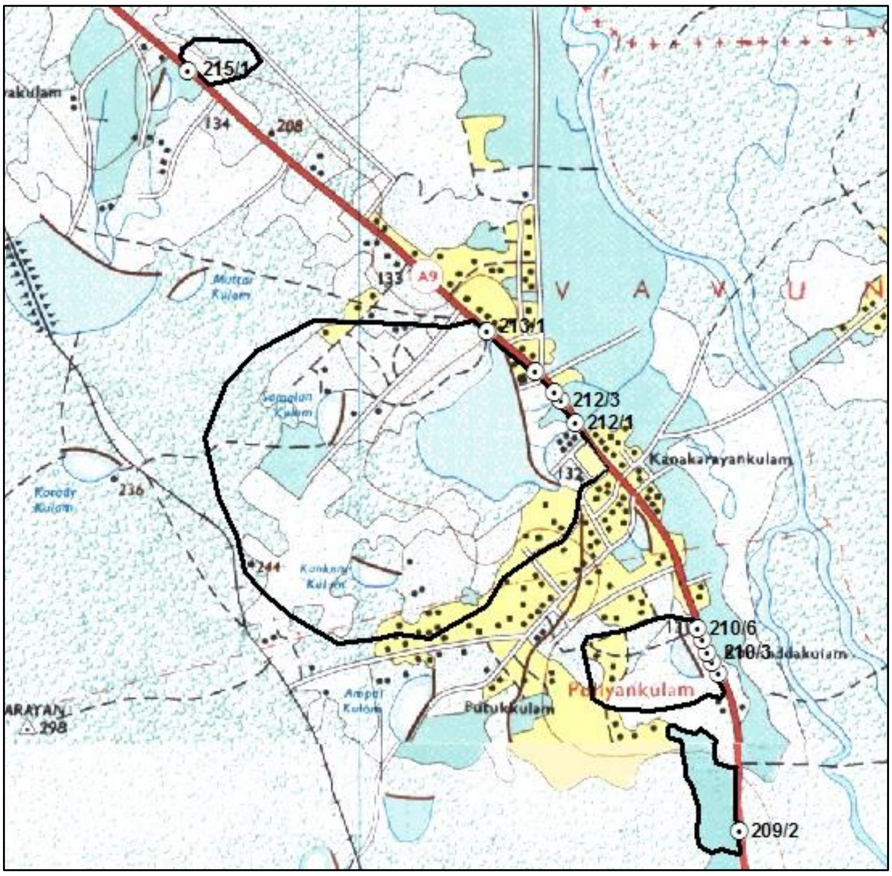


Figure B-6 Catchment Areas of A009 Road (209/2-215/1)

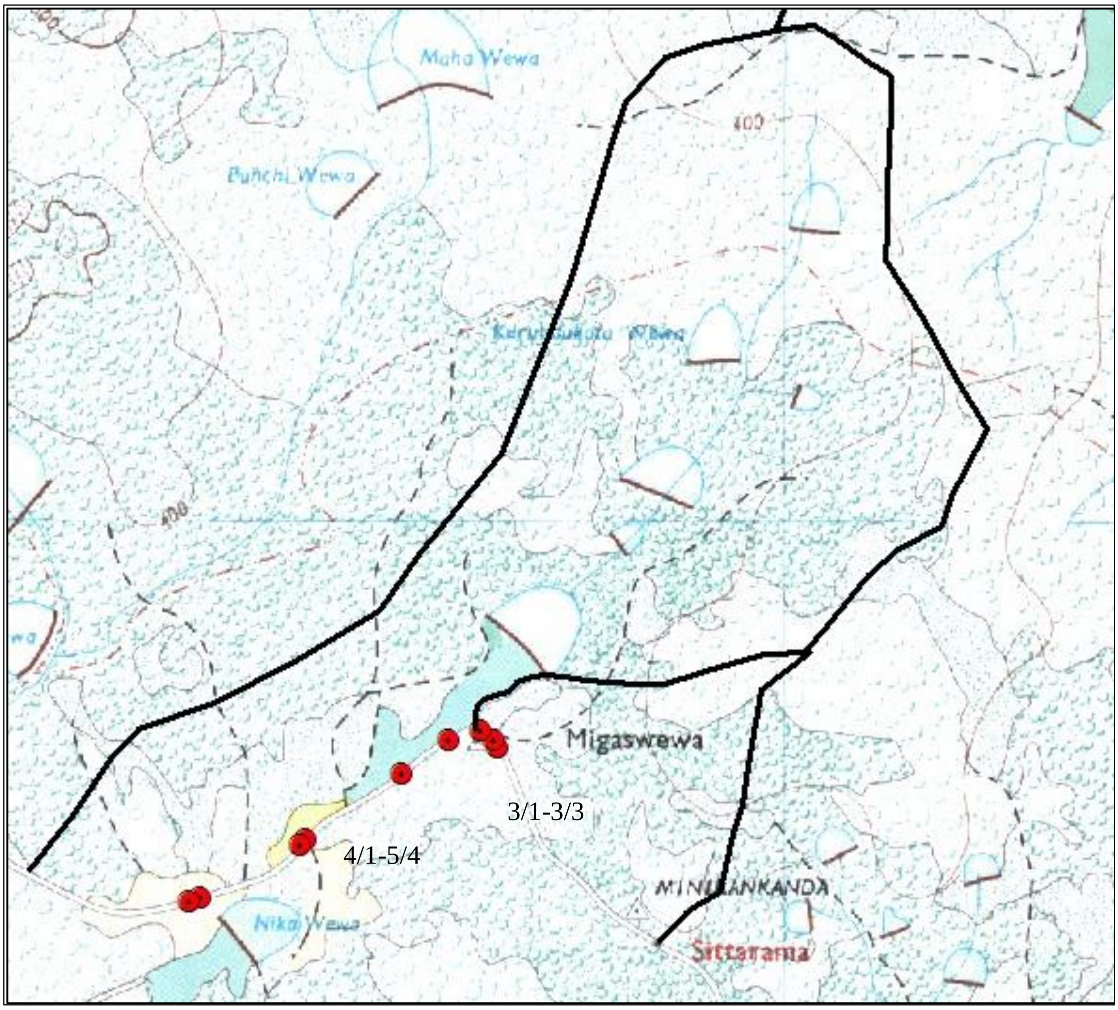


Figure B-7 Catchment Areas of B528 Road (3/1-5/4)

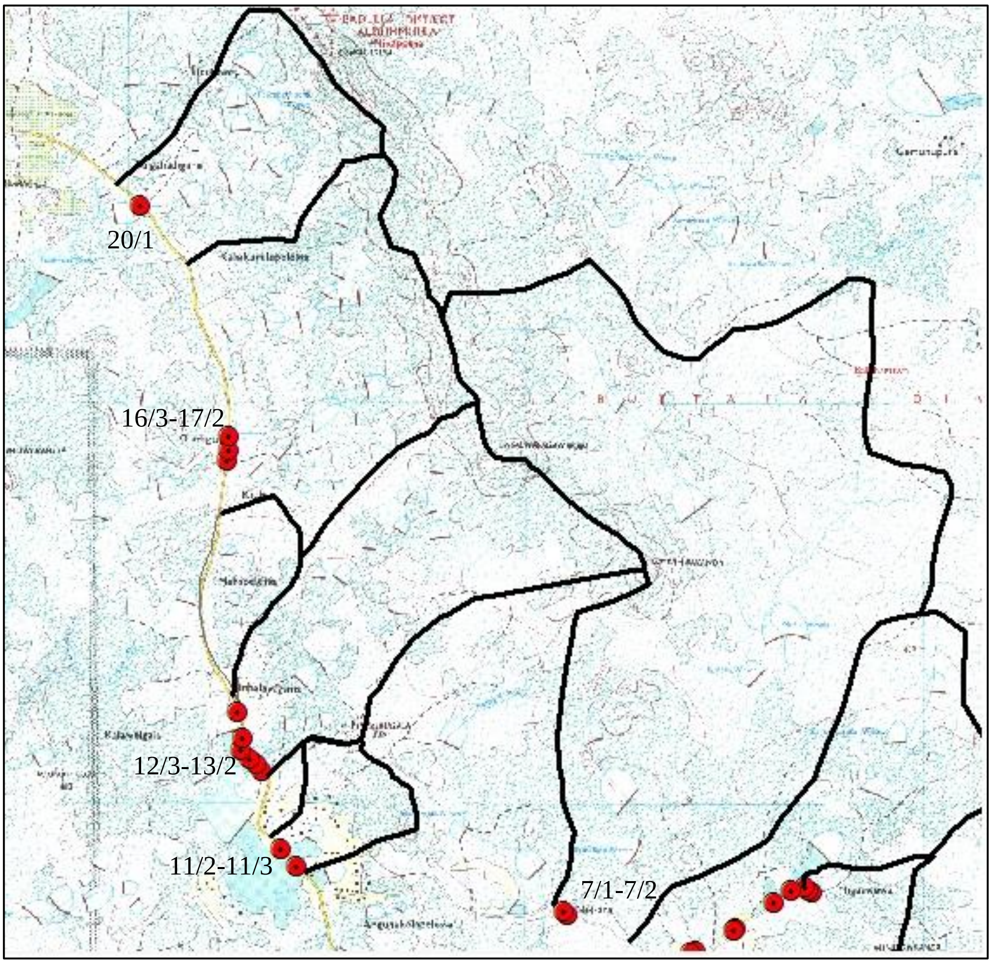


Figure B-8 Catchment Areas of B528 Road (7/1-20/1)

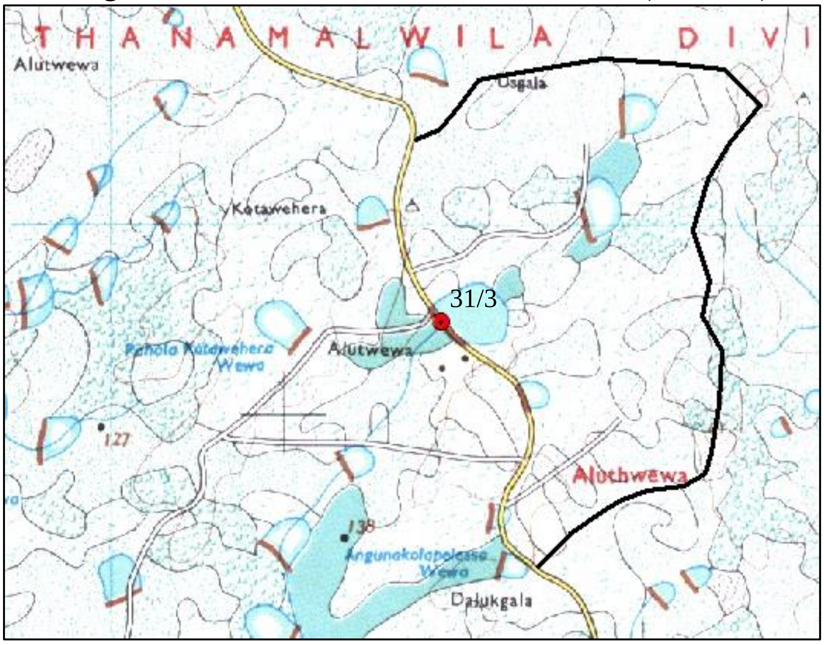


Figure B-9 Catchment Areas of B528 Road (31/3)

APPENDIX C. HYDROLOGIC SOIL COVER COMPLEXES

Land Use

- Fallow is the land use with the highest potential for runoff because the land is kept as bare as possible to conserve moisture for use by a succeeding crop.
- A row crop is any field crop planted in rows far enough apart that most of the soil surface is exposed to rainfall impact during the early growing season (i.e.: corn, soybeans, sorghum).
- Small grain is planted in rows close enough together that the soil surface is not exposed except during planting and shortly thereafter.
- Close-seeded legumes or rotation meadow are either planted in close rows or broadcast. This cover may be allowed to remain for more than a year so that year-round protection is given to the soil.
- Pasture is a long term stand of forage plants which gives year-round protection to the soil.
- Meadow is a field in which grass is continually grown, protected from grazing, and generally mowed for hay.
- Woods are forested areas that have at least 30 percent canopy coverage as viewed by aerial photography.
- Farmsteads include the area surrounding the farm headquarters including buildings, lots, driveways, etc.
- Roads are improved travel ways; hard surface roads include any type of asphalt or concrete paving.

Treatment

- Straight row fields are those farmed in straight rows either up and down hill or across the slope.
- Contoured fields are those farmed as nearly as possible on the contour. The hydrologic effect of contouring is due to the surface storage provided by the furrows because the storage prolongs the time during which infiltration can take

place. The magnitude of the storage depends not only on the dimensions of the furrows but also on the land slope, crop, and manner of planting and cultivation.

- The contoured and terraced condition is to be used for systems containing open-end level or graded terraces with grassed waterway outlets where all tillage is done on the contour between the terraces.

Hydrologic Condition

- Ratings as to “poor” or “good” are based largely on the proportion of dense vegetation in the rotation.
- Pasture is considered poor if it is heavily grazed and has no mulch or has plant cover on less than half of the area. Fair pasture has plant cover on 50 to 75 percent of the area. Heavily grazed pasture in Iowa is generally considered to be fair pasture. Good pasture is lightly grazed and has plant cover on more than 75 percent of the area.
- Poor woods are heavily grazed or are regularly burned and have no litter or new young growth. Fair woods are grazed but not burned. There may be some litter but these woods are not protected. Good woods are protected from grazing and have litter and shrubs covering the soil.

Table C-1 Runoff Curve Numbers for Urban Areas

SCS TR-55 Table 2-2a – Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acre	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c					

[1] Average runoff condition, and $I_a = 0.2S$.
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (imperviousness area percentage) and the CN's for the newly graded pervious areas.

Source: HEC-HMS Technical Reference Manual, Appendix A (p.115)

Table C-2 Runoff Curve Numbers for Cultivated Agricultural lands

SCS TR-55 Table 2-2b – Runoff curve numbers for cultivated agricultural lands[1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	–	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C & T)	Poor	66	74	80	82
		Good	62	71	78	81
	C & T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	838
	C & T	Poor	61	72	79	82
		Good	59	70	78	81
	C & T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C & T	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition, and Ia = 0.2S.
[2] *Crop residue cover* applies only if residue is on at least 5% of the surface throughout the year.
[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.
Good: Factors impair infiltration and tend to increase runoff.
Poor: Factors encourage average and better than average infiltration and tend to decrease runoff.

Source: HEC-HMS Technical Reference Manual, Appendix A (p.116)

Table C-3 Runoff Curve Numbers for Cultivated Agricultural lands

SCS TR-55 Table 2-2c – Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Hydrologic condition	A	B	C	D
Pasture, grassland, or range ñ continuous forage for graving.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow ñ continuous grass, protected from grazing and generally mowed for hay.	–	30	58	71	78
Brush ñ brush-weed mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods ñ grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads ñ buildings, lanes, driveways, and surrounding lots.	–	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.

2 *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use CN=30 for runoff computations.

5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Source: HEC-HMS Technical Reference Manual, Appendix A (p.117)

Table C-4 Runoff Curve Numbers for arid and semiarid lands

SCS TR-55 Table 2-2d – Runoff curve numbers for arid and semiarid rangelands[1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous ñ mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen ñ mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper ñ pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub ñ major plants include saltbrush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and $I_a = 0.2S$.

2 *Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.

3 Curve numbers for group A have been developed only for desert shrub.

Source: HEC-HMS Technical Reference Manual, Appendix A (p.118)

Table C-5 CN values for Catchments in B 312 Road

Catchment ID	Catchment Area (km^2)	Land Cover Type & Area (km^2)								Reclassified Land Cover Type & % of Area					$CN_{composite}$
		Homestead	Scrub	Paddy	Forest	Rock	Cemetery	Water Bodies	Grassland	Pasture/ Grassland	Scrub	Paddy	Wood	Water Bodies	
34/3 - 34/4	7.685	0.592	2.829	0.022	3.633	0.000	0.000	0.127	0.483	14	37	0	47	2	56
35/1 - 36/1	0.178	0.000	0.133	0.000	0.044	0.000	0.000	0.000	0.000	0	75	0	25	0	51
36/2 - 37/1	17.091	0.270	8.707	0.048	7.699	0.342	0.000	0.026	0.000	4	51	0	45	0	54
38/1 - 38/5	5.092	1.562	3.100	0.337	0.000	0.054	0.009	0.030	0.000	32	61	7	0	1	54
38/6 - 38/7	0.114	0.074	0.037	0.002	0.000	0.000	0.000	0.000	0.000	65	32	2	0	0	57
39/1	0.271	0.077	0.195	0.000	0.000	0.000	0.000	0.000	0.000	28	72	0	0	0	52
39/2	0.103	0.063	0.040	0.000	0.000	0.000	0.000	0.000	0.000	61	39	0	0	0	56
40/1 - 42/3	9.782	2.481	0.997	1.966	4.156	0.116	0.065	0.000	0.000	27	10	20	42	0	61
42/4 - 44/3	4.916	0.094	0.084	0.081	4.585	0.073	0.000	0.000	0.000	3	2	2	93	0	60
58/1 - 58/2	0.183	0.043	0.000	0.000	0.140	0.000	0.000	0.000	0.000	23	0	0	77	0	60
58/3 - 58/6A	1.020	0.100	0.000	0.000	0.920	0.000	0.000	0.000	0.000	10	0	0	90	0	60
58/7 - 59/1	0.228	0.049	0.000	0.000	0.179	0.000	0.000	0.000	0.000	21	0	0	79	0	60
59/2	5.439	0.772	0.001	0.014	4.594	0.058	0.000	0.000	0.000	15	0	0	84	0	60
59/3	0.122	0.051	0.000	0.000	0.070	0.000	0.000	0.000	0.000	42	0	0	58	0	60

Table C-6 CN values for Catchments in A 035 Road

Catchment ID	Catchment Area (km²)	Land Cover Type & Area (km²)					Reclassified Land Cover Type & % of Area					$CN_{composite}$
		Homestead	Scrub	Paddy	Forest	Water Bodies	Pasture/ Grassland	Scrub	Paddy	Wood	Water Bodies	
2/1-2/2	0.708	0.000	0.000	0.708	0.000	0.000	0	0	100	0	0	71
2/3-2/4	0.456	0.000	0.000	0.456	0.000	0.000	0	0	100	0	0	71
4/2-5/1	1.533	0.235	0.000	1.298	0.000	0.000	15	0	85	0	0	69
16/1	0.091	0.091	0.000	0.000	0.000	0.000	100	0	0	0	0	61
21/1	48.111	7.978	6.320	0.781	30.745	2.287	17	13	2	64	5	61
22/1 - 22/2	5.455	2.371	2.004	0.000	1.079	0.000	43	37	0	20	0	56
24/1 - 26/1	66.626	2.865	2.840	4.033	52.436	4.452	4	4	6	79	7	63
28/1-28/4	22.688	1.465	3.213	0.819	16.905	0.287	6	14	4	75	1	59
30/2	0.175	0.120	0.000	0.000	0.000	0.055	68	0	0	0	32	73

Table C-7 CN values for Catchments in A 009 Road

Catchment ID	Catchment Area (km^2)	Land Cover Type & Area (km^2)						Reclassified Land Cover Type & % of Area						$CN_{composite}$
		Homestead	Scrub	Paddy	Forest	Water Bodies	Chena	Pasture/ Grassland	Scrub	Paddy	Wood	Water Bodies	Cultivation	
123/3-123/4	3.030	0.148	0.752	0.339	1.692	0.100	0.000	5	25	11	56	3	0	60
125/1	0.674	0.087	0.474	0.000	0.113	0.000	0.000	13	70	0	17	0	0	52
126/1	4.868	0.626	1.877	0.284	0.656	0.367	1.059	13	39	6	13	8	22	61
127/2	1.144	0.051	0.493	0.000	0.118	0.036	0.447	4	43	0	10	3	39	59
128/1	0.125	0.114	0.000	0.000	0.000	0.000	0.011	91	0	0	0	0	9	62
129/2	0.259	0.114	0.000	0.000	0.000	0.000	0.145	44	0	0	0	0	56	64
130/1-130/2	0.401	0.074	0.127	0.000	0.000	0.000	0.199	19	32	0	0	0	50	60
131/1	0.682	0.283	0.211	0.000	0.000	0.000	0.188	42	31	0	0	0	28	59
205/2-206/1	7.937	0.773	0.000	0.314	6.246	0.604	0.000	10	0	4	79	8	0	64
206/3	0.348	0.259	0.000	0.000	0.090	0.000	0.000	74	0	0	26	0	0	61
207/1-207/2	6.065	1.052	0.000	0.229	4.536	0.247	0.000	17	0	4	75	4	0	62
209/2	0.202	0.000	0.000	0.202	0.000	0.000	0.000	0	0	100	0	0	0	71
210/2-210/6	0.413	0.075	0.234	0.000	0.000	0.033	0.072	18	57	0	0	8	17	58
212/1-213/1	3.846	0.276	0.968	0.148	1.186	0.518	0.751	7	25	4	31	13	20	64
215/1	0.107	0.000	0.038	0.000	0.069	0.000	0.000	0	35	0	65	0	0	56

Table C-8 CN values for Catchments in B 528 Road

Catchment ID	Catchment Area (km^2)	Land Cover Type & Area (km^2)						Reclassified Land Cover Type & % of Area						$CN_{composite}$
		Homestead	Scrub	Paddy	Forest	Water Bodies	Chena	Pasture/ Grassland	Scrub	Paddy	Wood	Water Bodies	Cultivation	
3/1 - 3/3	1.289	0.000	0.348	0.000	0.691	0.000	0.250	0	27	0	54	0	19	58
4/1-5/4	7.388	0.120	2.979	0.205	3.211	0.326	0.547	2	40	3	43	4	7	58
7/1-7/2	30.266	0.000	11.822	0.000	13.342	0.772	4.331	0	39	0	44	3	14	57
11/2-11/3	1.852	0.369	0.555	0.089	0.805	0.034	0.000	20	30	5	43	2	0	58
12/3-13/2	8.895	0.300	2.771	0.000	4.650	0.419	0.754	3	31	0	52	5	8	59
16/3-17/2	10.126	0.000	2.621	0.000	5.027	0.605	1.872	0	26	0	50	6	18	60
20/1	5.803	0.036	1.501	0.000	3.138	0.496	0.632	1	26	0	54	9	11	60
31/3	4.279	0.085	1.862	0.225	0.355	0.135	1.616	2	44	5	8	3	38	59

APPENDIX D. DESIGN RAINFALL INTENSITY CALCULATIONS

Table 0-1 Rainfall Intensity

Catchment ID	Catchment Area (ha)	Design Rainfall Intensity (mm/hr)											
		tc from ID			tc from KIR			tc from B-W			tc from UK		
		25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years
B 312Road													
39/2	10.2593	114.47	123.65	132.35	132.89	143.39	153.11	122.84	132.62	141.78	93.13	100.75	108.17
38/6 - 38/7	11.3763	111.74	120.72	129.26	129.31	139.55	149.07	121.24	130.91	139.99	86.94	94.11	101.14
59/3	12.1606	115.23	124.46	133.20	136.08	146.80	156.69	122.03	131.75	140.87	99.97	108.09	115.93
35/1 - 36/1	17.7511	115.28	124.51	133.25	132.41	142.87	152.56	121.39	131.07	140.15	92.22	99.77	107.14
58/1 - 58/2	18.2918	113.70	122.82	131.47	132.71	143.19	152.90	116.52	125.85	134.66	92.78	100.37	107.77
58/7 - 59/1	22.7579	111.41	120.37	128.88	130.47	140.80	150.38	111.21	120.15	128.65	88.82	96.12	103.28
39/1	27.1074	109.59	118.41	126.82	126.42	136.46	145.82	113.05	122.12	130.73	82.74	89.59	96.36
58/3 - 58/6A	102.0480	98.60	106.62	114.38	117.44	126.83	135.69	92.43	100.00	107.38	72.34	78.40	84.49
42/4 - 44/3	491.6382	88.28	95.54	102.66	109.99	118.84	127.28	78.10	84.60	91.07	65.61	71.16	76.79
38/1 - 38/5	509.2448	73.03	79.15	85.29	99.11	107.17	114.95	70.11	76.01	81.95	57.54	62.48	67.54
59/2	543.8840	64.84	70.33	75.91	87.40	94.60	101.67	58.10	63.07	68.18	50.32	54.68	59.22
34/3 - 34/4	768.5286	66.10	71.69	77.35	89.57	96.93	104.13	69.77	75.64	81.55	51.57	56.04	60.67
40/1 - 42/3	978.1636	75.86	82.19	88.51	99.12	107.18	114.97	68.41	74.18	80.00	57.55	62.49	67.55
36/2 - 37/1	1709.1110	45.72	49.73	53.92	72.55	78.63	84.73	42.43	46.17	50.12	42.41	46.14	50.09
A035 Road													
16/1	9.0800	194.13	213.99	246.95	391.69	431.25	500.62	305.93	336.97	389.49	106.52	117.54	136.30
30/2	17.5200	130.59	144.05	166.68	197.84	218.08	251.65	142.65	157.33	181.90	70.21	77.53	90.41
2/3-2/4	45.6400	105.01	115.88	134.40	112.84	124.50	144.27	94.66	104.47	121.33	49.83	55.06	64.56

Catchment ID	Catchment Area (ha)	Design Rainfall Intensity (mm/hr)											
		tc from ID			tc from KIR			tc from B-W			tc from UK		
		25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years
2/1-2/2	70.7800	100.30	110.69	128.46	118.58	130.82	151.52	96.66	106.68	123.86	51.37	56.75	66.51
4/2-5/1	153.3170	75.67	83.55	97.33	90.27	99.64	115.78	71.77	79.24	92.39	43.49	48.06	56.48
22/1 - 22/2	545.5000	52.16	57.63	67.52	76.48	84.44	98.35	55.87	61.72	72.24	39.30	43.44	51.15
28/1-28/4	2268.8400	28.07	31.04	36.76	44.59	49.28	57.89	31.44	34.76	41.08	28.28	31.27	37.03
21/1	4811.0600	20.22	22.37	26.65	31.58	34.93	41.27	22.64	25.05	29.78	22.91	25.35	30.13
24/1 - 26/1	6662.6100	19.47	21.54	25.68	31.51	34.84	41.18	22.63	25.03	29.76	22.88	25.31	30.08
A009 Road													
215/1	10.7070	191.51	211.11	243.63	358.65	394.94	457.60	255.47	281.48	324.89	100.94	111.40	129.26
128/1	12.5070	116.36	129.76	142.89	148.47	166.37	183.33	130.38	145.70	160.50	79.44	88.10	96.90
209/2	20.2220	193.04	212.79	245.57	429.89	473.23	550.75	297.54	327.75	378.72	112.75	124.40	144.16
129/2	25.8840	105.81	117.81	129.70	139.31	155.89	171.75	122.91	137.20	151.11	71.92	79.67	87.60
206/3	34.8430	104.14	114.92	133.30	170.44	187.93	216.99	114.21	126.02	146.01	64.10	70.79	82.68
130/1-130/2	40.0680	112.74	125.65	138.35	143.97	161.21	177.64	127.79	142.76	157.25	75.56	83.76	92.11
210/2-210/6	41.3080	120.76	133.23	154.28	193.84	213.68	246.59	140.04	154.46	178.60	69.34	76.57	89.31
125/1	67.4210	97.68	108.63	119.56	130.96	146.36	161.23	106.82	118.95	130.95	66.09	73.14	80.41
131/1	68.2420	93.42	103.82	114.25	123.41	137.77	151.73	98.56	109.62	120.65	61.41	67.92	74.65
127/2	114.4310	90.04	100.02	110.05	122.77	137.04	150.93	97.56	108.49	119.40	61.04	67.50	74.19
123/3-123/4	303.0000	85.38	94.78	104.27	111.83	124.63	137.22	73.62	81.58	89.71	55.05	60.82	66.82
212/1-213/1	384.6240	67.97	75.06	87.58	102.28	112.88	130.96	75.89	83.79	97.61	46.93	51.86	60.88
126/1	486.7990	55.00	60.77	66.76	77.41	85.82	94.39	60.72	67.15	73.80	39.44	43.46	47.71
207/1-207/2	606.4920	66.17	73.07	85.29	111.31	122.82	142.35	80.45	88.82	103.38	49.42	54.61	64.04
205/2-206/1	793.6700	47.89	52.92	62.10	81.90	90.41	105.21	56.23	62.12	72.69	40.98	45.29	53.29

Catchment ID	Catchment Area (ha)	Design Rainfall Intensity (mm/hr)											
		tc from ID			tc from KIR			tc from B-W			tc from UK		
		25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years
B528 Road													
3/1 - 3/3	128.9200	67.63	75.43	82.96	97.05	106.85	116.55	75.71	84.18	92.38	48.39	54.32	60.01
11/2-11/3	185.1921	73.28	81.55	89.55	102.38	112.43	122.45	77.34	85.93	94.26	50.99	57.19	63.15
31/3	427.9100	75.29	83.72	91.88	101.35	111.36	121.31	71.95	80.12	88.01	50.48	56.63	62.53
20/1	580.3100	78.12	86.76	95.15	102.72	112.78	122.82	69.22	77.16	84.82	51.16	57.38	63.35
4/1-5/4	738.7500	35.07	39.45	43.69	54.07	60.59	66.86	38.38	43.16	47.77	30.22	34.01	37.69
12/3-13/2	889.4600	53.31	59.76	65.95	76.32	84.83	93.08	47.68	53.52	59.14	39.22	44.11	48.81
16/3-17/2	1012.5800	69.86	77.85	85.57	98.32	108.18	117.96	69.68	77.66	85.36	49.00	54.99	60.74
7/1-7/2	3026.6124	34.80	39.15	43.36	58.41	65.36	72.05	39.07	43.94	48.63	31.95	35.96	39.83

Table 0-2 Percentage (%) Difference in Rainfall Intensity

Catchment ID	Catchment Area (ha)	% Difference in Design Rainfall Intensity over ID Guideline								
		tc from KIR			tc from B-W			tc from UK		
		25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years
B 312 Road										
39/2	10.2593	16	16	16	7	7	7	-19	-19	-18
38/6 - 38/7	11.3763	16	16	15	9	8	8	-22	-22	-22
59/3	12.1606	18	18	18	6	6	6	-13	-13	-13
35/1 - 36/1	17.7511	15	15	14	5	5	5	-20	-20	-20
58/1 - 58/2	18.2918	17	17	16	2	2	2	-18	-18	-18
58/7 - 59/1	22.7579	17	17	17	0	0	0	-20	-20	-20
39/1	27.1074	15	15	15	3	3	3	-24	-24	-24
58/3 - 58/6A	102.0480	19	19	19	-6	-6	-6	-27	-26	-26
42/4 - 44/3	491.6382	25	24	24	-12	-11	-11	-26	-26	-25
38/1 - 38/5	509.2448	36	35	35	-4	-4	-4	-21	-21	-21
59/2	543.8840	35	35	34	-10	-10	-10	-22	-22	-22
34/3 - 34/4	768.5286	36	35	35	6	6	5	-22	-22	-22
40/1 - 42/3	978.1636	31	30	30	-10	-10	-10	-24	-24	-24
36/2 - 37/1	1709.1110	59	58	57	-7	-7	-7	-7	-7	-7
A035 Road										
16/1	9.0800	102	102	103	58	57	58	-45	-45	-45
30/2	17.5200	51	51	51	9	9	9	-46	-46	-46

Catchment ID	Catchment Area (ha)	% Difference in Design Rainfall Intensity over ID Guideline								
		tc from KIR			tc from B-W			tc from UK		
		25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years
2/3-2/4	45.6400	7	7	7	-10	-10	-10	-53	-52	-52
2/1-2/2	70.7800	18	18	18	-4	-4	-4	-49	-49	-48
4/2-5/1	153.3170	19	19	19	-5	-5	-5	-43	-42	-42
22/1 - 22/2	545.5000	47	47	46	7	7	7	-25	-25	-24
28/1-28/4	2268.8400	59	59	57	12	12	12	1	1	1
21/1	4811.0600	56	56	55	12	12	12	13	13	13
24/1 - 26/1	6662.6100	62	62	60	16	16	16	18	17	17
A009 Road										
215/1	10.7070	87	87	88	33	33	33	-47	-47	-47
128/1	12.5070	28	28	28	12	12	12	-32	-32	-32
209/2	20.2220	123	122	124	54	54	54	-42	-42	-41
129/2	25.8840	32	32	32	16	16	17	-32	-32	-32
206/3	34.8430	64	64	63	10	10	10	-38	-38	-38
130/1-130/2	40.0680	28	28	28	13	14	14	-33	-33	-33
210/2-210/6	41.3080	61	60	60	16	16	16	-43	-43	-42
125/1	67.4210	34	35	35	9	10	10	-32	-33	-33
131/1	68.2420	32	33	33	6	6	6	-34	-35	-35
127/2	114.4310	36	37	37	8	8	8	-32	-33	-33
123/3-123/4	303.0000	31	32	32	-14	-14	-14	-36	-36	-36

Catchment ID	Catchment Area (ha)	% Difference in Design Rainfall Intensity over ID Guideline								
		tc from KIR			tc from B-W			tc from UK		
		25 Years	50 Years	100 Years	25 Years	50 Years	100 Years	25 Years	50 Years	100 Years
212/1-213/1	384.6240	50	50	50	12	12	11	-31	-31	-30
126/1	486.7990	41	41	41	10	11	11	-28	-28	-29
207/1-207/2	606.4920	68	68	67	22	22	21	-25	-25	-25
205/2-206/1	793.6700	71	71	69	17	17	17	-14	-14	-14
B528 Road										
3/1 - 3/3	128.9200	44	42	40	12	12	11	-28	-28	-28
11/2-11/3	185.1921	40	38	37	6	5	5	-30	-30	-29
31/3	427.9100	35	33	32	-4	-4	-4	-33	-32	-32
20/1	580.3100	31	30	29	-11	-11	-11	-35	-34	-33
4/1-5/4	738.7500	54	54	53	9	9	9	-14	-14	-14
12/3-13/2	889.4600	43	42	41	-11	-10	-10	-26	-26	-26
16/3-17/2	1012.5800	41	39	38	0	0	0	-30	-29	-29
7/1-7/2	3026.6124	68	67	66	12	12	12	-8	-8	-8

