INFLUENCE OF STATION DENSITY AND INTERPOLATION METHODS ON SPATIAL AVERAGING OF RAINFALL FOR WATER RESOURCES MANAGEMENT

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Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Water Resources Engineering and Management

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DECLARATION

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The above candidate has carried out research for the Master's thesis under my supervision.

....

Professor N.T.S. Wijesekera Date

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Abstract

Rainfall is a major concern when dealing with water resources because it is the major input for estimation of streamflow using mathematical models. Rainfall which is a point measurement, needs conversion as a spatially distributed entity for watershed applications. Though there are many concerns regarding the representativeness of the method, conversion of rainfall from several stations generally use station configuration as the basis. However, going further towards the reality, some methods suggest the use of watershed characteristics for this purpose. There are diverse views regarding the recommended station densities. Some work indicate that higher station densities do not lead to the watershed average rainfall value while there is documentation supporting that even one station would be adequate for hydrologic modelling. Based on a comprehensive literature review it was identified that focused research efforts on the selection of rainfall stations to determine areal average rainfall is required. The ongoing literature show that most opted option to compute the areal average is the Thiessen method. The present study explored the influence of station density and spatial intepolation methods when computing spatially averaged rainfall using monthly data for water resources planning and engineering applications. Monthly rainfall data of twelve stations from the Ellagawa (1395 km^2) sub catchment in Kalu Ganga basin over the period from 2006-2014 was used. Station density influence on areal average rainfall was evaluated with different station configuration scenarios while selecting mostly opted Thiessen rainfall method as the spatial averaging method. Monthly, seasonal and annual watershed average rainfall was evaluated using 283 rational configurations determined by the location of raingauges. The comprehensive study of station density influence was carried out by evaluating only rainfall input and by evaluating runoff estimated with a water balance model. Mean ration of absolute error was selected as the objective function for the comparative analysis. The influence of spatial interpolation method for spatial averaging of rainfall was tested by comparing Thiessen polygon, Inverse Distance, and Spline and Kriging methods and using four types of station layouts under two different station density configurations.

Annual, seasonal and monthly rainfall only analysis revealed that 8 stations and above a density of 175 km^2 per station will provide consistent rainfall for any configuration. Comparison of rain gauging density influence on watershed streamflow by using a set of parameters derived from atypical model also indicated that consistent streamflow estimations can be achieved only with a station configuration denser than 175km^2/station. Streamflow comparisons carried out by optimising model parameters for each rainfall configuration also resulted in the same threshold density for consistent streamflow estimations. However the best model performance was with a two gauging stations layout having a density of 698 km^2/station. Comparison of Thiessen weights corresponding to best streamflow estimation inputs revealed that there are three rain gauges mostly contributing to the streamflow of Ellagawa watershed. These results showed that it is prudent to commence watershed modelling with a consistent station density and then carryout optimisation of station weights along with model parameters. Analysis of the influence of spatial interpolation methods on streamflow estimations indicated only a marginal difference in the output derived from selected methods. In all methods, the weakest results were when maximum stations were located outside the watershed. Consideration of computation resource requirement concluded that the Thiessen method is the best option to compute watershed areal rainfall.

Achieving both rainfall input consistency and consistent streamflow estimations using a monthly watershed model, was at a threshold density of one station per 175 km^2. The best streamflow estimations could be obtained with a two-rain gauging station layout.

KEYWORDS: Rainfall, Spatial Interpolation, Station Configuration, Station Density, Two-Parameter model, Thiessen Average, Inverse Distance weighted, Spline, Kriging, Mean Ration of Absolute Error

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ABBREVIATIONS

c	–	Monthly evaporation coefficient
FDC	–	Flow Duration Curve
GIS	–	Geographic Information System
IDW	–	Inverse Distance Weighted
IS	–	Indian Standards
MRAE	–	Mean Ratio of Absolute Error
MSL	–	Mean Sea Level
PoR	–	Period of Record
RO	–	Rainfall Only
RR	–	Rainfall-Runoff
SC	–	Catchment field capacity Coefficient
WMO	–	World Meteorological Organisation

1 INTRODUCTION

Rainfall is the most important variable that defines water resources in a region. Rainfall spatial and temporal distribution are key factors when estimating watershed runoff using mathematical models. The major factors which influence rainfall and its spatial variability are, latitudinal location, orographic effects and wind fields (Grist & Nicholson, 2001; Oki, Musiake, & Koike, 1991). Rainfall spatial distribution and temporal variations are the key characteristics for runoff estimation for water resources management (Abtew, Obeysekera, & Shih, 1993; Buytaert, Celleri, Willems, Bièvre, & Wyseure, 2006; Chua & Bras, 1982; Dong, Dohmen-Janssen, & Booij, 2005; Mishra & Coulibaly, 2009; Wagener, McIntyre, Lees, Wheater, & Gupta, 2003; Zeng et al., 2018). The spatial resolution of rainfall measurements depends on the location of gauges while the temporal resolution of the same vary between events, daily, monthly and annual. Planning of water resources with water balance requires the determination of mean areal rainfall in monthly, seasonal and annual scales while the same for flood studies are on mean areal rainfall of an event (Rodríguez-Iturbe & Mejía, 1974). Representativeness of areal rainfall is a very important factor in the development and application of hydrologic models for sustainable water resources management because, poor determination of rainfall spatial variability poses challenges such as planning of water storage and conveyance structures which in turn threatens sectors dealing with water and food security (Lundqvist, Falkenmark, & Bird, 2010). Measurement of rainfall is based on gauges placed at selected locations in a desired geographic area. The pattern and magnitude of precipitation depend upon the density of gauging stations and the adopted procedure for analysis (Frei & Schär, 1998). It has been observed that average annual rainfall increases with increasing station elevations (Taesombat & Sriwongsitanon, 2009).

High station densities in high elevated upper watersheds improve the performance of sensor networks (Lopez, Wennerström, Nordén, & Seibert, 2015). Typically, rainfall values from the most denser station network is considered as the closest input that would enable the computation of actual areal rainfall on a watershed (Lebel, Bastin, Obled, & Creutin, 1987; H. Xu, Xu, Chen, Zhang, & Li, 2013). In contrast, the work by Anctil, Lauzon, Andréassian, Oudin, and Perrin (2006) has presented the existence of an optimum gauging station density for the forecasting of watershed mean areal rainfall. Work by Wijesekera and Musiake (1990a, 1990c, 1990b) show that optimisation of rain gauge weights and hydrologic model parameters provides the opportunity to arrive at a representative streamflow series. Selection of station network and densities also influence the outputs from a selected spatial interpolation technique (Otieno, Yang, Liu, & Han, 2014). Point rainfall measurements require conversion to spatial information for estimations using watershed models. Therefore, computation of watershed rainfall depends not only on the location of gauging stations and temporal resolution but also on the method of interpolation used to obtain rainfall values in between the gauge locations.

Therefore, a station network used for watershed model calibrations also has a considerable impact on the derived streamflow (Bardossy & Das, 2008). It is important to note that station location identification has to consider the spatial and temporal distribution of rainfall while on the other hand, rainfall spatial and temporal distribution identification depends on the location of selected gauging stations. Though it is mentioned that rainfall measurements play an important role in streamflow modelling, Hydrologic modellers do not find adequately conclusive guidance on the number of the gauging stations, the station density or the method of data interpolation. Hence the determination of an appropriate station number and spatial interpolation method for spatial average computation is the prime objective of this study. A case study was carried out for Kalu Ganga basin up to Ellagawa with twelve rainfall gauging stations and using a two-parameter model.

In the present work 8 number of rainfall gauging stations in the Ratnapura District, 2 number of rainfall gauging stations in Kalutara District, Sri Lanka and another 2 number of rain gauging stations from Colombo and Nuwaraeliya Districts are considered to evaluate the spatial averaging methods. The project area, rain gauging stations and monthly rainfall variation are shown in Figure 1-1. The two parameter monthly water balance model calibrated and verified for the Kalu Ganga watershed at Ellagawa (Dissanayake, 2017) using Thiessen averaging method with five rainfall gauging station data is taken as the base model to evaluate the streamflow prediction capablity of various methods and station configurations.

1.1 Problem Statement

Lack of recommendation to determine the appropriate rainfall gauging station density and method of spatial averaging of rainfall to estimate monthly streamflow for sustainable water resources management.

1.2 Study Area and Data

Kalu Ganga is one of the largest rivers in Sri Lanka (129 km) which drains through a multiple landcover setting with a high variation of topography and elevation. The elevation drops approximately from 2250 m to 14 m MSL in the first 36 km (Nandalal & Ratnayake, 2010) while the rest is on relatively flat terrain with a varying floodplain. Kalu river located in the wet zone of Sri Lanka experience rainfall from both South-West (April-September) and North East (October-March). Watershed at Ellagawa (Figure 1-1) with an area of 1395 km^2 receives an average annual rainfall of 4000 mm.

Monthly rainfall corresponding to the eight-year period from 2006 to 2014 were available for 12 gauging stations. Out of these, eight stations are located within the watershed while and the rest are in the near vicinity. Evaporation values at Ratnapura station and streamflow records corresponding to Ellagawa station were also available. Annual rainfall, evaporation and streamflow at each station are shown in Table 1-1.

1.3 Objectives

1.3.1 Overall Objective

Overall objective is to identify the most appropriate gauging station configuration and the spatial averaging technique for better streamflow estimation leading to sustainable water resources management.

1.3.2 Specific Objectives

1. Identify the state of art gauging station network determination techniques, rainfall spatial averaging methodology and verification methods.
2. Evaluate the rainfall data of a selected watershed, compute areal average rainfall, develop and calibrate a suitable hydrologic model and an appropriate GIS model in order to compare selected configurations and spatial averaging methods.
3. Evaluate alternatives for spatial averaging method and select the gauging station density for monthly streamflow estimations.
4. Make recommendations to select rainfall gauging station densities and the spatial averaging method for sustainable water resources management.

Table 1-1: Annual rainfall, evaporation and streamflow at each station

Data	**Water year** / **Station**	**2006/ 2007**	**2007/ 2008**	**2008/ 2009**	**2009/ 2010**	**2010/ 2011**	**2011/ 2012**	**2012/ 2013**	**2013/ 2014**
Rainfall (mm/year)	*Alupola*	3,853	4,520	3,773	4,482	4,284	3,080	5,900	4,132
	Nivithigala	1,838	2,094	1,722	1,654	1,455	1,273	2,133	2,146
	Pelmadulla	1,415	1,610	2,169	2,688	2,952	1,942	3,393	2,842
	Ratnapura	3,345	3,856	3,409	3,941	4,277	1,946	4,236	3,762
	Eheliyagoda	4,324	4,939	5,304	3,909	4,421	2,937	4,261	3,863
	Galutara Estate	4,104	4,035	3,727	3,489	3,222	3,007	3,863	4,476
	Pussalla S.P.	4,114	4,703	3,893	4,344	4,873	3,601	4,168	3,832
	Kuruvita (Keragala)	3,520	5,072	4,456	4,662	4,928	3,182	4,501	4,267
	Halwatura	3,267	2,041	3,292	4,001	3,218	4,351	5,727	4,054
	Uskvalley	4,930	7,108	7,040	4,255	5,780	4,906	6,224	5,929
	Hanwella	3,400	3,722	2,718	2,399	2,890	2,224	2,860	2,395
	Maussakelle	3,133	2,319	3,339	3,047	2,874	1,778	4,578	2,624
Evaporation (mm/year)	*Ratnapura*	981	1,069	1,001	945	966	942	919	920
Streamflow (mm/year)	*Ellagawa*	1,371	2,054	1,380	1,594	1,741	736	1,732	1,330

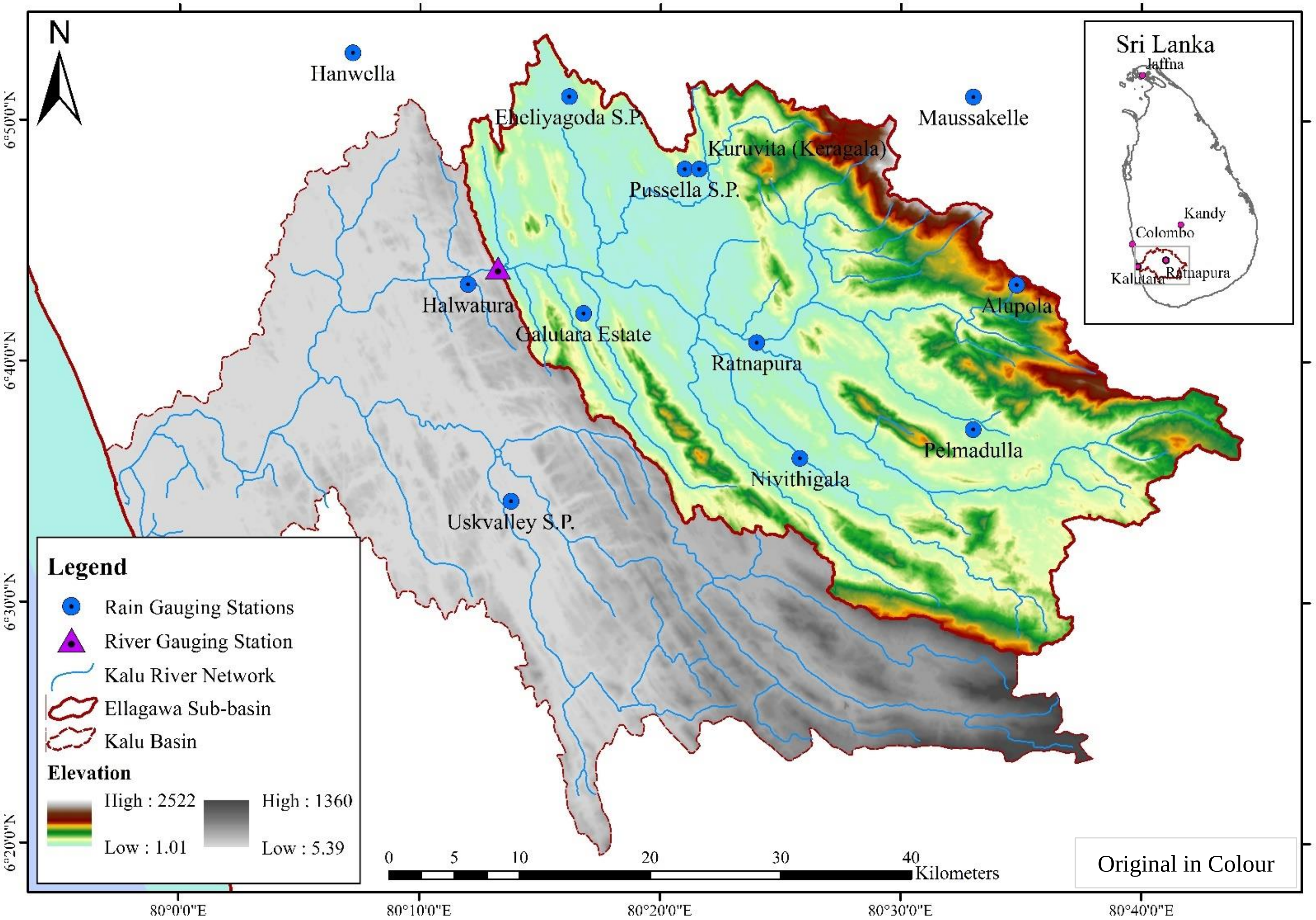

Figure 1-1: Study area

2 LITERATURE SUMMARY AND REVIEW

2.1 General

This literature summary and review looks at the influence of station density and interpolation methods to obtain the best rainfall estimate for water resources management. A literature survey using scientific search engines and peer reviewed research was carried out to capture available guidance when selecting rainfall stations and spatial interpolation methods. Popular scientific search engines on web and keywords encompassing station density, station distribution, data resolution and spatial interpolation method on the estimation of watershed streamflow using mathematical models were the basis for the selection of reviewed publications. 5 guidelines on rainfall station selection, 36 publications specifically related to rainfall station selection and 94 watershed rainfall runoff case studies were reviewed for rainfall station density. Similarly, for rainfall spatial interpolation 71 publications with 112 watershed rainfall runoff case studies were reviewed.