APPENDIX E. PEAK FLOW ESTIMATION USING SNYDER'S METHOD

Table E-1 Unit Hydrograph Ordinates

Catchment ID	Catchment Area (km^2)	L (m)	Lca (m)	Ct	Cp	Unit Hydrograph Parameters													
						tp	D	D'	tpi	Qpi	W_{50}	W_{75}	0.5Qpi	0.75Qpi	W_{50}x(1/3)	W_{50}x(2/3)	W_{75}x(1/3)	W_{75}x(2/3)	Tb
						hrs	hrs	hrs	hrs	m^3/s	hrs	hrs	m^3/s	m^3/s	hrs	hrs	hrs	hrs	hrs
B 312 Road																			
34/3 - 34/4	7.685	3317	1800	2.22	1.00	3.79	0.69	3	4.37	4.887	3.49	1.99	2.443	3.665	1.16	2.33	0.66	1.33	17.49
35/1 - 36/1	0.178	505	207	2.22	1.00	1.13	0.21	3	1.83	0.270	1.36	0.77	0.135	0.203	0.45	0.91	0.26	0.52	7.31
36/2 - 37/1	17.091	9935	4727	2.22	1.00	7.04	1.28	3	7.47	6.357	6.23	3.55	3.178	4.767	2.08	4.15	1.18	2.37	29.90
38/1 - 38/5	5.092	3937	2050	2.22	1.00	4.15	0.76	3	4.71	3.003	3.79	2.16	1.501	2.252	1.26	2.52	0.72	1.44	18.86
38/6 - 38/7	0.114	380	211	2.22	1.00	1.04	0.19	3	1.74	0.181	1.29	0.74	0.091	0.136	0.43	0.86	0.25	0.49	6.98
39/1	0.271	693	302	2.22	1.00	1.39	0.25	3	2.08	0.363	1.56	0.89	0.182	0.272	0.52	1.04	0.30	0.59	8.30
39/2	0.103	421	167	2.22	1.00	1.00	0.18	3	1.71	0.167	1.26	0.72	0.084	0.125	0.42	0.84	0.24	0.48	6.82
40/1 - 42/3	9.782	4760	1789	2.22	1.00	4.22	0.77	3	4.78	5.690	3.84	2.19	2.845	4.267	1.28	2.56	0.73	1.46	19.12
42/4 - 44/3	4.916	3743	1672	2.22	1.00	3.85	0.70	3	4.42	3.090	3.53	2.01	1.545	2.317	1.18	2.36	0.67	1.34	17.69
58/1 - 58/2	0.183	771	300	2.22	1.00	1.43	0.26	3	2.12	0.240	1.59	0.91	0.120	0.180	0.53	1.06	0.30	0.61	8.46
58/3 - 58/6A	1.020	1876	690	2.22	1.00	2.40	0.44	3	3.04	0.933	2.36	1.34	0.467	0.700	0.79	1.57	0.45	0.90	12.16
58/7 - 59/1	0.228	981	389	2.22	1.00	1.66	0.30	3	2.34	0.271	1.77	1.01	0.135	0.203	0.59	1.18	0.34	0.67	9.35
59/2	5.439	5189	3079	2.22	1.00	5.10	0.93	3	5.62	2.692	4.57	2.61	1.346	2.019	1.52	3.05	0.87	1.74	22.47
59/3	0.122	635	316	2.22	1.00	1.37	0.25	3	2.06	0.164	1.55	0.88	0.082	0.123	0.52	1.03	0.29	0.59	8.24
A035 Road																			
2/1-2/2	0.708	1264	514	4.42	0.87	3.88	0.71	2	4.21	0.407	3.89	2.22	0.203	0.305	1.30	2.59	0.74	1.48	16.83
2/3-2/4	0.456	1162	552	4.42	0.87	3.87	0.70	2	4.19	0.263	3.88	2.21	0.132	0.197	1.29	2.58	0.74	1.47	16.77
4/2-5/1	1.533	2053	1209	4.42	0.87	5.81	1.06	2	6.04	0.614	5.75	3.28	0.307	0.460	1.92	3.83	1.09	2.19	24.17
16/1	0.091	267	93	4.42	0.87	1.46	0.27	1	1.64	0.134	1.41	0.80	0.067	0.100	0.47	0.94	0.27	0.54	6.57
21/1	48.111	14600	7878	4.42	0.87	18.35	3.34	10	20.02	5.813	20.97	11.96	2.907	4.360	6.99	13.98	3.99	7.97	80.07
22/1 - 22/2	5.455	3690	2144	4.42	0.87	8.22	1.49	10	10.35	1.275	10.28	5.86	0.638	0.956	3.43	6.86	1.95	3.91	41.39
24/1 - 26/1	66.626	15400	9159	4.42	0.87	19.51	3.55	10	21.12	7.629	22.23	12.67	3.815	5.722	7.41	14.82	4.22	8.45	84.49

Catchment ID	Catchment Area (km^2)	L (m)	Lca (m)	Ct	Cp	Unit Hydrograph Parameters													
						tp	D	D'	tpi	Qpi	W_{50}	W_{75}	0.5Qpi	0.75Qpi	W_{50}x(1/3)	W_{50}x(2/3)	W_{75}x(1/3)	W_{75}x(2/3)	Tb
						hrs	hrs	hrs	hrs	m^3/s	hrs	hrs	m^3/s	m^3/s	hrs	hrs	hrs	hrs	hrs
28/1-28/4	22.688	9170	4993	4.42	0.87	13.92	2.53	6	14.79	3.711	15.12	8.62	1.855	2.783	5.04	10.08	2.87	5.75	59.15
30/2	0.175	756	318	4.42	0.87	2.88	0.52	1	3.00	0.141	2.70	1.54	0.071	0.106	0.90	1.80	0.51	1.03	12.00
A009 Road																			
123/3-123/4	3.030	2920	1731	4.42	0.87	7.19	1.31	2	7.36	0.996	7.12	4.06	0.498	0.747	2.37	4.75	1.35	2.71	29.44
125/1	0.674	978	605	4.42	0.87	3.78	0.69	2	4.10	0.397	3.79	2.16	0.199	0.298	1.26	2.53	0.72	1.44	16.42
126/1	4.868	2735	1586	4.42	0.87	6.86	1.25	2	7.05	1.669	6.80	3.88	0.835	1.252	2.27	4.53	1.29	2.58	28.21
127/2	1.144	1261	614	4.42	0.87	4.09	0.74	2	4.41	0.628	4.09	2.33	0.314	0.471	1.36	2.73	0.78	1.56	17.63
128/1	0.125	450	267	4.42	0.87	2.34	0.43	2	2.73	0.111	2.44	1.39	0.055	0.083	0.81	1.63	0.46	0.93	10.94
129/2	0.259	543	383	4.42	0.87	2.76	0.50	2	3.13	0.200	2.83	1.61	0.100	0.150	0.94	1.89	0.54	1.08	12.54
130/1-130/2	0.401	538	498	4.42	0.87	2.98	0.54	2	3.34	0.290	3.03	1.73	0.145	0.217	1.01	2.02	0.58	1.15	13.37
131/1	0.682	1130	689	4.42	0.87	4.10	0.75	2	4.41	0.374	4.10	2.34	0.187	0.280	1.37	2.73	0.78	1.56	17.66
205/2-206/1	7.937	4198	2699	4.42	0.87	9.16	1.66	3	9.49	2.023	9.37	5.34	1.011	1.517	3.12	6.24	1.78	3.56	37.96
206/3	0.348	1180	555	4.42	0.87	3.89	0.71	3	4.47	0.189	4.15	2.37	0.094	0.142	1.38	2.77	0.79	1.58	17.86
207/1-207/2	6.065	2550	1275	4.42	0.87	6.30	1.14	3	6.76	2.170	6.49	3.70	1.085	1.628	2.16	4.33	1.23	2.47	27.04
209/2	0.202	363	182	4.42	0.87	1.96	0.36	3	2.62	0.187	2.33	1.33	0.093	0.140	0.78	1.55	0.44	0.89	10.47
210/2-210/6	0.413	888	397	4.42	0.87	3.23	0.59	3	3.84	0.260	3.52	2.01	0.130	0.195	1.17	2.35	0.67	1.34	15.34
212/1-213/1	3.846	2443	1162	4.42	0.87	6.04	1.10	3	6.52	1.427	6.25	3.56	0.713	1.070	2.08	4.16	1.19	2.37	26.08
215/1	0.107	373	169	4.42	0.87	1.93	0.35	3	2.59	0.100	2.31	1.31	0.050	0.075	0.77	1.54	0.44	0.88	10.36
B528 Road																			
3/1 - 3/3	1.289	1649	707	1.13	1.07	1.18	0.22	2	1.63	2.353	1.12	0.64	1.177	1.765	0.37	0.74	0.21	0.42	6.52
4/1-5/4	7.388	5180	2626	1.13	1.07	2.47	0.45	2	2.86	7.683	2.05	1.17	3.841	5.762	0.68	1.37	0.39	0.78	11.44
7/1-7/2	30.266	6986	4541	1.13	1.07	3.19	0.58	2	3.54	25.411	2.58	1.47	12.706	19.058	0.86	1.72	0.49	0.98	14.17
11/2-11/3	1.852	1833	897	1.13	1.07	1.31	0.24	2	1.75	3.144	1.21	0.69	1.572	2.358	0.40	0.81	0.23	0.46	7.01
12/3-13/2	8.895	5260	3012	1.13	1.07	2.59	0.47	2	2.97	8.906	2.14	1.22	4.453	6.680	0.71	1.42	0.41	0.81	11.88
16/3-17/2	10.126	3070	1341	1.13	1.07	1.73	0.31	2	2.15	14.015	1.51	0.86	7.008	10.511	0.50	1.00	0.29	0.57	8.60

Catchment ID	Catchment Area (km^2)	L (m)	Lca (m)	Ct	Cp	Unit Hydrograph Parameters													
						tp	D	D'	tpi	Qpi	W_{50}	W_{75}	0.5Qpi	0.75Qpi	W_{50}x(1/3)	W_{50}x(2/3)	W_{75}x(1/3)	W_{75}x(2/3)	Tb
						hrs	hrs	hrs	hrs	m^3/s	hrs	hrs	m^3/s	m^3/s	hrs	hrs	hrs	hrs	hrs
20/1	5.803	3130	1724	1.13	1.07	1.87	0.34	2	2.29	7.543	1.61	0.92	3.771	5.657	0.54	1.07	0.31	0.61	9.15
31/3	4.279	2576	916	1.13	1.07	1.46	0.27	2	1.90	6.715	1.32	0.75	3.358	5.036	0.44	0.88	0.25	0.50	7.58

Table E-2 Design Hydrographs Developed using Snyder's Unit Hydrographs

Road : B312, Cat. ID : 34/3 - 34/4													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	1.118	1.006			1.006	1.229			1.229	1.229			1.229
2	2.235	2.012	4.694		6.706	2.459	5.030		7.489	2.459	5.812		8.271
3	3.353	3.018	9.389	4.359	16.766	3.688	10.059	4.918	18.666	3.688	11.624	5.477	20.790
4	4.471	4.024	14.083	8.718	26.825	4.918	15.089	9.836	29.843	4.918	17.436	10.954	33.308
5	4.644	4.179	18.778	13.077	36.034	5.108	20.119	14.754	39.981	5.108	23.249	16.431	44.787
6	4.257	3.831	19.504	17.436	40.771	4.682	20.897	19.672	45.251	4.682	24.147	21.907	50.737
7	3.870	3.483	17.878	18.111	39.472	4.257	19.155	20.432	43.845	4.257	22.135	22.754	49.146
8	3.483	3.135	16.253	16.601	35.989	3.831	17.414	18.730	39.975	3.831	20.123	20.858	44.812
9	3.096	2.786	14.628	15.092	32.506	3.405	15.673	17.027	36.105	3.405	18.111	18.962	40.478
10	2.709	2.438	13.002	13.583	29.023	2.980	13.931	15.324	32.235	2.980	16.098	17.066	36.144
11	2.322	2.090	11.377	12.074	25.541	2.554	12.190	13.622	28.366	2.554	14.086	15.170	31.810
12	1.935	1.741	9.752	10.565	22.058	2.128	10.448	11.919	24.496	2.128	12.074	13.273	27.475
13	1.548	1.393	8.127	9.055	18.575	1.703	8.707	10.216	20.626	1.703	10.061	11.377	23.141
14	1.161	1.045	6.501	7.546	15.092	1.277	6.966	8.514	16.756	1.277	8.049	9.481	18.807
15	0.774	0.697	4.876	6.037	11.609	0.851	5.224	6.811	12.886	0.851	6.037	7.585	14.473
16	0.387	0.348	3.251	4.528	8.127	0.426	3.483	5.108	9.017	0.426	4.025	5.689	10.139
			1.625	3.018	4.644		1.741	3.405	5.147		2.012	3.792	5.805
				1.509	1.509			1.703	1.703			1.896	1.896

Road : B312, Cat. ID : 35/1 - 36/1													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.148	0.133			0.133	0.163			0.163	0.163			0.163
2	0.261	0.235	0.621		0.856	0.287	0.666		0.953	0.287	0.769		1.057
3	0.209	0.188	1.097	0.577	1.862	0.230	1.175	0.651	2.056	0.230	1.358	0.725	2.313
4	0.157	0.141	0.877	1.018	2.037	0.172	0.940	1.149	2.261	0.172	1.086	1.280	2.538
5	0.104	0.094	0.658	0.815	1.567	0.115	0.705	0.919	1.739	0.115	0.815	1.024	1.953
6	0.052	0.047	0.439	0.611	1.097	0.057	0.470	0.689	1.217	0.057	0.543	0.768	1.368
			0.219	0.407	0.627		0.235	0.460	0.695		0.272	0.512	0.783
				0.204	0.204			0.230	0.230			0.256	0.256

Road : B312, Cat. ID : 36/2 - 37/1													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.850	0.765			0.765	0.935			0.935	0.935			0.935
2	1.701	1.531	3.572		5.102	1.871	3.827		5.698	1.871	4.422		6.293
3	2.551	2.296	7.143	3.317	12.756	2.806	7.654	3.742	14.202	2.806	8.844	4.167	15.817
4	3.402	3.061	10.715	6.633	20.410	3.742	11.480	7.484	22.706	3.742	13.266	8.334	25.342
5	4.252	3.827	14.287	9.950	28.063	4.677	15.307	11.225	31.210	4.677	17.688	12.501	34.866
6	6.773	6.095	17.858	13.266	37.220	7.450	19.134	14.967	41.551	7.450	22.110	16.668	46.228
7	6.490	5.841	28.445	16.583	50.869	7.140	30.477	18.709	56.325	7.140	35.218	20.835	63.192
8	6.208	5.587	27.260	26.413	59.261	6.829	29.207	29.800	65.836	6.829	33.751	33.186	73.766
9	5.926	5.333	26.075	25.313	56.721	6.519	27.937	28.558	63.014	6.519	32.283	31.803	70.605
10	5.644	5.080	24.890	24.212	54.181	6.208	26.667	27.316	60.192	6.208	30.816	30.421	67.445
11	5.362	4.826	23.704	23.112	51.642	5.898	25.398	26.075	57.370	5.898	29.348	29.038	64.284
12	5.080	4.572	22.519	22.011	49.102	5.587	24.128	24.833	54.548	5.587	27.881	27.655	61.123
13	4.797	4.318	21.334	20.911	46.562	5.277	22.858	23.591	51.726	5.277	26.413	26.272	57.963
14	4.515	4.064	20.149	19.810	44.022	4.967	21.588	22.350	48.904	4.967	24.946	24.890	54.802
15	4.233	3.810	18.963	18.710	41.483	4.656	20.318	21.108	46.082	4.656	23.479	23.507	51.642
16	3.951	3.556	17.778	17.609	38.943	4.346	19.048	19.867	43.260	4.346	22.011	22.124	48.481
17	3.669	3.302	16.593	16.508	36.403	4.035	17.778	18.625	40.439	4.035	20.544	20.741	45.320
18	3.386	3.048	15.408	15.408	33.863	3.725	16.508	17.383	37.617	3.725	19.076	19.359	42.160
19	3.104	2.794	14.223	14.307	31.324	3.415	15.239	16.142	34.795	3.415	17.609	17.976	38.999
20	2.822	2.540	13.037	13.207	28.784	3.104	13.969	14.900	31.973	3.104	16.142	16.593	35.839

21	2.540	2.286	11.852	12.106	26.244	2.794	12.699	13.658	29.151	2.794	14.674	15.210	32.678
22	2.258	2.032	10.667	11.006	23.704	2.483	11.429	12.417	26.329	2.483	13.207	13.828	29.518
23	1.975	1.778	9.482	9.905	21.165	2.173	10.159	11.175	23.507	2.173	11.739	12.445	26.357
24	1.693	1.524	8.297	8.804	18.625	1.862	8.889	9.933	20.685	1.862	10.272	11.062	23.196
25	1.411	1.270	7.111	7.704	16.085	1.552	7.619	8.692	17.863	1.552	8.804	9.679	20.036
26	1.129	1.016	5.926	6.603	13.545	1.242	6.349	7.450	15.041	1.242	7.337	8.297	16.875
27	0.847	0.762	4.741	5.503	11.006	0.931	5.080	6.208	12.219	0.931	5.870	6.914	13.715
28	0.564	0.508	3.556	4.402	8.466	0.621	3.810	4.967	9.397	0.621	4.402	5.531	10.554
29	0.282	0.254	2.370	3.302	5.926	0.310	2.540	3.725	6.575	0.310	2.935	4.148	7.394
			1.185	2.201	3.386		1.270	2.483	3.753		1.467	2.766	4.233
				1.101	1.101			1.242	1.242			1.383	1.383
Road : B312, Cat. ID : 38/1 - 38/5													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.637	0.573			0.573	0.701			0.701	0.701			0.701
2	1.274	1.146	2.675		3.821	1.401	2.866		4.267	1.401	3.312		4.713
3	1.911	1.719	5.350	2.484	9.553	2.102	5.732	2.802	10.635	2.102	6.623	3.121	11.845
4	2.547	2.293	8.024	4.967	15.284	2.802	8.597	5.604	17.004	2.802	9.935	6.241	18.978
5	2.943	2.648	10.699	7.451	20.799	3.237	11.463	8.406	23.107	3.237	13.247	9.362	25.845
6	2.733	2.459	12.359	9.935	24.754	3.006	13.242	11.209	27.457	3.006	15.302	12.482	30.790
7	2.522	2.270	11.477	11.477	25.223	2.775	12.296	12.948	28.019	2.775	14.209	14.419	31.403
8	2.312	2.081	10.594	10.657	23.331	2.543	11.350	12.023	25.917	2.543	13.116	13.389	29.049
9	2.102	1.892	9.711	9.837	21.440	2.312	10.405	11.098	23.815	2.312	12.023	12.359	26.695
10	1.892	1.703	8.828	9.017	19.548	2.081	9.459	10.173	21.713	2.081	10.930	11.329	24.340
11	1.682	1.513	7.945	8.198	17.656	1.850	8.513	9.249	19.611	1.850	9.837	10.299	21.986
12	1.471	1.324	7.063	7.378	15.765	1.618	7.567	8.324	17.509	1.618	8.744	9.270	19.632
13	1.261	1.135	6.180	6.558	13.873	1.387	6.621	7.399	15.407	1.387	7.651	8.240	17.278
14	1.051	0.946	5.297	5.738	11.981	1.156	5.675	6.474	13.305	1.156	6.558	7.210	14.924
15	0.841	0.757	4.414	4.919	10.089	0.925	4.729	5.549	11.203	0.925	5.465	6.180	12.570
16	0.631	0.568	3.531	4.099	8.198	0.694	3.783	4.624	9.101	0.694	4.372	5.150	10.215
17	0.420	0.378	2.648	3.279	6.306	0.462	2.838	3.699	6.999	0.462	3.279	4.120	7.861
18	0.210	0.189	1.766	2.459	4.414	0.231	1.892	2.775	4.898	0.231	2.186	3.090	5.507
			0.883	1.640	2.522		0.946	1.850	2.796		1.093	2.060	3.153
				0.820	0.820			0.925	0.925			1.030	1.030
Road : B312, Cat. ID : 38/6 - 38/7													

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.104	0.094			0.094	0.114			0.114	0.114			0.114
2	0.173	0.155	0.437		0.592	0.190	0.468		0.658	0.190	0.541		0.730
3	0.138	0.124	0.725	0.406	1.254	0.152	0.776	0.458	1.386	0.152	0.897	0.510	1.558
4	0.104	0.093	0.580	0.673	1.346	0.114	0.621	0.759	1.494	0.114	0.718	0.845	1.677
5	0.069	0.062	0.435	0.538	1.035	0.076	0.466	0.607	1.149	0.076	0.538	0.676	1.290
6	0.035	0.031	0.290	0.404	0.725	0.038	0.311	0.455	0.804	0.038	0.359	0.507	0.904
			0.145	0.269	0.414		0.155	0.304	0.459		0.179	0.338	0.518
				0.135	0.135			0.152	0.152			0.169	0.169
Road : B312, Cat. ID : 39/1													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.175	0.157			0.157	0.192			0.192	0.192			0.192
2	0.350	0.315	0.735		1.050	0.385	0.787		1.172	0.385	0.910		1.295
3	0.306	0.276	1.470	0.682	2.428	0.337	1.574	0.770	2.681	0.337	1.819	0.857	3.014
4	0.245	0.221	1.287	1.365	2.872	0.270	1.379	1.540	3.188	0.270	1.593	1.714	3.578
5	0.184	0.165	1.030	1.195	2.390	0.202	1.103	1.348	2.654	0.202	1.275	1.502	2.979
6	0.123	0.110	0.772	0.956	1.839	0.135	0.827	1.079	2.041	0.135	0.956	1.201	2.292
7	0.061	0.055	0.515	0.717	1.287	0.067	0.552	0.809	1.428	0.067	0.637	0.901	1.606
			0.257	0.478	0.735		0.276	0.539	0.815		0.319	0.601	0.919
				0.239	0.239			0.270	0.270			0.300	0.300
Road : B312, Cat. ID : 39/2													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.098	0.088			0.088	0.108			0.108	0.108			0.108
2	0.158	0.142	0.412		0.554	0.174	0.441		0.615	0.174	0.510		0.684
3	0.126	0.114	0.663	0.382	1.159	0.139	0.711	0.431	1.281	0.139	0.821	0.480	1.441
4	0.095	0.085	0.531	0.616	1.232	0.104	0.569	0.695	1.368	0.104	0.657	0.774	1.535
5	0.063	0.057	0.398	0.493	0.948	0.069	0.426	0.556	1.052	0.069	0.493	0.619	1.181
6	0.032	0.028	0.265	0.370	0.663	0.035	0.284	0.417	0.736	0.035	0.328	0.464	0.828
			0.133	0.246	0.379		0.142	0.278	0.420		0.164	0.310	0.474
				0.123	0.123			0.139	0.139			0.155	0.155

Road : B312, Cat. ID : 40/1 - 42/3													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	1.191	1.072			1.072	1.310			1.310	1.310			1.310
2	2.381	2.143	5.000		7.143	2.619	5.358		7.977	2.619	6.191		8.810
3	3.572	3.215	10.001	4.643	17.858	3.929	10.715	5.238	19.882	3.929	12.382	5.834	22.144
4	4.762	4.286	15.001	9.286	28.574	5.238	16.073	10.477	31.788	5.238	18.573	11.668	35.479
5	5.602	5.041	20.001	13.930	38.972	6.162	21.430	15.715	43.307	6.162	24.764	17.501	48.427
6	5.201	4.681	23.526	18.573	46.781	5.722	25.207	20.954	51.882	5.722	29.128	23.335	58.185
7	4.801	4.321	21.846	21.846	48.013	5.281	23.406	24.647	53.335	5.281	27.047	27.448	59.776
8	4.401	3.961	20.166	20.286	44.412	4.841	21.606	22.886	49.334	4.841	24.967	25.487	55.295
9	4.001	3.601	18.485	18.725	40.811	4.401	19.805	21.126	45.332	4.401	22.886	23.526	50.814
10	3.601	3.241	16.805	17.165	37.210	3.961	18.005	19.365	41.331	3.961	20.806	21.566	46.333
11	3.201	2.881	15.124	15.604	33.609	3.521	16.204	17.605	37.330	3.521	18.725	19.605	41.851
12	2.801	2.521	13.444	14.044	30.008	3.081	14.404	15.844	33.329	3.081	16.645	17.645	37.370
13	2.401	2.161	11.763	12.483	26.407	2.641	12.603	14.084	29.328	2.641	14.564	15.684	32.889
14	2.001	1.800	10.083	10.923	22.806	2.201	10.803	12.323	25.327	2.201	12.483	13.724	28.408
15	1.600	1.440	8.402	9.363	19.205	1.760	9.002	10.563	21.326	1.760	10.403	11.763	23.927
16	1.200	1.080	6.722	7.802	15.604	1.320	7.202	8.802	17.325	1.320	8.322	9.803	19.445
17	0.800	0.720	5.041	6.242	12.003	0.880	5.401	7.042	13.324	0.880	6.242	7.842	14.964
18	0.400	0.360	3.361	4.681	8.402	0.440	3.601	5.281	9.323	0.440	4.161	5.882	10.483
			1.680	3.121	4.801		1.800	3.521	5.321		2.081	3.921	6.002
				1.560	1.560			1.760	1.760			1.961	1.961

Road : B312, Cat. ID : 42/4 - 44/3													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.698	0.629			0.629	0.768			0.768	0.768			0.768
2	1.397	1.257	2.934		4.191	1.537	3.143		4.680	1.537	3.632		5.169
3	2.095	1.886	5.867	2.724	10.477	2.305	6.286	3.073	11.664	2.305	7.264	3.423	12.992
4	2.794	2.514	8.801	5.448	16.763	3.073	9.429	6.147	18.649	3.073	10.896	6.845	20.814
5	2.959	2.663	11.734	8.172	22.569	3.254	12.572	9.220	25.047	3.254	14.528	10.268	28.050
6	2.731	2.458	12.426	10.896	25.780	3.004	13.313	12.293	28.611	3.004	15.384	13.690	32.078
7	2.503	2.253	11.470	11.538	25.261	2.754	12.289	13.018	28.061	2.754	14.201	14.497	31.451
8	2.276	2.048	10.514	10.651	23.213	2.503	11.265	12.016	25.785	2.503	13.018	13.382	28.903

9	2.048	1.843	9.558	9.763	21.165	2.253	10.241	11.015	23.509	2.253	11.834	12.267	26.354
10	1.821	1.639	8.603	8.876	19.117	2.003	9.217	10.013	21.233	2.003	10.651	11.151	23.805
11	1.593	1.434	7.647	7.988	17.068	1.752	8.193	9.012	18.957	1.752	9.467	10.036	21.256
12	1.365	1.229	6.691	7.100	15.020	1.502	7.169	8.011	16.682	1.502	8.284	8.921	18.707
13	1.138	1.024	5.735	6.213	12.972	1.252	6.145	7.009	14.406	1.252	7.100	7.806	16.158
14	0.910	0.819	4.779	5.325	10.924	1.001	5.121	6.008	12.130	1.001	5.917	6.691	13.609
15	0.683	0.614	3.823	4.438	8.876	0.751	4.096	5.007	9.854	0.751	4.734	5.576	11.060
16	0.455	0.410	2.868	3.550	6.827	0.501	3.072	4.005	7.578	0.501	3.550	4.461	8.511
17	0.228	0.205	1.912	2.663	4.779	0.250	2.048	3.004	5.303	0.250	2.367	3.345	5.963
			0.956	1.775	2.731		1.024	2.003	3.027		1.183	2.230	3.414
				0.888	0.888			1.001				1.115	1.115

Road : B312, Cat. ID : 58/1-58/2

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.114	0.102			0.102	0.125			0.125	0.125			0.125
2	0.227	0.204	0.477		0.682	0.250	0.511		0.761	0.250	0.591		0.841
3	0.204	0.184	0.954	0.443	1.581	0.225	1.022	0.500	1.747	0.225	1.181	0.557	1.963
4	0.163	0.147	0.858	0.886	1.891	0.180	0.919	1.000	2.098	0.180	1.062	1.113	2.355
5	0.123	0.110	0.686	0.796	1.593	0.135	0.735	0.899	1.769	0.135	0.850	1.001	1.985
6	0.082	0.074	0.515	0.637	1.225	0.090	0.551	0.719	1.360	0.090	0.637	0.801	1.528
7	0.041	0.037	0.343	0.478	0.858	0.045	0.368	0.539	0.952	0.045	0.425	0.600	1.070
			0.172	0.319	0.490		0.184	0.359	0.543		0.212	0.400	0.613
				0.159	0.159			0.180	0.180			0.200	0.200

Road : B312, Cat. ID : 58/3-58/6A

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.307	0.276			0.276	0.338			0.338	0.338			0.338
2	0.614	0.553	1.290		1.842	0.675	1.382		2.057	0.675	1.597		2.272
3	0.921	0.829	2.579	1.197	4.606	1.013	2.763	1.351	5.128	1.013	3.193	1.504	5.711
4	0.833	0.750	3.869	2.395	7.014	0.917	4.145	2.702	7.764	0.917	4.790	3.009	8.715
5	0.729	0.656	3.500	3.592	7.748	0.802	3.750	4.053	8.605	0.802	4.333	4.513	9.649
6	0.625	0.562	3.062	3.250	6.875	0.687	3.281	3.666	7.635	0.687	3.791	4.083	8.562

7	0.521	0.469	2.625	2.844	5.937	0.573	2.812	3.208	6.593	0.573	3.250	3.573	7.395
8	0.417	0.375	2.187	2.437	5.000	0.458	2.344	2.750	5.552	0.458	2.708	3.062	6.229
9	0.312	0.281	1.750	2.031	4.062	0.344	1.875	2.292	4.510	0.344	2.167	2.552	5.062
10	0.208	0.187	1.312	1.625	3.125	0.229	1.406	1.833	3.469	0.229	1.625	2.042	3.896
11	0.104	0.094	0.875	1.219	2.187	0.115	0.937	1.375	2.427	0.115	1.083	1.531	2.729
			0.437	0.812	1.250		0.469	0.917	1.385		0.542	1.021	1.562
				0.406	0.406			0.458	0.458			0.510	0.510
Road : B312, Cat. ID : 58/7-59/1													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.116	0.104			0.104	0.127			0.127	0.127			0.127
2	0.232	0.208	0.486		0.695	0.255	0.521		0.776	0.255	0.602		0.857
3	0.244	0.219	0.973	0.452	1.644	0.268	1.042	0.510	1.820	0.268	1.205	0.568	2.040
4	0.203	0.183	1.024	0.903	2.110	0.223	1.097	1.019	2.340	0.223	1.268	1.135	2.626
5	0.163	0.146	0.853	0.951	1.950	0.179	0.914	1.073	2.165	0.179	1.056	1.194	2.430
6	0.122	0.110	0.683	0.792	1.584	0.134	0.731	0.894	1.759	0.134	0.845	0.995	1.975
7	0.081	0.073	0.512	0.634	1.219	0.089	0.548	0.715	1.353	0.089	0.634	0.796	1.519
8	0.041	0.037	0.341	0.475	0.853	0.045	0.366	0.536	0.947	0.045	0.423	0.597	1.064
			0.171	0.317	0.488		0.183	0.358	0.540		0.211	0.398	0.609
				0.158	0.158			0.179	0.179			0.199	0.199
Road : B312, Cat. ID : 59/2													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.479	0.431			0.431	0.527			0.527	0.527			0.527
2	0.959	0.863	2.013		2.876	1.055	2.157		3.212	1.055	2.493		3.547
3	1.438	1.294	4.027	1.869	7.190	1.582	4.314	2.109	8.005	1.582	4.985	2.349	8.916
4	1.917	1.726	6.040	3.739	11.504	2.109	6.471	4.218	12.799	2.109	7.478	4.698	14.285
5	2.397	2.157	8.053	5.608	15.819	2.636	8.628	6.327	17.592	2.636	9.970	7.046	19.653
6	2.629	2.366	10.066	7.478	19.910	2.892	10.785	8.437	22.114	2.892	12.463	9.395	24.750
7	2.465	2.218	11.042	9.347	22.608	2.711	11.831	10.546	25.088	2.711	13.671	11.744	28.127
8	2.300	2.070	10.352	10.254	22.676	2.531	11.092	11.568	25.190	2.531	12.817	12.883	28.230
9	2.136	1.923	9.662	9.613	21.197	2.350	10.352	10.845	23.547	2.350	11.962	12.077	26.390
10	1.972	1.775	8.972	8.972	19.718	2.169	9.613	10.122	21.904	2.169	11.108	11.272	24.549
11	1.808	1.627	8.282	8.331	18.239	1.988	8.873	9.399	20.261	1.988	10.254	10.467	22.709