Key factors affecting the areal rainfall input for a hydrological model was captured, discussed and then an evaluation criterion was developed. Literature survey was further carried out to fill missing data, hydrological model selection and objective functions selection.

2.2 Rainfall Station Density Selection

2.2.1 Guidelines and Inclination

Existence of a national guideline for rainfall station selection and spatial density determination is very important, especially when water infrastructure planning and design depends on streamflow estimations using mathematical models. A guideline for gauging station selection is expected to guide the identification of station locations that suitably capture the temporal and spatial variability rainfall. Normally the optimum density of rain gauges can only be obtained through enough sampling of rainfall within a region (Rainbird, 1964). Recommendations of minimum station densities for different physiographic units such as for coastal, mountainous, interior planes, hilly/undulating area and small islands are available in WMO hand books (World Meteorological Organization, 1965, 1972, 2008). Emphasizing the importance of primary and secondary gauging station networks, Bureau of Indian Standards IS-4987, present station density recommendations based on the elevation and geography (Bureau of Indian Standards, 1994). Handbook for the Meteorological Observation of the Netherlands (Nederlands, 2000) recommends a station density of roughly one precipitation station per 100 km^2 for highly localised rainfalls and unstable atmospheric conditions. Rainfall station distribution must not only consider the objective of the desired application but also ensure satisfactory representation of the country's climatic characteristics (Plummer, Allsopp, & Lopez, 2003).

A good knowledge of the distribution of average rainfall over an area is very important for the selection of minimum number of gauging stations. In order to estimate monthly areal rainfall over the catchment area, UK Meteorological office uses a power function relationship between the station number and extent covered by each station (Bleasdale, 1965; Shaw, 1994).

Many research work had attempted to identify suitable gauging station network densities and appropriate locations to capture rainfall data to represent watershed hydrological processes (Anctil et al., 2006; Andiego, Waseem, Usman, & Mani, 2018; Dong et al., 2005; MacKenzie, Urbonas, Jansekok, & Guo, 2007; H. Xu et al., 2013; Zeng et al., 2018)**.** Rainbird (1964) concluded that, at least one representative catchment (500 sq.mi. or less) with a network density exceeding the WMO recommended minimum for the region by a factor of at least 3 to 5 should be established in each principal climatic and or physiographic region. Reviewing the developments in hydrometric network design, Mishra and Coulibaly (2009), support the prevailing general impression that finer temporal and spatial resolution of hydrometric data stations enable the achievement of higher streamflow prediction accuracies. A higher density of rainfall stations have shown a significantly improved streamflow estimation model performances, particularly in small watersheds with extents varying from 600 - 1,600 km^2 (Masih, Maskey, Uhlenbrook, & Smakhtin, 2011). The common inclination is to capture and use the highest number of rainfall gauging stations within and around the study area thus leading to the highest possible station density (Lebel et al., 1987; H. Xu et al., 2013). Lebel et al., (1987) using most number of available stations for their work, classified a very dense gauge network as a setting with one gauge approximately representing a watershed area of 16 km^2. On some occasions, areal rainfall has been captured by selecting a sufficiently dense gauging station network to represent different homogenous zones within the project extent (Wakachala, Shilenje, Nguyo, Shaka, & Apondo, 2015). Presently there are climate models which are capable of generating rainfall variations at high spatial resolutions thus making dense rainfall inputs available for catchment model computations. Use of a Regional Climate Model (RCM) has shown that a 12 km grid spatial resolution has provided a good representation of catchment hydrology (Tramblay, Ruelland, Somot, Bouaicha, & Servat, 2013). In a recent study Yoon and Lee (2017), demonstrated the need of high density rainfall data at 3 km^2 per station for urban runoff analysis because of the high spatial variation that can occur even in small urban areas.

2.2.2 Threshold Station Density

A very closely spaced rainfall station network would be the best option to capture the spatial variability of rainfall within a watershed. However, resource constraints with respect to establishment and maintenance compels the restriction of selection to optimum numbers. Many studies indicate that, instead of attempting to achieve the highest possible station densities, water managers must target to capture the most representative rainfall spatial distribution which makes the best contribution to the watershed streamflow estimation using mathematical models.

Higher station densities demonstrate a tendency to even out the spatial variability by reaching a threshold density beyond which there is insignificant change to areal average rainfall. Lopez et al., (2015) reported that the areal rainfall reaches a threshold density of approximately 24 rain gauges per 1000 km^2 beyond which there is a levelling off of the interpolation errors with no or negligible contribution from further increases to the station density. Otieno et al. (2014) while showing that high station densities provide improved areal rainfall estimations, arrived at an approximate threshold density of 4.82 km^2 per station for a 135.2 km^2 catchment. In a watershed of

8 km^2 with 5 rain gauges, areal mean rainfall improvement with higher station densities had reached a threshold density of 2.6km^2/station beyond which improvements in peak flows and total runoff volumes were marginal (MacKenzie et al., 2007).

Also comparison of errors in streamflow estimations have shown that the high density station network does not always achieve good performance but lesser densities performs well due to the topographical variations and the orographic rainfall (Anctil et al., 2006). It also illustrated the same for mean areal rainfall estimations.

2.2.3 Effects of Spatial Distribution

Guidance materials on rainfall station selection recommend a well distributed gauge network (Bureau of Indian Standards, 1994; Nederlands, 2000; Shaw, 1994; World Meteorological Organization, 1965, 1972, 2008; Yoon & Lee, 2017)**.** There are cases which demonstrate that better areal rainfall estimates can be achieved by considering the spatial distribution of gauging stations. By using error indices of precipitation estimations Lopez et al. (2015) confirmed that an increment in the rain gauge density considerably improved the performance of the sensor network while low densities in high elevated upper catchment showed a decline in performance.

Expected improvements in the rainfall estimation and in the hydrological model performance had been either small or none when the outside catchment gauges were used (Bardossy & Das, 2008). Similarly, Morrissey, Maliekal, Greene, and Wang (1995) demonstrated that not only the density but also the spatial geometry should be accounted. Adhikary, Yilmaz, and Muttil, (2014) proposing a method to identify gauging station redundancies for appropriate station relocation presented a case of 4044 square kilometer catchment with 18 gauging stations where the achieved optimum station density after relocation was 212 km^2 per station.

Using a study in Sangamon River, Illinois, Chow, (1978) concluded that "the precipitation record at one station only is sufficient for the description of the precipitation influence on streamflow". Work by MacKenzie et al. (2007) which showed that "largest variations in runoff simulations occurred when only one rain gage was used to represent the rainfall over the entire watershed" also does not show a disagreement with the said Chow (1978) conclusion. In this study, the least error with a single gauge had been when located close to the centroid, while in a two-gauge situation, the preferred locations had been at upper and lower 1/3 portions of the watershed.

2.2.4 Reality of Selection

Practice of selecting rainfall gauges to compute areal rainfall for a watershed shows very little concern regarding the density or the spatial distribution. There are instances when the same catchment is modelled by different researchers using different combinations of rainfall inputs either with different mathematical models or to fulfill a distinct water management objective. The choices appear to follow the belief that availability is acceptable, personal discretion is rational, or considering that any combination is capable of delivering reasonable results. Different rainfall station settings with the Xiangjiang model had been satisfactorily used for the study of Xiangjiang river basin with an extent of 94,660 km^2 by H. Xu et al., (2013) and Zeng et al. (2018). In the Aller-Leine river basin of Germany, one sub basin had been modelled for rainfall spatial density options by using 53 rainfall stations having only one gauge within the basin (Andiego et al., 2018). In the same basin five sub basins had been modelled with a network comprising of 344 stations in order to evaluate hydrologic modelling strategies. Schulz and Kingston (2017), Nandalal and Ratnayake (2010), Kanchanamala, Herath, and Nandalal (2016), Muthuwatta, Perera, Eriyagama, Surangika, and Premachandra (2017), Wijesekera and Musiake (1990b), Dissanayake (2017), Jayadeera (2016), Sharifi (2015), used 1,13,7,15,6,5,5 and 5 rain gauges respectively for hydrologic model studies of Kalu River in Sri Lanka. Several of the studies indicated the adherence to WMO (168) standards. However, a majority of above studies showed station densities between 200 – 400 km^2 per station.

The selection of rainfall gauging stations to achieve desired densities faces obstacles such as discontinued gauging stations, long periods of missing data and inconsistencies in the temporal resolution of available data. Mishra and Coulibaly (2009) in their work comment that there are problems when finding the right amount of stations with data because of the decreasing trend in the number of hydrometric stations over the years. Though Wallner, Haberlandt, and Dietrich (2012) selected 244 precipitation stations with a daily resolution, only 11 stations had an observation period of more than 10 years and thus the study was limited to 6 years due to data unavailability. Dissanayake (2017) with a station density of 79.3 km^2/station and Khandu (2015) with 92.2 km^2/station have used two different gauging station networks for the Gin River basin of Sri Lanka because of the non-accessibility of daily resolution data in all stations where monthly data was available. Even though, rainfall station maps of Sri Lanka show the possibility of selecting rainfall stations with a high density of 86.1 km^2/station for an evaluation of Kalu river basin, the data availability for a monthly evaluation over a common 10-year period limits the density to a near one third value of 298 km^2/station.

Though there are a large number of publications targeting high rainfall network densities with several rainfall gauging stations per watershed, a few research publications indicate that one gauging station per watershed would be sufficient to determine the rainfall input for a representative modelling of streamflow. Subsequent to Chow (1978) mentioning of a single gauge being capable of representing watershed rainfall, Beven and Hornberger (1982) compared lumped Thiessen rainfall with a distributed input approach, to investigate the effect of rainfall spatial variability using two rainfall recording experiments and concluded that in relatively homogeneous watersheds, the effect of spatial pattern on peak-flow is small, and effect on stormflow volumes is relatively minor. Sufficiency of a single gauge for the entire catchment has been supported for the use of small watersheds having relatively small time of concentrations with respect to computational time (Cho & Olivera, 2009). A streamflow model with data from a single rainfall station for estimations, had produced excellent daily Nash Sutcliffe efficiency values and a good year-round mean monthly streamflow, which can be recommended for policy and management recommendations with respect to climate change impacts on water resources (Schulz & Kingston, 2017). MacKenzie et al. (2007) indicate that one rain gauging station near the centroid would be capable of representing the watershed mean areal rainfall for total runoff computations and estimating the peak flows to a competitive accuracy.

Shaghaghian and Abedini (2013) mentions that a one gauge scenario should have the gauge at the centroid of watershed.

2.3 Spatial Interpolation Method

The main reason for establishing rain gauging stations or selecting a gauged rainfall dataset is to determine the watershed averaged rainfall for water management. Spatially distributed rainfall data provides better streamflow estimates than point records (Masih et al., 2011). There are many methods to determine areal average rainfall from the collected point rainfall. Therefore, it is not only important to select the appropriate rain gauging stations but also chose a suitable method for areal averaging. The arithmetic mean method is the simplest and is satisfactory when the gauges are uniformly distributed. Thiessen method assumes that the rainfall in the watershed is the same as that at the nearest gauge up to a distance halfway to the next station at any direction. Isohyetal method requires a dense network of gauging stations for accurate representations. Inverse Distance Weighted (IDW) and Spline methods are among other surface interpolation methods for areal rainfall computations. All methods produce comparable results especially when the time period is long but vary more from one another when applied to daily rainfall than when applied to annual data (Chow, Maidment, & Mays, 1988). A comparison of Thiessen, IDW, Thin Plate Spline and Kriging interpolation methods by Otieno et al. (2014) had shown that at a spatial density of 4.8 stations per km^2, monthly rainfall estimates from all methods vary by a maximum of 7%.

Methods for the computation of areal rainfall have a mixed set of opinions. Spline method has been found more suitable for gently varying surface generation (Tao, Chocat, Liu, & Xin, 2009), Kriging is the most frequently used for comparative studies (Li & Heap, 2008), IDW method is considered better in comparison with Spline and Kriging (Otieno et al., 2014; Yang et al., 2015). Thiessen method when compared with IDW, Kriging and Multiquadric Equations, had performed better in the estimation of annual rainfall in semi and arid region of Brazil (Barbalho, Silva, & Formiga, 2014). At a station density of 373 km^2/station, the Thin plate Spline technique proved to provide more accurate results of rainfall estimation than Isohyetal and Thiessen polygon techniques (Taesombat & Sriwongsitanon, 2009). On the other hand, comparison of mean annual precipitation values computed with radar rainfall data had demonstrated 5-10% lower values when compared with Thiessen averages (Johnson, Smith, Koren, & Finnerty, 1999). Lack of a firm opinion calls for remedial measures. As a perquisite for any application, a proper study of spatial averaging methods for the applicable region has been recommended by Burrough (1986).

Thiessen method has attracted many modelers (Lebel et al., 1987). Unlike the other interpolation methods which utilize volume of point rainfall at each time step along with the station geometry, Thiessen method is dependent only on the station geometry. This provides a computational ease. Though comparison of rainfall interpolation methods have cited that the best options are IDW and Kriging (Andiego et al., 2018; Goovaerts, 2000; Keblouti, Ouerdachi, & Boutaghane, 2012; Otieno et al., 2014), the popular choice appear as Thiessen Method (M. M. G. T. De Silva, Weerakoon, & Herath, 2014; Johnson et al., 1999; Kanchanamala et al., 2016; Nandalal & Ratnayake, 2010; Perera & Wijesekera, 2012). In case of many Sri Lankan streamflow model studies Thiessen method has been used (M. M. G. T. De Silva et al., 2014; Kanchanamala et al., 2016; Nandalal & Ratnayake, 2010; Perera & Wijesekera, 2012) and this points to the suitability of the method in Sri Lankan terrains.