12	1.643	1.479	7.592	7.690	16.761	1.808	8.134	8.676	18.617	1.808	9.399	9.662	20.869
13	1.479	1.331	6.901	7.049	15.282	1.627	7.394	7.953	16.974	1.627	8.545	8.857	19.028
14	1.315	1.183	6.211	6.408	13.803	1.446	6.655	7.230	15.331	1.446	7.690	8.052	17.188
15	1.150	1.035	5.521	5.768	12.324	1.265	5.916	6.507	13.688	1.265	6.836	7.246	15.347
16	0.986	0.887	4.831	5.127	10.845	1.085	5.176	5.784	12.045	1.085	5.981	6.441	13.507
17	0.822	0.739	4.141	4.486	9.366	0.904	4.437	5.061	10.401	0.904	5.127	5.636	11.667
18	0.657	0.592	3.451	3.845	7.887	0.723	3.697	4.338	8.758	0.723	4.272	4.831	9.826
19	0.493	0.444	2.761	3.204	6.408	0.542	2.958	3.615	7.115	0.542	3.418	4.026	7.986
20	0.329	0.296	2.070	2.563	4.930	0.362	2.218	2.892	5.472	0.362	2.563	3.221	6.146
21	0.164	0.148	1.380	1.923	3.451	0.181	1.479	2.169	3.829	0.181	1.709	2.415	4.305
			0.690	1.282	1.972		0.739	1.446	2.185		0.854	1.610	2.465
				0.641	0.641			0.723	0.723			0.805	0.805

Road : B312, Cat. ID : 59/3

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.9	4.2	3.9		1.1	4.5	4.4		1.1	5.2	4.9	
1	0.080	0.072			0.072	0.088			0.088	0.088			0.088
2	0.160	0.144	0.335		0.479	0.175	0.359		0.534	0.175	0.415		0.590
3	0.138	0.124	0.670	0.311	1.105	0.152	0.718	0.351	1.221	0.152	0.829	0.391	1.372
4	0.111	0.099	0.580	0.622	1.302	0.122	0.622	0.702	1.445	0.122	0.719	0.782	1.622
5	0.083	0.075	0.464	0.539	1.078	0.091	0.497	0.608	1.197	0.091	0.575	0.677	1.343
6	0.055	0.050	0.348	0.431	0.829	0.061	0.373	0.486	0.920	0.061	0.431	0.542	1.034
7	0.028	0.025	0.232	0.323	0.580	0.030	0.249	0.365	0.644	0.030	0.287	0.406	0.724
			0.116	0.216	0.332		0.124	0.243	0.368		0.144	0.271	0.415
				0.158	0.158			0.179	0.179			0.199	0.199

Road : A035, Cat. ID : 2/1-2/2									
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years	
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.8	7.7		9.0	8.7		10.0	10.0	
1	0.097	0.754		0.754	0.870		0.870	0.967		0.967
2	0.193	1.509	0.745	2.254	1.741	0.841	2.582	1.934	0.967	2.902
3	0.290	2.263	1.489	3.753	2.611	1.683	4.294	2.902	1.934	4.836
4	0.387	3.018	2.234	5.252	3.482	2.524	6.006	3.869	2.902	6.770
5	0.382	2.977	2.979	5.956	3.435	3.366	6.801	3.817	3.869	7.686
6	0.350	2.729	2.939	5.668	3.149	3.321	6.470	3.499	3.817	7.316
7	0.318	2.481	2.694	5.175	2.863	3.044	5.907	3.181	3.499	6.679
8	0.286	2.233	2.449	4.682	2.576	2.767	5.344	2.863	3.181	6.043
9	0.254	1.985	2.204	4.189	2.290	2.490	4.781	2.545	2.863	5.407
10	0.223	1.737	1.959	3.696	2.004	2.214	4.218	2.226	2.545	4.771
11	0.191	1.489	1.714	3.203	1.718	1.937	3.655	1.908	2.226	4.135
12	0.159	1.240	1.469	2.710	1.431	1.660	3.092	1.590	1.908	3.499
13	0.127	0.992	1.225	2.217	1.145	1.384	2.529	1.272	1.590	2.863
14	0.095	0.744	0.980	1.724	0.859	1.107	1.966	0.954	1.272	2.226
15	0.064	0.496	0.735	1.231	0.573	0.830	1.403	0.636	0.954	1.590
16	0.032	0.248	0.490	0.738	0.286	0.553	0.840	0.318	0.636	0.954
			0.245	0.245		0.277	0.277		0.318	0.318

Road : A035, Cat. ID : 2/3-2/4										
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.8	7.7		9.0	8.7		10.0	10.0	
1	0.063	0.490		0.490	0.565		0.565	0.628		0.628
2	0.126	0.980	0.483	1.463	1.130	0.546	1.676	1.256	0.628	1.884
3	0.188	1.469	0.967	2.436	1.695	1.093	2.788	1.884	1.256	3.139
4	0.251	1.959	1.450	3.409	2.260	1.639	3.899	2.512	1.884	4.395
5	0.247	1.924	1.934	3.858	2.220	2.185	4.405	2.467	2.512	4.978
6	0.226	1.764	1.899	3.663	2.035	2.146	4.181	2.261	2.467	4.728
7	0.206	1.603	1.741	3.345	1.850	1.967	3.817	2.056	2.261	4.317
8	0.185	1.443	1.583	3.026	1.665	1.788	3.453	1.850	2.056	3.906
9	0.164	1.283	1.425	2.707	1.480	1.610	3.090	1.645	1.850	3.495
10	0.144	1.122	1.266	2.389	1.295	1.431	2.726	1.439	1.645	3.083
11	0.123	0.962	1.108	2.070	1.110	1.252	2.362	1.233	1.439	2.672

Road : A035, Cat. ID : 2/1-2/2

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.8	7.7		9.0	8.7		10.0	10.0	
12	0.103	0.802	0.950	1.751	0.925	1.073	1.998	1.028	1.233	2.261
13	0.082	0.641	0.791	1.433	0.740	0.894	1.634	0.822	1.028	1.850
14	0.062	0.481	0.633	1.114	0.555	0.715	1.270	0.617	0.822	1.439
15	0.041	0.321	0.475	0.796	0.370	0.537	0.907	0.411	0.617	1.028
16	0.021	0.160	0.317	0.477	0.185	0.358	0.543	0.206	0.411	0.617
			0.158	0.158		0.179	0.179		0.206	0.206

Road : A035, Cat. ID : 4/2-5/1

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.8	7.7		9.0	8.7		10.0	10.0	
1	0.102	0.792		0.792	0.914		0.914	1.016		1.016
2	0.203	1.585	0.782	2.367	1.828	0.884	2.712	2.032	1.016	3.047
3	0.305	2.377	1.564	3.941	2.743	1.767	4.510	3.047	2.032	5.079
4	0.406	3.169	2.346	5.516	3.657	2.651	6.308	4.063	3.047	7.110
5	0.508	3.962	3.129	7.090	4.571	3.535	8.106	5.079	4.063	9.142
6	0.609	4.754	3.911	8.665	5.485	4.419	9.904	6.095	5.079	11.174
7	0.581	4.532	4.693	9.225	5.229	5.302	10.531	5.810	6.095	11.905
8	0.547	4.265	4.474	8.739	4.921	5.055	9.976	5.468	5.810	11.278
9	0.513	3.999	4.210	8.209	4.614	4.757	9.371	5.126	5.468	10.594
10	0.478	3.732	3.947	7.679	4.306	4.460	8.766	4.785	5.126	9.911
11	0.444	3.465	3.684	7.150	3.999	4.163	8.161	4.443	4.785	9.227
12	0.410	3.199	3.421	6.620	3.691	3.865	7.556	4.101	4.443	8.544
13	0.376	2.932	3.158	6.090	3.383	3.568	6.951	3.759	4.101	7.860
14	0.342	2.666	2.895	5.560	3.076	3.271	6.346	3.418	3.759	7.177
15	0.308	2.399	2.632	5.031	2.768	2.973	5.742	3.076	3.418	6.493
16	0.273	2.133	2.368	4.501	2.461	2.676	5.137	2.734	3.076	5.810
17	0.239	1.866	2.105	3.971	2.153	2.379	4.532	2.392	2.734	5.126
18	0.205	1.599	1.842	3.441	1.845	2.081	3.927	2.051	2.392	4.443
19	0.171	1.333	1.579	2.912	1.538	1.784	3.322	1.709	2.051	3.759
20	0.137	1.066	1.316	2.382	1.230	1.487	2.717	1.367	1.709	3.076
21	0.103	0.800	1.053	1.852	0.923	1.189	2.112	1.025	1.367	2.392
22	0.068	0.533	0.789	1.323	0.615	0.892	1.507	0.684	1.025	1.709

Road : A035, Cat. ID : 2/1-2/2										
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.8	7.7		9.0	8.7		10.0	10.0	
23	0.034	0.267	0.526	0.793	0.308	0.595	0.902	0.342	0.684	1.025
			0.263	0.263		0.297	0.297		0.342	0.342

Road : A035, Cat. ID : 16/1				
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years	Return Period-50 Years	Return Period-100 Years
		Excess Rainfall in cm	Excess Rainfall in cm	Excess Rainfall in cm
		7.7	9.0	10.0
1	0.081	0.627	0.733	0.814
2	0.123	0.945	1.105	1.227
3	0.092	0.709	0.829	0.921
4	0.061	0.473	0.552	0.614
5	0.031	0.236	0.276	0.307

Road : A035, Cat. ID : 30/2				
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years	Return Period-50 Years	Return Period-100 Years
		Excess Rainfall in cm	Excess Rainfall in cm	Excess Rainfall in cm
		7.7	9.0	10.0
1	0.047	0.362	0.423	0.470
2	0.094	0.725	0.847	0.941
3	0.141	1.087	1.270	1.411
4	0.126	0.967	1.130	1.255
5	0.110	0.846	0.988	1.098
6	0.094	0.725	0.847	0.941
7	0.078	0.604	0.706	0.785
8	0.063	0.483	0.565	0.628
9	0.047	0.362	0.424	0.471
10	0.031	0.242	0.282	0.314
11	0.016	0.121	0.141	0.157

Road : A035, Cat. ID : 21/1								
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years						
		Excess Rainfall in cm						DRH (m^3/s)
		0.2	0.8	7.8	7.7	0.6	0.1	
1	0.290	0.058						0.058
2	0.581	0.116	0.232					0.349
3	0.871	0.174	0.465	2.265				2.904
4	1.162	0.232	0.697	4.531	2.236			7.696
5	1.452	0.290	0.929	6.796	4.472	0.174		12.662
6	1.743	0.349	1.162	9.061	6.709	0.349	0.029	17.657
7	2.033	0.407	1.394	11.326	8.945	0.523	0.058	22.653
8	2.323	0.465	1.626	13.592	11.181	0.697	0.087	27.648
9	2.614	0.523	1.859	15.857	13.417	0.871	0.116	32.643
10	2.904	0.581	2.091	18.122	15.654	1.046	0.145	37.638
11	3.195	0.639	2.323	20.387	17.890	1.220	0.174	42.633
12	3.485	0.697	2.556	22.653	20.126	1.394	0.203	47.629
13	3.775	0.755	2.788	24.918	22.362	1.568	0.232	52.624
14	4.066	0.813	3.020	27.183	24.598	1.743	0.261	57.619
15	4.356	0.871	3.253	29.448	26.835	1.917	0.290	62.614
16	4.647	0.929	3.485	31.714	29.071	2.091	0.319	67.609
17	4.937	0.987	3.717	33.979	31.307	2.265	0.349	72.605
18	5.228	1.046	3.950	36.244	33.543	2.440	0.378	77.600
19	5.518	1.104	4.182	38.510	35.780	2.614	0.407	82.595
20	5.808	1.162	4.414	40.775	38.016	2.788	0.436	87.590
21	5.718	1.144	4.647	43.040	40.252	2.962	0.465	92.509
22	5.621	1.124	4.574	45.305	42.488	3.137	0.494	97.122
23	5.524	1.105	4.497	44.600	44.724	3.311	0.523	98.759
24	5.427	1.085	4.419	43.844	44.028	3.485	0.552	97.413
25	5.330	1.066	4.342	43.088	43.282	3.431	0.581	95.789
26	5.233	1.047	4.264	42.332	42.535	3.373	0.572	94.122
27	5.136	1.027	4.187	41.576	41.789	3.314	0.562	92.455
28	5.039	1.008	4.109	40.820	41.043	3.256	0.552	90.788
29	4.943	0.989	4.032	40.064	40.297	3.198	0.543	89.122
30	4.846	0.969	3.954	39.308	39.550	3.140	0.533	87.455
31	4.749	0.950	3.877	38.552	38.804	3.082	0.523	85.788
32	4.652	0.930	3.799	37.796	38.058	3.024	0.514	84.121
33	4.555	0.911	3.721	37.040	37.312	2.966	0.504	82.454
34	4.458	0.892	3.644	36.284	36.565	2.907	0.494	80.787
35	4.361	0.872	3.566	35.528	35.819	2.849	0.485	79.120
36	4.264	0.853	3.489	34.773	35.073	2.791	0.475	77.453
37	4.167	0.833	3.411	34.017	34.327	2.733	0.465	75.786
38	4.070	0.814	3.334	33.261	33.580	2.675	0.455	74.119
39	3.973	0.795	3.256	32.505	32.834	2.617	0.446	72.452
40	3.877	0.775	3.179	31.749	32.088	2.559	0.436	70.786
41	3.780	0.756	3.101	30.993	31.342	2.500	0.426	69.119
42	3.683	0.737	3.024	30.237	30.596	2.442	0.417	67.452
43	3.586	0.717	2.946	29.481	29.849	2.384	0.407	65.785
44	3.489	0.698	2.869	28.725	29.103	2.326	0.397	64.118
45	3.392	0.678	2.791	27.969	28.357	2.268	0.388	62.451
46	3.295	0.659	2.714	27.213	27.611	2.210	0.378	60.784
47	3.198	0.640	2.636	26.457	26.864	2.151	0.368	59.117
48	3.101	0.620	2.559	25.701	26.118	2.093	0.359	57.450
49	3.004	0.601	2.481	24.945	25.372	2.035	0.349	55.783
50	2.907	0.581	2.403	24.190	24.626	1.977	0.339	54.116
51	2.810	0.562	2.326	23.434	23.879	1.919	0.330	52.450
52	2.714	0.543	2.248	22.678	23.133	1.861	0.320	50.783
53	2.617	0.523	2.171	21.922	22.387	1.803	0.310	49.116

54	2.520	0.504	2.093	21.166	21.641	1.744	0.300	47.449
55	2.423	0.485	2.016	20.410	20.895	1.686	0.291	45.782
56	2.326	0.465	1.938	19.654	20.148	1.628	0.281	44.115
57	2.229	0.446	1.861	18.898	19.402	1.570	0.271	42.448
58	2.132	0.426	1.783	18.142	18.656	1.512	0.262	40.781
59	2.035	0.407	1.706	17.386	17.910	1.454	0.252	39.114
60	1.938	0.388	1.628	16.630	17.163	1.396	0.242	37.447
61	1.841	0.368	1.551	15.874	16.417	1.337	0.233	35.780
62	1.744	0.349	1.473	15.118	15.671	1.279	0.223	34.113
63	1.648	0.330	1.396	14.363	14.925	1.221	0.213	32.447
64	1.551	0.310	1.318	13.607	14.178	1.163	0.204	30.780
65	1.454	0.291	1.240	12.851	13.432	1.105	0.194	29.113
66	1.357	0.271	1.163	12.095	12.686	1.047	0.184	27.446
67	1.260	0.252	1.085	11.339	11.940	0.989	0.174	25.779
68	1.163	0.233	1.008	10.583	11.193	0.930	0.165	24.112
69	1.066	0.213	0.930	9.827	10.447	0.872	0.155	22.445
70	0.969	0.194	0.853	9.071	9.701	0.814	0.145	20.778
71	0.872	0.174	0.775	8.315	8.955	0.756	0.136	19.111
72	0.775	0.155	0.698	7.559	8.209	0.698	0.126	17.444
73	0.678	0.136	0.620	6.803	7.462	0.640	0.116	15.777
74	0.581	0.116	0.543	6.047	6.716	0.581	0.107	14.111
75	0.485	0.097	0.465	5.291	5.970	0.523	0.097	12.444
76	0.388	0.078	0.388	4.536	5.224	0.465	0.087	10.777
77	0.291	0.058	0.310	3.780	4.477	0.407	0.078	9.110
78	0.194	0.039	0.233	3.024	3.731	0.349	0.068	7.443
79	0.097	0.019	0.155	2.268	2.985	0.291	0.058	5.776
			0.078	1.512	2.239	0.233	0.048	4.109
				0.756	1.492	0.174	0.039	2.462
					0.746	0.116	0.029	0.892
						0.058	0.019	0.078
							0.010	0.010

Road : A035, Cat. ID : 21/1										
Time (hr)	UH (m^3/s/cm)	Return Period-50 Years								
		Excess Rainfall in cm								DRH (m^3/s)
		0.1	0.1	1.2	9.0	8.7	0.8	0.1	0.1	
1	0.290	0.029								0.029
2	0.581	0.058	0.029							0.087
3	0.871	0.087	0.058	0.349						0.494
4	1.162	0.116	0.087	0.697	2.614					3.514
5	1.452	0.145	0.116	1.046	5.228	2.527				9.061
6	1.743	0.174	0.145	1.394	7.841	5.053	0.232			14.840
7	2.033	0.203	0.174	1.743	10.455	7.580	0.465	0.029		20.649
8	2.323	0.232	0.203	2.091	13.069	10.107	0.697	0.058	0.029	26.486
9	2.614	0.261	0.232	2.440	15.683	12.633	0.929	0.087	0.058	32.324
10	2.904	0.290	0.261	2.788	18.296	15.160	1.162	0.116	0.087	38.161
11	3.195	0.319	0.290	3.137	20.910	17.687	1.394	0.145	0.116	43.998
12	3.485	0.349	0.319	3.485	23.524	20.213	1.626	0.174	0.145	49.836
13	3.775	0.378	0.349	3.834	26.138	22.740	1.859	0.203	0.174	55.673
14	4.066	0.407	0.378	4.182	28.751	25.266	2.091	0.232	0.203	61.511
15	4.356	0.436	0.407	4.531	31.365	27.793	2.323	0.261	0.232	67.348
16	4.647	0.465	0.436	4.879	33.979	30.320	2.556	0.290	0.261	73.186
17	4.937	0.494	0.465	5.228	36.593	32.846	2.788	0.319	0.290	79.023
18	5.228	0.523	0.494	5.576	39.207	35.373	3.020	0.349	0.319	84.860
19	5.518	0.552	0.523	5.925	41.820	37.900	3.253	0.378	0.349	90.698
20	5.808	0.581	0.552	6.273	44.434	40.426	3.485	0.407	0.378	96.535
21	5.718	0.572	0.581	6.622	47.048	42.953	3.717	0.436	0.407	102.335
22	5.621	0.562	0.572	6.970	49.662	45.480	3.950	0.465	0.436	108.095

23	5.524	0.552	0.562	6.861	52.275	48.006	4.182	0.494	0.465	113.398
24	5.427	0.543	0.552	6.745	51.461	50.533	4.414	0.523	0.494	115.265
25	5.330	0.533	0.543	6.629	50.589	49.746	4.647	0.552	0.523	113.760
26	5.233	0.523	0.533	6.513	49.717	48.902	4.574	0.581	0.552	111.895
27	5.136	0.514	0.523	6.396	48.844	48.059	4.497	0.572	0.581	109.986
28	5.039	0.504	0.514	6.280	47.972	47.216	4.419	0.562	0.572	108.039
29	4.943	0.494	0.504	6.164	47.100	46.373	4.342	0.552	0.562	106.091
30	4.846	0.485	0.494	6.047	46.228	45.530	4.264	0.543	0.552	104.143
31	4.749	0.475	0.485	5.931	45.355	44.687	4.187	0.533	0.543	102.195
32	4.652	0.465	0.475	5.815	44.483	43.844	4.109	0.523	0.533	100.247
33	4.555	0.455	0.465	5.699	43.611	43.000	4.032	0.514	0.523	98.299
34	4.458	0.446	0.455	5.582	42.739	42.157	3.954	0.504	0.514	96.351
35	4.361	0.436	0.446	5.466	41.867	41.314	3.877	0.494	0.504	94.403
36	4.264	0.426	0.436	5.350	40.994	40.471	3.799	0.485	0.494	92.455
37	4.167	0.417	0.426	5.233	40.122	39.628	3.721	0.475	0.485	90.507
38	4.070	0.407	0.417	5.117	39.250	38.785	3.644	0.465	0.475	88.559
39	3.973	0.397	0.407	5.001	38.378	37.942	3.566	0.455	0.465	86.611
40	3.877	0.388	0.397	4.884	37.505	37.098	3.489	0.446	0.455	84.664
41	3.780	0.378	0.388	4.768	36.633	36.255	3.411	0.436	0.446	82.716
42	3.683	0.368	0.378	4.652	35.761	35.412	3.334	0.426	0.436	80.768
43	3.586	0.359	0.368	4.536	34.889	34.569	3.256	0.417	0.426	78.820
44	3.489	0.349	0.359	4.419	34.017	33.726	3.179	0.407	0.417	76.872
45	3.392	0.339	0.349	4.303	33.144	32.883	3.101	0.397	0.407	74.924
46	3.295	0.330	0.339	4.187	32.272	32.040	3.024	0.388	0.397	72.976
47	3.198	0.320	0.330	4.070	31.400	31.196	2.946	0.378	0.388	71.028
48	3.101	0.310	0.320	3.954	30.528	30.353	2.869	0.368	0.378	69.080
49	3.004	0.300	0.310	3.838	29.655	29.510	2.791	0.359	0.368	67.132
50	2.907	0.291	0.300	3.721	28.783	28.667	2.714	0.349	0.359	65.184
51	2.810	0.281	0.291	3.605	27.911	27.824	2.636	0.339	0.349	63.236
52	2.714	0.271	0.281	3.489	27.039	26.981	2.559	0.330	0.339	61.288
53	2.617	0.262	0.271	3.373	26.167	26.138	2.481	0.320	0.330	59.340
54	2.520	0.252	0.262	3.256	25.294	25.294	2.403	0.310	0.320	57.392
55	2.423	0.242	0.252	3.140	24.422	24.451	2.326	0.300	0.310	55.444
56	2.326	0.233	0.242	3.024	23.550	23.608	2.248	0.291	0.300	53.496
57	2.229	0.223	0.233	2.907	22.678	22.765	2.171	0.281	0.291	51.548
58	2.132	0.213	0.223	2.791	21.806	21.922	2.093	0.271	0.281	49.600
59	2.035	0.204	0.213	2.675	20.933	21.079	2.016	0.262	0.271	47.652
60	1.938	0.194	0.204	2.559	20.061	20.236	1.938	0.252	0.262	45.704
61	1.841	0.184	0.194	2.442	19.189	19.392	1.861	0.242	0.252	43.756
62	1.744	0.174	0.184	2.326	18.317	18.549	1.783	0.233	0.242	41.808
63	1.648	0.165	0.174	2.210	17.444	17.706	1.706	0.223	0.233	39.860
64	1.551	0.155	0.165	2.093	16.572	16.863	1.628	0.213	0.223	37.913
65	1.454	0.145	0.155	1.977	15.700	16.020	1.551	0.204	0.213	35.965
66	1.357	0.136	0.145	1.861	14.828	15.177	1.473	0.194	0.204	34.017
67	1.260	0.126	0.136	1.744	13.956	14.333	1.396	0.184	0.194	32.069
68	1.163	0.116	0.126	1.628	13.083	13.490	1.318	0.174	0.184	30.121
69	1.066	0.107	0.116	1.512	12.211	12.647	1.240	0.165	0.174	28.173
70	0.969	0.097	0.107	1.396	11.339	11.804	1.163	0.155	0.165	26.225
71	0.872	0.087	0.097	1.279	10.467	10.961	1.085	0.145	0.155	24.277
72	0.775	0.078	0.087	1.163	9.594	10.118	1.008	0.136	0.145	22.329
73	0.678	0.068	0.078	1.047	8.722	9.275	0.930	0.126	0.136	20.381
74	0.581	0.058	0.068	0.930	7.850	8.431	0.853	0.116	0.126	18.433
75	0.485	0.048	0.058	0.814	6.978	7.588	0.775	0.107	0.116	16.485
76	0.388	0.039	0.048	0.698	6.106	6.745	0.698	0.097	0.107	14.537
77	0.291	0.029	0.039	0.581	5.233	5.902	0.620	0.087	0.097	12.589
78	0.194	0.019	0.029	0.465	4.361	5.059	0.543	0.078	0.087	10.641
79	0.097	0.010	0.019	0.349	3.489	4.216	0.465	0.068	0.078	8.693

			0.010	0.233	2.617	3.373	0.388	0.058	0.068	6.745
				0.116	1.744	2.529	0.310	0.048	0.058	4.807
					0.872	1.686	0.233	0.039	0.048	2.878
						0.843	0.155	0.029	0.039	1.066
							0.078	0.019	0.029	0.126
								0.010	0.019	0.029
									0.010	0.010
Road : A035, Cat. ID : 21/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-100 Years								
		Excess Rainfall in cm								DRH (m^3/s)
		0.1	0.1	1.4	10.0	10.0	1.1	0.1	0.1	
1	0.290	0.029								0.029
2	0.581	0.058	0.029							0.087
3	0.871	0.087	0.058	0.407						0.552
4	1.162	0.116	0.087	0.813	2.904					3.921
5	1.452	0.145	0.116	1.220	5.808	2.904				10.194
6	1.743	0.174	0.145	1.626	8.713	5.808	0.319			16.786
7	2.033	0.203	0.174	2.033	11.617	8.713	0.639	0.029		23.408
8	2.323	0.232	0.203	2.440	14.521	11.617	0.958	0.058	0.029	30.058
9	2.614	0.261	0.232	2.846	17.425	14.521	1.278	0.087	0.058	36.709
10	2.904	0.290	0.261	3.253	20.329	17.425	1.597	0.116	0.087	43.360
11	3.195	0.319	0.290	3.659	23.234	20.329	1.917	0.145	0.116	50.010
12	3.485	0.349	0.319	4.066	26.138	23.234	2.236	0.174	0.145	56.661
13	3.775	0.378	0.349	4.472	29.042	26.138	2.556	0.203	0.174	63.311
14	4.066	0.407	0.378	4.879	31.946	29.042	2.875	0.232	0.203	69.962
15	4.356	0.436	0.407	5.286	34.850	31.946	3.195	0.261	0.232	76.612
16	4.647	0.465	0.436	5.692	37.754	34.850	3.514	0.290	0.261	83.263
17	4.937	0.494	0.465	6.099	40.659	37.754	3.834	0.319	0.290	89.914
18	5.228	0.523	0.494	6.505	43.563	40.659	4.153	0.349	0.319	96.564
19	5.518	0.552	0.523	6.912	46.467	43.563	4.472	0.378	0.349	103.215
20	5.808	0.581	0.552	7.319	49.371	46.467	4.792	0.407	0.378	109.865
21	5.718	0.572	0.581	7.725	52.275	49.371	5.111	0.436	0.407	116.478
22	5.621	0.562	0.572	8.132	55.180	52.275	5.431	0.465	0.436	123.052
23	5.524	0.552	0.562	8.005	58.084	55.180	5.750	0.494	0.465	129.092
24	5.427	0.543	0.552	7.869	57.179	58.084	6.070	0.523	0.494	131.313
25	5.330	0.533	0.543	7.734	56.210	57.179	6.389	0.552	0.523	129.662
26	5.233	0.523	0.533	7.598	55.241	56.210	6.290	0.581	0.552	127.527
27	5.136	0.514	0.523	7.462	54.271	55.241	6.183	0.572	0.581	125.347
28	5.039	0.504	0.514	7.327	53.302	54.271	6.076	0.562	0.572	123.128
29	4.943	0.494	0.504	7.191	52.333	53.302	5.970	0.552	0.562	120.909
30	4.846	0.485	0.494	7.055	51.364	52.333	5.863	0.543	0.552	118.690
31	4.749	0.475	0.485	6.920	50.395	51.364	5.757	0.533	0.543	116.470
32	4.652	0.465	0.475	6.784	49.426	50.395	5.650	0.523	0.533	114.251
33	4.555	0.455	0.465	6.648	48.457	49.426	5.543	0.514	0.523	112.032
34	4.458	0.446	0.455	6.513	47.488	48.457	5.437	0.504	0.514	109.813
35	4.361	0.436	0.446	6.377	46.518	47.488	5.330	0.494	0.504	107.593
36	4.264	0.426	0.436	6.241	45.549	46.518	5.224	0.485	0.494	105.374
37	4.167	0.417	0.426	6.106	44.580	45.549	5.117	0.475	0.485	103.155
38	4.070	0.407	0.417	5.970	43.611	44.580	5.010	0.465	0.475	100.935
39	3.973	0.397	0.407	5.834	42.642	43.611	4.904	0.455	0.465	98.716
40	3.877	0.388	0.397	5.699	41.673	42.642	4.797	0.446	0.455	96.497
41	3.780	0.378	0.388	5.563	40.704	41.673	4.691	0.436	0.446	94.277
42	3.683	0.368	0.378	5.427	39.734	40.704	4.584	0.426	0.436	92.058
43	3.586	0.359	0.368	5.291	38.765	39.734	4.477	0.417	0.426	89.839
44	3.489	0.349	0.359	5.156	37.796	38.765	4.371	0.407	0.417	87.619
45	3.392	0.339	0.349	5.020	36.827	37.796	4.264	0.397	0.407	85.400
46	3.295	0.330	0.339	4.884	35.858	36.827	4.158	0.388	0.397	83.181

47	3.198	0.320	0.330	4.749	34.889	35.858	4.051	0.378	0.388	80.961
48	3.101	0.310	0.320	4.613	33.920	34.889	3.944	0.368	0.378	78.742
49	3.004	0.300	0.310	4.477	32.951	33.920	3.838	0.359	0.368	76.523
50	2.907	0.291	0.300	4.342	31.981	32.951	3.731	0.349	0.359	74.303
51	2.810	0.281	0.291	4.206	31.012	31.981	3.625	0.339	0.349	72.084
52	2.714	0.271	0.281	4.070	30.043	31.012	3.518	0.330	0.339	69.865
53	2.617	0.262	0.271	3.935	29.074	30.043	3.411	0.320	0.330	67.646
54	2.520	0.252	0.262	3.799	28.105	29.074	3.305	0.310	0.320	65.426
55	2.423	0.242	0.252	3.663	27.136	28.105	3.198	0.300	0.310	63.207
56	2.326	0.233	0.242	3.528	26.167	27.136	3.092	0.291	0.300	60.988
57	2.229	0.223	0.233	3.392	25.197	26.167	2.985	0.281	0.291	58.768
58	2.132	0.213	0.223	3.256	24.228	25.197	2.878	0.271	0.281	56.549
59	2.035	0.204	0.213	3.121	23.259	24.228	2.772	0.262	0.271	54.330
60	1.938	0.194	0.204	2.985	22.290	23.259	2.665	0.252	0.262	52.110
61	1.841	0.184	0.194	2.849	21.321	22.290	2.559	0.242	0.252	49.891
62	1.744	0.174	0.184	2.714	20.352	21.321	2.452	0.233	0.242	47.672
63	1.648	0.165	0.174	2.578	19.383	20.352	2.345	0.223	0.233	45.452
64	1.551	0.155	0.165	2.442	18.414	19.383	2.239	0.213	0.223	43.233
65	1.454	0.145	0.155	2.307	17.444	18.414	2.132	0.204	0.213	41.014
66	1.357	0.136	0.145	2.171	16.475	17.444	2.025	0.194	0.204	38.794
67	1.260	0.126	0.136	2.035	15.506	16.475	1.919	0.184	0.194	36.575
68	1.163	0.116	0.126	1.900	14.537	15.506	1.812	0.174	0.184	34.356
69	1.066	0.107	0.116	1.764	13.568	14.537	1.706	0.165	0.174	32.136
70	0.969	0.097	0.107	1.628	12.599	13.568	1.599	0.155	0.165	29.917
71	0.872	0.087	0.097	1.492	11.630	12.599	1.492	0.145	0.155	27.698
72	0.775	0.078	0.087	1.357	10.660	11.630	1.386	0.136	0.145	25.479
73	0.678	0.068	0.078	1.221	9.691	10.660	1.279	0.126	0.136	23.259
74	0.581	0.058	0.068	1.085	8.722	9.691	1.173	0.116	0.126	21.040
75	0.485	0.048	0.058	0.950	7.753	8.722	1.066	0.107	0.116	18.821
76	0.388	0.039	0.048	0.814	6.784	7.753	0.959	0.097	0.107	16.601
77	0.291	0.029	0.039	0.678	5.815	6.784	0.853	0.087	0.097	14.382
78	0.194	0.019	0.029	0.543	4.846	5.815	0.746	0.078	0.087	12.163
79	0.097	0.010	0.019	0.407	3.877	4.846	0.640	0.068	0.078	9.943
			0.010	0.271	2.907	3.877	0.533	0.058	0.068	7.724
				0.136	1.938	2.907	0.426	0.048	0.058	5.514
					0.969	1.938	0.320	0.039	0.048	3.314
						0.969	0.213	0.029	0.039	1.250
							0.107	0.019	0.029	0.155
								0.010	0.019	0.029
									0.010	0.010

Road : A035, Cat. ID : 22/1-22/2

Time (hr)	UH (m^3/s/cm)	Return Period-25 Years						
		Excess Rainfall in cm						DRH (m^3/s)
		0.2	0.8	7.8	7.7	0.6	0.1	
1	0.123	0.025						0.025
2	0.246	0.049	0.099					0.148
3	0.370	0.074	0.197	0.961				1.232
4	0.493	0.099	0.296	1.923	0.949			3.266
5	0.616	0.123	0.394	2.884	1.898	0.074		5.373
6	0.739	0.148	0.493	3.845	2.847	0.148	0.012	7.493
7	0.863	0.173	0.592	4.806	3.796	0.222	0.025	9.613
8	0.986	0.197	0.690	5.768	4.745	0.296	0.037	11.732
9	1.109	0.222	0.789	6.729	5.694	0.370	0.049	13.852
10	1.232	0.246	0.887	7.690	6.643	0.444	0.062	15.972
11	1.248	0.250	0.986	8.651	7.591	0.518	0.074	18.070
12	1.206	0.241	0.998	9.613	8.540	0.592	0.086	20.070
13	1.165	0.233	0.965	9.734	9.489	0.665	0.099	21.185

14	1.123	0.225	0.932	9.410	9.609	0.739	0.111	21.026
15	1.082	0.216	0.899	9.085	9.289	0.749	0.123	20.361
16	1.040	0.208	0.865	8.761	8.969	0.724	0.125	19.651
17	0.998	0.200	0.832	8.436	8.648	0.699	0.121	18.936
18	0.957	0.191	0.799	8.112	8.328	0.674	0.116	18.220
19	0.915	0.183	0.765	7.787	8.008	0.649	0.112	17.505
20	0.874	0.175	0.732	7.463	7.687	0.624	0.108	16.789
21	0.832	0.166	0.699	7.138	7.367	0.599	0.104	16.074
22	0.790	0.158	0.666	6.814	7.047	0.574	0.100	15.358
23	0.749	0.150	0.632	6.489	6.726	0.549	0.096	14.643
24	0.707	0.141	0.599	6.165	6.406	0.524	0.092	13.927
25	0.666	0.133	0.566	5.840	6.086	0.499	0.087	13.212
26	0.624	0.125	0.532	5.516	5.766	0.474	0.083	12.496
27	0.582	0.116	0.499	5.191	5.445	0.449	0.079	11.781
28	0.541	0.108	0.466	4.867	5.125	0.424	0.075	11.065
29	0.499	0.100	0.433	4.543	4.805	0.399	0.071	10.350
30	0.458	0.092	0.399	4.218	4.484	0.374	0.067	9.634
31	0.416	0.083	0.366	3.894	4.164	0.349	0.062	8.919
32	0.374	0.075	0.333	3.569	3.844	0.324	0.058	8.203
33	0.333	0.067	0.300	3.245	3.523	0.300	0.054	7.488
34	0.291	0.058	0.266	2.920	3.203	0.275	0.050	6.772
35	0.250	0.050	0.233	2.596	2.883	0.250	0.046	6.057
36	0.208	0.042	0.200	2.271	2.562	0.225	0.042	5.341
37	0.166	0.033	0.166	1.947	2.242	0.200	0.037	4.626
38	0.125	0.025	0.133	1.622	1.922	0.175	0.033	3.910
39	0.083	0.017	0.100	1.298	1.602	0.150	0.029	3.195
40	0.042	0.008	0.067	0.973	1.281	0.125	0.025	2.479
			0.033	0.649	0.961	0.100	0.021	1.764
				0.324	0.641	0.075	0.017	1.057
					0.320	0.050	0.012	0.383
						0.025	0.008	0.033
							0.004	0.004

Road : A035, Cat. ID : 22/1-22/2										
Time (hr)	UH (m^3/s/cm)	Return Period-50 Years								
		Excess Rainfall in cm								DRH (m^3/s)
		0.1	0.1	1.2	9.0	8.7	0.8	0.1	0.1	
1	0.123	0.012								0.012
2	0.246	0.025	0.012							0.037
3	0.370	0.037	0.025	0.148						0.210
4	0.493	0.049	0.037	0.296	1.109					1.491
5	0.616	0.062	0.049	0.444	2.218	1.072				3.845
6	0.739	0.074	0.062	0.592	3.327	2.144	0.099			6.297
7	0.863	0.086	0.074	0.739	4.437	3.217	0.197	0.012		8.762
8	0.986	0.099	0.086	0.887	5.546	4.289	0.296	0.025	0.012	11.239
9	1.109	0.111	0.099	1.035	6.655	5.361	0.394	0.037	0.025	13.716
10	1.232	0.123	0.111	1.183	7.764	6.433	0.493	0.049	0.037	16.193
11	1.248	0.125	0.123	1.331	8.873	7.505	0.592	0.062	0.049	18.660
12	1.206	0.121	0.125	1.479	9.982	8.577	0.690	0.074	0.062	21.110
13	1.165	0.116	0.121	1.498	11.091	9.650	0.789	0.086	0.074	23.425
14	1.123	0.112	0.116	1.448	11.232	10.722	0.887	0.099	0.086	24.702
15	1.082	0.108	0.112	1.398	10.857	10.857	0.986	0.111	0.099	24.528
16	1.040	0.104	0.108	1.348	10.483	10.495	0.998	0.123	0.111	23.770
17	0.998	0.100	0.104	1.298	10.108	10.133	0.965	0.125	0.123	22.957
18	0.957	0.096	0.100	1.248	9.734	9.771	0.932	0.121	0.125	22.126
19	0.915	0.092	0.096	1.198	9.360	9.410	0.899	0.116	0.121	21.290
20	0.874	0.087	0.092	1.148	8.985	9.048	0.865	0.112	0.116	20.454
21	0.832	0.083	0.087	1.098	8.611	8.686	0.832	0.108	0.112	19.618

22	0.790	0.079	0.083	1.048	8.236	8.324	0.799	0.104	0.108	18.782
23	0.749	0.075	0.079	0.998	7.862	7.962	0.765	0.100	0.104	17.946
24	0.707	0.071	0.075	0.948	7.488	7.600	0.732	0.096	0.100	17.109
25	0.666	0.067	0.071	0.899	7.113	7.238	0.699	0.092	0.096	16.273
26	0.624	0.062	0.067	0.849	6.739	6.876	0.666	0.087	0.092	15.437
27	0.582	0.058	0.062	0.799	6.365	6.514	0.632	0.083	0.087	14.601
28	0.541	0.054	0.058	0.749	5.990	6.152	0.599	0.079	0.083	13.765
29	0.499	0.050	0.054	0.699	5.616	5.790	0.566	0.075	0.079	12.929
30	0.458	0.046	0.050	0.649	5.241	5.429	0.532	0.071	0.075	12.093
31	0.416	0.042	0.046	0.599	4.867	5.067	0.499	0.067	0.071	11.257
32	0.374	0.037	0.042	0.549	4.493	4.705	0.466	0.062	0.067	10.420
33	0.333	0.033	0.037	0.499	4.118	4.343	0.433	0.058	0.062	9.584
34	0.291	0.029	0.033	0.449	3.744	3.981	0.399	0.054	0.058	8.748
35	0.250	0.025	0.029	0.399	3.369	3.619	0.366	0.050	0.054	7.912
36	0.208	0.021	0.025	0.349	2.995	3.257	0.333	0.046	0.050	7.076
37	0.166	0.017	0.021	0.300	2.621	2.895	0.300	0.042	0.046	6.240
38	0.125	0.012	0.017	0.250	2.246	2.533	0.266	0.037	0.042	5.404
39	0.083	0.008	0.012	0.200	1.872	2.171	0.233	0.033	0.037	4.567
40	0.042	0.004	0.008	0.150	1.498	1.810	0.200	0.029	0.033	3.731
			0.004	0.100	1.123	1.448	0.166	0.025	0.029	2.895
				0.050	0.749	1.086	0.133	0.021	0.025	2.063
					0.374	0.724	0.100	0.017	0.021	1.235
						0.362	0.067	0.012	0.017	0.458
							0.033	0.008	0.012	0.054
								0.004	0.008	0.012
Road : A035, Cat. ID : 22/1-22/2										
Time (hr)	UH ($m^3/s/cm$)	Return Period-100 Years								
		Excess Rainfall in cm								DRH (m^3/s)
		0.1	0.1	1.4	10.0	10.0	1.1	0.1	0.1	
1	0.123	0.012								0.012
2	0.246	0.025	0.012							0.037
3	0.370	0.037	0.025	0.173						0.234
4	0.493	0.049	0.037	0.345	1.232					1.664
5	0.616	0.062	0.049	0.518	2.465	1.232				4.326
6	0.739	0.074	0.062	0.690	3.697	2.465	0.136			7.123
7	0.863	0.086	0.074	0.863	4.930	3.697	0.271	0.012		9.933
8	0.986	0.099	0.086	1.035	6.162	4.930	0.407	0.025	0.012	12.755
9	1.109	0.111	0.099	1.208	7.394	6.162	0.542	0.037	0.025	15.577
10	1.232	0.123	0.111	1.380	8.627	7.394	0.678	0.049	0.037	18.399
11	1.248	0.125	0.123	1.553	9.859	8.627	0.813	0.062	0.049	21.211
12	1.206	0.121	0.125	1.725	11.091	9.859	0.949	0.074	0.062	24.006
13	1.165	0.116	0.121	1.747	12.324	11.091	1.084	0.086	0.074	26.644
14	1.123	0.112	0.116	1.689	12.480	12.324	1.220	0.099	0.086	28.126
15	1.082	0.108	0.112	1.631	12.064	12.480	1.356	0.111	0.099	27.959
16	1.040	0.104	0.108	1.572	11.648	12.064	1.373	0.123	0.111	27.103
17	0.998	0.100	0.104	1.514	11.232	11.648	1.327	0.125	0.123	26.172
18	0.957	0.096	0.100	1.456	10.816	11.232	1.281	0.121	0.125	25.225
19	0.915	0.092	0.096	1.398	10.400	10.816	1.235	0.116	0.121	24.273
20	0.874	0.087	0.092	1.339	9.984	10.400	1.190	0.112	0.116	23.320
21	0.832	0.083	0.087	1.281	9.568	9.984	1.144	0.108	0.112	22.367
22	0.790	0.079	0.083	1.223	9.152	9.568	1.098	0.104	0.108	21.415
23	0.749	0.075	0.079	1.165	8.736	9.152	1.052	0.100	0.104	20.462
24	0.707	0.071	0.075	1.107	8.320	8.736	1.007	0.096	0.100	19.510
25	0.666	0.067	0.071	1.048	7.904	8.320	0.961	0.092	0.096	18.557
26	0.624	0.062	0.067	0.990	7.488	7.904	0.915	0.087	0.092	17.604
27	0.582	0.058	0.062	0.932	7.072	7.488	0.869	0.083	0.087	16.652
28	0.541	0.054	0.058	0.874	6.656	7.072	0.824	0.079	0.083	15.699

29	0.499	0.050	0.054	0.815	6.240	6.656	0.778	0.075	0.079	14.747
30	0.458	0.046	0.050	0.757	5.824	6.240	0.732	0.071	0.075	13.794
31	0.416	0.042	0.046	0.699	5.408	5.824	0.686	0.067	0.071	12.841
32	0.374	0.037	0.042	0.641	4.992	5.408	0.641	0.062	0.067	11.889
33	0.333	0.033	0.037	0.582	4.576	4.992	0.595	0.058	0.062	10.936
34	0.291	0.029	0.033	0.524	4.160	4.576	0.549	0.054	0.058	9.984
35	0.250	0.025	0.029	0.466	3.744	4.160	0.503	0.050	0.054	9.031
36	0.208	0.021	0.025	0.408	3.328	3.744	0.458	0.046	0.050	8.078
37	0.166	0.017	0.021	0.349	2.912	3.328	0.412	0.042	0.046	7.126
38	0.125	0.012	0.017	0.291	2.496	2.912	0.366	0.037	0.042	6.173
39	0.083	0.008	0.012	0.233	2.080	2.496	0.320	0.033	0.037	5.221
40	0.042	0.004	0.008	0.175	1.664	2.080	0.275	0.029	0.033	4.268
			0.004	0.116	1.248	1.664	0.229	0.025	0.029	3.315
				0.058	0.832	1.248	0.183	0.021	0.025	2.367
					0.416	0.832	0.137	0.017	0.021	1.423
						0.416	0.092	0.012	0.017	0.537
							0.046	0.008	0.012	0.067
								0.004	0.008	0.012

Road : A035, Cat. ID : 24/1-26/1

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years						
		Excess Rainfall in cm						DRH (m^3/s)
		0.2	0.8	7.8	7.7	0.6	0.1	
1	0.361	0.072						0.072
2	0.722	0.144	0.289					0.433
3	1.084	0.217	0.578	2.817				3.612
4	1.445	0.289	0.867	5.635	2.781			9.571
5	1.806	0.361	1.156	8.452	5.562	0.217		15.748
6	2.167	0.433	1.445	11.269	8.343	0.433	0.036	21.960
7	2.528	0.506	1.734	14.086	11.125	0.650	0.072	28.173
8	2.890	0.578	2.023	16.904	13.906	0.867	0.108	34.385
9	3.251	0.650	2.312	19.721	16.687	1.084	0.144	40.597
10	3.612	0.722	2.601	22.538	19.468	1.300	0.181	46.810
11	3.973	0.795	2.890	25.355	22.249	1.517	0.217	53.022
12	4.334	0.867	3.178	28.173	25.030	1.734	0.253	59.235
13	4.695	0.939	3.467	30.990	27.811	1.950	0.289	65.447
14	5.057	1.011	3.756	33.807	30.593	2.167	0.325	71.660
15	5.418	1.084	4.045	36.624	33.374	2.384	0.361	77.872
16	5.779	1.156	4.334	39.442	36.155	2.601	0.397	84.084
17	6.140	1.228	4.623	42.259	38.936	2.817	0.433	90.297
18	6.501	1.300	4.912	45.076	41.717	3.034	0.470	96.509
19	6.863	1.373	5.201	47.893	44.498	3.251	0.506	102.722
20	7.224	1.445	5.490	50.711	47.279	3.467	0.542	108.934
21	7.585	1.517	5.779	53.528	50.061	3.684	0.578	115.147
22	7.523	1.505	6.068	56.345	52.842	3.901	0.614	121.274
23	7.401	1.480	6.018	59.163	55.623	4.118	0.650	127.051
24	7.280	1.456	5.921	58.676	58.404	4.334	0.686	129.477
25	7.159	1.432	5.824	57.729	57.924	4.551	0.722	128.182
26	7.037	1.407	5.727	56.783	56.989	4.514	0.758	126.179
27	6.916	1.383	5.630	55.837	56.055	4.441	0.752	124.098
28	6.795	1.359	5.533	54.890	55.121	4.368	0.740	122.011
29	6.673	1.335	5.436	53.944	54.187	4.295	0.728	119.924
30	6.552	1.310	5.339	52.998	53.252	4.222	0.716	117.837
31	6.431	1.286	5.242	52.051	52.318	4.150	0.704	115.750
32	6.309	1.262	5.144	51.105	51.384	4.077	0.692	113.663
33	6.188	1.238	5.047	50.158	50.450	4.004	0.679	111.576
34	6.067	1.213	4.950	49.212	49.515	3.931	0.667	109.489
35	5.945	1.189	4.853	48.266	48.581	3.858	0.655	107.402

36	5.824	1.165	4.756	47.319	47.647	3.786	0.643	105.316
37	5.703	1.141	4.659	46.373	46.713	3.713	0.631	103.229
38	5.581	1.116	4.562	45.426	45.778	3.640	0.619	101.142
39	5.460	1.092	4.465	44.480	44.844	3.567	0.607	99.055
40	5.339	1.068	4.368	43.534	43.910	3.494	0.595	96.968
41	5.217	1.043	4.271	42.587	42.976	3.422	0.582	94.881
42	5.096	1.019	4.174	41.641	42.041	3.349	0.570	92.794
43	4.975	0.995	4.077	40.695	41.107	3.276	0.558	90.707
44	4.853	0.971	3.980	39.748	40.173	3.203	0.546	88.620
45	4.732	0.946	3.883	38.802	39.239	3.130	0.534	86.533
46	4.611	0.922	3.786	37.855	38.304	3.058	0.522	84.447
47	4.489	0.898	3.688	36.909	37.370	2.985	0.510	82.360
48	4.368	0.874	3.591	35.963	36.436	2.912	0.497	80.273
49	4.247	0.849	3.494	35.016	35.502	2.839	0.485	78.186
50	4.125	0.825	3.397	34.070	34.567	2.766	0.473	76.099
51	4.004	0.801	3.300	33.123	33.633	2.694	0.461	74.012
52	3.883	0.777	3.203	32.177	32.699	2.621	0.449	71.925
53	3.761	0.752	3.106	31.231	31.765	2.548	0.437	69.838
54	3.640	0.728	3.009	30.284	30.830	2.475	0.425	67.751
55	3.519	0.704	2.912	29.338	29.896	2.402	0.413	65.664
56	3.397	0.679	2.815	28.392	28.962	2.330	0.400	63.578
57	3.276	0.655	2.718	27.445	28.028	2.257	0.388	61.491
58	3.155	0.631	2.621	26.499	27.093	2.184	0.376	59.404
59	3.033	0.607	2.524	25.552	26.159	2.111	0.364	57.317
60	2.912	0.582	2.427	24.606	25.225	2.038	0.352	55.230
61	2.791	0.558	2.330	23.660	24.291	1.966	0.340	53.143
62	2.669	0.534	2.232	22.713	23.356	1.893	0.328	51.056
63	2.548	0.510	2.135	21.767	22.422	1.820	0.315	48.969
64	2.427	0.485	2.038	20.820	21.488	1.747	0.303	46.882
65	2.305	0.461	1.941	19.874	20.554	1.674	0.291	44.796
66	2.184	0.437	1.844	18.928	19.619	1.602	0.279	42.709
67	2.063	0.413	1.747	17.981	18.685	1.529	0.267	40.622
68	1.941	0.388	1.650	17.035	17.751	1.456	0.255	38.535
69	1.820	0.364	1.553	16.089	16.817	1.383	0.243	36.448
70	1.699	0.340	1.456	15.142	15.882	1.310	0.231	34.361
71	1.577	0.315	1.359	14.196	14.948	1.238	0.218	32.274
72	1.456	0.291	1.262	13.249	14.014	1.165	0.206	30.187
73	1.335	0.267	1.165	12.303	13.080	1.092	0.194	28.100
74	1.213	0.243	1.068	11.357	12.145	1.019	0.182	26.013
75	1.092	0.218	0.971	10.410	11.211	0.946	0.170	23.927
76	0.971	0.194	0.874	9.464	10.277	0.874	0.158	21.840
77	0.849	0.170	0.777	8.517	9.343	0.801	0.146	19.753
78	0.728	0.146	0.679	7.571	8.408	0.728	0.133	17.666
79	0.607	0.121	0.582	6.625	7.474	0.655	0.121	15.579
80	0.485	0.097	0.485	5.678	6.540	0.582	0.109	13.492
81	0.364	0.073	0.388	4.732	5.606	0.510	0.097	11.405
82	0.243	0.049	0.291	3.786	4.671	0.437	0.085	9.318
83	0.121	0.024	0.194	2.839	3.737	0.364	0.073	7.231
			0.097	1.893	2.803	0.291	0.061	5.144
				0.946	1.869	0.218	0.049	3.082
					0.934	0.146	0.036	1.116
						0.073	0.024	0.097
							0.012	0.012

Road : A035, Cat. ID : 24/1-26/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-50 Years								
		Excess Rainfall in cm								DRH (m^3/s)
		0.1	0.1	1.2	9.0	8.7	0.8	0.1	0.1	
1	0.361	0.036								0.036
2	0.722	0.072	0.036							0.108
3	1.084	0.108	0.072	0.433						0.614
4	1.445	0.144	0.108	0.867	3.251					4.370
5	1.806	0.181	0.144	1.300	6.501	3.142				11.269
6	2.167	0.217	0.181	1.734	9.752	6.285	0.289			18.457
7	2.528	0.253	0.217	2.167	13.003	9.427	0.578	0.036		25.680
8	2.890	0.289	0.253	2.601	16.253	12.569	0.867	0.072	0.036	32.940
9	3.251	0.325	0.289	3.034	19.504	15.712	1.156	0.108	0.072	40.200
10	3.612	0.361	0.325	3.467	22.755	18.854	1.445	0.144	0.108	47.460
11	3.973	0.397	0.361	3.901	26.006	21.996	1.734	0.181	0.144	54.720
12	4.334	0.433	0.397	4.334	29.256	25.139	2.023	0.217	0.181	61.980
13	4.695	0.470	0.433	4.768	32.507	28.281	2.312	0.253	0.217	69.240
14	5.057	0.506	0.470	5.201	35.758	31.423	2.601	0.289	0.253	76.500
15	5.418	0.542	0.506	5.635	39.008	34.566	2.890	0.325	0.289	83.759
16	5.779	0.578	0.542	6.068	42.259	37.708	3.178	0.361	0.325	91.019
17	6.140	0.614	0.578	6.501	45.510	40.850	3.467	0.397	0.361	98.279
18	6.501	0.650	0.614	6.935	48.760	43.993	3.756	0.433	0.397	105.539
19	6.863	0.686	0.650	7.368	52.011	47.135	4.045	0.470	0.433	112.799
20	7.224	0.722	0.686	7.802	55.262	50.277	4.334	0.506	0.470	120.059
21	7.585	0.758	0.722	8.235	58.512	53.420	4.623	0.542	0.506	127.319
22	7.523	0.752	0.758	8.669	61.763	56.562	4.912	0.578	0.542	134.536
23	7.401	0.740	0.752	9.102	65.014	59.704	5.201	0.614	0.578	141.705
24	7.280	0.728	0.740	9.027	68.264	62.847	5.490	0.650	0.614	148.360
25	7.159	0.716	0.728	8.881	67.703	65.989	5.779	0.686	0.650	151.133
26	7.037	0.704	0.716	8.736	66.611	65.446	6.068	0.722	0.686	149.689
27	6.916	0.692	0.704	8.590	65.519	64.391	6.018	0.758	0.722	147.394
28	6.795	0.679	0.692	8.445	64.427	63.335	5.921	0.752	0.758	145.009
29	6.673	0.667	0.679	8.299	63.335	62.279	5.824	0.740	0.752	142.576
30	6.552	0.655	0.667	8.153	62.243	61.224	5.727	0.728	0.740	140.138
31	6.431	0.643	0.655	8.008	61.151	60.168	5.630	0.716	0.728	137.699
32	6.309	0.631	0.643	7.862	60.059	59.113	5.533	0.704	0.716	135.260
33	6.188	0.619	0.631	7.717	58.967	58.057	5.436	0.692	0.704	132.821
34	6.067	0.607	0.619	7.571	57.875	57.001	5.339	0.679	0.692	130.383
35	5.945	0.595	0.607	7.425	56.783	55.946	5.242	0.667	0.679	127.944
36	5.824	0.582	0.595	7.280	55.691	54.890	5.144	0.655	0.667	125.505
37	5.703	0.570	0.582	7.134	54.599	53.835	5.047	0.643	0.655	123.066
38	5.581	0.558	0.570	6.989	53.507	52.779	4.950	0.631	0.643	120.628
39	5.460	0.546	0.558	6.843	52.415	51.724	4.853	0.619	0.631	118.189
40	5.339	0.534	0.546	6.697	51.323	50.668	4.756	0.607	0.619	115.750
41	5.217	0.522	0.534	6.552	50.231	49.612	4.659	0.595	0.607	113.311
42	5.096	0.510	0.522	6.406	49.139	48.557	4.562	0.582	0.595	110.873
43	4.975	0.497	0.510	6.261	48.047	47.501	4.465	0.570	0.582	108.434
44	4.853	0.485	0.497	6.115	46.955	46.446	4.368	0.558	0.570	105.995
45	4.732	0.473	0.485	5.969	45.863	45.390	4.271	0.546	0.558	103.556
46	4.611	0.461	0.473	5.824	44.771	44.334	4.174	0.534	0.546	101.117
47	4.489	0.449	0.461	5.678	43.679	43.279	4.077	0.522	0.534	98.679
48	4.368	0.437	0.449	5.533	42.587	42.223	3.980	0.510	0.522	96.240
49	4.247	0.425	0.437	5.387	41.495	41.168	3.883	0.497	0.510	93.801
50	4.125	0.413	0.425	5.242	40.403	40.112	3.786	0.485	0.497	91.362
51	4.004	0.400	0.413	5.096	39.311	39.057	3.688	0.473	0.485	88.924
52	3.883	0.388	0.400	4.950	38.219	38.001	3.591	0.461	0.473	86.485
53	3.761	0.376	0.388	4.805	37.127	36.945	3.494	0.449	0.461	84.046

54	3.640	0.364	0.376	4.659	36.035	35.890	3.397	0.437	0.449	81.607
55	3.519	0.352	0.364	4.514	34.943	34.834	3.300	0.425	0.437	79.169
56	3.397	0.340	0.352	4.368	33.851	33.779	3.203	0.413	0.425	76.730
57	3.276	0.328	0.340	4.222	32.759	32.723	3.106	0.400	0.413	74.291
58	3.155	0.315	0.328	4.077	31.667	31.667	3.009	0.388	0.400	71.852
59	3.033	0.303	0.315	3.931	30.575	30.612	2.912	0.376	0.388	69.414
60	2.912	0.291	0.303	3.786	29.484	29.556	2.815	0.364	0.376	66.975
61	2.791	0.279	0.291	3.640	28.392	28.501	2.718	0.352	0.364	64.536
62	2.669	0.267	0.279	3.494	27.300	27.445	2.621	0.340	0.352	62.097
63	2.548	0.255	0.267	3.349	26.208	26.390	2.524	0.328	0.340	59.659
64	2.427	0.243	0.255	3.203	25.116	25.334	2.427	0.315	0.328	57.220
65	2.305	0.231	0.243	3.058	24.024	24.278	2.330	0.303	0.315	54.781
66	2.184	0.218	0.231	2.912	22.932	23.223	2.232	0.291	0.303	52.342
67	2.063	0.206	0.218	2.766	21.840	22.167	2.135	0.279	0.291	49.904
68	1.941	0.194	0.206	2.621	20.748	21.112	2.038	0.267	0.279	47.465
69	1.820	0.182	0.194	2.475	19.656	20.056	1.941	0.255	0.267	45.026
70	1.699	0.170	0.182	2.330	18.564	19.000	1.844	0.243	0.255	42.587
71	1.577	0.158	0.170	2.184	17.472	17.945	1.747	0.231	0.243	40.149
72	1.456	0.146	0.158	2.038	16.380	16.889	1.650	0.218	0.231	37.710
73	1.335	0.133	0.146	1.893	15.288	15.834	1.553	0.206	0.218	35.271
74	1.213	0.121	0.133	1.747	14.196	14.778	1.456	0.194	0.206	32.832
75	1.092	0.109	0.121	1.602	13.104	13.723	1.359	0.182	0.194	30.393
76	0.971	0.097	0.109	1.456	12.012	12.667	1.262	0.170	0.182	27.955
77	0.849	0.085	0.097	1.310	10.920	11.611	1.165	0.158	0.170	25.516
78	0.728	0.073	0.085	1.165	9.828	10.556	1.068	0.146	0.158	23.077
79	0.607	0.061	0.073	1.019	8.736	9.500	0.971	0.133	0.146	20.638
80	0.485	0.049	0.061	0.874	7.644	8.445	0.874	0.121	0.133	18.200
81	0.364	0.036	0.049	0.728	6.552	7.389	0.777	0.109	0.121	15.761
82	0.243	0.024	0.036	0.582	5.460	6.333	0.679	0.097	0.109	13.322
83	0.121	0.012	0.024	0.437	4.368	5.278	0.582	0.085	0.097	10.883
			0.012	0.291	3.276	4.222	0.485	0.073	0.085	8.445
				0.146	2.184	3.167	0.388	0.061	0.073	6.018
					1.092	2.111	0.291	0.049	0.061	3.604
						1.056	0.194	0.036	0.049	1.335
							0.097	0.024	0.036	0.158
								0.012	0.024	0.036
									0.012	0.012

Road : A035, Cat. ID : 24/1-26/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-100 Years								
		Excess Rainfall in cm								DRH (m^3/s)
		0.1	0.1	1.4	10.0	10.0	1.1	0.1	0.1	
1	0.361	0.036								0.036
2	0.722	0.072	0.036							0.108
3	1.084	0.108	0.072	0.506						0.686
4	1.445	0.144	0.108	1.011	3.612					4.876
5	1.806	0.181	0.144	1.517	7.224	3.612				12.678
6	2.167	0.217	0.181	2.023	10.836	7.224	0.397			20.877
7	2.528	0.253	0.217	2.528	14.448	10.836	0.795	0.036		29.112
8	2.890	0.289	0.253	3.034	18.059	14.448	1.192	0.072	0.036	37.383
9	3.251	0.325	0.289	3.540	21.671	18.059	1.589	0.108	0.072	45.654
10	3.612	0.361	0.325	4.045	25.283	21.671	1.987	0.144	0.108	53.925
11	3.973	0.397	0.361	4.551	28.895	25.283	2.384	0.181	0.144	62.196
12	4.334	0.433	0.397	5.057	32.507	28.895	2.781	0.217	0.181	70.468
13	4.695	0.470	0.433	5.562	36.119	32.507	3.178	0.253	0.217	78.739
14	5.057	0.506	0.470	6.068	39.731	36.119	3.576	0.289	0.253	87.010
15	5.418	0.542	0.506	6.574	43.343	39.731	3.973	0.325	0.289	95.281
16	5.779	0.578	0.542	7.079	46.954	43.343	4.370	0.361	0.325	103.552

17	6.140	0.614	0.578	7.585	50.566	46.954	4.768	0.397	0.361	111.824
18	6.501	0.650	0.614	8.091	54.178	50.566	5.165	0.433	0.397	120.095
19	6.863	0.686	0.650	8.596	57.790	54.178	5.562	0.470	0.433	128.366
20	7.224	0.722	0.686	9.102	61.402	57.790	5.960	0.506	0.470	136.637
21	7.585	0.758	0.722	9.608	65.014	61.402	6.357	0.542	0.506	144.908
22	7.523	0.752	0.758	10.113	68.626	65.014	6.754	0.578	0.542	153.137
23	7.401	0.740	0.752	10.619	72.238	68.626	7.152	0.614	0.578	161.318
24	7.280	0.728	0.740	10.532	75.849	72.238	7.549	0.650	0.614	168.900
25	7.159	0.716	0.728	10.362	75.225	75.849	7.946	0.686	0.650	172.163
26	7.037	0.704	0.716	10.192	74.012	75.225	8.343	0.722	0.686	170.601
27	6.916	0.692	0.704	10.022	72.799	74.012	8.275	0.758	0.722	167.984
28	6.795	0.679	0.692	9.852	71.585	72.799	8.141	0.752	0.758	165.259
29	6.673	0.667	0.679	9.682	70.372	71.585	8.008	0.740	0.752	162.487
30	6.552	0.655	0.667	9.512	69.159	70.372	7.874	0.728	0.740	159.708
31	6.431	0.643	0.655	9.343	67.946	69.159	7.741	0.716	0.728	156.930
32	6.309	0.631	0.643	9.173	66.732	67.946	7.607	0.704	0.716	154.151
33	6.188	0.619	0.631	9.003	65.519	66.732	7.474	0.692	0.704	151.373
34	6.067	0.607	0.619	8.833	64.306	65.519	7.341	0.679	0.692	148.594
35	5.945	0.595	0.607	8.663	63.092	64.306	7.207	0.667	0.679	145.816
36	5.824	0.582	0.595	8.493	61.879	63.092	7.074	0.655	0.667	143.037
37	5.703	0.570	0.582	8.323	60.666	61.879	6.940	0.643	0.655	140.259
38	5.581	0.558	0.570	8.153	59.452	60.666	6.807	0.631	0.643	137.480
39	5.460	0.546	0.558	7.984	58.239	59.452	6.673	0.619	0.631	134.702
40	5.339	0.534	0.546	7.814	57.026	58.239	6.540	0.607	0.619	131.924
41	5.217	0.522	0.534	7.644	55.812	57.026	6.406	0.595	0.607	129.145
42	5.096	0.510	0.522	7.474	54.599	55.812	6.273	0.582	0.595	126.367
43	4.975	0.497	0.510	7.304	53.386	54.599	6.139	0.570	0.582	123.588
44	4.853	0.485	0.497	7.134	52.172	53.386	6.006	0.558	0.570	120.810
45	4.732	0.473	0.485	6.964	50.959	52.172	5.872	0.546	0.558	118.031
46	4.611	0.461	0.473	6.795	49.746	50.959	5.739	0.534	0.546	115.253
47	4.489	0.449	0.461	6.625	48.533	49.746	5.606	0.522	0.534	112.474
48	4.368	0.437	0.449	6.455	47.319	48.533	5.472	0.510	0.522	109.696
49	4.247	0.425	0.437	6.285	46.106	47.319	5.339	0.497	0.510	106.917
50	4.125	0.413	0.425	6.115	44.893	46.106	5.205	0.485	0.497	104.139
51	4.004	0.400	0.413	5.945	43.679	44.893	5.072	0.473	0.485	101.360
52	3.883	0.388	0.400	5.775	42.466	43.679	4.938	0.461	0.473	98.582
53	3.761	0.376	0.388	5.606	41.253	42.466	4.805	0.449	0.461	95.803
54	3.640	0.364	0.376	5.436	40.039	41.253	4.671	0.437	0.449	93.025
55	3.519	0.352	0.364	5.266	38.826	40.039	4.538	0.425	0.437	90.246
56	3.397	0.340	0.352	5.096	37.613	38.826	4.404	0.413	0.425	87.468
57	3.276	0.328	0.340	4.926	36.399	37.613	4.271	0.400	0.413	84.689
58	3.155	0.315	0.328	4.756	35.186	36.399	4.137	0.388	0.400	81.911
59	3.033	0.303	0.315	4.586	33.973	35.186	4.004	0.376	0.388	79.132
60	2.912	0.291	0.303	4.416	32.759	33.973	3.870	0.364	0.376	76.354
61	2.791	0.279	0.291	4.247	31.546	32.759	3.737	0.352	0.364	73.575
62	2.669	0.267	0.279	4.077	30.333	31.546	3.604	0.340	0.352	70.797
63	2.548	0.255	0.267	3.907	29.120	30.333	3.470	0.328	0.340	68.018
64	2.427	0.243	0.255	3.737	27.906	29.120	3.337	0.315	0.328	65.240
65	2.305	0.231	0.243	3.567	26.693	27.906	3.203	0.303	0.315	62.461
66	2.184	0.218	0.231	3.397	25.480	26.693	3.070	0.291	0.303	59.683
67	2.063	0.206	0.218	3.227	24.266	25.480	2.936	0.279	0.291	56.904
68	1.941	0.194	0.206	3.058	23.053	24.266	2.803	0.267	0.279	54.126
69	1.820	0.182	0.194	2.888	21.840	23.053	2.669	0.255	0.267	51.347
70	1.699	0.170	0.182	2.718	20.626	21.840	2.536	0.243	0.255	48.569
71	1.577	0.158	0.170	2.548	19.413	20.626	2.402	0.231	0.243	45.790
72	1.456	0.146	0.158	2.378	18.200	19.413	2.269	0.218	0.231	43.012
73	1.335	0.133	0.146	2.208	16.986	18.200	2.135	0.206	0.218	40.233