Selection of gauging station number and also the method of areal averaging can be classified as ad hoc. In literature it appears that when reporting the rainfall input for streamflow modelling work, many modelers and reviewers do not mention the technique and/or the reason for selecting the method used for areal averaging. Some as examples are, Chang, Talei, Alaghmand, and Ooi (2017), Chen, Chen, and Xu (2006), Halwatura and Najim (2013), Jothityangkoon, Sivapalan, and Farmer (2001), Kirchner (2009), Lidén and Harlin (2000), Loague and Freeze (1985), Lü et al. (2013), Makhlouf and Michel (1994), Masseroni, Cislaghi, Camici, Massari, and Brocca (2017), Nilsson, Uvo, and Berndtsson (2006), Schulz and Kingston (2017), Seibert, Uhlenbrook, Leibundgutf, and Halldin (1999), Tomy and Sumam (2016) and Yoon and Lee (2017).

2.4 Optimum Station Influence

There are many rainfall station selection options when attempting to compute watershed rainfall from point rainfall measurements. Irrespective of the option, it is accepted that only a set of measurements with very fine spatial resolution would provide the areal average near enough to consider as a representation of the actual rainfall field. It is also accepted that the desirable fine resolutions are far from reality because of the resource constraints and the variability of rainfall fields.

In all available options, a watershed manager can identify two overarching concepts. One is the determination of optimum gauging stations based on the characteristics of rainfall, location of the gauging station and considering that any value at a measured location would either remain unchanged or decay with distance. This is the most commonly used concept. The other is the identification of rainfall stations and their influence that would deliver an areal rainfall which mostly contributes to the observed streamflow from a watershed. This is associated with the optimization of gauging station influence to match the watershed response.

There is a strong need to ensure rainfall gauging station selection considering the performance of streamflow estimation models ensuring minimum modelling error (Chacon-Hurtado, Alfonso, & Solomatine, 2017). Observing the errors in streamflow estimation with areal average rainfall, Anctil et al. (2006) showed that high density networks do not always lead to well performing streamflow estimations due to the rainfall spatial variability. Stating that an ideal rain gauge network would neither be over-saturated with redundant rain gauges, nor suffer from lack of rain gauges, Shaghaghian and Abedini (2013) show the importance of prioritizing the rain gauge stations. In their work which compared a large number of combinations from a total of 34 gauging stations covering a watershed of 25,000 km^2, it has been concluded that a six-gauge combination as the most contributory option.

Optimization of gauging station weights and Sugawara's Tank model parameters using a single objective function had shown a very good agreement between observed and computed hydrographs (Wijesekera & Musiake, 1990a, 1990c, 1990b). In the work of Arsenault and Brissette (2014), the optimization algorithm had clearly identified that combinations of two or three rain gauging stations can result in better hydrological performance than if a high density network is fed to the model. Clark and Slater (2006) used a locally weighted regression in which spatial attributes from stations locations are used as explanatory variable to predict spatial variability in precipitation.

2.5 Fill Missing Data

The one of the major limitations that occur normally in a study is the presence of missing data. There are statistical methods as well as interpolation techniques which lead to fill the gaps in missing data (Hasana & Crokea, 2013; Simolo, Brunetti, Maugeri, & Nanni, 2010). Traditional method is to fill the data by mean values, however in past decade interest has arisen in gap filling by regression methods (Presti, Barca, & Passarella, 2010). A study in Sri Lanka by R P De Silva, Dayawansa, and Ratnasiri (2007) indicated that the suitability of Inverse Distance Weighted method for low country wet, intermediate, and dry zones, while normal ratio for mid and up country zones to fill missing data. They further suggested arithmetic mean method for upcountry wet zones and areal precipitation ratio for mid-wet zones. The most commonly discussed nearest neighbor method predicts the missing values by nearest sampled point. Thiessen method is one example and for high powers, Inverse Distance method is also converted to nearest neighboring filling method (Hartkamp, De Beurs, Stein, & White, 1999).

Caldera, Piyathisse, and Nandalal (2016) concluded in their study that filling missing rainfall data at a gauging station based on the number of neighboring gauging stations and their correlations with that particular station for which data are filled. However, Lee and Kang (2015) explained that if the precipitation data have a nonlinear trend, it is difficult to effectively reconstruct the missing values.

The study by filling the gaps using the closest station by B. I. L. Garcia, Sentelhas, Tapia, and Sparovek (2006) had performed well with a few missing data but for about 85% missing data the closest station method may not be applicable. Presti et al. (2010) also accepted that the simple substitution method particularly when the similarity of values are significantly high. Thus, the filling with nearest neighboring station can be adopted for fill the gaps in rainfall data if missing percentages are low.

2.6 Hydrological Modelling

Rainfall - runoff modelling has become an effective tool for solving in many water related issues since mid-19th century (C. Xu, 2002). As Wheater, Sorooshian, and Sharma (2007) explained, model is a simplified representation of the real world using mathematical equations. As cited in Alley (1984), Dunne and Leopold (1978) explained models are essentially book keeping procedures, which enable managing the water balance of inflow and the outflow of a hydraulic system.

Models which are capable of providing watershed responses as surface runoff by using the input of rainfall measurements are further discussed here. Streamflow estimations with application of rainfall in different density configurations as the input to a hydrological model is the most common method of evaluation (M. Garcia, Peters-Lidard, & Goodrich, 2008; Morrissey et al., 1995; H. Xu et al., 2013).

2.6.1 Monthly Water Balance Model

There are different kinds of monthly water balance models used in the world. Depending on the requirement, models are selected for any study or research. Evaluating five monthly water balance models; T, T_{λ} and T_{γ} models by Thornthwaite and Mather (1955) and Thomas (1981), P model by Palmer (1965) and *abcd* model by Thomas (1981), Alley (1984) concluded that all of the models perform well in simulating monthly flows while producing same calibration errors. Spatial patterns of monthly rainfall had been analysed to simulate streamflow through a mixed deterministic/stochastic modelling procedure by Beven & Hornberger (1982). H. Xu et al., (2013) selected the popular Xianjiang Model to evaluate the effect of varying the rain gauge densities.

Monthly modelling is the mostly used application for water resources planning and management. Monthly water balance models are popular because they use the principle of conservation of mass in the annual hydrological cycle, they are simple in structure and are less data demanding (Gan & Biftu, 1996; Gan, Dlamini, & Biftu, 1997). There are many monthly water balance models with varying number of parameters to represent hydrological complexities (Gan et al., 1997; Michaud & Sorooshian, 1994)

Among these models the two-parameter monthly water balance model (Dissanayake, 2017; Khandu, 2015; Sharifi, 2015) proposed by Xiong and Guo (1999) has several applications in Sri Lanka.

2.6.2 Model Calibration and Parameter Optimization

Streamflow model calibration is the process by which model parameters are determined. This is carried out by using a representative input dataset to find the best set of model parameters by simulating the outputs that match a corresponding set of streamflow observations. Identification of best set of parameters is called parameter optimization and this is achieved by using an objective function that represents the modelling objective (Shaw, 1994; Wheater et al., 2007).

2.6.2.1 Model calibration

Beven and Hornberger (1982) calibrated a rainfall – runoff model for Friend creek sub catchment of Sangamon River by optimizing paramers using Rosenbrock automatic optimization procedure available with the Institute of hydrology modeling package. Xiong and Guo, (1999) proposed two step procedure to optimize the two parametrs in the model. Initially the goodness of fit achieving through Relative Error criterion by optimizing c and SC parameter. Then the model is calibrated by optimizing parameter SC while keeping c fixed for the criterion R2.

2.6.2.2 Optimization techniques

Optimization can be either maximization or minimization of variables. C. Xu (2002) discussed two optimization algorithms in details; a) Local search method and b) Global search method. In the same literature a comprehensive explanation of the procedures has been clearly mentioned. Generally, a hydrological model is calibrated to obtain the optimized parameters. The multi-objective complex evolution (MOCOM-UA) global optimization method by Yapo, Gupta, and Sorooshian (1998);

an extension of the shuffled complex evolution (SCE-UA) single-objective global optimization algorithm (Duan, Sorooshian, & Gupta, 1994), is an effective and efficient methodology to reveal multiple objective global optimization problem.

2.6.2.3 Warmup period

Daggupati, et al.(2015) explained that a warmup period is a period which allows a model to run for a sufficient period prior to the simulation period to initialize important model variables or allow important processes to reach a dynamic equilibrium. Same literature further explained that length of the warm-up period may vary for different watershed-scale processes and period might range from studies may range from months to decades, with one to four years being common for watershed-scale modeling; An example study is Douglas-Mankin, Srinivasan, and Arnold (2010). Daggupati, et al. (2015) indicated that due to the complexity of watershed-scale processes, it is unable to provide a comprehensive guideline for warm-up period. However, this paper further mentions that using warm-up periods of two to three years for hydrological processes and five to ten years for sediment and nutrient related processes had been recommended by model developers.

2.7 Objective Function

The objective function is a measure of model evaluation to identify the goodness of fit between the estimated and observed measurements. Error/deviation and the fluctuations of the deviations between actual value and estimated, are represented by the error mean and the standard deviation of error respectively. Root Mean Square Error (RMSE) also shows similar results to mean error and Standard Deviation (SD) of error (R. P. De Silva et al., 2007).

Nash–Sutcliffe efficiency (NSE) (Nash & Sutcliffe, 1970), Mean ratio of absolute Error (MRAE) (Dissanayake, 2017; Jayadeera, 2016; Wijesekera, 2000; Wijesekera & Musiake, 1990b, 1990c), Relative absolute error (RAE), Relative mean absolute error (RMAE) and Root mean square error (RMSE) (Li & Heap, 2008) are functions which are commonly used in rainfall-runoff simulations.

Wijesekera (2000) and Jayadeera (2016) showed that Mean Ratio of Absolute Error (MRAE) is better to reflect the contrast over the observed and simulated flows at each data point as it explained the difference between simulated and observed flow with respect to the particular data point of observation. Thus, MRAE has a greater capability to use in water resources management. MRAE is explained in equation 1 below.

$$MRAE = \frac{1}{n}\sum\left|\frac{Q_{obs} - Q_{cal}}{Q_{obs}}\right| \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

In this equation, the suffixes *Obs* and *Cal* stands for observed and calculated values respectively. Letter *n*, represents the number of records used for the computation of average error.

2.7.1 Input Data Verification through Streamflow Estimations

The hydrograph match is considered as the best method to evaluate the rainfall inputs with various station configurations. A rigorous evaluation of input rainfall on the model performance has allowed the planners to recognize an optimal station density configuration (Bardossy & Das, 2008; H. Xu et al., 2013).

To evaluate the contrast of estimations at each point of observed, MRAE was adopted to evaluate the accuracy of streamflow estimations for this study.

2.8 Summary

A practicing water manager must always perform a critical evaluation of station network and the gauged data to identify the station influence on catchment streamflow. Recommendations of prevailing guidelines and ongoing research indicate a wide variety of opinion regarding the station densities.

The factors influencing rainfall and spatial variability are catchment characteristics, temporal variations, wind directions etc., while the station density, station distribution, temporal data resolution, catchment size and method of computation are the major influential factors when determining spatial average rainfall. The few available guidelines quantitatively recommend station densities while providing an indication that stations must be well distributed. Ongoing research and the practice commonly resort to higher spatial densities. Guide of Institute of water engineers, WMO guide on mountainous islands (World Meteorological Organization, 1972) and UK Met office (Bleasdale, 1965; Shaw, 1994) show station requirements have not been adhered to by many. It is also important to note that upper medium and large catchments have settled to work with lower densities while the small and lower medium catchments show the capability to fulfill the recommendations. Therefore, the most rational option would be to select a suitable station density considering both the time-tested guidelines and the median values of prevailing watershed studies.

The current guidelines recommended the values in different physiographic units none of them exactly matching to the Ellagawa catchment. It is neither a coastal, interior plain, island, polar region nor fully Mountainous region but a somewhat hilly undulating area. Thus the WMO-168 (2008) preferred gauging density would be 575km^2/ station. From the Indian standard IS – 4987 (1994), most suitable category is plains as, in not too elevated region specifically mentioned that area should be with average elevation one kilometer above sea level and areas predominantly hilly where very heavy rainfall is experienced for the Kalu basin. According to Nederlands (2000), it is better to have one station in 100 km^2. Thus the requirement for Ellagawa basin (1395 km^2) will be 14 stations. To estimate monthly areal rainfall over the catchment area, UK Meteorological office suggested 12-15 gauges for a catchment as the size of Ellagawa (Bleasdale, 1965; Shaw, 1994). The current practice is for Kalu basin 86-2658 km^2/station. Therefore, the overall best density range for Ellagawa catchment would be 86 – 575 km^2/station.

Considering the difference of opinion regarding the accuracy of available options, comparison of computational easiness, resource demand and acceptance of practicing personnel, Thiessen method is the best available option to compute areal average rainfall computation. Since there were different recommendations in different studies, comprehensive analysis to evaluate the influence of most recommended other spatial interpolation methods would be beneficial in sustainable water resources management. Considering the vagueness in the information available for the selection of rainfall stations for water resources management, it is important to deploy more research efforts to evaluate the influence of rain gauging stations and their distribution.

Rainfall-runoff model can be used to evaluate the input rainfall by comparing the error between estimated streamflow and measured streamflow. Considering the factors such as, lesser number of parameters, simple model structure, requirement of only rainfall and evaporation as inputs and availability of a typical model for the same watershed (Dissanayake, 2017), the present work selected the two parameter monthly water balance model (Xiong & Guo, 1999) to generate watershed streamflow to verify the input rainfall. This water balance model has a simple structure with two parameters c (Monthly evaporation coefficient) and SC (Catchment field capacity Coefficient), uses monthly rainfall and evaporation as inputs, and estimates monthly streamflow while providing an indication of soil moisture storage status in the catchment.

After a comparison of several objective functions, the Mean Ratio of Absolute Error (MRAE) which would be the best available objective function to obtain the streamflow simulation error was selected for this study. MRAE compares the relative matching of modelled and observed streamflow at each time point to arrive at an average error value to represent overall matching which is the best for water resources assessments. This method attempted to capture the impact of model response with changing rainfall combinations.

The commonly used three spatial averaging methods for rainfall; Inverse Distance Weighted, Kriging, Spline and Thiessen Polygon (Abtew et al., 1993; Apaydin, Sonmez, & Yildirim, 2004; Keblouti et al., 2012; Lebel et al., 1987; Li & Heap, 2008; Mahalingam, Deldar, & Vinay, 2015; Tao et al., 2009; Wijemannage, Ranagalage, & Perera, 2016) are used to obtain the areal rainfall in this comparative analysis as main spatial averaging techniques.