74	1.213	0.121	0.133	2.038	15.773	16.986	2.002	0.194	0.206	37.455
75	1.092	0.109	0.121	1.869	14.560	15.773	1.869	0.182	0.194	34.676
76	0.971	0.097	0.109	1.699	13.346	14.560	1.735	0.170	0.182	31.898
77	0.849	0.085	0.097	1.529	12.133	13.346	1.602	0.158	0.170	29.120
78	0.728	0.073	0.085	1.359	10.920	12.133	1.468	0.146	0.158	26.341
79	0.607	0.061	0.073	1.189	9.707	10.920	1.335	0.133	0.146	23.563
80	0.485	0.049	0.061	1.019	8.493	9.707	1.201	0.121	0.133	20.784
81	0.364	0.036	0.049	0.849	7.280	8.493	1.068	0.109	0.121	18.006
82	0.243	0.024	0.036	0.679	6.067	7.280	0.934	0.097	0.109	15.227
83	0.121	0.012	0.024	0.510	4.853	6.067	0.801	0.085	0.097	12.449
			0.012	0.340	3.640	4.853	0.667	0.073	0.085	9.670
				0.170	2.427	3.640	0.534	0.061	0.073	6.904
					1.213	2.427	0.400	0.049	0.061	4.150
						1.213	0.267	0.036	0.049	1.565
							0.133	0.024	0.036	0.194
								0.012	0.024	0.036
									0.012	0.012

Road : A035, Cat. ID : 28/1-28/4

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years					
		Excess Rainfall in cm					DRH (m^3/s)
		0.2	0.8	7.8	7.7	0.6	
1	0.251	0.050					0.050
2	0.502	0.100	0.201				0.301
3	0.753	0.151	0.402	1.957			2.510
4	1.004	0.201	0.602	3.915	1.932		6.650
5	1.255	0.251	0.803	5.872	3.865	0.151	10.941
6	1.506	0.301	1.004	7.830	5.797	0.301	15.233
7	1.757	0.351	1.205	9.787	7.729	0.452	19.524
8	2.008	0.402	1.405	11.744	9.662	0.602	23.815
9	2.259	0.452	1.606	13.702	11.594	0.753	28.106
10	2.510	0.502	1.807	15.659	13.526	0.903	32.398
11	2.760	0.552	2.008	17.617	15.459	1.054	36.689
12	3.011	0.602	2.208	19.574	17.391	1.205	40.980
13	3.262	0.652	2.409	21.532	19.323	1.355	45.271
14	3.513	0.703	2.610	23.489	21.255	1.506	49.563
15	3.693	0.739	2.811	25.446	23.188	1.656	53.840
16	3.609	0.722	2.954	27.404	25.120	1.807	58.007
17	3.525	0.705	2.887	28.806	27.052	1.957	61.408
18	3.441	0.688	2.820	28.151	28.436	2.108	62.204
19	3.357	0.671	2.753	27.496	27.790	2.216	60.927
20	3.273	0.655	2.686	26.842	27.144	2.165	59.491
21	3.189	0.638	2.619	26.187	26.498	2.115	58.056
22	3.106	0.621	2.552	25.532	25.851	2.065	56.621
23	3.022	0.604	2.484	24.878	25.205	2.014	55.186
24	2.938	0.588	2.417	24.223	24.559	1.964	53.750
25	2.854	0.571	2.350	23.568	23.912	1.914	52.315
26	2.770	0.554	2.283	22.914	23.266	1.863	50.880
27	2.686	0.537	2.216	22.259	22.620	1.813	49.445
28	2.602	0.520	2.149	21.604	21.974	1.763	48.009
29	2.518	0.504	2.082	20.950	21.327	1.712	46.574
30	2.434	0.487	2.014	20.295	20.681	1.662	45.139
31	2.350	0.470	1.947	19.640	20.035	1.612	43.704
32	2.266	0.453	1.880	18.986	19.388	1.561	42.269
33	2.182	0.436	1.813	18.331	18.742	1.511	40.833
34	2.098	0.420	1.746	17.676	18.096	1.460	39.398
35	2.014	0.403	1.679	17.022	17.450	1.410	37.963
36	1.930	0.386	1.612	16.367	16.803	1.360	36.528

37	1.847	0.369	1.544	15.712	16.157	1.309	35.092
38	1.763	0.353	1.477	15.058	15.511	1.259	33.657
39	1.679	0.336	1.410	14.403	14.864	1.209	32.222
40	1.595	0.319	1.343	13.748	14.218	1.158	30.787
41	1.511	0.302	1.276	13.093	13.572	1.108	29.351
42	1.427	0.285	1.209	12.439	12.926	1.058	27.916
43	1.343	0.269	1.141	11.784	12.279	1.007	26.481
44	1.259	0.252	1.074	11.129	11.633	0.957	25.046
45	1.175	0.235	1.007	10.475	10.987	0.906	23.610
46	1.091	0.218	0.940	9.820	10.341	0.856	22.175
47	1.007	0.201	0.873	9.165	9.694	0.806	20.740
48	0.923	0.185	0.806	8.511	9.048	0.755	19.305
49	0.839	0.168	0.739	7.856	8.402	0.705	17.869
50	0.755	0.151	0.671	7.201	7.755	0.655	16.434
51	0.671	0.134	0.604	6.547	7.109	0.604	14.999
52	0.588	0.118	0.537	5.892	6.463	0.554	13.564
53	0.504	0.101	0.470	5.237	5.817	0.504	12.128
54	0.420	0.084	0.403	4.583	5.170	0.453	10.693
55	0.336	0.067	0.336	3.928	4.524	0.403	9.258
56	0.252	0.050	0.269	3.273	3.878	0.353	7.823
57	0.168	0.034	0.201	2.619	3.231	0.302	6.387
58	0.084	0.017	0.134	1.964	2.585	0.252	4.952
			0.067	1.309	1.939	0.201	3.517
				0.655	1.293	0.151	2.098
					0.646	0.101	0.747
						0.050	0.050

Road : A035, Cat. ID : 28/1-28/4

Time (hr)	UH (m^3/s/cm)	Return Period-50 Years					
		Excess Rainfall in cm					DRH (m^3/s)
		0.1	1.2	9.0	8.7	0.8	
1	0.251	0.025					0.025
2	0.502	0.050	0.301				0.351
3	0.753	0.075	0.602	2.259			2.936
4	1.004	0.100	0.903	4.517	2.183		7.704
5	1.255	0.125	1.205	6.776	4.367	0.201	12.673
6	1.506	0.151	1.506	9.034	6.550	0.402	17.642
7	1.757	0.176	1.807	11.293	8.733	0.602	22.611
8	2.008	0.201	2.108	13.551	10.916	0.803	27.579
9	2.259	0.226	2.409	15.810	13.100	1.004	32.548
10	2.510	0.251	2.710	18.068	15.283	1.205	37.517
11	2.760	0.276	3.011	20.327	17.466	1.405	42.486
12	3.011	0.301	3.313	22.586	19.649	1.606	47.455
13	3.262	0.326	3.614	24.844	21.833	1.807	52.424
14	3.513	0.351	3.915	27.103	24.016	2.008	57.392
15	3.693	0.369	4.216	29.361	26.199	2.208	62.354
16	3.609	0.361	4.432	31.620	28.382	2.409	67.204
17	3.525	0.353	4.331	33.237	30.566	2.610	71.096
18	3.441	0.344	4.230	32.482	32.129	2.811	71.996
19	3.357	0.336	4.129	31.727	31.399	2.954	70.545
20	3.273	0.327	4.029	30.971	30.669	2.887	68.884
21	3.189	0.319	3.928	30.216	29.939	2.820	67.222
22	3.106	0.311	3.827	29.460	29.209	2.753	65.560
23	3.022	0.302	3.727	28.705	28.478	2.686	63.898
24	2.938	0.294	3.626	27.950	27.748	2.619	62.236
25	2.854	0.285	3.525	27.194	27.018	2.552	60.574
26	2.770	0.277	3.424	26.439	26.288	2.484	58.912
27	2.686	0.269	3.324	25.683	25.558	2.417	57.250

28	2.602	0.260	3.223	24.928	24.827	2.350	55.589
29	2.518	0.252	3.122	24.173	24.097	2.283	53.927
30	2.434	0.243	3.022	23.417	23.367	2.216	52.265
31	2.350	0.235	2.921	22.662	22.637	2.149	50.603
32	2.266	0.227	2.820	21.906	21.906	2.082	48.941
33	2.182	0.218	2.719	21.151	21.176	2.014	47.279
34	2.098	0.210	2.619	20.396	20.446	1.947	45.617
35	2.014	0.201	2.518	19.640	19.716	1.880	43.956
36	1.930	0.193	2.417	18.885	18.986	1.813	42.294
37	1.847	0.185	2.317	18.129	18.255	1.746	40.632
38	1.763	0.176	2.216	17.374	17.525	1.679	38.970
39	1.679	0.168	2.115	16.619	16.795	1.612	37.308
40	1.595	0.159	2.014	15.863	16.065	1.544	35.646
41	1.511	0.151	1.914	15.108	15.335	1.477	33.984
42	1.427	0.143	1.813	14.352	14.604	1.410	32.322
43	1.343	0.134	1.712	13.597	13.874	1.343	30.661
44	1.259	0.126	1.612	12.842	13.144	1.276	28.999
45	1.175	0.118	1.511	12.086	12.414	1.209	27.337
46	1.091	0.109	1.410	11.331	11.683	1.141	25.675
47	1.007	0.101	1.309	10.576	10.953	1.074	24.013
48	0.923	0.092	1.209	9.820	10.223	1.007	22.351
49	0.839	0.084	1.108	9.065	9.493	0.940	20.689
50	0.755	0.076	1.007	8.309	8.763	0.873	19.028
51	0.671	0.067	0.906	7.554	8.032	0.806	17.366
52	0.588	0.059	0.806	6.799	7.302	0.739	15.704
53	0.504	0.050	0.705	6.043	6.572	0.671	14.042
54	0.420	0.042	0.604	5.288	5.842	0.604	12.380
55	0.336	0.034	0.504	4.532	5.112	0.537	10.718
56	0.252	0.025	0.403	3.777	4.381	0.470	9.056
57	0.168	0.017	0.302	3.022	3.651	0.403	7.394
58	0.084	0.008	0.201	2.266	2.921	0.336	5.733
			0.101	1.511	2.191	0.269	4.071
				0.755	1.460	0.201	2.417
					0.730	0.134	0.865
						0.067	0.067

Road : A035, Cat. ID : 28/1-28/4							
Time (hr)	UH (m^3/s/cm)	Return Period-100 Years					
		Excess Rainfall in cm					DRH (m^3/s)
		0.1	1.4	10.0	10.0	1.1	
1	0.251	0.025					0.025
2	0.502	0.050	0.351				0.402
3	0.753	0.075	0.703	2.510			3.287
4	1.004	0.100	1.054	5.019	2.510		8.683
5	1.255	0.125	1.405	7.529	5.019	0.276	14.354
6	1.506	0.151	1.757	10.038	7.529	0.552	20.026
7	1.757	0.176	2.108	12.548	10.038	0.828	25.697
8	2.008	0.201	2.459	15.057	12.548	1.104	31.369
9	2.259	0.226	2.811	17.567	15.057	1.380	37.040
10	2.510	0.251	3.162	20.076	17.567	1.656	42.712
11	2.760	0.276	3.513	22.586	20.076	1.932	48.383
12	3.011	0.301	3.865	25.095	22.586	2.208	54.055
13	3.262	0.326	4.216	27.605	25.095	2.484	59.726
14	3.513	0.351	4.567	30.114	27.605	2.760	65.398
15	3.693	0.369	4.919	32.624	30.114	3.036	71.062
16	3.609	0.361	5.170	35.133	32.624	3.313	76.600
17	3.525	0.353	5.053	36.930	35.133	3.589	81.057
18	3.441	0.344	4.935	36.091	36.930	3.865	82.165

19	3.357	0.336	4.818	35.252	36.091	4.062	80.559
20	3.273	0.327	4.700	34.412	35.252	3.970	78.662
21	3.189	0.319	4.583	33.573	34.412	3.878	76.765
22	3.106	0.311	4.465	32.734	33.573	3.785	74.868
23	3.022	0.302	4.348	31.894	32.734	3.693	72.971
24	2.938	0.294	4.230	31.055	31.894	3.601	71.074
25	2.854	0.285	4.113	30.216	31.055	3.508	69.177
26	2.770	0.277	3.995	29.376	30.216	3.416	67.280
27	2.686	0.269	3.878	28.537	29.376	3.324	65.384
28	2.602	0.260	3.760	27.698	28.537	3.231	63.487
29	2.518	0.252	3.643	26.858	27.698	3.139	61.590
30	2.434	0.243	3.525	26.019	26.858	3.047	59.693
31	2.350	0.235	3.408	25.180	26.019	2.954	57.796
32	2.266	0.227	3.290	24.340	25.180	2.862	55.899
33	2.182	0.218	3.173	23.501	24.340	2.770	54.002
34	2.098	0.210	3.055	22.662	23.501	2.677	52.105
35	2.014	0.201	2.938	21.822	22.662	2.585	50.209
36	1.930	0.193	2.820	20.983	21.822	2.493	48.312
37	1.847	0.185	2.703	20.144	20.983	2.400	46.415
38	1.763	0.176	2.585	19.305	20.144	2.308	44.518
39	1.679	0.168	2.468	18.465	19.305	2.216	42.621
40	1.595	0.159	2.350	17.626	18.465	2.123	40.724
41	1.511	0.151	2.233	16.787	17.626	2.031	38.827
42	1.427	0.143	2.115	15.947	16.787	1.939	36.930
43	1.343	0.134	1.998	15.108	15.947	1.847	35.034
44	1.259	0.126	1.880	14.269	15.108	1.754	33.137
45	1.175	0.118	1.763	13.429	14.269	1.662	31.240
46	1.091	0.109	1.645	12.590	13.429	1.570	29.343
47	1.007	0.101	1.528	11.751	12.590	1.477	27.446
48	0.923	0.092	1.410	10.911	11.751	1.385	25.549
49	0.839	0.084	1.293	10.072	10.911	1.293	23.652
50	0.755	0.076	1.175	9.233	10.072	1.200	21.755
51	0.671	0.067	1.058	8.393	9.233	1.108	19.858
52	0.588	0.059	0.940	7.554	8.393	1.016	17.962
53	0.504	0.050	0.823	6.715	7.554	0.923	16.065
54	0.420	0.042	0.705	5.875	6.715	0.831	14.168
55	0.336	0.034	0.588	5.036	5.875	0.739	12.271
56	0.252	0.025	0.470	4.197	5.036	0.646	10.374
57	0.168	0.017	0.353	3.357	4.197	0.554	8.477
58	0.084	0.008	0.235	2.518	3.357	0.462	6.580
			0.118	1.679	2.518	0.369	4.683
				0.839	1.679	0.277	2.795
					0.839	0.185	1.024
						0.092	0.092

Road : A009, Cat. ID : 123/3-123/4										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.135	0.974		0.974	1.082		1.082	1.258		1.258
2	0.271	1.948	0.947	2.895	2.165	1.082	3.247	2.516	1.245	3.761
3	0.406	2.922	1.894	4.816	3.247	2.165	5.411	3.774	2.489	6.264
4	0.541	3.896	2.841	6.737	4.329	3.247	7.576	5.033	3.734	8.767
5	0.676	4.870	3.788	8.658	5.411	4.329	9.741	6.291	4.979	11.269
6	0.812	5.844	4.735	10.579	6.494	5.411	11.905	7.549	6.223	13.772
7	0.947	6.818	5.682	12.500	7.576	6.494	14.070	8.807	7.468	16.275
8	0.966	6.957	6.629	13.586	7.730	7.576	15.306	8.986	8.712	17.699
9	0.920	6.626	6.764	13.390	7.362	7.730	15.092	8.558	8.890	17.448
10	0.874	6.294	6.442	12.736	6.994	7.362	14.356	8.130	8.466	16.597
11	0.828	5.963	6.120	12.083	6.626	6.994	13.620	7.702	8.043	15.745
12	0.782	5.632	5.798	11.429	6.258	6.626	12.883	7.275	7.620	14.894
13	0.736	5.301	5.475	10.776	5.890	6.258	12.147	6.847	7.196	14.043
14	0.690	4.969	5.153	10.123	5.521	5.890	11.411	6.419	6.773	13.192
15	0.644	4.638	4.831	9.469	5.153	5.521	10.675	5.991	6.350	12.340
16	0.598	4.307	4.509	8.816	4.785	5.153	9.939	5.563	5.926	11.489
17	0.552	3.975	4.187	8.163	4.417	4.785	9.202	5.135	5.503	10.638
18	0.506	3.644	3.865	7.509	4.049	4.417	8.466	4.707	5.080	9.787
19	0.460	3.313	3.543	6.856	3.681	4.049	7.730	4.279	4.656	8.936
20	0.414	2.982	3.221	6.202	3.313	3.681	6.994	3.851	4.233	8.084
21	0.368	2.650	2.899	5.549	2.945	3.313	6.258	3.423	3.810	7.233
22	0.322	2.319	2.577	4.896	2.577	2.945	5.521	2.995	3.386	6.382
23	0.276	1.988	2.255	4.242	2.209	2.577	4.785	2.567	2.963	5.531
24	0.230	1.656	1.933	3.589	1.840	2.209	4.049	2.140	2.540	4.679
25	0.184	1.325	1.610	2.936	1.472	1.840	3.313	1.712	2.117	3.828
26	0.138	0.994	1.288	2.282	1.104	1.472	2.577	1.284	1.693	2.977
27	0.092	0.663	0.966	1.629	0.736	1.104	1.840	0.856	1.270	2.126
28	0.046	0.331	0.644	0.975	0.368	0.736	1.104	0.428	0.847	1.275
			0.322	0.322		0.368	0.368		0.423	0.423

Road : A009, Cat. ID : 125/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.097	0.697		0.697	0.774		0.774	0.900		0.900
2	0.194	1.394	0.678	2.071	1.549	0.774	2.323	1.800	0.890	2.691
3	0.290	2.091	1.355	3.446	2.323	1.549	3.872	2.700	1.781	4.481
4	0.387	2.788	2.033	4.820	3.097	2.323	5.420	3.601	2.671	6.272
5	0.367	2.645	2.710	5.355	2.939	3.097	6.036	3.417	3.562	6.978
6	0.334	2.405	2.572	4.976	2.672	2.939	5.611	3.106	3.380	6.486
7	0.301	2.164	2.338	4.502	2.405	2.672	5.076	2.795	3.073	5.868
8	0.267	1.924	2.104	4.028	2.137	2.405	4.542	2.485	2.765	5.250
9	0.234	1.683	1.870	3.554	1.870	2.137	4.008	2.174	2.458	4.632
10	0.200	1.443	1.636	3.079	1.603	1.870	3.473	1.864	2.151	4.014
11	0.167	1.202	1.403	2.605	1.336	1.603	2.939	1.553	1.844	3.397
12	0.134	0.962	1.169	2.131	1.069	1.336	2.405	1.242	1.536	2.779
13	0.100	0.721	0.935	1.657	0.802	1.069	1.870	0.932	1.229	2.161
14	0.067	0.481	0.701	1.182	0.534	0.802	1.336	0.621	0.922	1.543
15	0.033	0.240	0.468	0.708	0.267	0.534	0.802	0.311	0.615	0.925
			0.234	0.234		0.267	0.267		0.307	0.307

Road : A009, Cat. ID : 126/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.237	1.704		1.704	1.894		1.894	2.202		2.202
2	0.473	3.409	1.657	5.066	3.788	1.894	5.681	4.403	2.178	6.581
3	0.710	5.113	3.314	8.427	5.681	3.788	9.469	6.605	4.356	10.960
4	0.947	6.818	4.971	11.789	7.575	5.681	13.257	8.806	6.534	15.340
5	1.184	8.522	6.628	15.150	9.469	7.575	17.044	11.008	8.712	19.719
6	1.420	10.227	8.285	18.512	11.363	9.469	20.832	13.209	10.889	24.099
7	1.657	11.931	9.942	21.873	13.257	11.363	24.620	15.411	13.067	28.478
8	1.594	11.476	11.600	23.076	12.752	13.257	26.008	14.824	15.245	30.069
9	1.514	10.903	11.158	22.060	12.114	12.752	24.866	14.083	14.664	28.747
10	1.435	10.329	10.600	20.929	11.476	12.114	23.590	13.341	13.931	27.272
11	1.355	9.755	10.042	19.797	10.839	11.476	22.315	12.600	13.198	25.798

12	1.275	9.181	9.484	18.665	10.201	10.839	21.040	11.859	12.465	24.324
13	1.195	8.607	8.926	17.533	9.564	10.201	19.765	11.118	11.731	22.849
14	1.116	8.034	8.368	16.402	8.926	9.564	18.490	10.377	10.998	21.375
15	1.036	7.460	7.810	15.270	8.289	8.926	17.215	9.635	10.265	19.900
16	0.956	6.886	7.252	14.138	7.651	8.289	15.939	8.894	9.532	18.426
17	0.877	6.312	6.695	13.007	7.013	7.651	14.664	8.153	8.799	16.952
18	0.797	5.738	6.137	11.875	6.376	7.013	13.389	7.412	8.065	15.477
19	0.717	5.164	5.579	10.743	5.738	6.376	12.114	6.671	7.332	14.003
20	0.638	4.591	5.021	9.612	5.101	5.738	10.839	5.929	6.599	12.528
21	0.558	4.017	4.463	8.480	4.463	5.101	9.564	5.188	5.866	11.054
22	0.478	3.443	3.905	7.348	3.825	4.463	8.289	4.447	5.133	9.580
23	0.398	2.869	3.347	6.216	3.188	3.825	7.013	3.706	4.399	8.105
24	0.319	2.295	2.789	5.085	2.550	3.188	5.738	2.965	3.666	6.631
25	0.239	1.721	2.232	3.953	1.913	2.550	4.463	2.224	2.933	5.156
26	0.159	1.148	1.674	2.821	1.275	1.913	3.188	1.482	2.200	3.682
27	0.080	0.574	1.116	1.690	0.638	1.275	1.913	0.741	1.466	2.208
			0.558	0.558		0.638	0.638		0.733	0.733

Road : A009, Cat. ID : 127/2

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.142	1.026		1.026	1.140		1.140	1.325		1.325
2	0.285	2.052	0.997	3.049	2.280	1.140	3.419	2.650	1.311	3.961
3	0.427	3.078	1.995	5.072	3.419	2.280	5.699	3.975	2.622	6.597
4	0.570	4.103	2.992	7.095	4.559	3.419	7.979	5.300	3.932	9.233
5	0.598	4.308	3.989	8.298	4.787	4.559	9.347	5.565	5.243	10.808
6	0.549	3.949	4.189	8.138	4.388	4.787	9.176	5.101	5.505	10.607
7	0.499	3.590	3.840	7.430	3.989	4.388	8.378	4.638	5.047	9.684
8	0.449	3.231	3.491	6.722	3.590	3.989	7.580	4.174	4.588	8.762
9	0.399	2.872	3.142	6.014	3.191	3.590	6.782	3.710	4.129	7.839
10	0.349	2.513	2.793	5.306	2.793	3.191	5.984	3.246	3.670	6.917
11	0.299	2.154	2.443	4.598	2.394	2.793	5.186	2.783	3.211	5.994
12	0.249	1.795	2.094	3.890	1.995	2.394	4.388	2.319	2.753	5.071
13	0.199	1.436	1.745	3.182	1.596	1.995	3.590	1.855	2.294	4.149
14	0.150	1.077	1.396	2.473	1.197	1.596	2.793	1.391	1.835	3.226

15	0.100	0.718	1.047	1.765	0.798	1.197	1.995	0.928	1.376	2.304
16	0.050	0.359	0.698	1.057	0.399	0.798	1.197	0.464	0.918	1.381
			0.349	0.349		0.399	0.399		0.459	0.459

Road : A009, Cat. ID : 128/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.040	0.291		0.291	0.324		0.324	0.376		0.376
2	0.081	0.583	0.283	0.866	0.647	0.324	0.971	0.753	0.372	1.125
3	0.107	0.771	0.566	1.337	0.857	0.647	1.504	0.996	0.744	1.740
4	0.094	0.675	0.750	1.424	0.750	0.857	1.606	0.871	0.985	1.856
5	0.080	0.578	0.656	1.234	0.642	0.750	1.392	0.747	0.862	1.609
6	0.067	0.482	0.562	1.044	0.535	0.642	1.178	0.622	0.739	1.361
7	0.054	0.385	0.468	0.854	0.428	0.535	0.964	0.498	0.616	1.114
8	0.040	0.289	0.375	0.664	0.321	0.428	0.750	0.373	0.493	0.866
9	0.027	0.193	0.281	0.474	0.214	0.321	0.535	0.249	0.369	0.618
10	0.013	0.096	0.187	0.284	0.107	0.214	0.321	0.124	0.246	0.371
			0.094	0.094		0.107	0.107		0.123	0.123

Road : A009, Cat. ID : 129/2										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.064	0.459		0.459	0.510		0.510	0.593		0.593
2	0.127	0.918	0.446	1.364	1.020	0.510	1.530	1.186	0.586	1.772
3	0.191	1.377	0.892	2.269	1.530	1.020	2.549	1.778	1.173	2.951
4	0.180	1.298	1.338	2.636	1.442	1.530	2.972	1.676	1.759	3.435
5	0.158	1.136	1.262	2.397	1.262	1.442	2.704	1.467	1.658	3.125
6	0.135	0.973	1.104	2.077	1.081	1.262	2.343	1.257	1.451	2.708
7	0.113	0.811	0.946	1.757	0.901	1.081	1.983	1.048	1.244	2.291
8	0.090	0.649	0.789	1.437	0.721	0.901	1.622	0.838	1.036	1.875
9	0.068	0.487	0.631	1.118	0.541	0.721	1.262	0.629	0.829	1.458
10	0.045	0.324	0.473	0.798	0.360	0.541	0.901	0.419	0.622	1.041
11	0.023	0.162	0.315	0.478	0.180	0.360	0.541	0.210	0.415	0.624

Road : A009, Cat. ID : 128/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
			0.158	0.158		0.180	0.180		0.207	0.207

Road : A009, Cat. ID : 130/1-130/2										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.087	0.625		0.625	0.694		0.694	0.807		0.807
2	0.174	1.249	0.607	1.857	1.388	0.694	2.082	1.614	0.798	2.412
3	0.260	1.874	1.215	3.089	2.082	1.388	3.471	2.421	1.597	4.017
4	0.270	1.946	1.822	3.768	2.162	2.082	4.244	2.513	2.395	4.908
5	0.240	1.729	1.892	3.621	1.922	2.162	4.083	2.234	2.486	4.720
6	0.210	1.513	1.681	3.195	1.681	1.922	3.603	1.955	2.210	4.164
7	0.180	1.297	1.471	2.768	1.441	1.681	3.122	1.675	1.934	3.609
8	0.150	1.081	1.261	2.342	1.201	1.441	2.642	1.396	1.657	3.053
9	0.120	0.865	1.051	1.916	0.961	1.201	2.162	1.117	1.381	2.498
10	0.090	0.649	0.841	1.489	0.721	0.961	1.681	0.838	1.105	1.943
11	0.060	0.432	0.631	1.063	0.480	0.721	1.201	0.558	0.829	1.387
12	0.030	0.216	0.420	0.637	0.240	0.480	0.721	0.279	0.552	0.832
			0.210	0.210		0.240	0.240		0.276	0.276

Road : A009, Cat. ID : 131/1										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		7.2	7.0		8.0	8.0		9.3	9.2	
1	0.085	0.610		0.610	0.678		0.678	0.788		0.788
2	0.169	1.220	0.593	1.813	1.355	0.678	2.033	1.576	0.779	2.355
3	0.254	1.830	1.186	3.016	2.033	1.355	3.389	2.364	1.559	3.922
4	0.339	2.440	1.779	4.219	2.711	2.033	4.744	3.151	2.338	5.490
5	0.357	2.567	2.372	4.939	2.852	2.711	5.563	3.316	3.118	6.433
6	0.327	2.353	2.496	4.849	2.614	2.852	5.467	3.039	3.280	6.319
7	0.297	2.139	2.288	4.427	2.377	2.614	4.991	2.763	3.007	5.770

8	0.267	1.925	2.080	4.005	2.139	2.377	4.516	2.487	2.733	5.220
9	0.238	1.711	1.872	3.583	1.901	2.139	4.041	2.210	2.460	4.670
10	0.208	1.497	1.664	3.161	1.664	1.901	3.565	1.934	2.187	4.121
11	0.178	1.283	1.456	2.739	1.426	1.664	3.090	1.658	1.913	3.571
12	0.149	1.070	1.248	2.317	1.188	1.426	2.614	1.382	1.640	3.022
13	0.119	0.856	1.040	1.895	0.951	1.188	2.139	1.105	1.367	2.472
14	0.089	0.642	0.832	1.474	0.713	0.951	1.664	0.829	1.093	1.922
15	0.059	0.428	0.624	1.052	0.475	0.713	1.188	0.553	0.820	1.373
16	0.030	0.214	0.416	0.630	0.238	0.475	0.713	0.276	0.547	0.823
			0.208	0.208		0.238	0.238		0.273	0.273

Road : A009, Cat. ID : 205/2-206/1

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.213	0.171			0.171	0.256			0.256	0.298			0.298
2	0.426	0.341	1.663		2.004	0.512	1.918		2.430	0.597	2.132		2.728
3	0.639	0.512	3.325	1.641	5.478	0.767	3.837	1.854	6.459	0.895	4.263	2.132	7.290
4	0.853	0.682	4.988	3.283	8.953	1.023	5.755	3.709	10.487	1.194	6.395	4.263	11.852
5	1.066	0.853	6.651	4.924	12.427	1.279	7.674	5.563	14.516	1.492	8.526	6.395	16.413
6	1.279	1.023	8.313	6.565	15.902	1.535	9.592	7.418	18.545	1.791	10.658	8.526	20.975
7	1.492	1.194	9.976	8.207	19.376	1.791	11.511	9.272	22.574	2.089	12.790	10.658	25.537
8	1.705	1.364	11.639	9.848	22.851	2.046	13.429	11.127	26.602	2.387	14.921	12.790	30.098
9	1.918	1.535	13.301	11.489	26.325	2.302	15.348	12.981	30.631	2.686	17.053	14.921	34.660
10	1.987	1.589	14.964	13.131	29.684	2.384	17.266	14.836	34.486	2.781	19.184	17.053	39.019
11	1.916	1.533	15.495	14.772	31.800	2.299	17.879	16.690	36.869	2.682	19.866	19.184	41.732
12	1.845	1.476	14.942	15.297	31.715	2.214	17.241	17.283	36.738	2.583	19.156	19.866	41.605
13	1.774	1.419	14.389	14.750	30.558	2.128	16.602	16.666	35.397	2.483	18.447	19.156	40.087
14	1.703	1.362	13.835	14.204	29.402	2.043	15.964	16.049	34.056	2.384	17.737	18.447	38.568
15	1.632	1.305	13.282	13.658	28.245	1.958	15.325	15.432	32.715	2.285	17.028	17.737	37.050
16	1.561	1.249	12.728	13.112	27.089	1.873	14.687	14.814	31.374	2.185	16.318	17.028	35.532
17	1.490	1.192	12.175	12.565	25.932	1.788	14.048	14.197	30.033	2.086	15.609	16.318	34.013
18	1.419	1.135	11.622	12.019	24.776	1.703	13.410	13.580	28.692	1.987	14.899	15.609	32.495
19	1.348	1.078	11.068	11.473	23.619	1.618	12.771	12.963	27.351	1.887	14.190	14.899	30.977
20	1.277	1.022	10.515	10.926	22.463	1.533	12.132	12.345	26.010	1.788	13.480	14.190	29.458
21	1.206	0.965	9.961	10.380	21.306	1.447	11.494	11.728	24.669	1.689	12.771	13.480	27.940

22	1.135	0.908	9.408	9.834	20.150	1.362	10.855	11.111	23.328	1.589	12.061	12.771	26.422
23	1.064	0.851	8.855	9.287	18.993	1.277	10.217	10.494	21.987	1.490	11.352	12.061	24.903
24	0.993	0.795	8.301	8.741	17.837	1.192	9.578	9.876	20.646	1.391	10.642	11.352	23.385
25	0.922	0.738	7.748	8.195	16.680	1.107	8.940	9.259	19.305	1.291	9.933	10.642	21.867
26	0.851	0.681	7.194	7.648	15.524	1.022	8.301	8.642	17.965	1.192	9.223	9.933	20.348
27	0.780	0.624	6.641	7.102	14.367	0.937	7.663	8.024	16.624	1.093	8.514	9.223	18.830
28	0.709	0.568	6.088	6.556	13.211	0.851	7.024	7.407	15.283	0.993	7.804	8.514	17.312
29	0.639	0.511	5.534	6.009	12.054	0.766	6.385	6.790	13.942	0.894	7.095	7.804	15.793
30	0.568	0.454	4.981	5.463	10.898	0.681	5.747	6.173	12.601	0.795	6.385	7.095	14.275
31	0.497	0.397	4.427	4.917	9.741	0.596	5.108	5.555	11.260	0.695	5.676	6.385	12.757
32	0.426	0.341	3.874	4.371	8.585	0.511	4.470	4.938	9.919	0.596	4.966	5.676	11.238
33	0.355	0.284	3.320	3.824	7.428	0.426	3.831	4.321	8.578	0.497	4.257	4.966	9.720
34	0.284	0.227	2.767	3.278	6.272	0.341	3.193	3.704	7.237	0.397	3.547	4.257	8.202
35	0.213	0.170	2.214	2.732	5.115	0.255	2.554	3.086	5.896	0.298	2.838	3.547	6.683
36	0.142	0.114	1.660	2.185	3.959	0.170	1.916	2.469	4.555	0.199	2.128	2.838	5.165
37	0.071	0.057	1.107	1.639	2.803	0.085	1.277	1.852	3.214	0.099	1.419	2.128	3.647
			0.553	1.093	1.646		0.639	1.235	1.873		0.709	1.419	2.128
				0.546	0.546			0.617	0.617			0.709	0.709

Road : A009, Cat. ID : 206/3

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.042	0.034			0.034	0.051			0.051	0.059			0.059
2	0.085	0.068	0.330		0.397	0.101	0.380		0.482	0.118	0.423		0.541
3	0.127	0.101	0.659	0.325	1.086	0.152	0.761	0.368	1.280	0.177	0.845	0.423	1.445
4	0.169	0.135	0.989	0.651	1.775	0.203	1.141	0.735	2.079	0.237	1.268	0.845	2.349
5	0.181	0.145	1.318	0.976	2.439	0.218	1.521	1.103	2.841	0.254	1.690	1.268	3.211
6	0.167	0.134	1.414	1.301	2.849	0.201	1.631	1.470	3.302	0.234	1.813	1.690	3.737
7	0.153	0.123	1.305	1.396	2.823	0.184	1.506	1.577	3.267	0.215	1.673	1.813	3.700
8	0.139	0.112	1.196	1.288	2.596	0.167	1.380	1.456	3.003	0.195	1.534	1.673	3.402
9	0.125	0.100	1.088	1.181	2.369	0.151	1.255	1.334	2.740	0.176	1.394	1.534	3.104
10	0.112	0.089	0.979	1.074	2.142	0.134	1.129	1.213	2.476	0.156	1.255	1.394	2.805
11	0.098	0.078	0.870	0.966	1.914	0.117	1.004	1.092	2.213	0.137	1.115	1.255	2.507
12	0.084	0.067	0.761	0.859	1.687	0.100	0.878	0.970	1.949	0.117	0.976	1.115	2.208
13	0.070	0.056	0.653	0.751	1.460	0.084	0.753	0.849	1.686	0.098	0.837	0.976	1.910

14	0.056	0.045	0.544	0.644	1.233	0.067	0.627	0.728	1.422	0.078	0.697	0.837	1.612
15	0.042	0.033	0.435	0.537	1.005	0.050	0.502	0.606	1.159	0.059	0.558	0.697	1.313
16	0.028	0.022	0.326	0.429	0.778	0.033	0.376	0.485	0.895	0.039	0.418	0.558	1.015
17	0.014	0.011	0.218	0.322	0.551	0.017	0.251	0.364	0.632	0.020	0.279	0.418	0.717
			0.109	0.215	0.323		0.125	0.243	0.368		0.139	0.279	0.418
				0.107	0.107			0.121	0.121			0.139	0.139

Road : A009, Cat. ID : 207/1-207/2													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.321	0.257			0.257	0.385			0.385	0.449			0.449
2	0.642	0.514	2.504		3.018	0.771	2.889		3.660	0.899	3.210		4.109
3	0.963	0.771	5.008	2.472	8.251	1.156	5.779	2.793	9.728	1.348	6.421	3.210	10.980
4	1.284	1.027	7.512	4.944	13.484	1.541	8.668	5.586	15.795	1.798	9.631	6.421	17.850
5	1.605	1.284	10.017	7.416	18.717	1.926	11.558	8.379	21.863	2.247	12.842	9.631	24.721
6	1.926	1.541	12.521	9.888	23.950	2.312	14.447	11.172	27.931	2.697	16.052	12.842	31.591
7	2.144	1.715	15.025	12.360	29.101	2.573	17.337	13.966	33.875	3.002	19.263	16.052	38.317
8	2.037	1.630	16.726	14.832	33.188	2.445	19.299	16.759	38.502	2.852	21.443	19.263	43.558
9	1.930	1.544	15.889	16.511	33.944	2.316	18.334	18.655	39.305	2.702	20.371	21.443	44.516
10	1.823	1.458	15.053	15.686	32.197	2.187	17.369	17.723	37.279	2.552	19.299	20.371	42.221
11	1.715	1.372	14.217	14.860	30.449	2.059	16.404	16.790	35.252	2.402	18.227	19.299	39.927
12	1.608	1.287	13.380	14.034	28.701	1.930	15.439	15.857	33.226	2.252	17.154	18.227	37.632
13	1.501	1.201	12.544	13.209	26.954	1.801	14.474	14.924	31.200	2.101	16.082	17.154	35.338
14	1.394	1.115	11.708	12.383	25.206	1.673	13.509	13.992	29.173	1.951	15.010	16.082	33.044
15	1.287	1.029	10.872	11.558	23.459	1.544	12.544	13.059	27.147	1.801	13.938	15.010	30.749
16	1.179	0.943	10.035	10.732	21.711	1.415	11.579	12.126	25.120	1.651	12.866	13.938	28.455
17	1.072	0.858	9.199	9.907	19.963	1.287	10.614	11.193	23.094	1.501	11.794	12.866	26.160
18	0.965	0.772	8.363	9.081	18.216	1.158	9.649	10.260	21.068	1.351	10.722	11.794	23.866
19	0.858	0.686	7.526	8.256	16.468	1.029	8.684	9.328	19.041	1.201	9.649	10.722	21.572
20	0.751	0.600	6.690	7.430	14.721	0.901	7.719	8.395	17.015	1.051	8.577	9.649	19.277
21	0.643	0.515	5.854	6.604	12.973	0.772	6.755	7.462	14.989	0.901	7.505	8.577	16.983

Road : A009, Cat. ID : 207/1-207/2													
Time (hr)	UH (m³/s/cm)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m³/s)	Excess Rainfall in cm			DRH (m³/s)	Excess Rainfall in cm			DRH (m³/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
22	0.536	0.429	5.018	5.779	11.225	0.643	5.790	6.529	12.962	0.751	6.433	7.505	14.688
23	0.429	0.343	4.181	4.953	9.478	0.515	4.825	5.597	10.936	0.600	5.361	6.433	12.394
24	0.322	0.257	3.345	4.128	7.730	0.386	3.860	4.664	8.910	0.450	4.289	5.361	10.100
25	0.214	0.172	2.509	3.302	5.983	0.257	2.895	3.731	6.883	0.300	3.216	4.289	7.805
26	0.107	0.086	1.673	2.477	4.235	0.129	1.930	2.798	4.857	0.150	2.144	3.216	5.511
			0.836	1.651	2.487		0.965	1.866	2.830		1.072	2.144	3.216
				0.826	0.826			0.933	0.933			1.072	1.072

Road : A009, Cat. ID : 209/2													
Time (hr)	UH (m³/s/cm)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m³/s)	Excess Rainfall in cm			DRH (m³/s)	Excess Rainfall in cm			DRH (m³/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.071	0.057			0.057	0.086			0.086	0.100			0.100
2	0.143	0.114	0.557		0.671	0.171	0.643		0.814	0.200	0.714		0.914
3	0.177	0.142	1.114	0.550	1.805	0.213	1.285	0.621	2.119	0.248	1.428	0.714	2.390
4	0.152	0.121	1.382	1.100	2.603	0.182	1.595	1.242	3.019	0.213	1.772	1.428	3.412
5	0.127	0.101	1.185	1.364	2.650	0.152	1.367	1.541	3.060	0.177	1.519	1.772	3.468
6	0.101	0.081	0.987	1.169	2.238	0.121	1.139	1.321	2.582	0.142	1.266	1.519	2.926
7	0.076	0.061	0.790	0.974	1.825	0.091	0.911	1.101	2.103	0.106	1.012	1.266	2.384
8	0.051	0.040	0.592	0.780	1.412	0.061	0.683	0.881	1.625	0.071	0.759	1.012	1.843
9	0.025	0.020	0.395	0.585	1.000	0.030	0.456	0.661	1.147	0.035	0.506	0.759	1.301
			0.197	0.390	0.587		0.228	0.440	0.668		0.253	0.506	0.759
				0.195	0.195			0.220	0.220			0.253	0.253

Road : A009, Cat. ID : 210/2-210/6													
Time (hr)	UH (m³/s/cm)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m³/s)	Excess Rainfall in cm			DRH (m³/s)	Excess Rainfall in cm			DRH (m³/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.068	0.054			0.054	0.081			0.081	0.095			0.095

Road : A009, Cat. ID : 209/2													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.071	0.057			0.057	0.086			0.086	0.100			0.100
2	0.143	0.114	0.557		0.671	0.171	0.643		0.814	0.200	0.714		0.914
3	0.177	0.142	1.114	0.550	1.805	0.213	1.285	0.621	2.119	0.248	1.428	0.714	2.390
4	0.152	0.121	1.382	1.100	2.603	0.182	1.595	1.242	3.019	0.213	1.772	1.428	3.412
5	0.127	0.101	1.185	1.364	2.650	0.152	1.367	1.541	3.060	0.177	1.519	1.772	3.468
6	0.101	0.081	0.987	1.169	2.238	0.121	1.139	1.321	2.582	0.142	1.266	1.519	2.926
7	0.076	0.061	0.790	0.974	1.825	0.091	0.911	1.101	2.103	0.106	1.012	1.266	2.384
8	0.051	0.040	0.592	0.780	1.412	0.061	0.683	0.881	1.625	0.071	0.759	1.012	1.843
9	0.025	0.020	0.395	0.585	1.000	0.030	0.456	0.661	1.147	0.035	0.506	0.759	1.301
			0.197	0.390	0.587		0.228	0.440	0.668		0.253	0.506	0.759
				0.195	0.195			0.220	0.220			0.253	0.253
Road : A009, Cat. ID : 210/2-210/6													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
2	0.136	0.109	0.530		0.638	0.163	0.611		0.774	0.190	0.679		0.869
3	0.204	0.163	1.059	0.523	1.745	0.244	1.222	0.591	2.057	0.285	1.358	0.679	2.322
4	0.257	0.205	1.589	1.046	2.840	0.308	1.833	1.181	3.323	0.359	2.037	1.358	3.754
5	0.233	0.187	2.002	1.568	3.757	0.280	2.310	1.772	4.362	0.327	2.566	2.037	4.930
6	0.210	0.168	1.820	1.976	3.964	0.252	2.100	2.233	4.584	0.294	2.333	2.566	5.193
7	0.187	0.149	1.638	1.796	3.583	0.224	1.890	2.030	4.143	0.261	2.100	2.333	4.694
8	0.163	0.131	1.456	1.617	3.203	0.196	1.680	1.827	3.702	0.229	1.866	2.100	4.195
9	0.140	0.112	1.274	1.437	2.823	0.168	1.470	1.624	3.261	0.196	1.633	1.866	3.695
10	0.117	0.093	1.092	1.257	2.443	0.140	1.260	1.421	2.821	0.163	1.400	1.633	3.196
11	0.093	0.075	0.910	1.078	2.062	0.112	1.050	1.218	2.380	0.131	1.166	1.400	2.697
12	0.070	0.056	0.728	0.898	1.682	0.084	0.840	1.015	1.939	0.098	0.933	1.166	2.198
13	0.047	0.037	0.546	0.719	1.302	0.056	0.630	0.812	1.498	0.065	0.700	0.933	1.698
14	0.023	0.019	0.364	0.539	0.922	0.028	0.420	0.609	1.057	0.033	0.467	0.700	1.199
			0.182	0.359	0.541		0.210	0.406	0.616		0.233	0.467	0.700
				0.180	0.180			0.203	0.203			0.233	0.233

Road : A009, Cat. ID : 212/1-213/1													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.219	0.175			0.175	0.263			0.263	0.306			0.306
2	0.438	0.350	1.707		2.057	0.525	1.970		2.495	0.613	2.188		2.801
3	0.657	0.525	3.414	1.685	5.624	0.788	3.939	1.904	6.631	0.919	4.377	2.188	7.485
4	0.875	0.700	5.121	3.370	9.192	1.050	5.909	3.808	10.767	1.226	6.565	4.377	12.168
5	1.094	0.875	6.828	5.055	12.759	1.313	7.878	5.712	14.903	1.532	8.754	6.565	16.851
6	1.313	1.050	8.535	6.740	16.326	1.576	9.848	7.616	19.040	1.838	10.942	8.754	21.534
7	1.392	1.113	10.242	8.426	19.781	1.670	11.818	9.520	23.007	1.948	13.131	10.942	26.021
8	1.318	1.055	10.855	10.111	22.020	1.582	12.525	11.424	25.531	1.846	13.916	13.131	28.893
9	1.245	0.996	10.284	10.716	21.995	1.494	11.866	12.107	25.467	1.743	13.184	13.916	28.844
10	1.172	0.938	9.712	10.152	20.801	1.406	11.206	11.470	24.083	1.641	12.452	13.184	27.276
11	1.099	0.879	9.141	9.588	19.608	1.318	10.547	10.833	22.698	1.538	11.719	12.452	25.709
12	1.025	0.820	8.570	9.024	18.414	1.231	9.888	10.196	21.314	1.436	10.987	11.719	24.141
13	0.952	0.762	7.998	8.460	17.220	1.143	9.229	9.558	19.930	1.333	10.254	10.987	22.574
14	0.879	0.703	7.427	7.896	16.026	1.055	8.570	8.921	18.545	1.231	9.522	10.254	21.006
15	0.806	0.645	6.856	7.332	14.832	0.967	7.910	8.284	17.161	1.128	8.789	9.522	19.439
16	0.732	0.586	6.284	6.768	13.638	0.879	7.251	7.647	15.777	1.025	8.057	8.789	17.872
17	0.659	0.527	5.713	6.204	12.444	0.791	6.592	7.009	14.393	0.923	7.324	8.057	16.304
18	0.586	0.469	5.142	5.640	11.250	0.703	5.933	6.372	13.008	0.820	6.592	7.324	14.737
19	0.513	0.410	4.570	5.076	10.056	0.615	5.274	5.735	11.624	0.718	5.860	6.592	13.169
20	0.439	0.352	3.999	4.512	8.863	0.527	4.614	5.098	10.240	0.615	5.127	5.860	11.602
21	0.366	0.293	3.428	3.948	7.669	0.439	3.955	4.461	8.855	0.513	4.395	5.127	10.034
22	0.293	0.234	2.857	3.384	6.475	0.352	3.296	3.823	7.471	0.410	3.662	4.395	8.467
23	0.220	0.176	2.285	2.820	5.281	0.264	2.637	3.186	6.087	0.308	2.930	3.662	6.900
24	0.146	0.117	1.714	2.256	4.087	0.176	1.978	2.549	4.702	0.205	2.197	2.930	5.332
25	0.073	0.059	1.143	1.692	2.893	0.088	1.318	1.912	3.318	0.103	1.465	2.197	3.765
			0.571	1.128	1.699		0.659	1.274	1.934		0.732	1.465	2.197
				0.564	0.564			0.637	0.637			0.732	0.732

Road : A009, Cat. ID : 215/1													
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years				Return Period-50 Years				Return Period-100 Years			
		Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)	Excess Rainfall in cm			DRH (m^3/s)
		0.8	7.8	7.7		1.2	9.0	8.7		1.4	10.0	10.0	
1	0.039	0.031			0.031	0.046			0.046	0.054			0.054
2	0.077	0.062	0.301		0.363	0.093	0.347		0.440	0.108	0.386		0.494
3	0.094	0.076	0.602	0.297	0.974	0.113	0.694	0.336	1.143	0.132	0.771	0.386	1.289
4	0.081	0.065	0.737	0.594	1.395	0.097	0.850	0.671	1.618	0.113	0.944	0.771	1.829
5	0.067	0.054	0.631	0.727	1.412	0.081	0.728	0.821	1.631	0.094	0.809	0.944	1.848
6	0.054	0.043	0.526	0.623	1.192	0.065	0.607	0.704	1.376	0.076	0.674	0.809	1.559
7	0.040	0.032	0.421	0.519	0.973	0.049	0.486	0.587	1.121	0.057	0.540	0.674	1.271
8	0.027	0.022	0.316	0.415	0.753	0.032	0.364	0.469	0.866	0.038	0.405	0.540	0.982
9	0.013	0.011	0.210	0.312	0.533	0.016	0.243	0.352	0.611	0.019	0.270	0.405	0.693
			0.105	0.208	0.313		0.121	0.235	0.356		0.135	0.270	0.405
				0.104	0.104			0.117	0.117			0.135	0.135

Road : B528, Cat. ID : 3/1-3/3										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		4.2	3.9		4.5	4.4		5.2	4.9	
1	1.444	6.066		6.066	6.499		6.499	7.511		7.511
2	2.191	9.203	5.633	14.835	9.860	6.355	16.215	11.394	7.077	18.471
3	1.753	7.362	8.545	15.907	7.888	9.641	17.529	9.115	10.736	19.851
4	1.315	5.522	6.836	12.358	5.916	7.713	13.629	6.836	8.589	15.425
5	0.876	3.681	5.127	8.808	3.944	5.784	9.728	4.557	6.442	10.999
6	0.438	1.841	3.418	5.259	1.972	3.856	5.828	2.279	4.295	6.573
			1.709	1.709		1.928	1.928		2.147	2.147

Road : B528, Cat. ID : 11/2-11/3										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		4.2	3.9		4.5	4.4		5.2	4.9	
1	1.794	7.536		7.536	8.074		8.074	9.330		9.330
2	2.995	12.581	6.998	19.579	13.480	7.895	21.375	15.576	8.792	24.369
3	2.396	10.065	11.682	21.747	10.784	13.180	23.964	12.461	14.678	27.139
4	1.797	7.549	9.346	16.894	8.088	10.544	18.632	9.346	11.742	21.088
5	1.198	5.032	7.009	12.042	5.392	7.908	13.300	6.231	8.807	15.037

6	0.599	2.516	4.673	7.189	2.696	5.272	7.968	3.115	5.871	8.986
			2.336	2.336		2.636	2.636		2.936	2.936

Road : B528, Cat. ID : 12/2-13/2										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		4.2	3.9		4.5	4.4		5.2	4.9	
1	2.998	12.591		12.591	13.491		13.491	15.589		15.589
2	5.996	25.183	11.692	36.875	26.982	13.191	40.173	31.179	14.690	45.869
3	8.877	37.285	23.384	60.669	39.948	26.382	66.330	46.162	29.380	75.542
4	7.891	33.142	34.621	67.763	35.509	39.060	74.569	41.033	43.499	84.532
5	6.905	28.999	30.775	59.774	31.071	34.720	65.791	35.904	38.666	74.569
6	5.918	24.856	26.928	51.784	26.632	30.380	57.012	30.775	33.832	64.607
7	4.932	20.714	23.081	43.795	22.193	26.040	48.233	25.646	28.999	54.645
8	3.945	16.571	19.234	35.805	17.755	21.700	39.455	20.516	24.166	44.682
9	2.959	12.428	15.387	27.816	13.316	17.360	30.676	15.387	19.333	34.720
10	1.973	8.285	11.540	19.826	8.877	13.020	21.897	10.258	14.500	24.758
11	0.986	4.143	7.694	11.836	4.439	8.680	13.119	5.129	9.666	14.795
			3.847	3.847		4.340	4.340		4.833	4.833

Road : B528, Cat. ID : 16/3-17/2										
Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		4.2	3.9		4.5	4.4		5.2	4.9	
1	6.521	27.390		27.390	29.347		29.347	33.912		33.912
2	13.043	54.781	25.434	80.214	58.693	28.695	87.388	67.824	31.955	99.779
3	11.977	50.304	50.868	101.171	53.897	57.389	111.286	62.281	63.911	126.191
4	9.582	40.243	46.710	86.953	43.117	52.699	95.816	49.824	58.687	108.512
5	7.186	30.182	37.368	67.551	32.338	42.159	74.497	37.368	46.950	84.318
6	4.791	20.121	28.026	48.148	21.559	31.619	53.178	24.912	35.212	60.125
7	2.395	10.061	18.684	28.745	10.779	21.080	31.859	12.456	23.475	35.931
			9.342	9.342		10.540	10.540		11.737	11.737

Road : B528, Cat. ID : 20/1										
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		4.2	3.9		4.5	4.4		5.2	4.9	
1	3.296	13.843		13.843	14.831		14.831	17.139		17.139
2	6.592	27.685	12.854	40.539	29.663	14.502	44.165	34.277	16.150	50.427
3	6.743	28.321	25.708	54.029	30.344	29.004	59.348	35.064	32.300	67.364
4	5.619	23.601	26.298	49.899	25.287	29.670	54.957	29.220	33.042	62.262
5	4.495	18.881	21.915	40.796	20.230	24.725	44.954	23.376	27.535	50.911
6	3.372	14.161	17.532	31.693	15.172	19.780	34.952	17.532	22.028	39.560
7	2.248	9.440	13.149	22.590	10.115	14.835	24.950	11.688	16.521	28.209
8	1.124	4.720	8.766	13.486	5.057	9.890	14.947	5.844	11.014	16.858
			4.383	4.383		4.945	4.945		5.507	5.507

Road : B528, Cat. ID : 31/3										
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years			Return Period-50 Years			Return Period-100 Years		
		Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)	Excess Rainfall in cm		DRH (m^3/s)
		4.2	3.9		4.5	4.4		5.2	4.9	
1	3.543	14.879		14.879	15.942		15.942	18.422		18.422
2	6.600	27.721	13.817	41.538	29.701	15.588	45.289	34.321	17.359	51.681
3	5.500	23.101	25.741	48.842	24.751	29.041	53.792	28.601	32.341	60.942
4	4.400	18.481	21.451	39.931	19.801	24.201	44.002	22.881	26.951	49.832
5	3.300	13.860	17.161	31.021	14.851	19.361	34.211	17.161	21.561	38.721
6	2.200	9.240	12.870	22.111	9.900	14.521	24.421	11.440	16.171	27.611
7	1.100	4.620	8.580	13.200	4.950	9.680	14.631	5.720	10.780	16.501
			4.290	4.290		4.840	4.840		5.390	5.390

Road : B528, Cat. ID : 4/1-5/4																
Time (hr)	UH (m^3/s/cm)	Return Period-25 Years					Return Period-50 Years					Return Period-100 Years				
		Excess Rainfall in cm				DRH (m^3/s)	Excess Rainfall in cm				DRH (m^3/s)	Excess Rainfall in cm				DRH (m^3/s)
		0.9	4.2	3.9	0.6		1.1	4.5	4.4	0.8		1.1	5.2	4.9	0.9	
1	1.946	1.752				1.752	2.141				2.141	2.141				2.141
2	3.892	3.503	8.174			11.677	4.282	8.758			13.039	4.282	10.120			14.402
3	6.784	6.106	16.348	7.590		30.043	7.462	17.515	8.563		33.541	7.462	20.240	9.536		37.239
4	6.106	5.495	28.493	15.180	1.168	50.336	6.716	30.528	17.126	1.557	55.927	6.716	35.277	19.072	1.752	62.817
5	5.427	4.884	25.644	26.458	2.335	59.321	5.970	27.475	29.850	3.114	66.409	5.970	31.749	33.242	3.503	74.464
6	4.749	4.274	22.794	23.812	4.070	54.951	5.224	24.422	26.865	5.427	61.938	5.224	28.221	29.917	6.106	69.468

7	4.070	3.663	19.945	21.166	3.663	48.438	4.477	21.370	23.880	4.884	54.611	4.477	24.694	26.593	5.495	61.260
8	3.392	3.053	17.096	18.520	3.256	41.925	3.731	18.317	20.895	4.342	47.285	3.731	21.166	23.269	4.884	53.051
9	2.714	2.442	14.246	15.875	2.849	35.413	2.985	15.264	17.910	3.799	39.958	2.985	17.638	19.945	4.274	44.842
10	2.035	1.832	11.397	13.229	2.442	28.900	2.239	12.211	14.925	3.256	32.631	2.239	14.111	16.621	3.663	36.634
11	1.357	1.221	8.548	10.583	2.035	22.387	1.492	9.158	11.940	2.714	25.304	1.492	10.583	13.297	3.053	28.425
12	0.678	0.611	5.699	7.937	1.628	15.875	0.746	6.106	8.955	2.171	17.978	0.746	7.055	9.972	2.442	20.216
			2.849	5.292	1.221	9.362		3.053	5.970	1.628	10.651		3.528	6.648	1.832	12.008
				2.646	0.814	3.460			2.985	1.085	4.070			3.324	1.221	4.545
					0.407	0.407				0.543	0.543				0.611	0.611

Road : B528, Cat. ID : 7/1-7/2

Time (hr)	UH ($m^3/s/cm$)	Return Period-25 Years					Return Period-50 Years					Return Period-100 Years				
		Excess Rainfall in cm				DRH (m^3/s)	Excess Rainfall in cm				DRH (m^3/s)	Excess Rainfall in cm				DRH (m^3/s)
		0.9	4.2	3.9	0.6		1.1	4.5	4.4	0.8		1.1	5.2	4.9	0.9	
1	5.508	4.957				4.957	6.059				6.059	6.059				6.059
2	11.016	9.914	23.134			33.048	12.118	24.786			36.904	12.118	28.642			40.760
3	16.524	14.872	46.268	21.481		82.621	18.177	49.572	24.235		91.984	18.177	57.284	26.989		102.450
4	22.348	20.114	69.401	42.963	3.305	135.782	24.583	74.359	48.471	4.406	151.819	24.583	85.925	53.979	4.957	169.445
5	20.486	18.437	93.863	64.444	6.610	183.355	22.535	100.568	72.706	8.813	204.622	22.535	116.212	80.968	9.914	229.629
6	18.624	16.761	86.041	87.159	9.914	199.876	20.486	92.187	98.333	13.219	224.226	20.486	106.528	109.507	14.872	251.393
7	16.761	15.085	78.220	79.896	13.409	186.609	18.437	83.807	90.139	17.879	210.261	18.437	96.843	100.382	20.114	235.776
8	14.899	13.409	70.398	72.632	12.292	168.731	16.389	75.426	81.944	16.389	190.148	16.389	87.159	91.256	18.437	213.241
9	13.037	11.733	62.576	65.369	11.174	150.852	14.340	67.045	73.750	14.899	170.034	14.340	77.475	82.130	16.761	190.707
10	11.174	10.057	54.754	58.106	10.057	132.973	12.292	58.665	65.555	13.409	149.921	12.292	67.790	73.005	15.085	168.172
11	9.312	8.381	46.932	50.843	8.939	115.094	10.243	50.284	57.361	11.919	129.807	10.243	58.106	63.879	13.409	145.637
12	7.449	6.705	39.110	43.579	7.822	97.216	8.194	41.903	49.167	10.429	109.694	8.194	48.422	54.754	11.733	123.103
13	5.587	5.028	31.288	36.316	6.705	79.337	6.146	33.523	40.972	8.939	89.580	6.146	38.737	45.628	10.057	100.568
14	3.725	3.352	23.466	29.053	5.587	61.458	4.097	25.142	32.778	7.449	69.466	4.097	29.053	36.502	8.381	78.033
15	1.862	1.676	15.644	21.790	4.470	43.579	2.049	16.761	24.583	5.960	49.353	2.049	19.369	27.377	6.705	55.499
			7.822	14.526	3.352	25.701		8.381	16.389	4.470	29.239		9.684	18.251	5.028	32.964
				7.263	2.235	9.498			8.194	2.980	11.174			9.126	3.352	12.478
					1.117	1.117				1.490	1.490				1.676	1.676

APPENDIX F. RESULTS OF PEAK FLOW ESTIMATIONS

Peak Flow Estimation using Rational Formula

Table F-1 Peak Flow Estimation for 25 Year Return Period using Rational Formula

Catchment ID	Road	A (ha)	C	Peak Flow - 25 Year (m^3/sec)			
				tc-ID	tc-KIR	tc-B-W	tc-UK
16/1	A035	9.0800	0.11	0.539	1.087	0.849	0.296
39/2	B312	10.259	0.21	0.685	0.795	0.735	0.557
215/1	A009	10.7070	0.27	1.538	2.880	2.051	0.811
38/6 - 38/7	B312	11.376	0.14	0.494	0.572	0.536	0.385
59/3	B312	12.161	0.40	1.557	1.839	1.649	1.351
128/1	A009	12.5070	0.14	0.566	0.722	0.634	0.386
30/2	A035	17.5200	0.39	2.479	3.755	2.708	1.333
35/1 - 36/1	B312	17.751	0.25	1.421	1.632	1.496	1.137
58/1 - 58/2	B312	18.292	0.42	2.426	2.832	2.487	1.980
209/2	A009	20.2220	0.33	3.578	7.969	5.516	2.090
58/7 - 59/1	B312	22.758	0.42	2.958	3.464	2.953	2.358
129/2	A009	25.8840	0.27	2.054	2.704	2.386	1.396
39/1	B312	27.107	0.21	1.733	1.999	1.788	1.308
206/3	A009	34.8430	0.16	1.613	2.639	1.769	0.993
130/1-130/2	A009	40.0680	0.28	3.513	4.487	3.983	2.355
210/2-210/6	A009	41.3080	0.28	3.880	6.228	4.499	2.228
2/3-2/4	A035	45.6400	0.33	4.393	4.721	3.960	2.085
125/1	A009	67.4210	0.21	3.842	5.151	4.201	2.599
131/1	A009	68.2420	0.22	3.896	5.147	4.110	2.561
2/1-2/2	A035	70.7800	0.33	6.508	7.694	6.272	3.333
58/3 - 58/6A	B312	102.048	0.38	10.621	12.650	9.956	7.792
127/2	A009	114.4310	0.31	8.873	12.097	9.613	6.015
3/1 - 3/3	B528	128.9200	0.30	7.266	10.426	8.134	5.199

Catchment ID	Road	A (ha)	C	Peak Flow - 25 Year (m^3/sec)			
				tc-ID	tc-KIR	tc-B-W	tc-UK
4/2-5/1	A035	153.3170	0.30	9.668	11.533	9.169	5.556
11/2-11/3	B528	185.1921	0.25	9.424	13.167	9.947	6.557
123/3-123/4	A009	303.0000	0.35	25.152	32.944	21.688	16.216
212/1-213/1	A009	384.6240	0.38	27.595	41.527	30.811	19.055
31/3	B528	427.9100	0.34	30.426	40.961	29.079	20.399
126/1	A009	486.7990	0.31	23.055	32.449	25.453	16.532
42/4 - 44/3	B312	491.638	0.45	54.250	67.595	47.994	40.319
38/1 - 38/5	B312	509.245	0.23	23.762	32.244	22.811	18.722
59/2	B312	543.884	0.38	37.223	50.178	33.354	28.887
22/1 - 22/2	A035	545.5000	0.18	14.226	20.860	15.239	10.720
20/1	B528	580.3100	0.40	50.370	66.235	44.632	32.985
207/1-207/2	A009	606.4920	0.30	33.441	56.257	40.663	24.978
4/1-5/4	B528	738.7500	0.30	21.587	33.286	23.625	18.605
34/3 - 34/4	B312	768.529	0.27	38.098	51.628	40.214	29.727
205/2-206/1	A009	793.6700	0.34	35.901	61.390	42.150	30.718
12/3-13/2	B528	889.4600	0.36	47.421	67.883	42.407	34.885
40/1 - 42/3	B312	978.164	0.33	68.021	88.877	61.343	51.606
16/3-17/2	B528	1012.5800	0.39	76.632	107.849	76.433	53.748
36/2 - 37/1	B312	1709.111	0.31	67.293	106.774	62.446	62.410
28/1-28/4	A035	2268.8400	0.29	51.294	81.501	57.456	51.680
7/1-7/2	B528	3026.6124	0.30	87.763	147.313	98.539	80.584
21/1	A035	4811.0600	0.30	81.059	126.630	90.783	91.845
24/1 - 26/1	A035	6662.6100	0.34	122.488	198.285	142.370	143.946