Thus, this study to evaluate the influence of station density and interpolation methods on spatial averaging of rainfall for water resources management is proposed.

3 METHODOLOGY

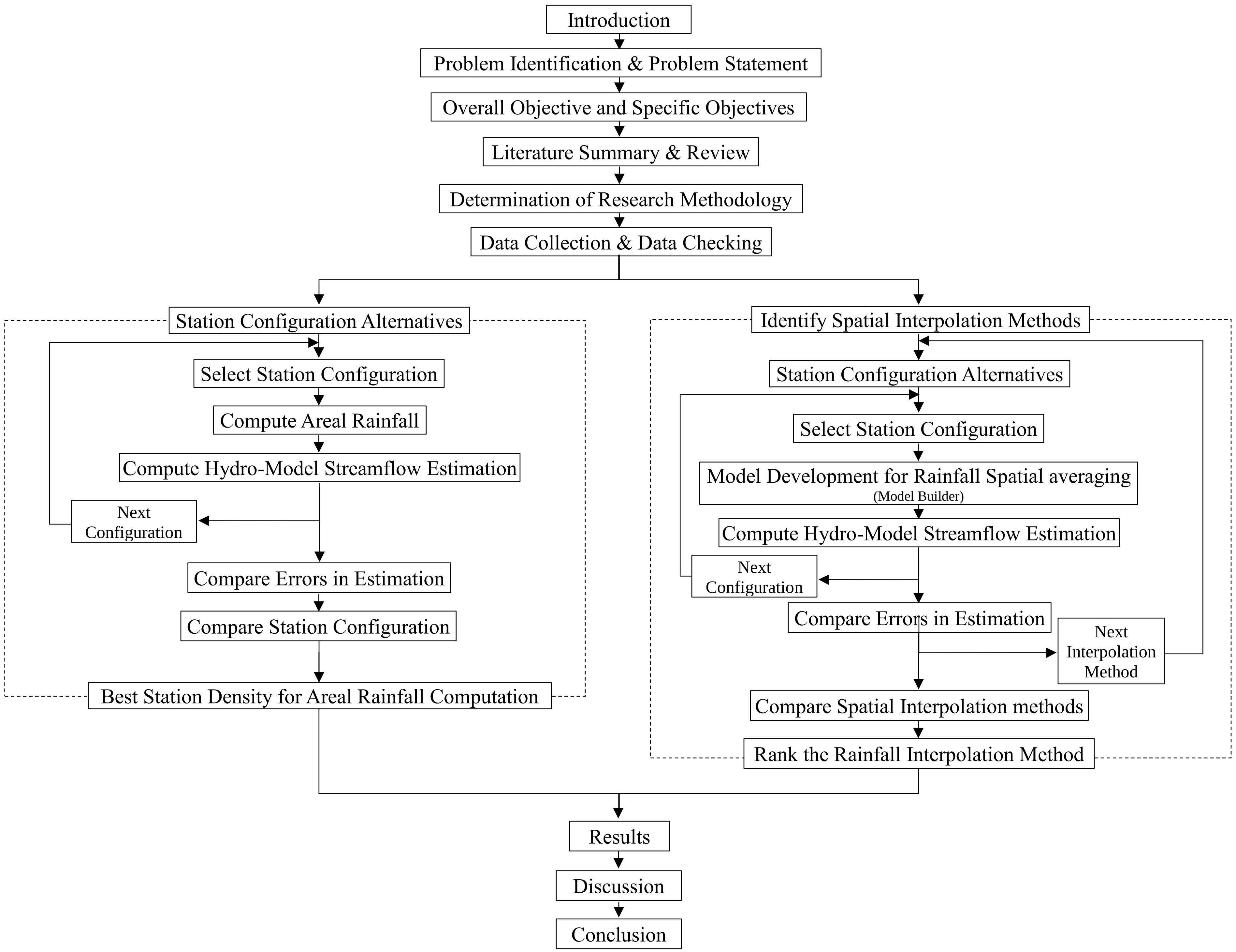

Figure 3-1: Methodology Flow Chart

The methodology followed in this research is shown in Figure 3-1. A comprehensive literature survey was carried out after identifying the overall objective and specific objectives.

Ellagawa sub-basin in Kaluganga catchment was selected for the analysis. Considering the data availability eight stations within the Ellagawa sub-basin and four outside stations were used with eight years monthly rainfall data. Data checking was done to identify the quality of data. After the data checking missing data was filled with the nearest available gauging station (Caldera et al., 2016; B. I. L. Garcia et al., 2006; Presti et al., 2010).

3.1 Influence of Rainfall Station Density

3.1.1 General

Analysis carried out for the selection of rainfall gauging stations was based on two methods. One is to select the gauging stations only by considering the rainfall values of the available stations. Hence the method is called "Rainfall only (RO) option". The other is by evaluating the areal rainfall that represents the watershed response. In this, the watershed response to rainfall is the measured streamflow at the outlet. If a watershed model fed by a particular rainfall is capable of estimating streamflow that best matches the observed streamflow, then that rainfall is considered as the closest to actual rainfall received at the watershed. Therefore, this method is called "Rainfall-Runoff (RR) option". In both options, the Thiessen averaging technique was used for the computation and comparison of average annual, seasonal and monthly areal rainfall values over the Ellagawa watershed.

3.1.2 Rainfall-Only Option (RO Option)

A GIS using the ArcGIS Model Builder was developed to compute the spatial average rainfall by varying the station numbers from 1 to 10 and computing the areal rainfall for all spatial distributions. The total number of spatial combinations used for the study amounted to 283. The details are in the Table 5-4. Station combinations with very small areal coverage were not considered for the comparison. Therefore, with some station combinations, there were a limited number of combinations. Notations of each configuration associated rainfall gauging stations and the Thiessen weights are in ANNEX B - Table B - 1.

3.1.3 Rainfall-Runoff Option (RR Option)

This option at first requires a hydrologic model to compute the estimated streamflow from a particular gauging station configuration. Then the estimated hydrograph is compared with the corresponding observed streamflow hydrograph in order to capture the representativeness of areal rainfall. Considering the factors such as, lesser number of parameters, simple model structure, requirement of only rainfall and evaporation as inputs and availability of a typical model for the same watershed (Dissanayake, 2017), the present work selected the two parameter monthly water balance model (Xiong & Guo, 1999) to generate watershed streamflow. This water balance model has a simple structure with two parameters c (Monthly evaporation coefficient) and SC (Catchment field capacity Coefficient), uses monthly rainfall and evaporation as inputs, and estimates monthly streamflow while providing an indication of soil moisture storage status in the catchment.

Initially the monthly rainfall and model developed by Dissanayake (2017) with its optimized parameters were used as the reference. This was considered as a typical case of model development where 5 rainfall stations have been selected considering data accessibility and a conceptualization of station distribution while fulfilling WMO (World Meteorological Organization, 2008). Hence this was called the "Typical Monthly Water Balance Model" for Kalu Ganga at Ellagawa watershed. The streamflow estimations used a model warmup period of 5 years to establish the initial conditions.

After a comparison of several objective functions, the Mean Ratio of Absolute Error (MRAE) which is the same used for the development of Typical model was selected for this study. MRAE shown in Equation 1 compares the relative matching of modelled and observed streamflow at each time point to arrive at an average error value to represent overall matching which is the best for water resources assessments.

Using the work by Wijesekera (2018), threshold exceedance probabilities for high and low flow were taken as <20% and >60% respectively.

3.1.3.1 Typical Model and Parameters (RR Option 1)

RR option was divided into two sections to seek better understanding from the point of view of a practicing watershed manager.

The RR option 1 is to solve a situation faced by a practicing watershed manager who possess a monthly water balance model that has already been calibrated and verified for the same watershed (the typical model). The need is to find the rainfall gauging station number that suits best for the application of the same model without recalibration. Accordingly, the RR option1 evaluated the response of typical model with its parameters to the areal rainfall from each station combination.

3.1.3.2 Model Performance (RR Option 2)

Response of a watershed to rainfall depends on the rainfall and also on the watershed. Therefore, an evaluation of the effect of a particular rainfall on a watershed requires the model to adequately represent the watershed. Only a watershed model that has been calibrated with a particular dataset can be categorized as representative model. Therefore, in the RR Option 2, the watershed response was evaluated by recalibrating the selected model for each input rainfall combination. MRAE values at each calibration was compared to capture the best station combination to compute the areal rainfall of the watershed.

Since the objective of the work is to perform a comparative evaluation of rainfall input by comparing streamflow from a model, it is important for the selected model to perform well within the given data period. Therefore, in the present work the entire eight-years dataset (from 2006 -2014) for model calibration assuring the reflection of data variability within the entire period.

3.2 Influence of Spatial Interpolation Methods

3.2.1 General

A literature survey was carried out to capture the current considerations or recommendation on interpolation method selection for rainfall spatial averaging for watershed modelling.

Areal average computation in the study was limited to two station densities as 279km^2/station (5 station) and 175 km^2/station (8 station). In this study selection of number of 5 stations are linked with the typical model. The 8-station setting is the threshold density identified through the optimum station density evaluation.

Combinations were selected with using 5 and 8 stations for the catchment under 4 categories, 1. All stations within the catchment; 2. Majority outside the catchment; 3. Most upstream stations;4. Most downstream stations.

These combinations were selected by considering both, 1) station availability and 2) evaluation of concepts identified through literature review.

3.2.2 Rainfall Surface Generation

An automated GIS model using the ArcGIS Model Builder was developed (Figure 3-2) to obtain each monthly spatial average rainfall over the area and then combined with the GIS model in Figure 3-3 to combine all monthly average rainfall to develop the monthly time series data for the entire data period of 2006/07 to 2013/14 water years.

Initially the monthly rainfall surfaces for the entire period was constructed. These surfaces were then averaged to analyse the rainfall annual, seasonal and monthly temporal resolutions.

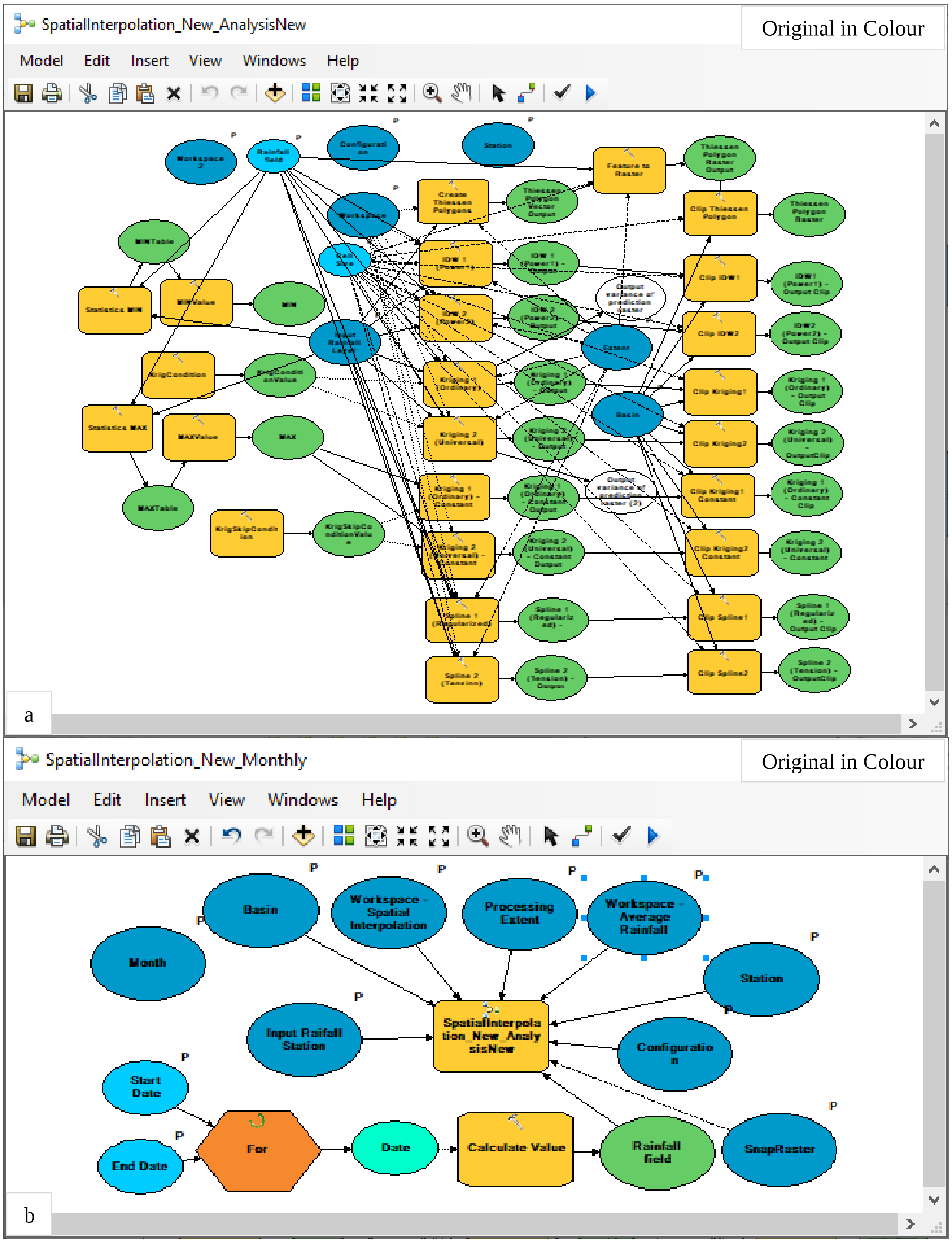

Figure 3-2: ArcGIS Model builder applications to generate monthly rainfall

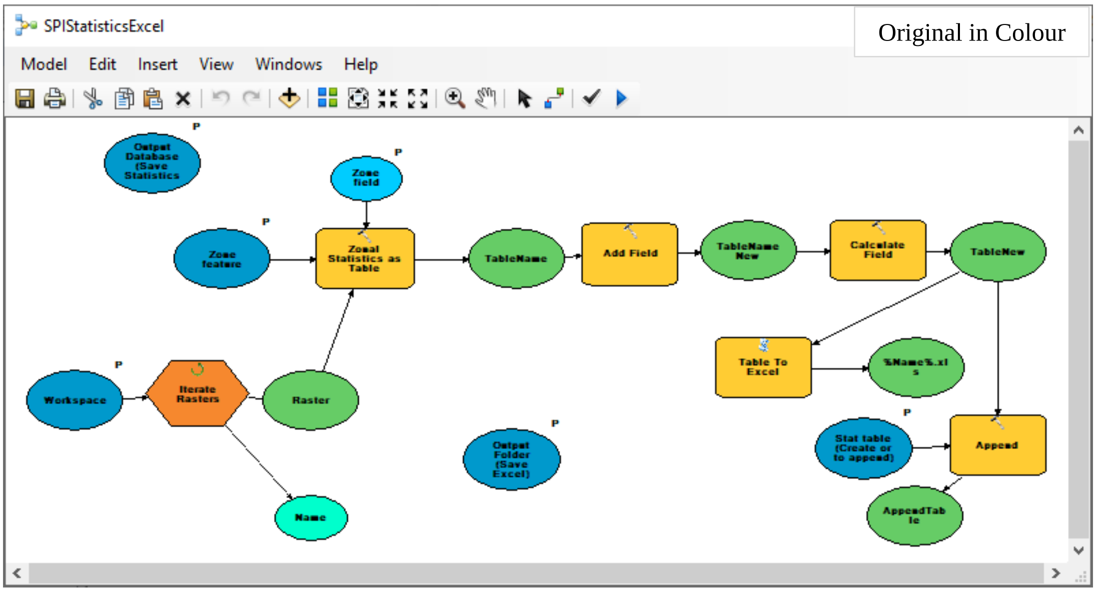

Figure 3-3: GIS model to calculate spatial average and combine all the monthly average rainfall

3.2.3 Comparison of Rainfall-Runoff Estimations

Similar to the RR option, this option requires a hydrologic model to evaluate the estimated streamflow from a particular interpolation method and the corresponding observed streamflow to compare the contribution towards the matching of hydrographs. The 2-parameter monthly water balance model used for the RR option was used in this study. Model performance was assessed with the Mean Ratio of Absolute Error (MRAE). The model was then calibrated for each selected station configuration. MRAE values at each calibration was compared to capture the best spatial averaging method representing the watershed hydrologic response.