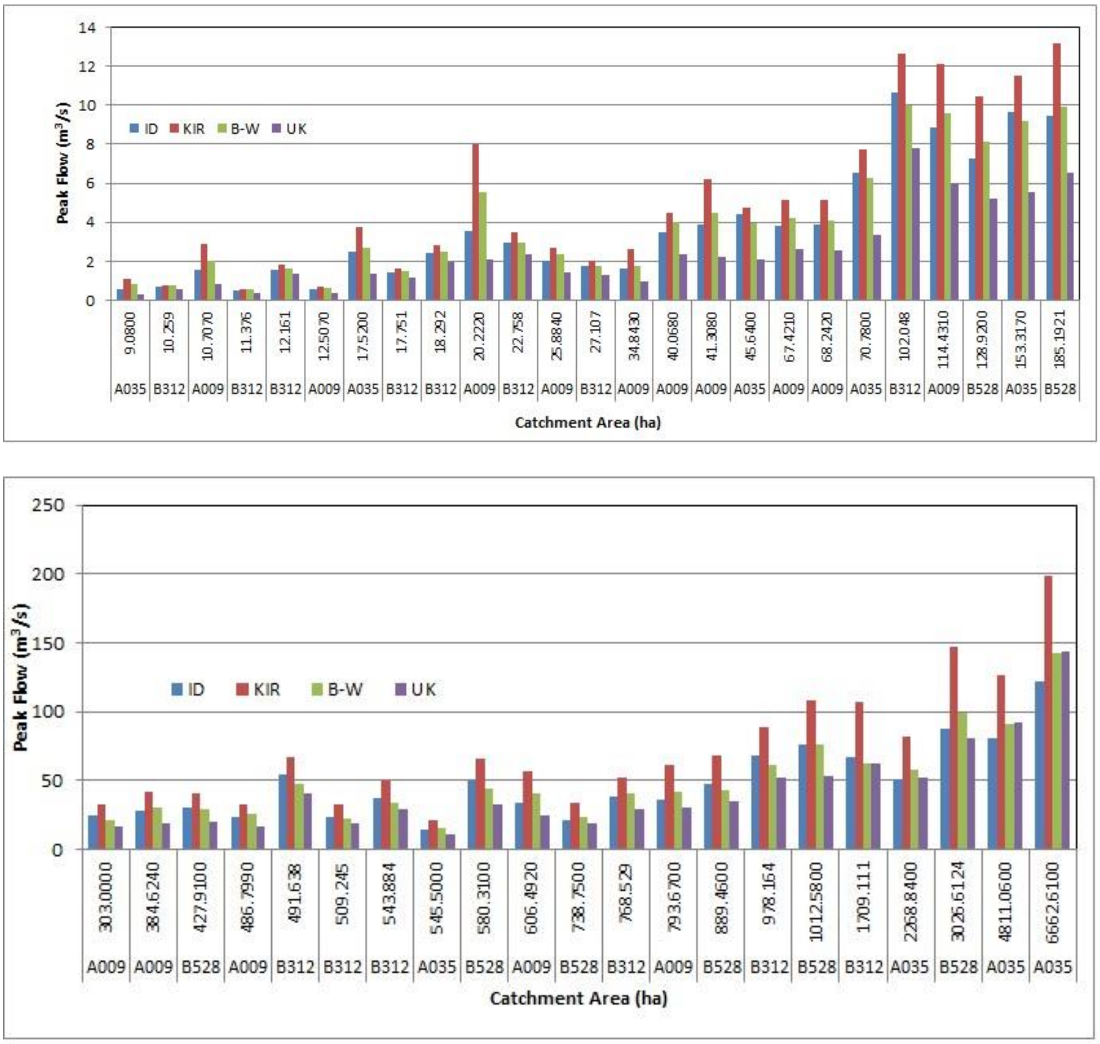


Figure F-1 Peak Flow Estimation using Rational Formula for 25 Year Return Period

Table F-2 Peak Flow Estimation for 50 Year Return Period using Rational Formula

Catchment ID	Road	A (ha)	C	Peak Flow - 50 Year (m^3/sec)			
				tc-ID	tc-KIR	tc-B-W	tc-UK
16/1	A035	9.0800	0.12	0.648	1.305	1.020	0.356
39/2	B312	10.2593	0.24	0.846	0.981	0.907	0.689
215/1	A009	10.7070	0.31	1.946	3.641	2.595	1.027
38/6 - 38/7	B312	11.3763	0.17	0.649	0.750	0.703	0.506
59/3	B312	12.1606	0.43	1.808	2.132	1.914	1.570
128/1	A009	12.5070	0.15	0.676	0.867	0.759	0.459
30/2	A035	17.5200	0.40	2.804	4.245	3.063	1.509
35/1 - 36/1	B312	17.7511	0.29	1.780	2.043	1.874	1.427
58/1 - 58/2	B312	18.2918	0.45	2.808	3.274	2.877	2.295

Catchment ID	Road	A (ha)	C	Peak Flow - 50 Year (m^3/sec)			
				tc-ID	tc-KIR	tc-B-W	tc-UK
209/2	A009	20.2220	0.70	8.367	18.608	12.887	4.891
58/7 - 59/1	B312	22.7579	0.45	3.424	4.005	3.418	2.734
129/2	A009	25.8840	0.29	2.457	3.250	2.861	1.661
39/1	B312	27.1074	0.24	2.140	2.466	2.207	1.619
206/3	A009	34.8430	0.18	2.002	3.274	2.195	1.233
130/1-130/2	A009	40.0680	0.31	4.335	5.562	4.926	2.890
210/2-210/6	A009	41.3080	0.31	4.739	7.601	5.494	2.724
2/3-2/4	A035	45.6400	0.70	10.284	11.048	9.271	4.886
125/1	A009	67.4210	0.24	4.883	6.579	5.347	3.288
131/1	A009	68.2420	0.24	4.723	6.268	4.987	3.090
2/1-2/2	A035	70.7800	0.70	15.235	18.005	14.682	7.811
58/3 - 58/6A	B312	102.0480	0.41	12.391	14.740	11.622	9.112
127/2	A009	114.4310	0.34	10.810	14.811	11.725	7.295
3/1 - 3/3	B528	128.9200	0.34	9.185	13.010	10.249	6.613
4/2-5/1	A035	153.3170	0.61	21.704	25.884	20.587	12.486
11/2-11/3	B528	185.1921	0.30	12.586	17.351	13.261	8.826
123/3-123/4	A009	303.0000	0.42	33.504	44.057	28.839	21.500
212/1-213/1	A009	384.6240	0.42	33.681	50.650	37.599	23.273
31/3	B528	427.9100	0.39	38.808	51.622	37.142	26.250
126/1	A009	486.7990	0.36	29.581	41.779	32.688	21.158
42/4 - 44/3	B312	491.6382	0.48	62.627	77.905	55.455	46.647
38/1 - 38/5	B312	509.2448	0.28	31.351	42.446	30.106	24.745
59/2	B312	543.8840	0.41	43.565	58.597	39.068	33.872
22/1 - 22/2	A035	545.5000	0.21	18.337	26.869	19.640	13.824
20/1	B528	580.3100	0.43	60.139	78.176	53.484	39.771
207/1-207/2	A009	606.4920	0.35	43.086	72.419	52.373	32.198
4/1-5/4	B528	738.7500	0.35	28.338	43.519	31.001	24.428
34/3 - 34/4	B312	768.5286	0.30	45.912	62.077	48.442	35.890
205/2-206/1	A009	793.6700	0.39	45.503	77.739	53.409	38.945
12/3-13/2	B528	889.4600	0.40	59.060	83.835	52.898	43.590
40/1 - 42/3	B312	978.1636	0.43	96.032	125.228	86.670	73.007
16/3-17/2	B528	1012.5800	0.42	91.971	127.799	91.739	64.960
36/2 - 37/1	B312	1709.1110	0.34	80.267	126.924	74.527	74.483
28/1-28/4	A035	2268.8400	0.34	66.512	105.597	74.487	67.011
7/1-7/2	B528	3026.6124	0.34	111.917	186.841	125.595	102.782
21/1	A035	4811.0600	0.33	98.671	154.026	110.486	111.776
24/1 - 26/1	A035	6662.6100	0.40	159.476	257.951	185.314	187.363

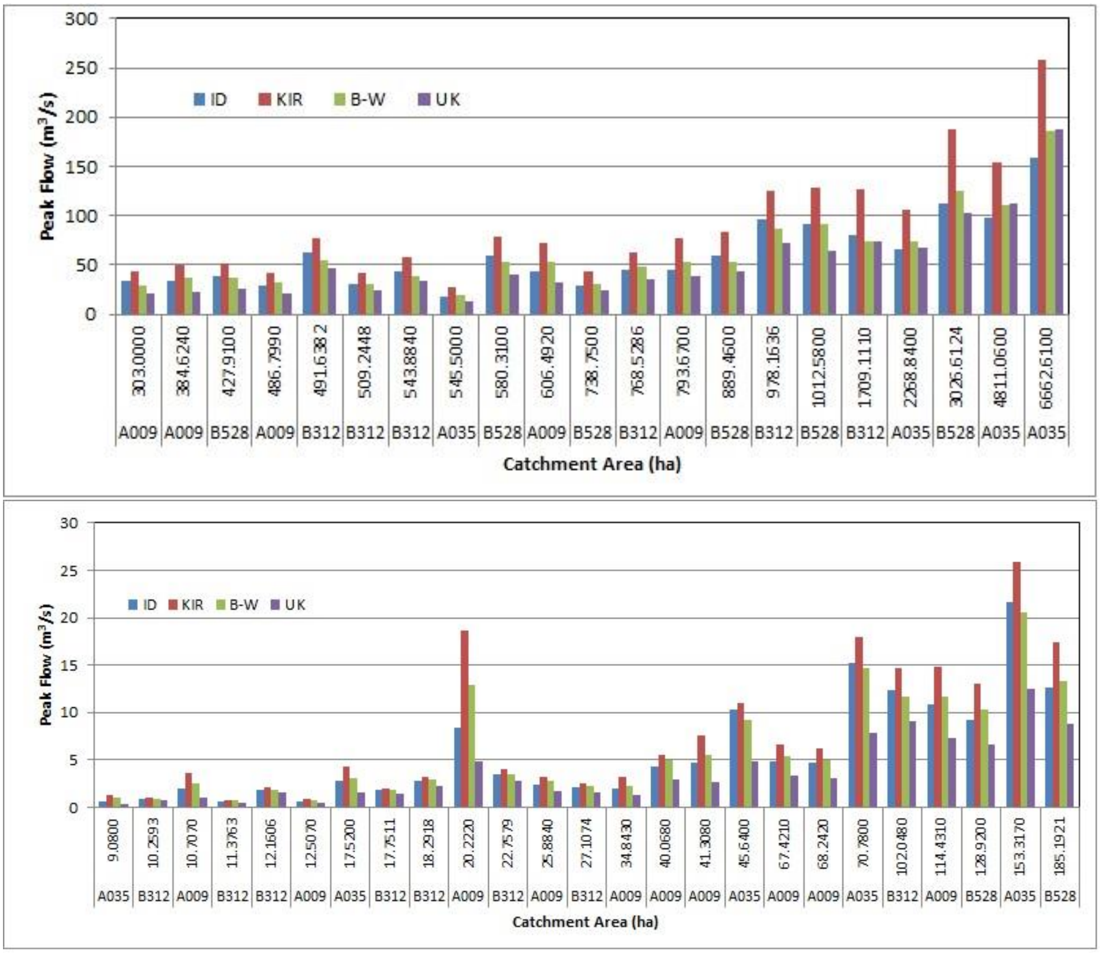


Figure F-2 Peak Flow Estimation using Rational Formula for 50 Year Return Period

Table F-3 Peak Flow Estimation for 100 Year Return Period using Rational Formula

Catchment ID	Road	A (ha)	C	Peak Flow - 100 Year (m^3/sec)			
				tc-ID	tc-KIR	tc-B-W	tc-UK
16/1	A035	9.0800	0.13	0.810	1.641	1.277	0.447
39/2	B312	10.2593	0.25	0.943	1.091	1.010	0.771
215/1	A009	10.7070	0.34	2.464	4.627	3.285	1.307
38/6 - 38/7	B312	11.3763	0.18	0.735	0.848	0.796	0.575
59/3	B312	12.1606	0.46	2.070	2.435	2.189	1.801
128/1	A009	12.5070	0.15	0.745	0.955	0.836	0.505
30/2	A035	17.5200	0.40	3.245	4.899	3.541	1.760
35/1 - 36/1	B312	17.7511	0.31	2.037	2.332	2.142	1.638
58/1 - 58/2	B312	18.2918	0.49	3.273	3.807	3.353	2.683
209/2	A009	20.2220	0.90	12.415	27.843	19.146	7.288
58/7 - 59/1	B312	22.7579	0.49	3.992	4.658	3.985	3.199

Catchment ID	Road	A (ha)	C	Peak Flow - 100 Year (m^3/sec)			
				tc-ID	tc-KIR	tc-B-W	tc-UK
129/2	A009	25.8840	0.32	2.984	3.952	3.477	2.016
39/1	B312	27.1074	0.25	2.387	2.745	2.461	1.814
206/3	A009	34.8430	0.19	2.451	3.990	2.685	1.520
130/1-130/2	A009	40.0680	0.34	5.236	6.722	5.950	3.486
210/2-210/6	A009	41.3080	0.32	5.665	9.054	6.558	3.279
2/3-2/4	A035	45.6400	0.90	15.335	16.461	13.843	7.367
125/1	A009	67.4210	0.26	5.822	7.851	6.376	3.915
131/1	A009	68.2420	0.26	5.631	7.478	5.946	3.679
2/1-2/2	A035	70.7800	0.90	22.730	26.811	21.917	11.770
58/3 - 58/6A	B312	102.0480	0.45	14.590	17.309	13.697	10.777
127/2	A009	114.4310	0.37	12.943	17.751	14.043	8.725
3/1 - 3/3	B528	128.9200	0.37	10.992	15.443	12.240	7.951
4/2-5/1	A035	153.3170	0.78	32.330	38.462	30.690	18.763
11/2-11/3	B528	185.1921	0.33	15.203	20.786	16.001	10.720
123/3-123/4	A009	303.0000	0.47	41.247	54.284	35.488	26.434
212/1-213/1	A009	384.6240	0.45	42.106	62.961	46.927	29.268
31/3	B528	427.9100	0.42	45.869	60.563	43.939	31.217
126/1	A009	486.7990	0.40	36.112	51.055	39.916	25.804
42/4 - 44/3	B312	491.6382	0.52	72.903	90.387	64.670	54.532
38/1 - 38/5	B312	509.2448	0.31	37.399	50.409	35.935	29.617
59/2	B312	543.8840	0.45	51.606	69.118	46.350	40.264
22/1 - 22/2	A035	545.5000	0.22	22.509	32.787	24.081	17.050
20/1	B528	580.3100	0.46	70.555	91.071	62.897	46.975
207/1-207/2	A009	606.4920	0.39	56.041	93.526	67.924	42.076
4/1-5/4	B528	738.7500	0.38	34.070	52.134	37.253	29.387
34/3 - 34/4	B312	768.5286	0.33	54.493	73.358	57.452	42.743
205/2-206/1	A009	793.6700	0.43	58.867	99.736	68.914	50.515
12/3-13/2	B528	889.4600	0.42	68.437	96.585	61.371	50.652
40/1 - 42/3	B312	978.1636	0.49	117.848	153.073	106.514	89.938
16/3-17/2	B528	1012.5800	0.45	108.308	149.304	108.039	76.881
36/2 - 37/1	B312	1709.1110	0.37	94.724	148.839	88.037	87.986
28/1-28/4	A035	2268.8400	0.38	88.035	138.644	98.392	88.684
7/1-7/2	B528	3026.6124	0.36	131.230	218.067	147.172	120.562
21/1	A035	4811.0600	0.36	128.234	198.573	143.294	144.936
24/1 - 26/1	A035	6662.6100	0.44	209.130	335.341	242.348	244.978

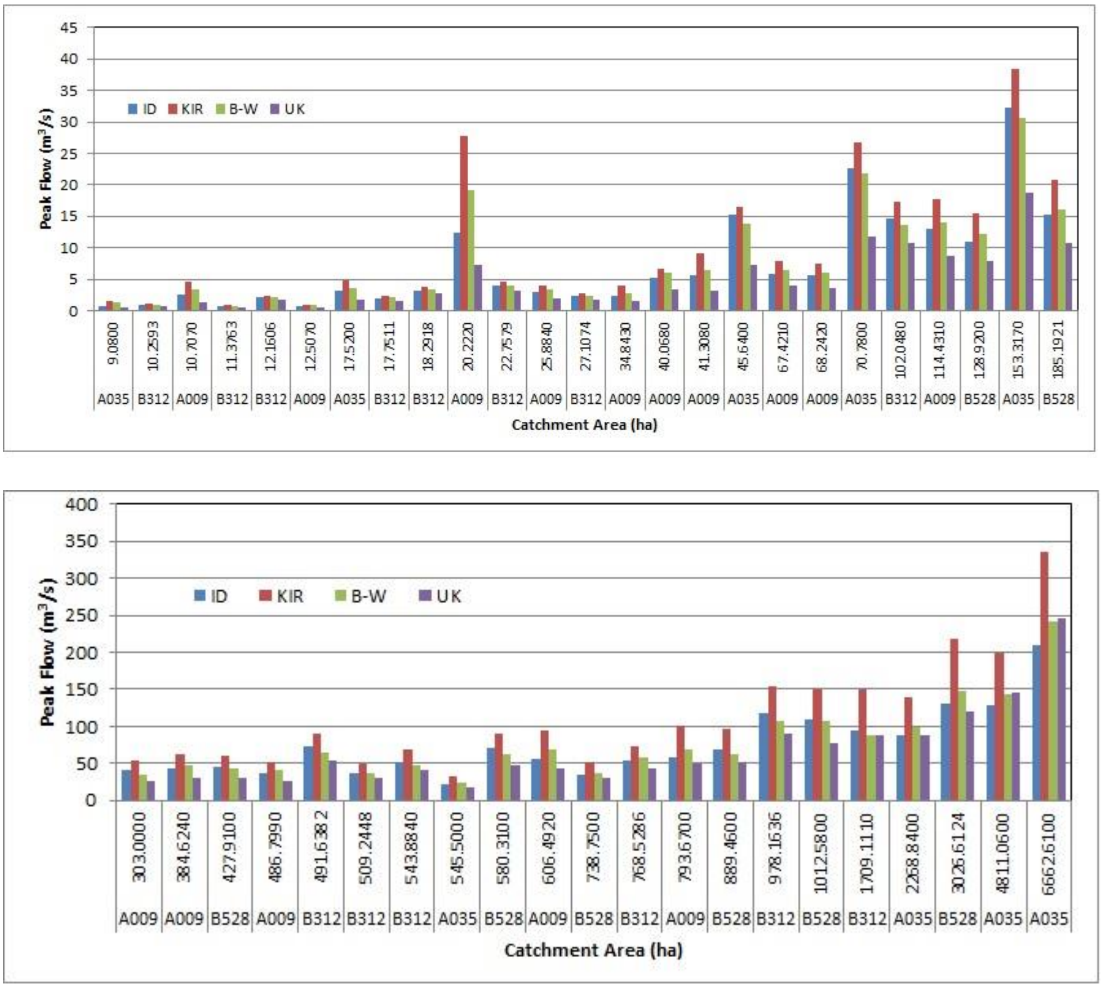


Figure F-3 Peak Flow Estimation using Rational Formula for 100 Year Return Period

Comparison of Peak Flow Alternatives

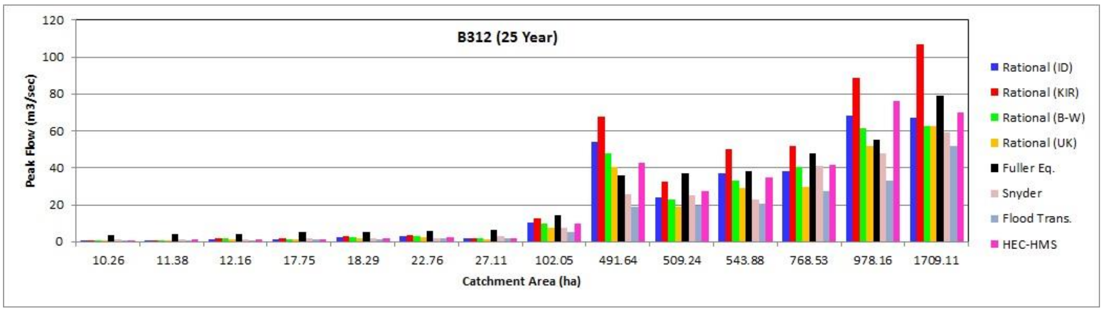


Figure F-4 Peak Flow Estimations for B 312 Road for 25 Year Return Period

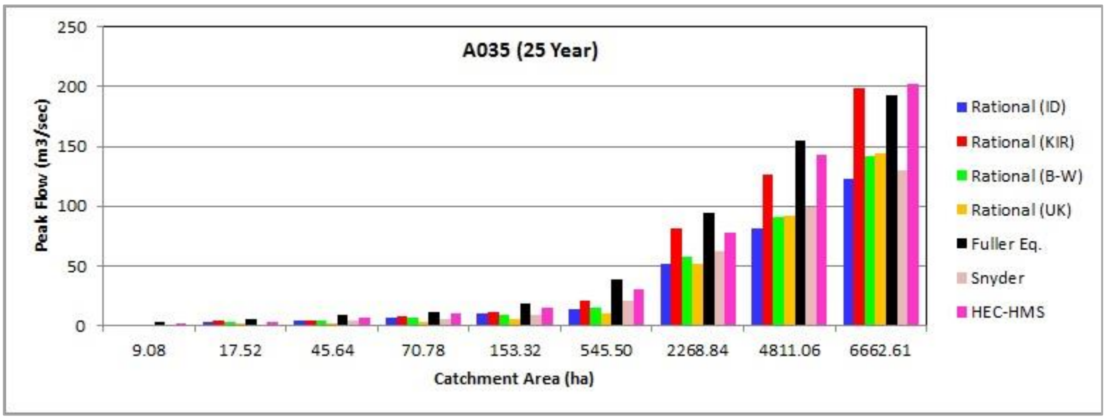


Figure F-5 Peak Flow Estimations for A 035 Road for 25 Year Return Period

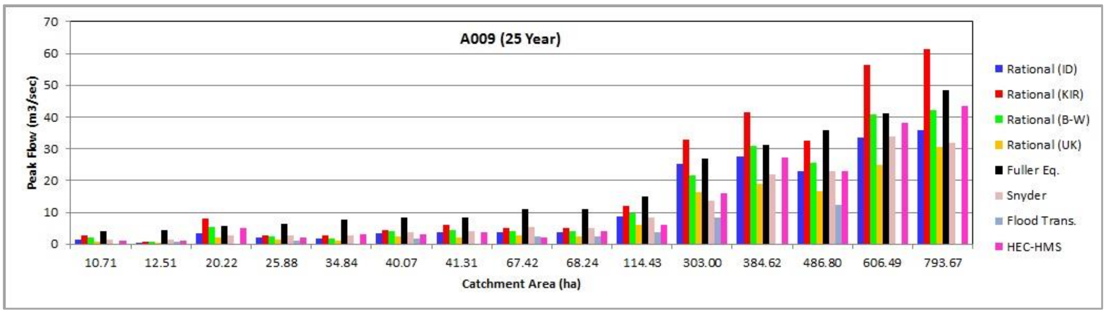


Figure F-6 Peak Flow Estimations for A 009 Road for 25 Year Return Period

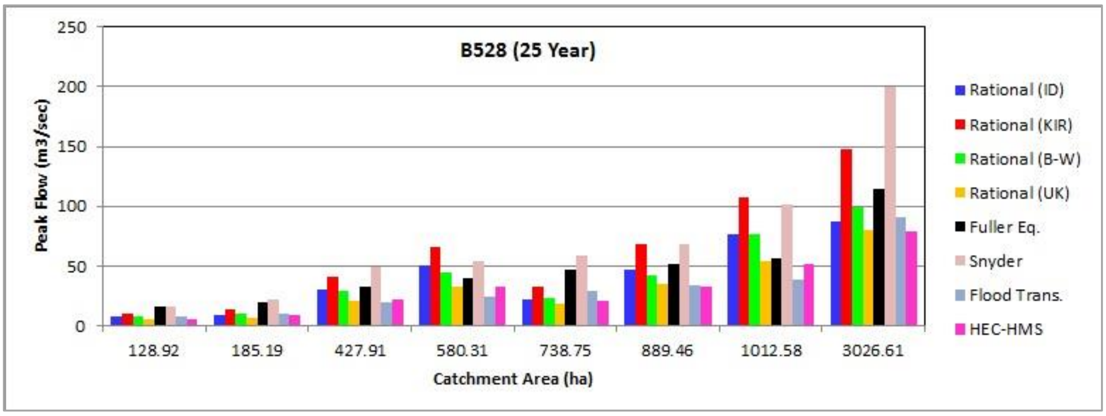


Figure F-7 Peak Flow Estimations for B 528 Road for 25 Year Return Period

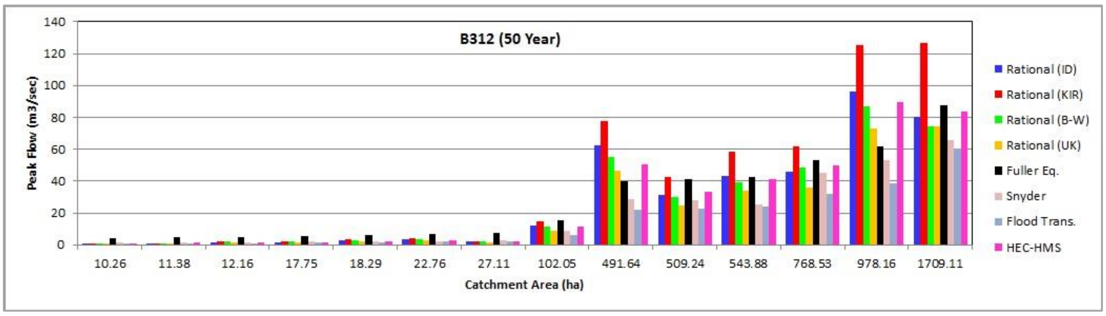


Figure F-8 Peak Flow Estimations for B 312 Road for 50 Year Return Period

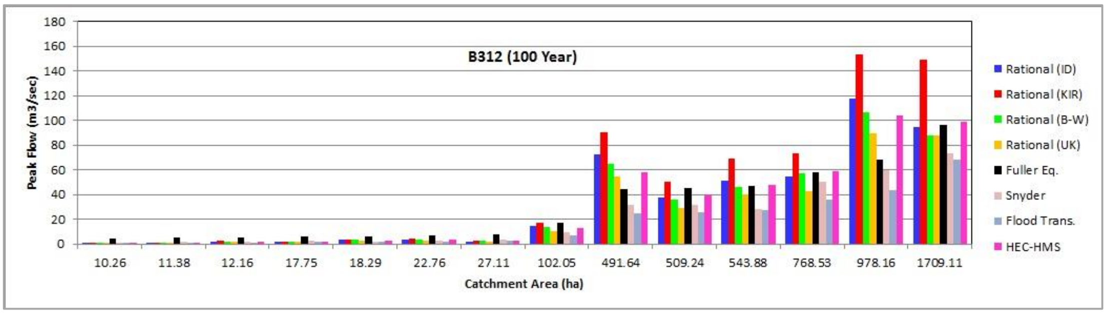


Figure F-9 Peak Flow Estimations for B 312 Road for 100 Year Return Period

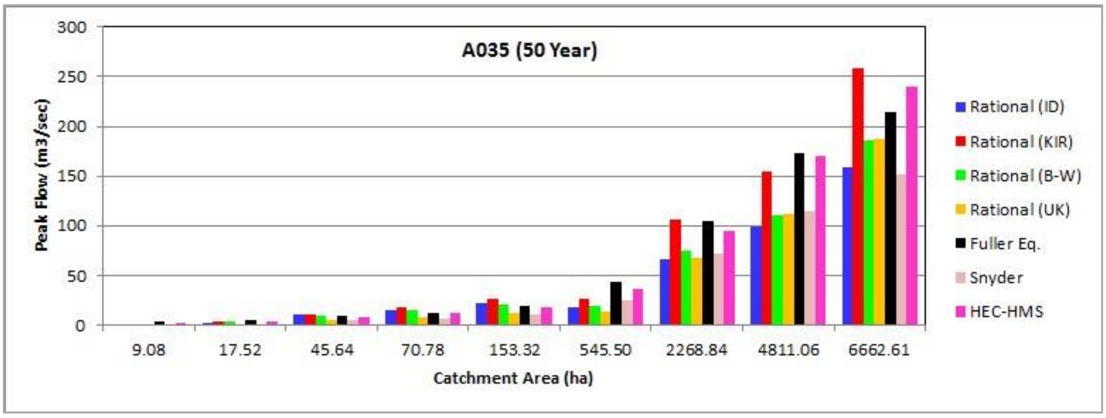


Figure F-10 Peak Flow Estimations for A 035 Road for 50 Year Return Period

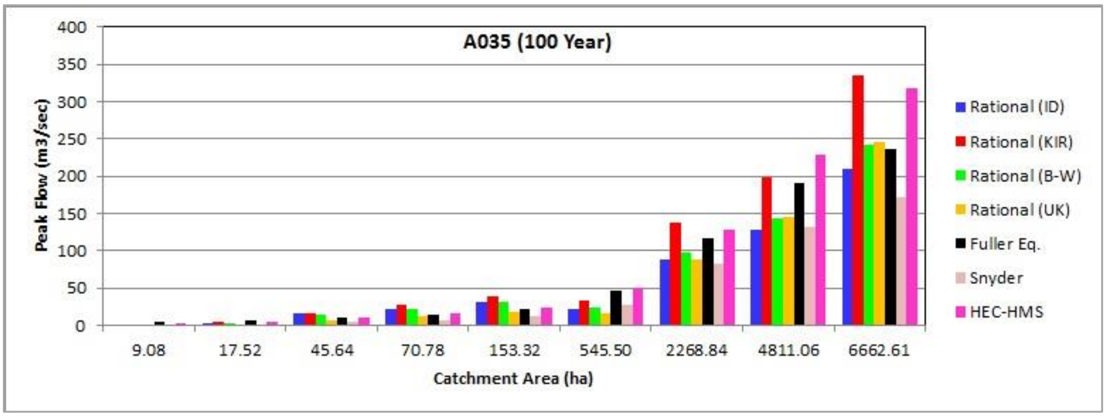


Figure F-11 Peak Flow Estimations for A 035 Road for 100 Year Return Period

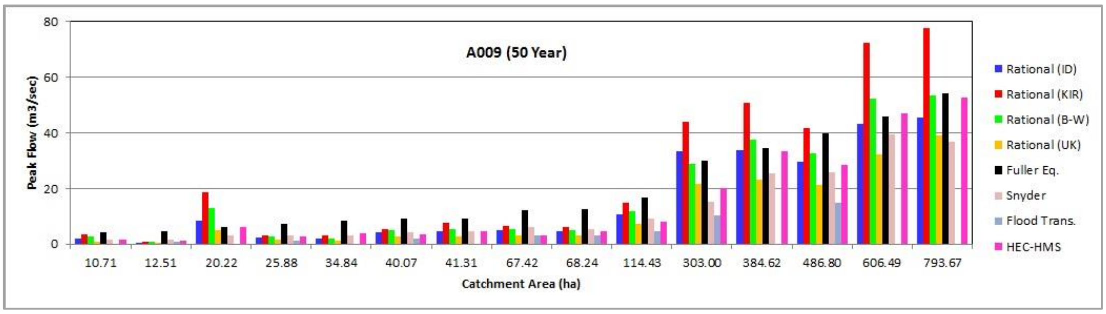


Figure F-12 Peak Flow Estimations for A 009 Road for 50 Year Return Period

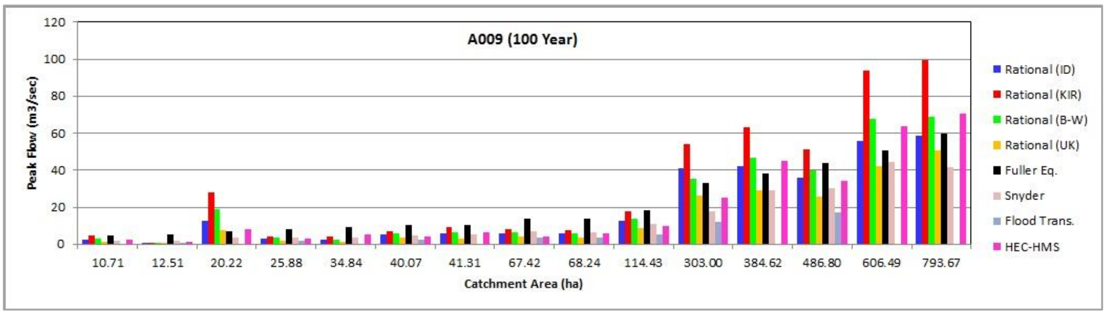


Figure F-13 Peak Flow Estimations for A 009 Road for 100 Year Return Period

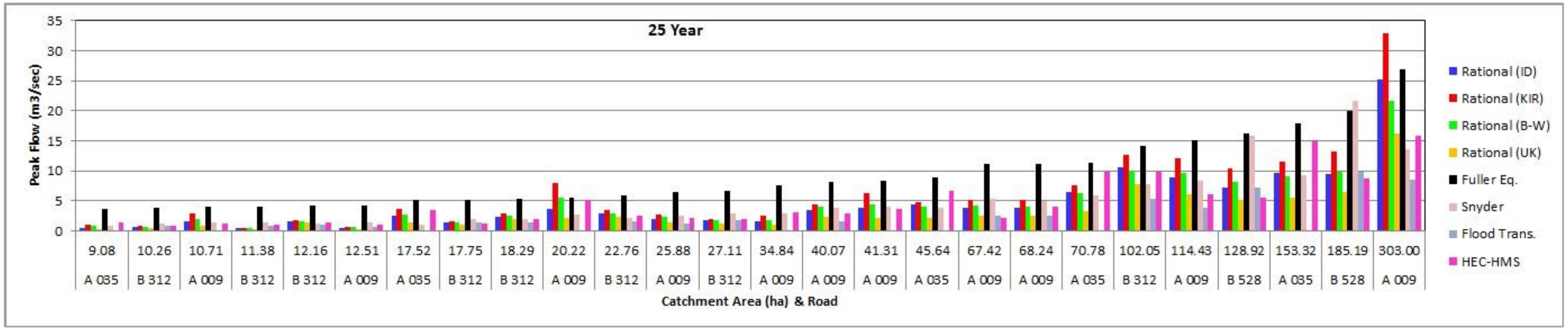


Figure F-14 Peak Flow Estimations for 25 Year Return Period (Area: 9-303 ha)