Since the objective is a comparative evaluation of different spatially averaged rainfall by comparing streamflow from a model, it is important for the selected model to perform well within a lengthier data period. Therefore, in the entire eight-year dataset (from 2006/07 -2013/14) was taken for model calibration to capture the influence of data variability within the entire period.

3.2.4 Computational Time

Spatial averaging of point data at each time step requires a significant resource requirement when the temporal resolution is fine. In case of daily data each averaging method has to generate a rainfall surface for a particular day, extract the surface corresponding to the watershed and then compute the average for the watershed. In the Thiessen method the spatial variability of influence area pertaining to each gauging station remains constant irrespective of the magnitude of rainfall received at a particular station. In all other selected methods various mathematical assumptions vary the spatial influence area depending on the rainfall magnitude. Therefore, not only the accuracy of areal rainfall, but also the resource requirement must be considered when selecting a rainfall averaging method for water resources applications. Considering the methodology of each method and complexities, computational time requirement was captured as an indicator to select an appropriate spatial averaging method.

Generation of rainfall using ArcGIS model builder was done in four main steps for all interpolation methods except the Thiessen Method. The four steps are, 1. Generating rainfall surfaces for each month in each spatial interpolation method for eight years; 2. Clipping all generated surfaces for catchment area; 3. Generating areal average rainfall for each month; and 4. Combining generated monthly rainfall averages according to the data duration. In case of Thiessen method, since weights are specific to the station geometry and calculations could be done using a simple mathematical operation to obtain the rainfall using MS. Excel spread sheet. In case of Thiessen method, the time to generate Thiessen average was computed and assessed.

4 DATA AND DATA CHECKING

4.1 Data

Monthly data of rainfall, evaporation and streamflow from 2006 to 2014 for Ellagawa sub basin in Kalu Ganga were collected. Visual data checking was done for rainfall, streamflow and evaporation data to check for inconsistencies. Annual water balance was carried out for data from each gauging station. Double mass curve was used to check the consistency of data. Selected River gauging stations was Ellagawa. Eight rain gauging stations namely, Ratnapura, Alupola, Pelmadulla, Nivithigala, Kuruvita (Keragala), Galutara Estate, Pussella State Plantation and Eheliyagoda State Plantation located within the study area and four stations namely Halwathura Hanwella, Maussakele and Uskvalley located outside the catchment (All together twelve stations) were selected. Locations of river and rain gauging stations are shown in Figure 1-1. Data sources and resolutions are in Table 4-1.

Table 4-1: Details of data for Ellagawa sub-basin

Data Types	Spatial Reference	Resolution	Data Period	Source
Rainfall	Alupola	Daily	2006 – 2014	Dept. of Meteorology And Dept. of Irrigation
	Nivithigala			
	Pelmadulla			
	Rathnapura			
	Kuruvita (Keragala)			
	Galutara Estate			
	Pussella S.P.			
	Eheliyagoda S.P.			
	Halwathura			
	Hanwella			
	Maussakele			
	Uskvalley			
Evaporation	Rathnapura	Daily	2006 – 2014	Dept. of Meteorology and Dept of Irrigation (Hydrological Annuals)
Streamflow	Ellagawa	Daily	2006 - 2014	Dept. of Irrigation

Figure 1-1 illustrated that the Rainfall stations selected within the catchment and outside the catchment. The Rainfall station, Ratnapura is common for both rainfall and evaporation. The stream gauging station, Ellagawa also shown in the same figure. Data tables are annexed in ANNEX A- Data and Data checking. The main consideration of the rainfall stations selection was based on the data availability.

4.1.1 Rainfall Data

Monthly variations of rainfall in each station are plotted in Figure 4-1. Table 4-3 shows the descriptive statistics of each stations. The average annual, seasonal and monthly rainfall variation is in Table 4-2.

Table 4-2: Rainfall variation in each station

Rainfall Stations	Average Annual	Average Seasonal	Average Maha	Average Yala	Average Monthly
Alupola	4253	2126	1898	2355	354
Nivithigala	1789	895	756	1033	149
Pelmadulla	2376	1188	1018	1358	198
Rathnapura	3596	1798	1365	2231	300
Eheliyagoda	4062	2031	1486	2575	353
Galutara Estate	3467	1733	1460	2006	301
Pussalla S.P.	4098	2049	1575	2523	349
Kuruvita (Keragala)	4323	2162	1613	2711	360
Halwatura	3744	1872	1597	2146	312
Uskvalley	5677	2839	2383	3294	488
Hanwella	2794	1397	1227	1567	235
Maussakelle	2961	1481	990	1971	247

Monthly variations of rainfall show significant variations in rainfall. No regularity can be identified among station rainfall except a two peak monsoon pattern (Figure 4-1). Descriptive statistics indicated that median of each station varied within 124.5 to 437.4 mm of monthly rainfall (Table 4-3). The summary of statistics is an explanation about the variation of rainfall values. The Nivithigala station showed the lowest rainfall while Uskvally indicated the highest rainfall values.

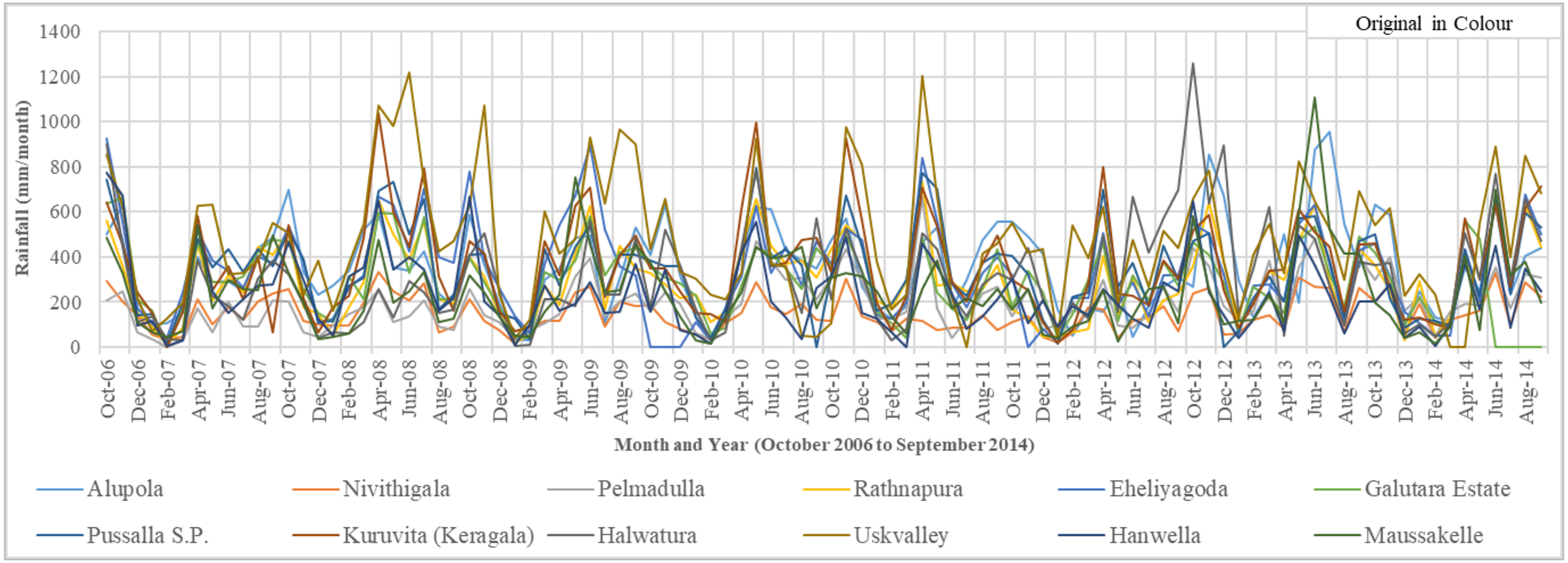

Figure 4-1: Monthly variation of rainfall

Table 4-3: Descriptive statistics of monthly rainfall data in each station

	Alupola	**Nivithigala**	**Pelmadulla**	**Ratnapura**	**Eheliyagoda**	**Galutara Estate**	**Pussalla S.P.**	**Kuruvita (Keragala)**	**Halwatura**	**Uskvalley**	**Hanwella**	**Maussakelle**
Mean	354.40	149.10	198.02	299.70	353.19	301.47	348.78	360.28	311.97	488.35	235.32	246.77
Standard Error	20.26	8.22	12.39	17.76	21.58	16.25	19.59	22.74	23.62	28.72	17.11	18.78
Median	336.02	124.50	171.45	287.20	325.00	293.25	358.05	325.00	266.95	437.40	203.90	233.20
Mode	133.60	178.00	74.00	365.00	104.00	179.00	#N/A	#N/A	#N/A	546.00	#N/A	257.10
Standard Deviation	198.54	80.58	121.36	174.05	207.02	155.87	189.93	222.79	231.39	276.99	166.72	184.01
Sample Variance	39416.64	6492.54	14727.57	30293.05	42855.78	24295.07	36072.46	49636.21	53541.38	76720.82	27796.90	33859.81
Kurtosis	0.07	-0.74	1.35	-0.47	-0.06	-0.63	-0.47	0.36	2.12	-0.14	0.98	4.22
Skewness	0.58	0.50	1.02	0.44	0.56	0.20	0.37	0.77	1.20	0.58	1.09	1.55
Range	927.30	318.00	665.77	722.70	904.00	661.00	777.30	1036.60	1255.00	1179.40	768.60	1093.30
Minimum	28.70	14.00	0.23	9.00	19.00	2.00	16.00	0.00	5.00	39.80	3.20	13.00
Maximum	956.00	332.00	666.00	731.70	923.00	663.00	793.30	1036.60	1260.00	1219.20	771.80	1106.30
Sum	34022.73	14313.13	19010.08	28771.40	32493.40	27734.90	32785.10	34587.10	29949.50	45416.30	22355.30	23690.30
Count	96.00	96.00	96.00	96.00	92.00	92.00	94.00	96.00	96.00	93.00	95.00	96.00
Confidence Level (95.0%)	40.23	16.33	24.59	35.27	42.87	32.28	38.90	45.14	46.88	57.04	33.96	37.28

4.1.2 Streamflow Data

Monthly streamflow data which used in this study are in Table A - 3. Average, minimum and maximum monthly streamflow variations are shown in Table 4-4. Monthly streamflow pattern and the streamflow variation are in Figure 4-2 and Figure 4-3.

Table 4-4: Streamflow Variation at Ellagawa

	Monthly (mm/Month)	Annual (mm/Year)
Max	515	2054
Mean	124	1492
Min	20	736

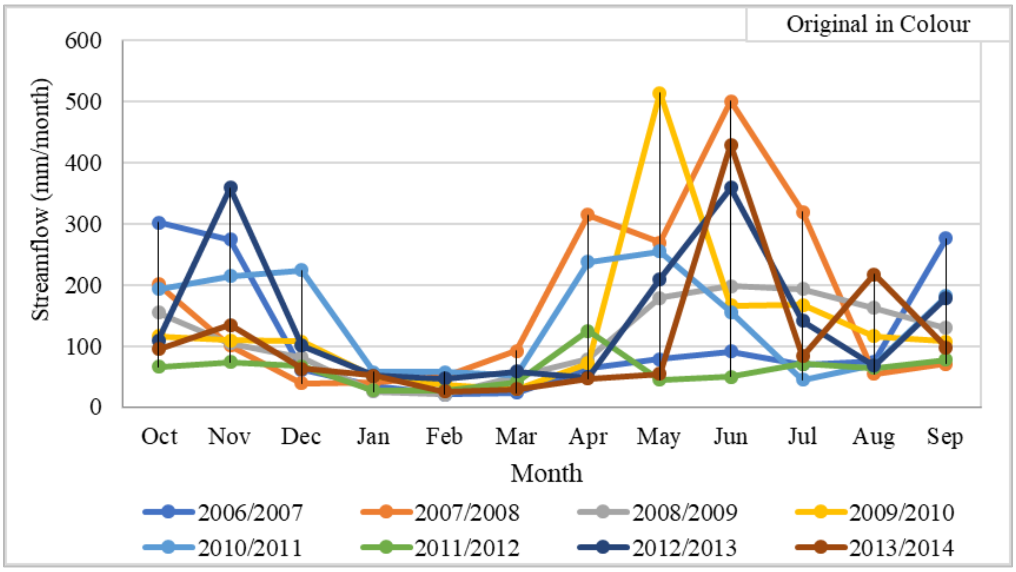

Figure 4-2: Monthly streamflow variation at Ellagawa Gauging Station - a

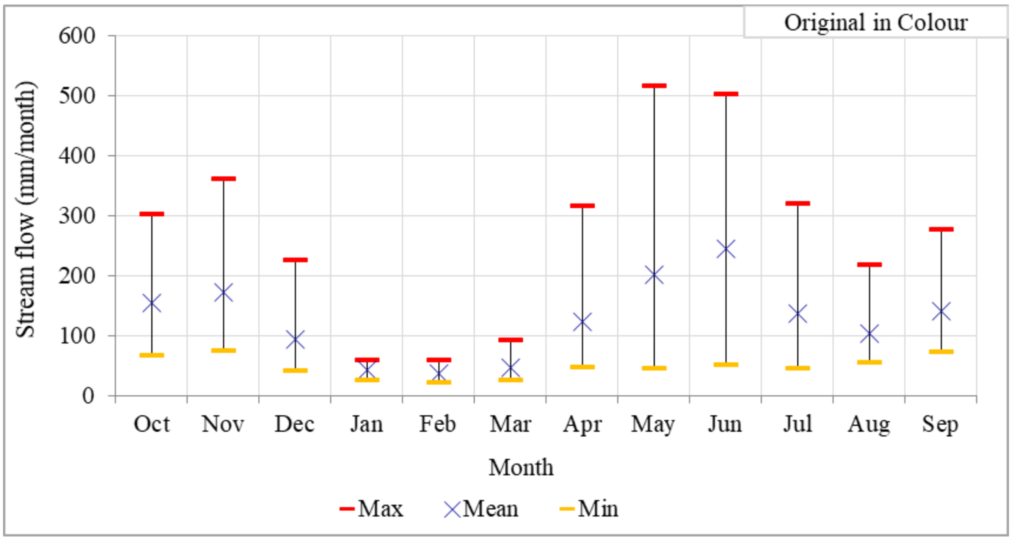

Figure 4-3: Monthly streamflow variation at Ellagawa Gauging Station - b

4.1.3 Evaporation Data

Ratnapura evaporation data (Table A - 3) was used for the study. The variation of evaporation, maximum, mean and minimum values of evaporation are shown in Table 4-5.