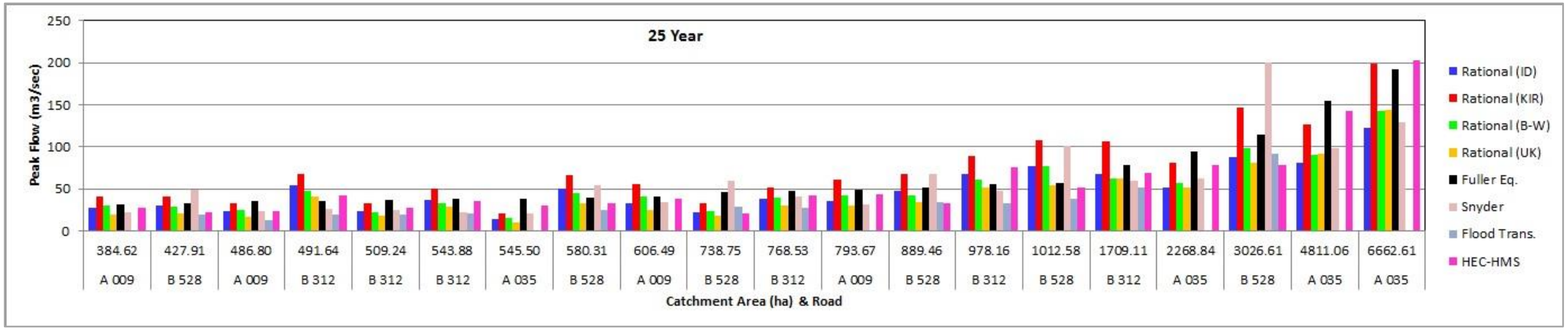


Figure F-15 Peak Flow Estimations for 25 Year Return Period (Area: 384-6663 ha)

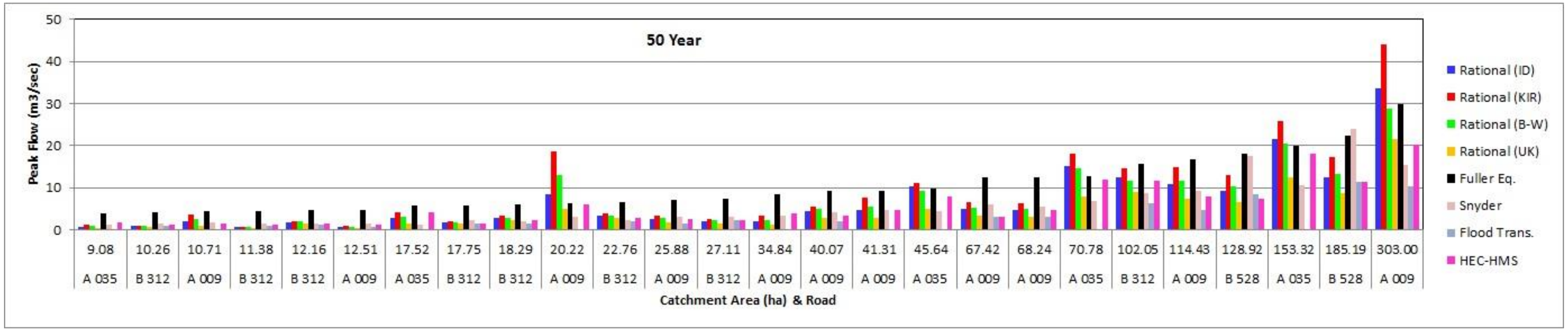


Figure F-16 Peak Flow Estimations for 50 Year Return Period (Area: 9-303 ha)

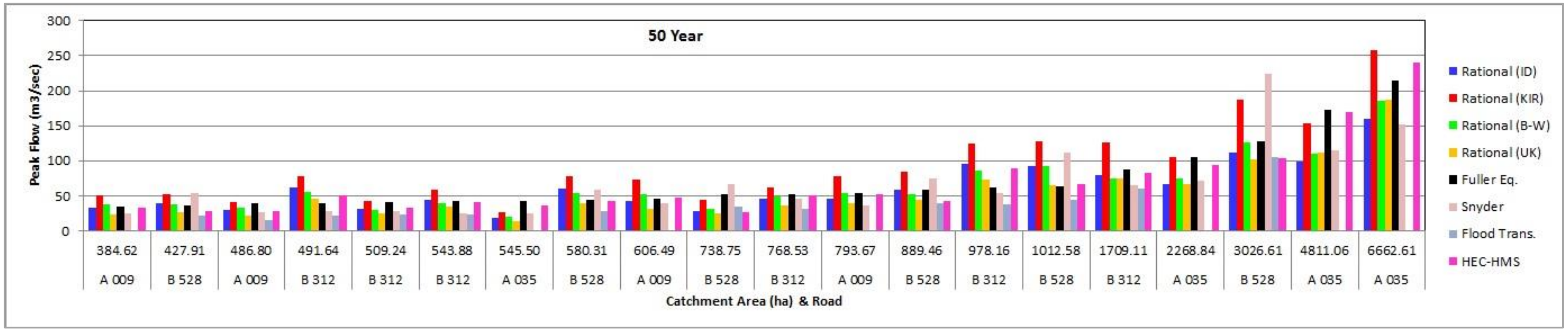


Figure F-17 Peak Flow Estimations for 50 Year Return Period (Area: 384-6663 ha)

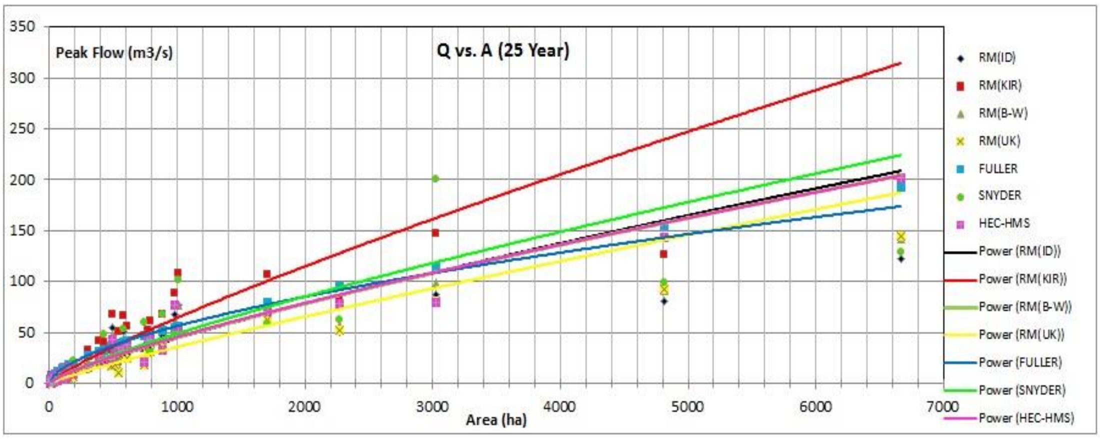


Figure F-18 Area vs. Discharge Relationship for 25 Year Return Period

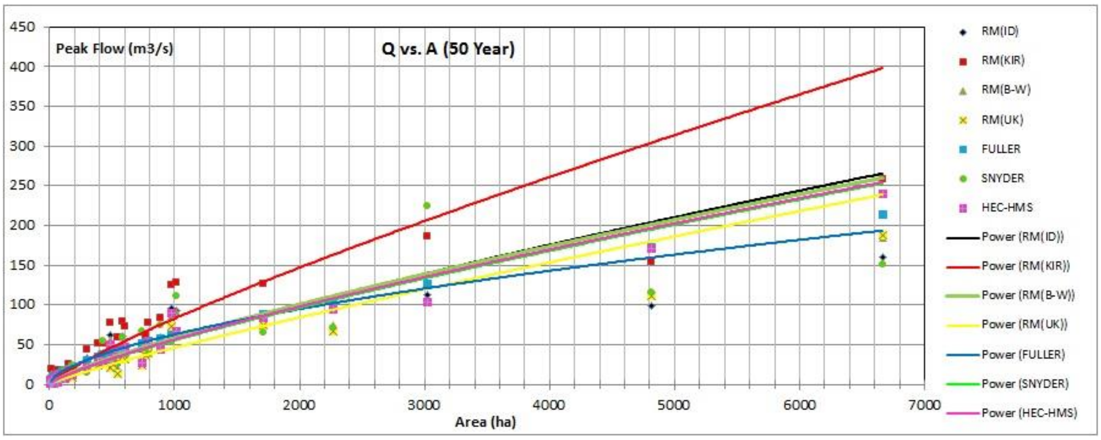


Figure F-19 Area vs. Discharge Relationship for 50 Year Return Period

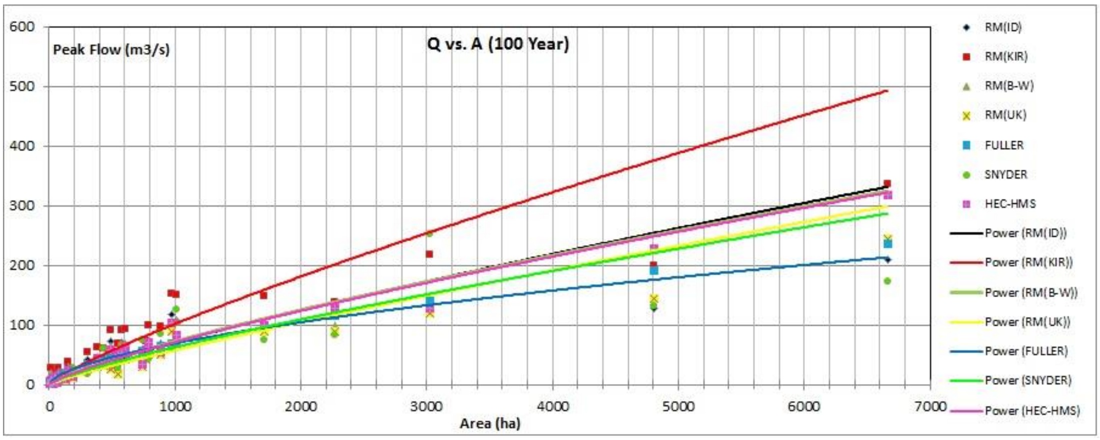


Figure F-20 Area vs. Discharge Relationship for 100 Year Return Period

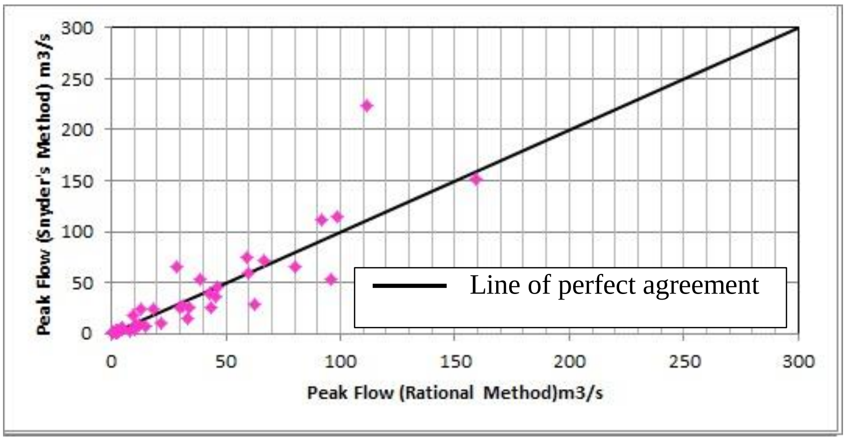


Figure F-21 Rational and Snyder's Method peak flow comparison (50 years)

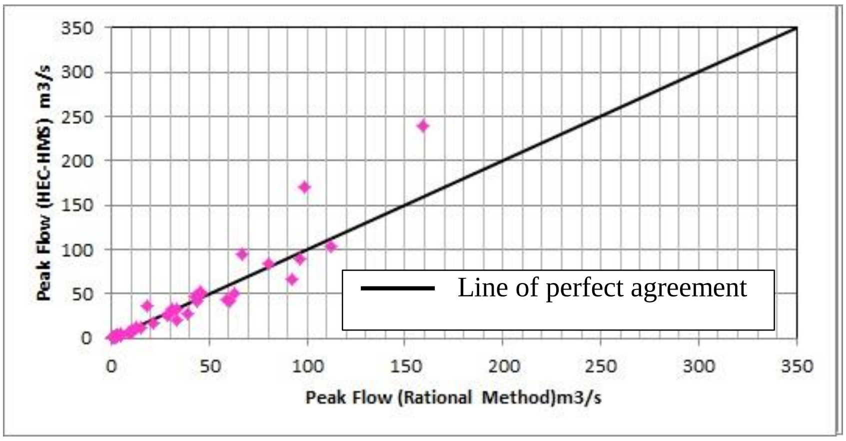


Figure F-22 Rational Method and HEC-HMS peak flow comparison (50 years)

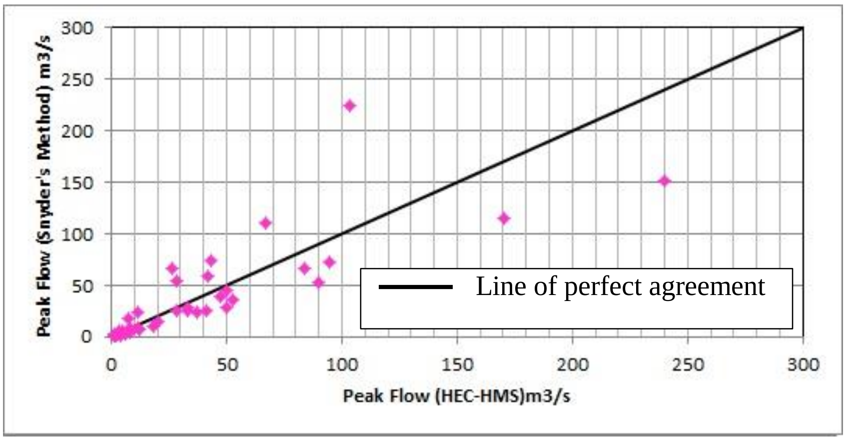
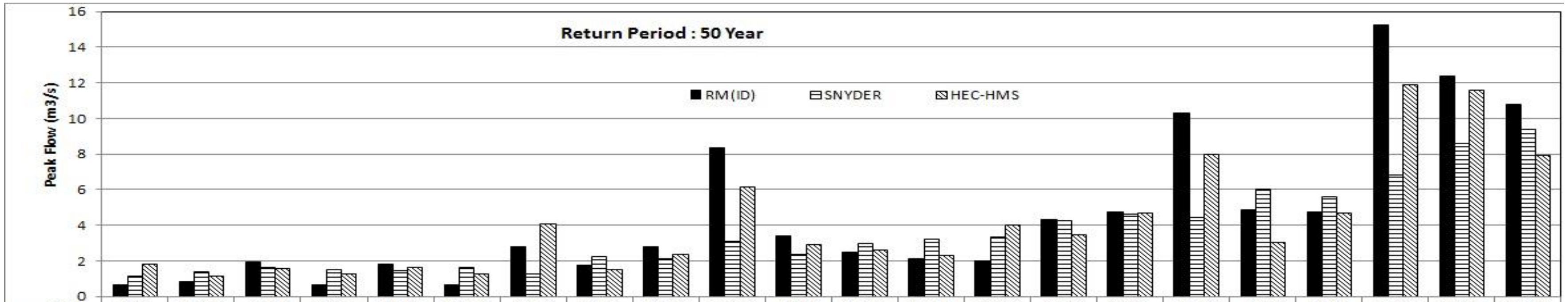
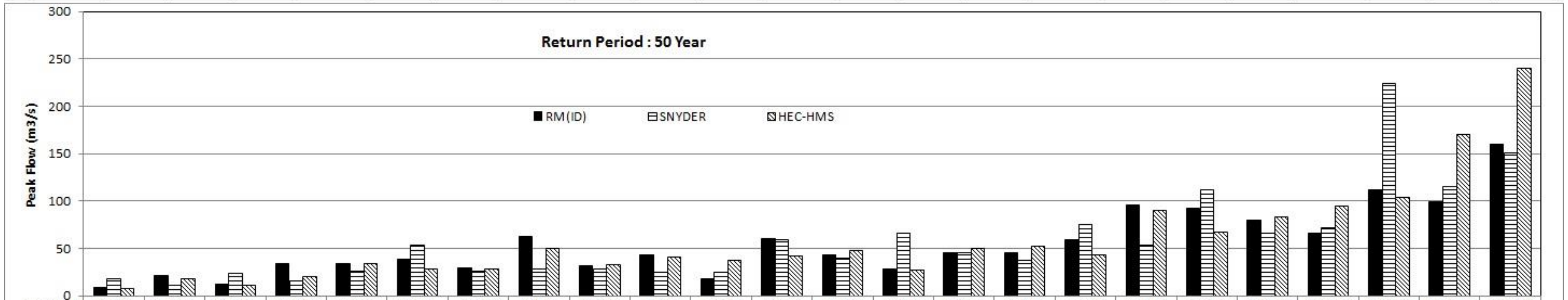


Figure F-23 HEC-HMS and Snyder's Method peak flow comparison (50 years)



Area (ha)	9.08	10.26	10.71	11.38	12.16	12.51	17.52	17.75	18.29	20.22	22.76	25.88	27.11	34.84	40.07	41.31	45.64	67.42	68.24	70.78	102.05	114.43
RM(ID)	0.648	0.846	1.946	0.649	1.808	0.676	2.804	1.780	2.808	8.367	3.424	2.457	2.140	2.002	4.335	4.739	10.284	4.883	4.723	15.235	12.391	10.810
SNYDER	1.105	1.368	1.631	1.494	1.445	1.606	1.270	2.261	2.098	3.060	2.340	2.972	3.188	3.302	4.244	4.584	4.405	6.036	5.563	6.801	8.605	9.347
HEC-HMS	1.803	1.131	1.588	1.282	1.602	1.227	4.046	1.514	2.378	6.142	2.912	2.596	2.318	3.984	3.429	4.649	7.985	2.998	4.666	11.855	11.600	7.931



Area (ha)	128.92	153.32	185.19	303.00	384.62	427.91	486.80	491.64	509.24	543.88	545.50	580.31	606.49	738.75	768.53	793.67	889.46	978.16	1012.58	1709.11	2268.84	3026.61	4811.06	6662.61
RM(ID)	9.185	21.704	12.586	33.504	33.681	38.808	29.581	62.627	31.351	43.565	18.337	60.139	43.086	28.338	45.912	45.503	59.060	96.032	91.971	80.267	66.512	111.917	98.671	159.476
SNYDER	17.529	10.531	23.964	15.306	25.531	53.792	26.008	28.611	28.019	25.190	24.702	59.348	39.305	66.409	45.251	36.869	74.569	53.335	111.286	65.836	71.996	224.226	115.265	151.133
HEC-HMS	7.414	18.026	11.435	20.291	33.354	28.567	28.320	50.254	33.140	41.212	36.925	42.171	47.005	26.600	50.049	52.577	43.497	89.855	66.668	83.476	94.785	103.106	170.281	239.997

Figure F-24 Comparison of Peak Flows for 50 Year Return Period

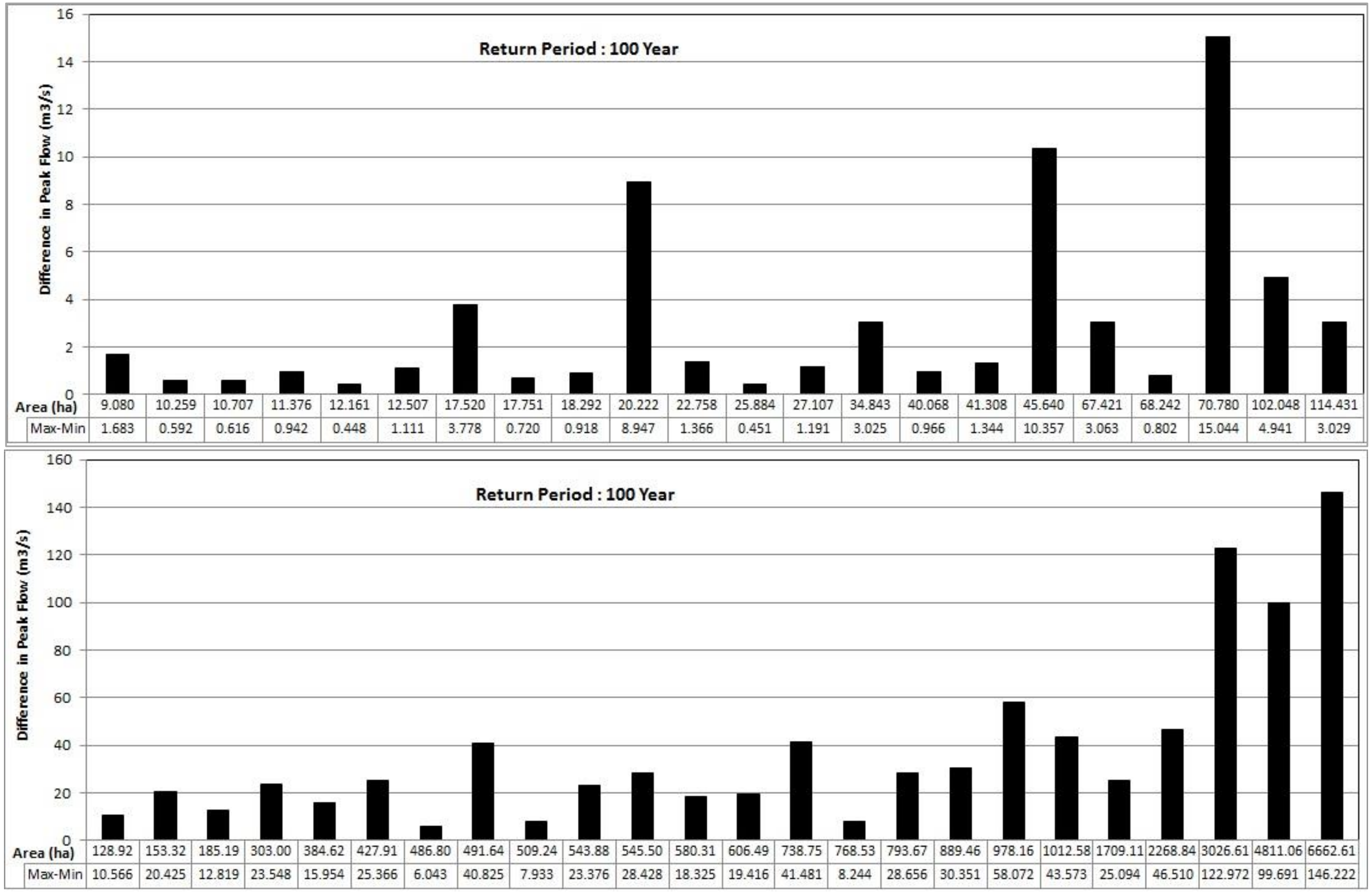
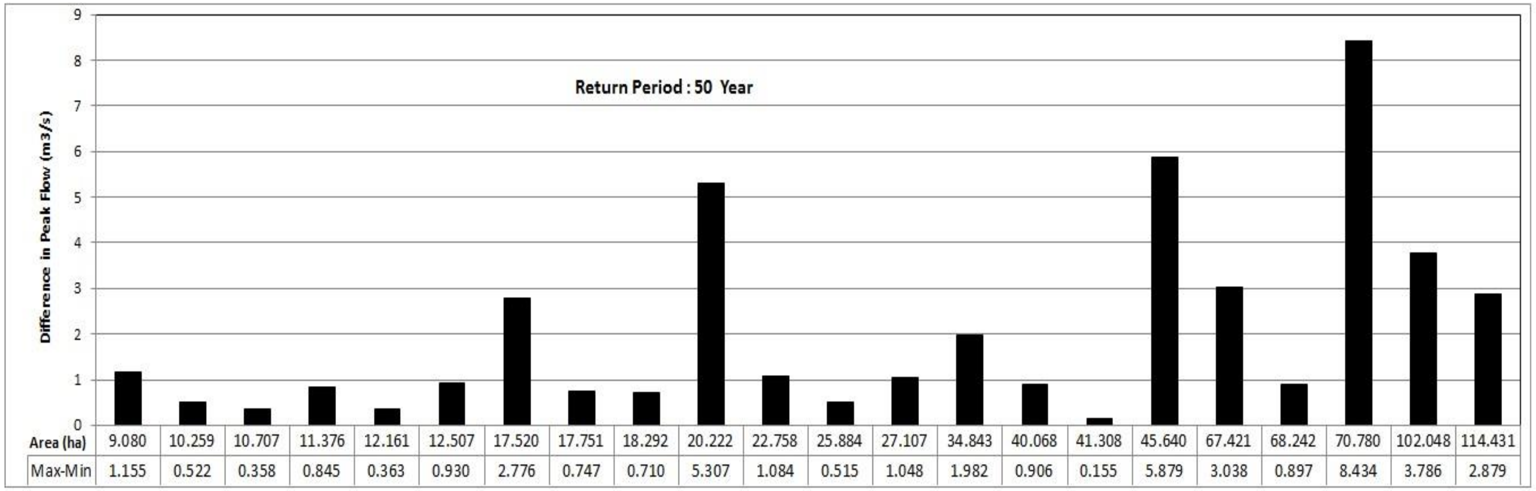
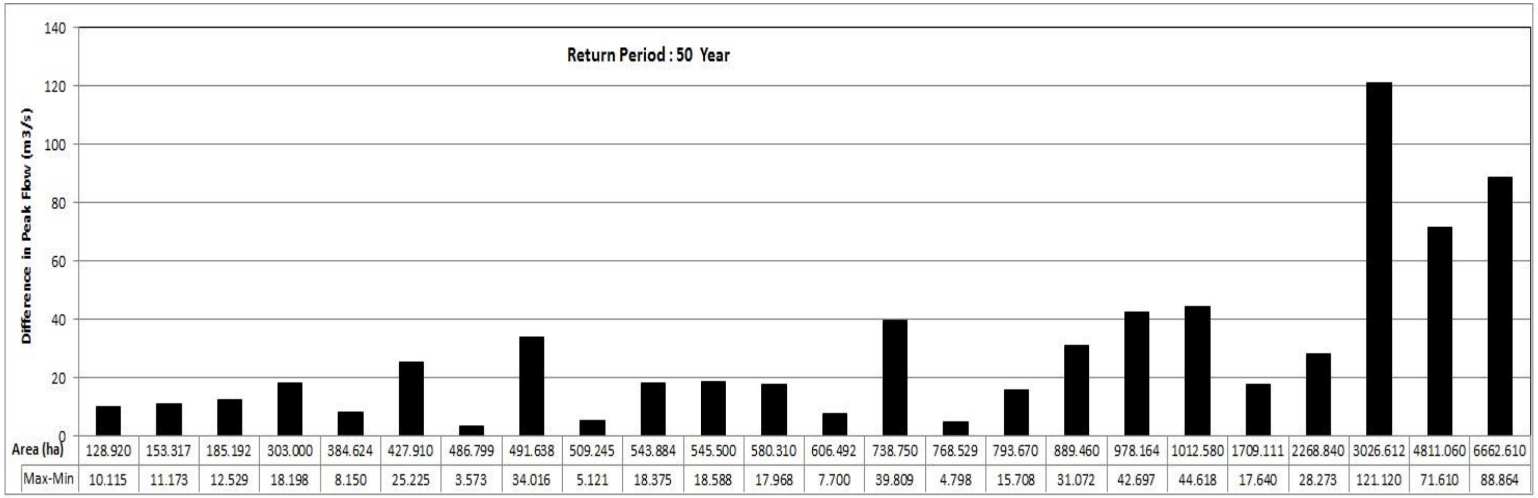


Figure F-25 Difference in Minimum and Maximum of Peak Flows (Rational Formula, Snyder’s Method and HEC-HMS) for 100 Year Return Period



Area (ha)	9.080	10.259	10.707	11.376	12.161	12.507	17.520	17.751	18.292	20.222	22.758	25.884	27.107	34.843	40.068	41.308	45.640	67.421	68.242	70.780	102.048	114.431
Max-Min	1.155	0.522	0.358	0.845	0.363	0.930	2.776	0.747	0.710	5.307	1.084	0.515	1.048	1.982	0.906	0.155	5.879	3.038	0.897	8.434	3.786	2.879



Area (ha)	128.920	153.317	185.192	303.000	384.624	427.910	486.799	491.638	509.245	543.884	545.500	580.310	606.492	738.750	768.529	793.670	889.460	978.164	1012.580	1709.111	2268.840	3026.612	4811.060	6662.610
Max-Min	10.115	11.173	12.529	18.198	8.150	25.225	3.573	34.016	5.121	18.375	18.588	17.968	7.700	39.809	4.798	15.708	31.072	42.697	44.618	17.640	28.273	121.120	71.610	88.864

Figure F-26 Difference in Minimum and Maximum of Peak Flows (Rational Formula, Snyder’s Method and HEC-HMS)for 50 Year Return Period

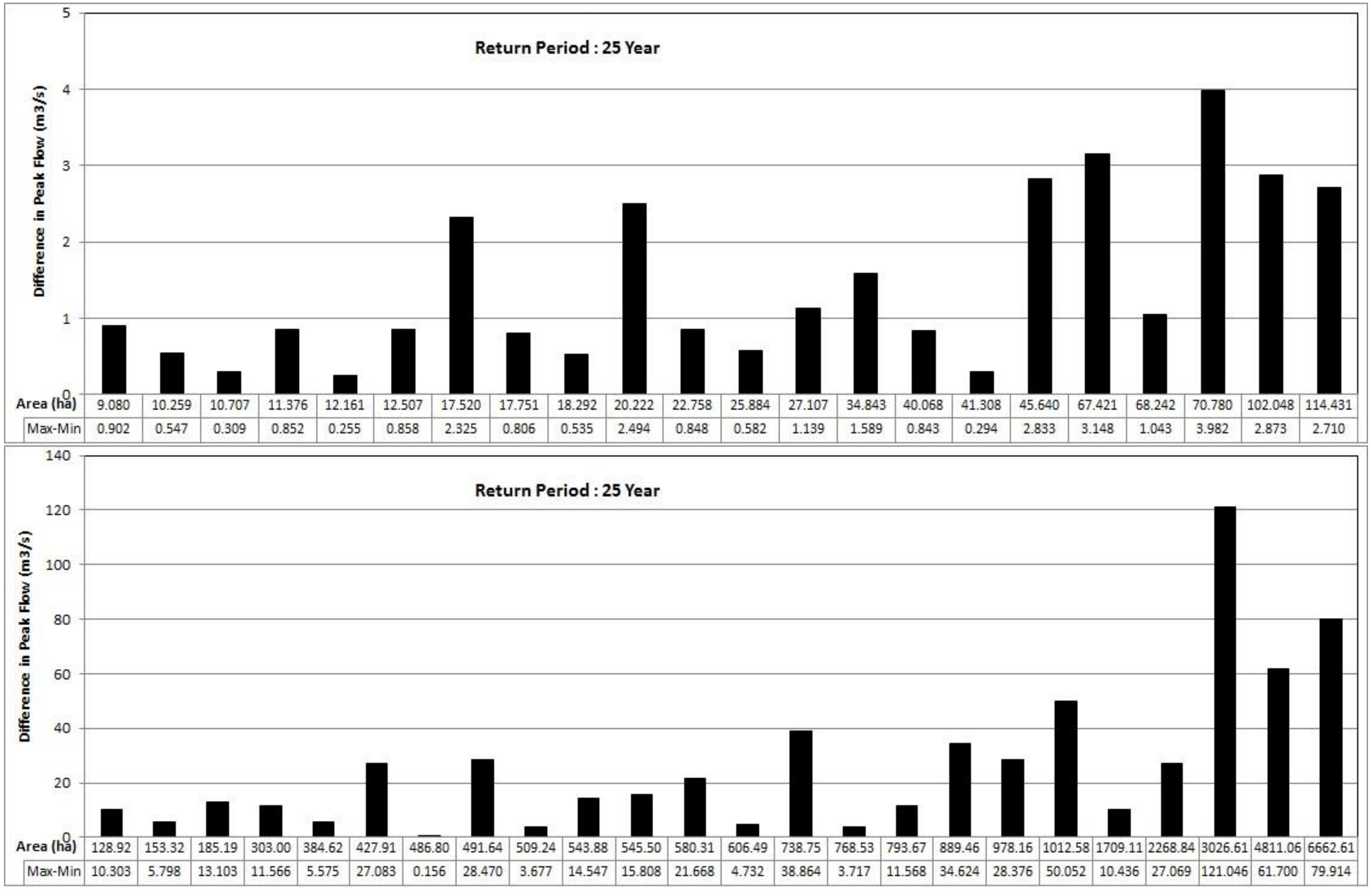


Figure F-27 Difference in Minimum and Maximum of Peak Flows (Rational Formula, Snyder’s Method and HEC-HMS) for 25 Year Return Period