Table 4-5: Evaporation Data at Ratnapura

	Monthly (mm/Month)	Annual (mm/Year)
Max	124	1,061
Mean	79	944
Min	49	869

4.1.4 Data filling

Stations with missing data and corresponding filling stations are in Table 4-6. Missing data months and percentages are in Table 4-7. Available monthly rainfall and the filled rainfall data are in Table A - 1 and Table A - 2.

It indicates that the error is minimal as 5% and thus, it is assumed to be acceptable to use filled data for the study.

Table 4-6: Stations with Missing Data and Filling Details

Station	Year	Missing Months	Data Fill station
Eheliyagoda S.P.	2009	October, November, December	Kalatuwawa (LAT - 6.48N; LON - 80.38E)
	2011	November	Pussella S.P.
Galatura Estate	2014	June, July, August, September	Halwatura
Pussella S.P.	2010	September	Kuruvita(Keragala)
	2012	December	
Uskvalley	2011	July	Halwatura
	2014	March, April	
Hanwella	2011	March	Millewa Estate (LAT - 6.80N; LON - 80.0 8E)

Table 4-7: Missing Data Percentages

Rainfall Station	Data Missing months	Missing Percentage
Eheliyagoda	4	4.3%
Galutara Estate	4	4.3%
Pussalla S.P.	2	2.1%
Uskvalley	3	3.2%
Hanwella	1	1.1%

4.2 Data Checking

Data checking was carried out with visual checking, graphical checking, consistency checking and water balance checking. Visual data checking was done, to identify the no-data records, outliers and inconsistencies. By graphical checking the correlations of stations and data patterns could be clearly identified. Double mass curves were used to check the consistency of data.

4.2.1 Visual Data checking

No data records identified in the dataset varied by one-month period to four months periods. To eliminate the no records data was filled with neighboring stations. Ellagawa streamflow response with each rainfall station are shown in Figure 4-4, Figure 4-5 and Figure 4-6. The circles are indicating the unresponsive streamflow to the rainfall. In some stations, even though the high rainfall was identified with very low streamflow responses.

In general, streamflow responses from 2006 to 2008 show an acceptable match with each station rainfall except Pussalla and Uskvalley stations. For all stations, Ellagawa streamflow is not responsive for some periods.

All together the Nivithigala station shows a satisfactory level match though it shows the lowest rainfall compared to other stations. Uskvalley shows the high levels of rainfall values than the other stations.

If an averaging method is used the responses of streamflow shows a better match than a single station. The Figure 4-8 illustrated that even for simple averaging the streamflow response is in satisfactory level. However, due the differences in peak flows vs high rainfall fluctuations further checking was done.

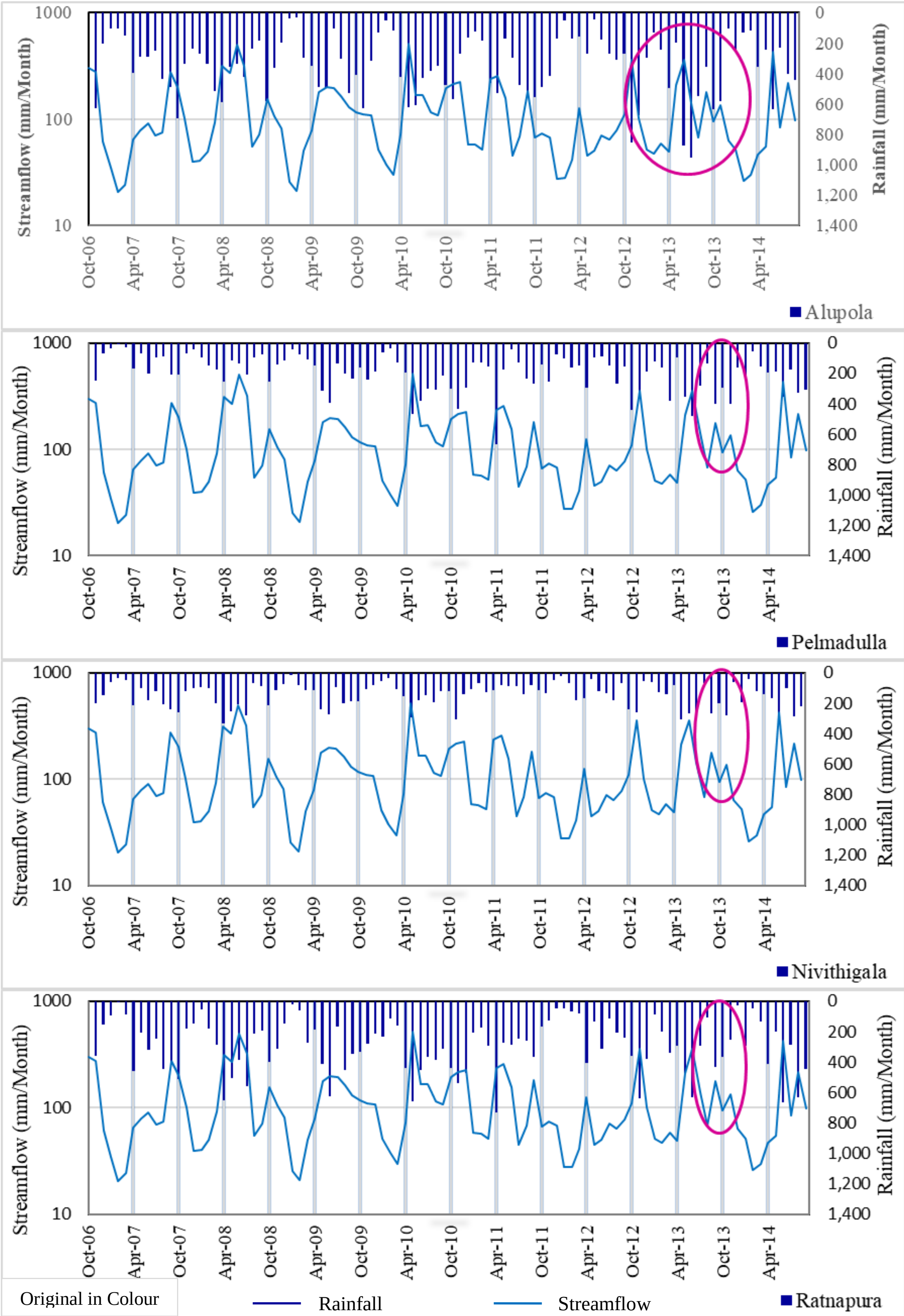

Figure 4-4: Ellagawa streamflow response with each rainfall station (a)

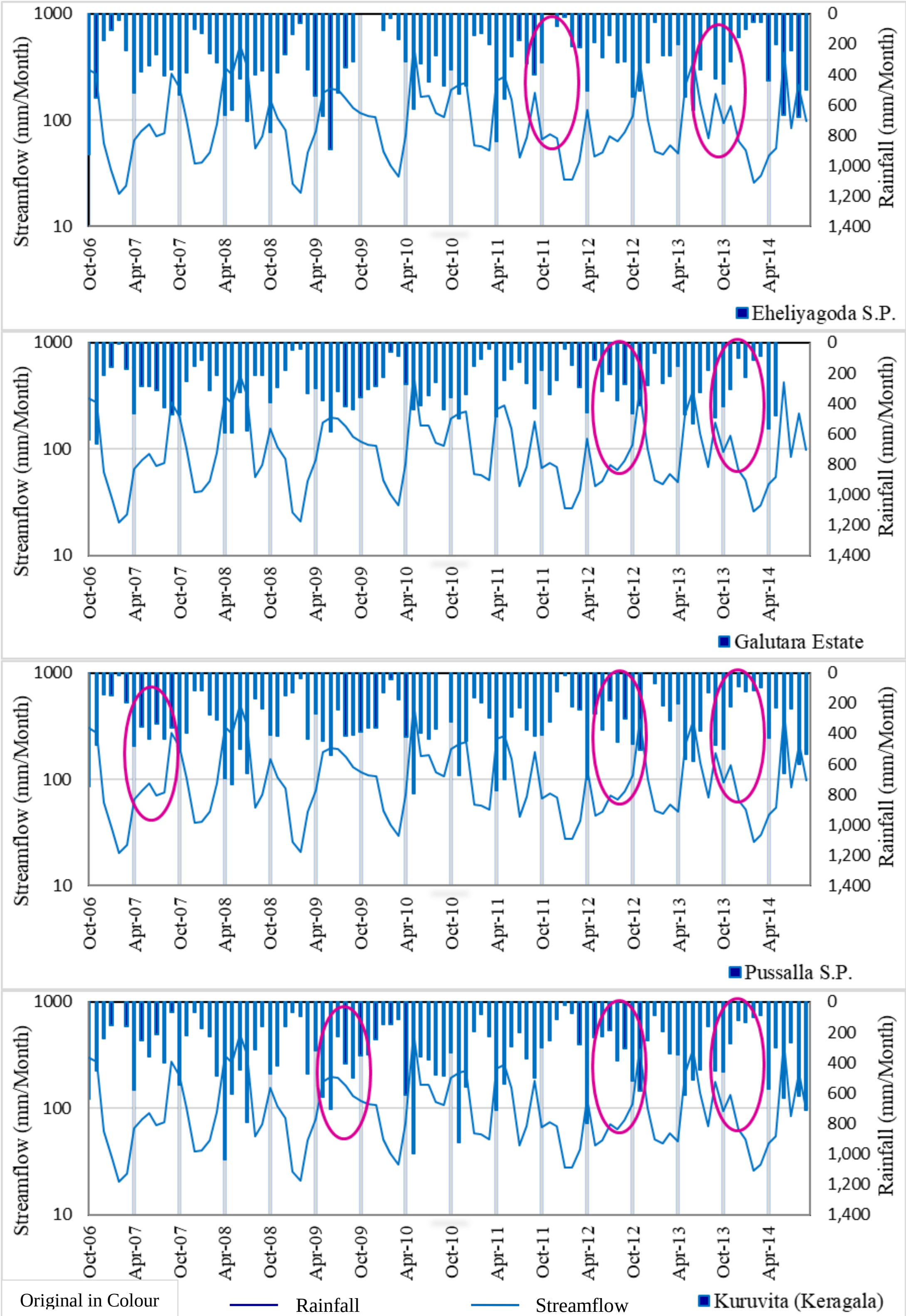

Figure 4-5: Ellagawa streamflow response with each rainfall station (b)

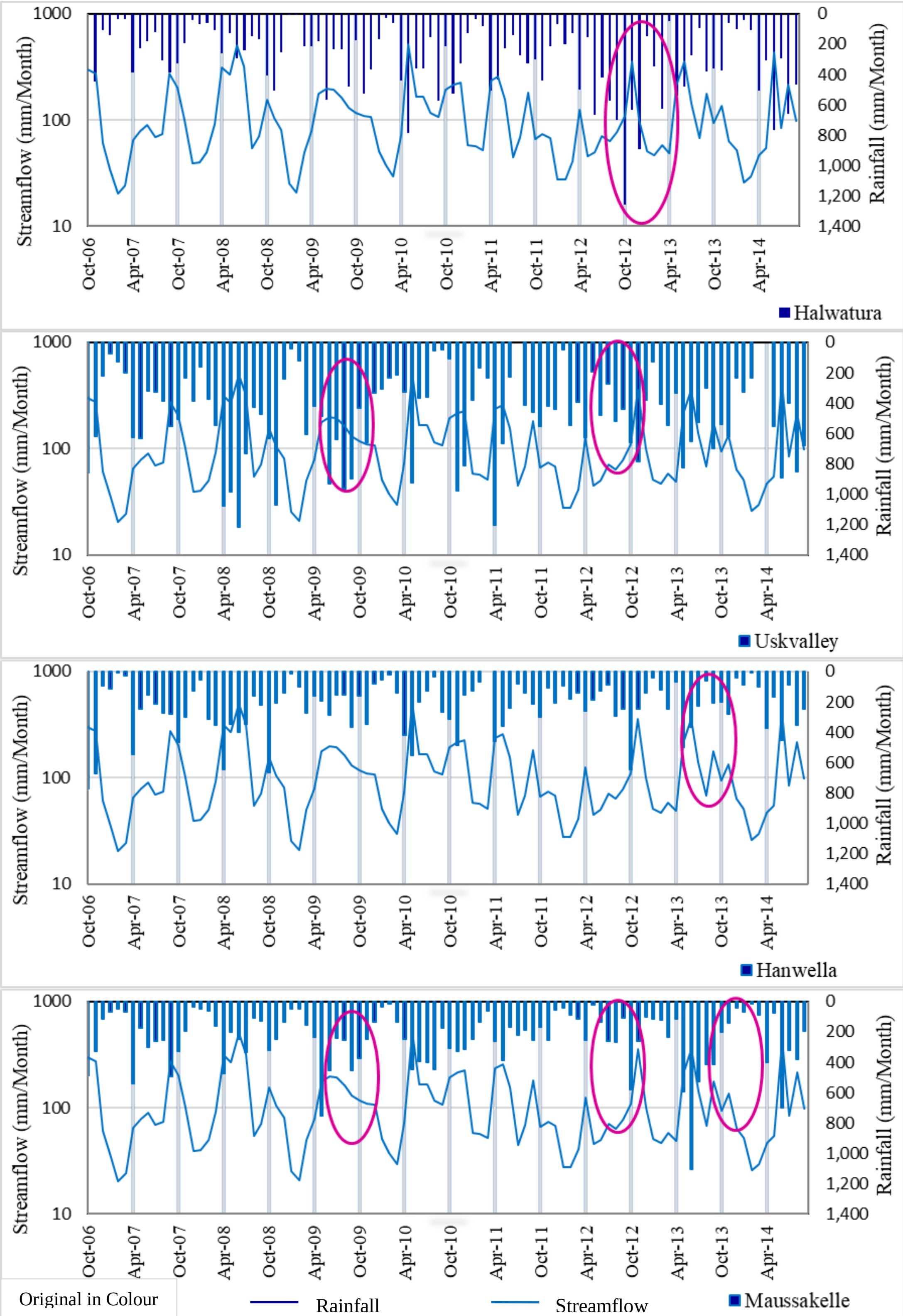

Figure 4-6: Ellagawa streamflow response with each rainfall station (c)

4.2.2 Outlier Checking

Outliers were checked visually and by a regression method to identify anomalies in rainfall data. The abnormality of minimum rainfall value at each rainfall station identified by visual checking as well as the regression method. However, no maximum rainfall was identified as abnormal value in each station. Sixteen outliers were identified out of 1152 monthly rainfall records (8 years monthly rainfall for 12 rainfall stations) Ellagawa watershed according to the regression method. Pussella S.P., Kuruvita (Keragala), Halwatura and Hanwella identified having two rainfall values as outliers in each station while other stations having one outlier at each rainfall station. However, data series was not changed and outliers were not replaced.

4.2.3 Graphical Checking

The annual rainfall was calculated as simple average of all the stations and plotted with observed streamflow to check the streamflow responses in rainfall simple averaging. However, the annual rainfall pattern is similar, with the streamflow response showing a reliable match (Figure 4-7).

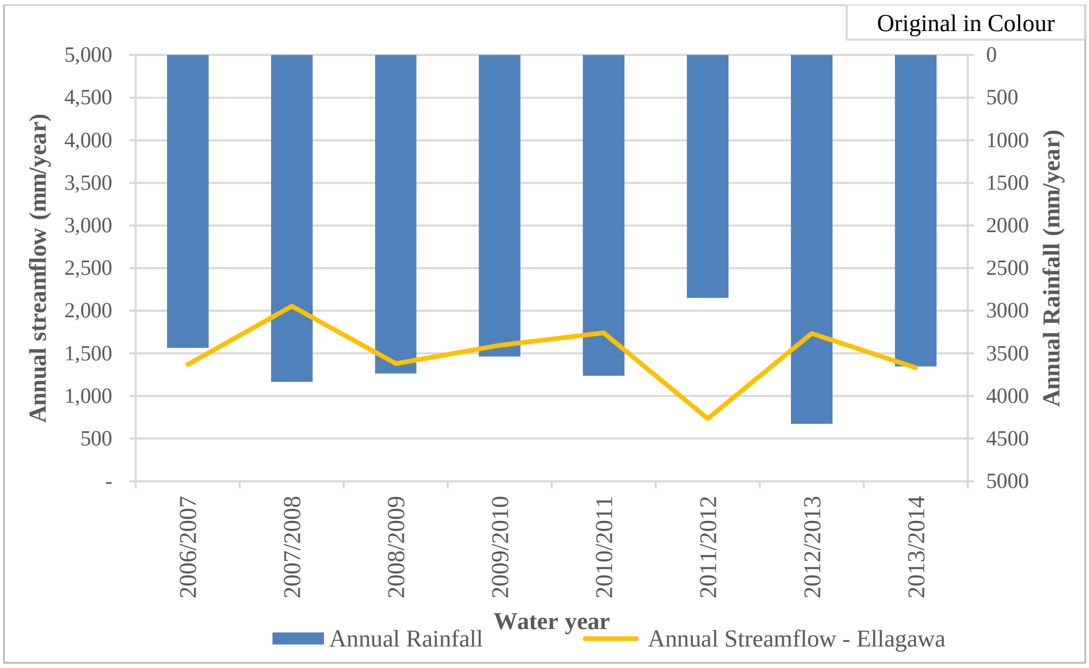

Figure 4-7: Simple Average Rainfall variation with streamflow annual

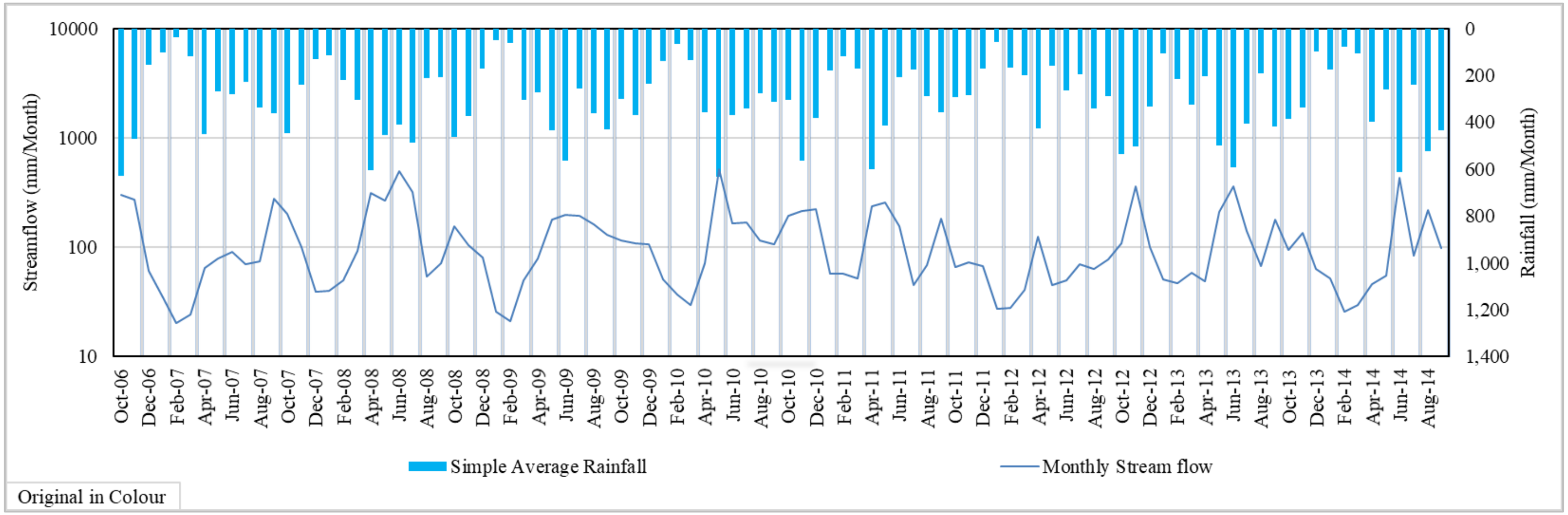

Figure 4-8: Streamflow responses with simple average rainfall (monthly)

Even though the monthly average rainfall (Figure 4-8) follows the similarity in rainfall pattern and streamflow variation pattern, the peak values have not indicated a similar range of values but annual rainfall (Figure 4-7) indicated a good match of value range.

4.2.4 Consistency Checking

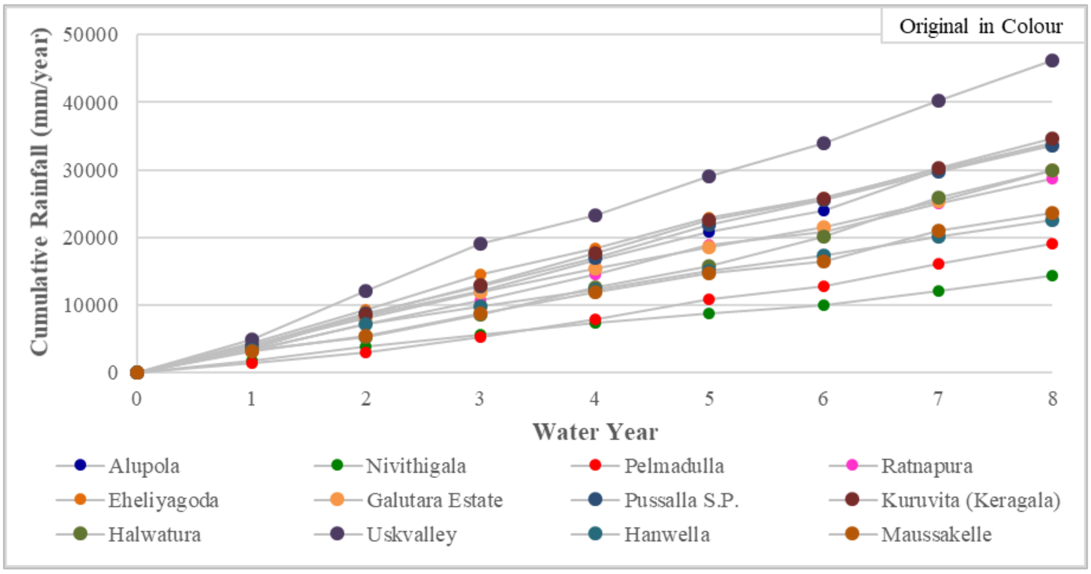

Figure 4-9: Single Mass Curve, Cumulative annual rainfall for all rainfall stations for 8years

Rainfall data consistency was checked with Single mass curve technique by plotting cumulative annual rainfall data against the time for each station (Figure 4-9). The test of Single mass curve technique is used to depict the homogeneity (Wakachala et al., 2015) and verify the rainfall stations consistency and continuity (Ketiem, Makeni, Maranga, & Omondi, 2017). Time of 1 to 8 years display the period of 2006/2007 to 2013/2014 water years

According to Figure 4-9, Halwatura and Ratnapura stations show a reliable correlation. Plemadulla and Nivithigala shows a very good correlation in first four years and beyond that also shows a different relation. Ratnapura with Galutara, Eheliyagoda, Kuruvita, Alupola with Pussella and Hanwella with Maussakelle show a good correlation in entire period. Halwatura also corelate with Hanwella and Maussakelle upto 5th year and then shows a different relation. Missing values are filled considering these correlations. Uskvalley shows highest cumulative values while Nivithigala showing the lowest of rainfall data.

Consistency check was further carried out with Double Mass Curve by comparing data for a single station with that of a pattern composed of the data from other stations. The cumulative rainfall data of one rainfall station with cumulative average of other stations in the catchment were plotted to check the consistency of rainfall data. All results of Double Mass Curve plots were attached to the ANNEX A - Figure A - 5 to Figure A - 8. All graphs show a straight line so that the relation between rainfall is a fixed ratio for each station thus, it illustrated that there is no significant inconsistency in rainfall data.

4.2.5 Water Balance Checking

Annual and monthly water balance was carried out for Ellagawa catchment to observe the watershed behavior over the study period. For the calculation of annual average rainfall, the simple averaging was used. Annual variation of water balance is shown in Table 4-8 and Figure 4-10. Annual Water balance varied from 1781 to 2595 mm/year showing a reliable deviation.

The lowest rainfall observed in 2011/2012 water year showing the lowest streamflow managed to maintain the average water balance (approximately) of the period. The lowest runoff coefficient of 0.26 also reported in same year. When the highest rainfall observed in 2012/2013 water year the streamflow did not reach its maximum and thus, return the water balance to the maximum.

Table 4-8: Annual Water Balance Variation

Water Year	Annual Rainfall (mm/year)	Annual Streamflow (mm/year)	Annual Pan Evaporation (mm/year)	Annual Water Balance (mm/year)	Runoff Coefficient
2006/2007	3436.78	1,370.93	952.1	2,066	0.40
2007/2008	3834.77	2,054.07	924.07	1,781	0.54
2008/2009	3736.7	1,379.57	1060.59	2,357	0.37
2009/2010	3538.3	1,594.46	944.03	1,944	0.45
2010/2011	3760.7	1,740.65	869.18	2,020	0.46
2011/2012	2849.2	736.10	994.01	2,113	0.26
2012/2013	4326.8	1,731.95	870.27	2,595	0.40
2013/2014	3652.9	1,329.95	898.86	2,323	0.36

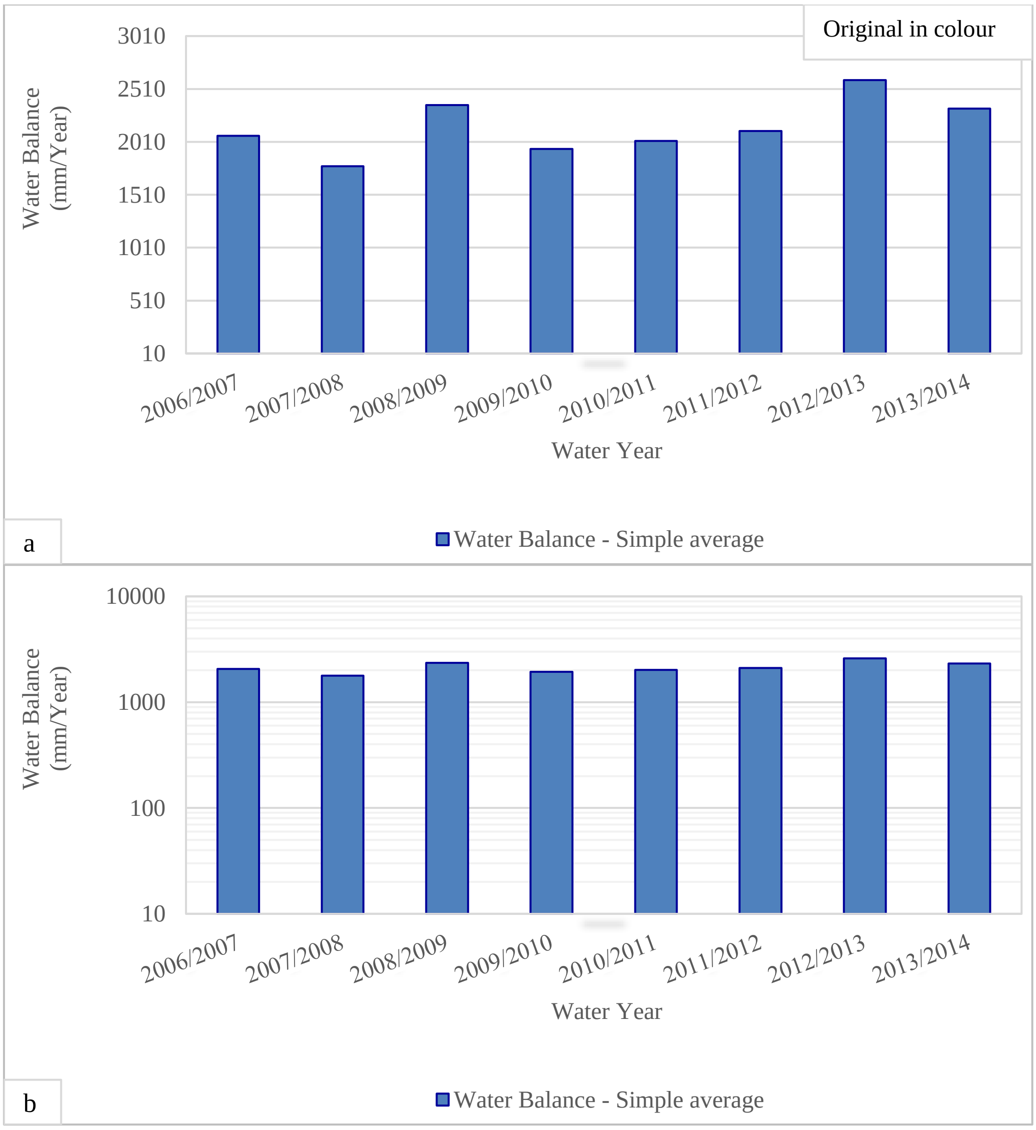

Figure 4-10: Annual water balance variation – Normal plot (a), Semi log plot (b)

The annual water balance shows a variation in normal plot, but semi log plot indicates a consistency in water balance. However, the runoff co-efficient varies significantly with showing unrealistic behavior in few years.

5 ANALYSIS AND RESULTS

5.1 Analysis of Station Selection in Practice

Literature review included a comparison of practices in relation to watershed sizes, number of stations used and their distribution, areal rainfall estimation methods, existence of stations within the catchment or outside etc. The criterion was then used to obtain a numerical indication of the availability and adequacy of methods available for the selection of rainfall stations to compute areal rainfall input for hydrologic models.

Literature illustrates that high densities of rainfall stations do not always provide the best streamflow estimations (H. Xu et al., 2013). Thresholds between 2.6 and 41.6km^2 per station has been quoted as densities beyond which improvements to areal rainfall would be marginal. In practice the median density values used for small, medium and large catchments are approximately 19, 117 and 470 square kilometers per station respectively (Figure 5-2 and Table 5-1). The applications very seldom appear as according to practice guideline recommendations (Figure 5-1). Very few research works appear as considering that careful gauging station selection and selection of an appropriate averaging method is important for meaningful streamflow modelling. On the other hand, there are major issues such as discontinued gauging stations, long periods of missing data and inconsistencies in the temporal resolution of available data that hinders a rational station selection. Working on selecting the appropriate number of gauging stations enabling the optimization of stations and there influence-weights appear as the most rational concept for the estimation of catchment streamflow using mathematical models.

After a review of recent research-works it was identified that, the Thiessen method is the selection of majority (approximately 45%), while Kriging is the next method with approximately 11%. It is noteworthy that approximately 16% of reviewed research has not mentioned the method used for spatial averaging (Figure 5-3).

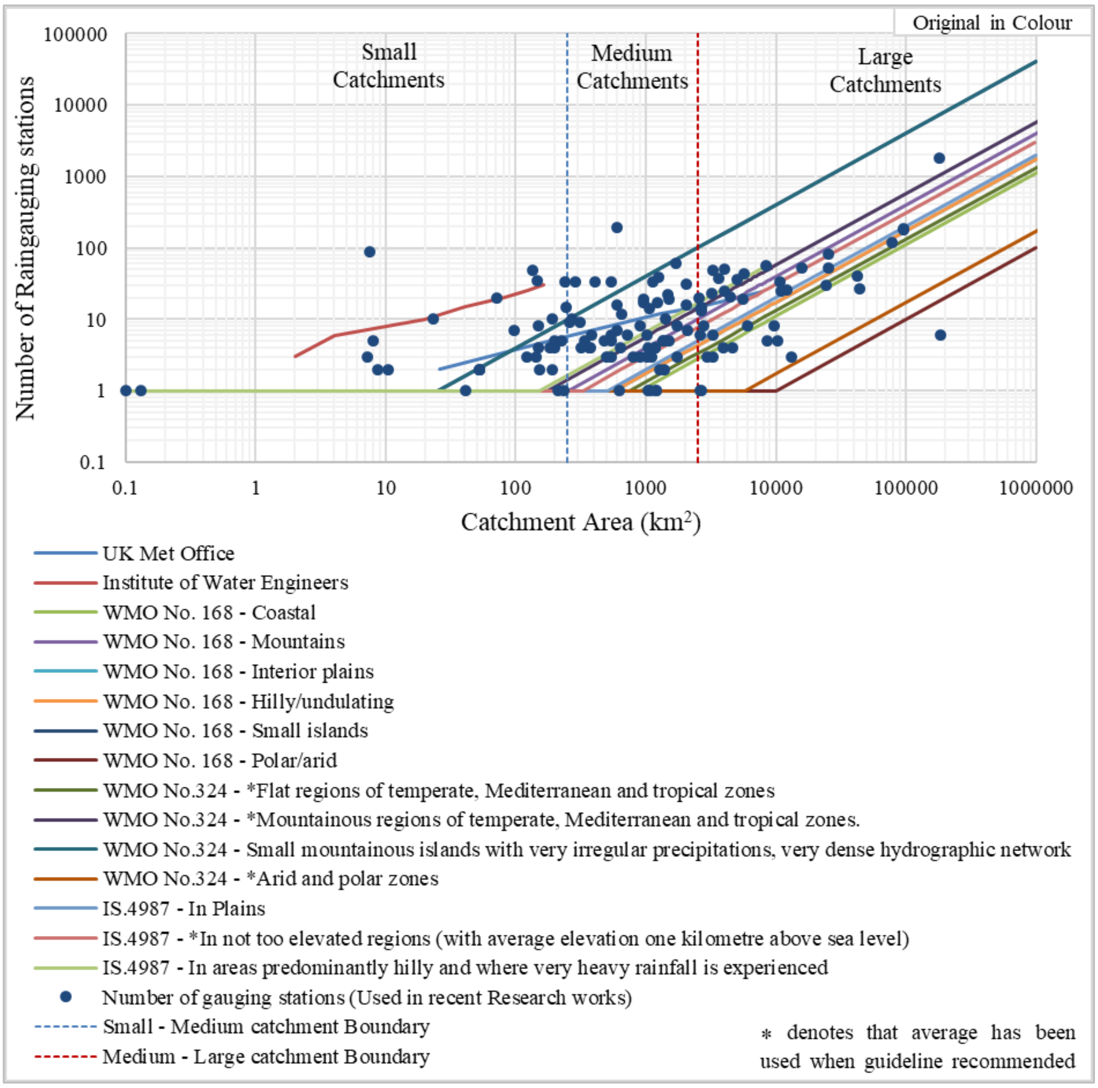

Figure 5-1: Practice of Rainfall Gauging Selection with respect to a Catchment Classifications

Table 5-1: Catchment and density variation of studies in past 40 years

Watershed Classification*	Area (Square Km)	Catchment size variation (km^2)	Station Density (km^2/Station)
Small	< 250	8 - 237	2 - 48
Medium	250-2500	337 - 2108	12 - 1202
Large	>2500	2545 - 180000	78 - 4373

* Classification based on Singh (1994)

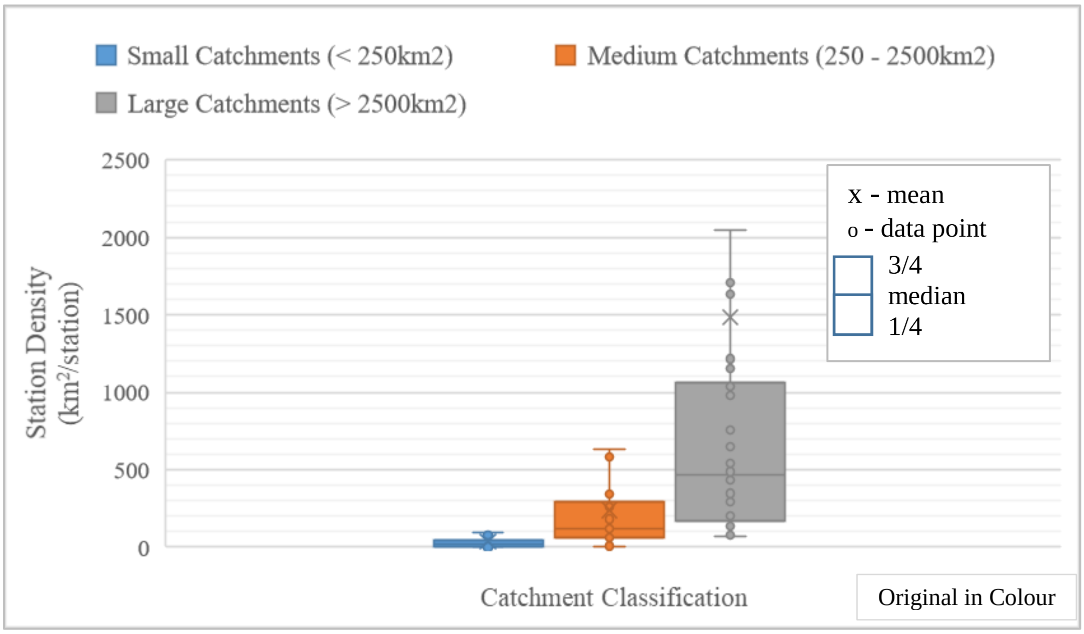

Figure 5-2: Practice of gauging station density corresponding to catchment classes

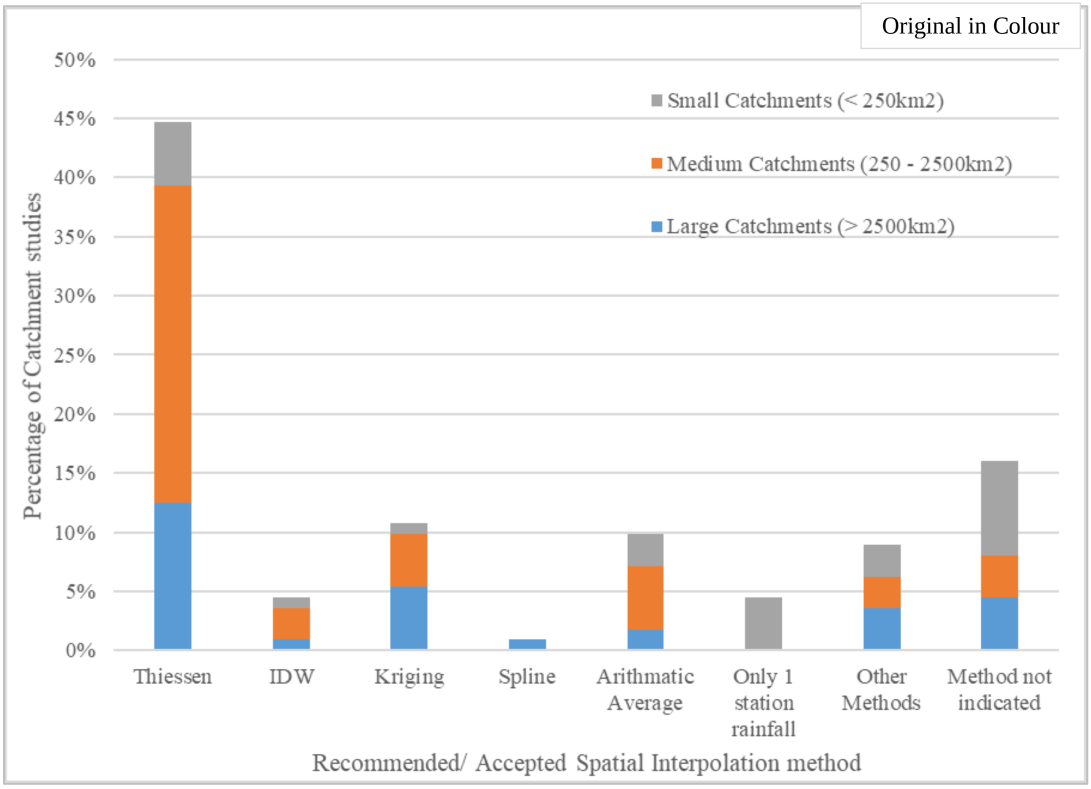

Figure 5-3:Spatial interpolation method recommendation/acceptance for different catchment sizes

5.2 Analysis of Influence of Station Density

The WMO (World Meteorological Organization, 2008) recommendation of station density for the study area is 575 km^2/station. As per literature review a station number for Ellagawa watershed is between 86 and 575 km^2/station (i.e. 16 and 3 stations/km^2) can be considered as the optimal density range. Highest density achieve for this research was 140 km^2/station (10 stations/1395 km^2) after considering limitations such as missing data, cost, distribution, distance to the catchment and etc. Using the selected rain gauge stations, a set of station combinations ranging from 1 -10 stations were used for the analysis. Combinations excluded the sets in which all stations were located outside the watersheds. In the selected combinations, the station density varied from 140 (10 stations/1395 km^2) to 1395 km^2/station (1 stations/1395 km^2). Thiessen weights of each station for a particular combination were calculated to compute the Thiessen averaged rainfall (ANNEX B - Table B - 1).

5.2.1 Rainfall Only option (RO Option)

Variation of annual rainfall with each station combination and the values corresponding to several statistical indicators are shown in Table 5-4. There were 40 of two station combinations and 10 number of ten station combinations in the comparison of Thiessen average rainfall.

5.2.1.1 Annual Rainfall

Data in the study area and over the study period shows that the annual rainfall has a wide variability ranging from 1273 mm/year at Pelmadulla to 7108 mm/year at Uskvalley. Distribution of Rainfall in the project area with respect to each water year and % time of exceedance in Figure 5-4 and Figure 5-5 reflect the yearly variation and the frequency of occurrence. The period of record (PoR) duration curve shows that the rainfall variation between 20% and 80% of the time is between 4482 and 2624 mm/year respectively (Figure 5-5). The average of watershed annual rainfall values computed by taking the average from Thiessen average values corresponding to each station combination show that the mean values vary between 3211 and 3651 mm/year (Table 5-4). Variation of average annual rainfall with each station combination are shown in Figure 5-6. In this analysis, deviation of values for station combination having the same density was chosen for the comparison. Percentage Deviation computation is as in Equation 2.

$$\text{Percentage Deviation} = \frac{(\text{Maximum Value} - \text{Minimum Value})}{\text{Minimum Value}} \times 100\% \quad \ldots\ldots \quad 2$$

Yealy rainfall variation is shown in Figure C - 3. The plots of yearly rainfall deviation when the station density changes over the catchment, are in Figure C - 1 and Figure C - 2. Analysis explains that the rainfall is converging to a specific value with increasing rainfall stations density.

Results for each combination show that the deviation from any combination of rain gauges become less than 10% only with a station configuration denser than 175km^2/station (Figure 5-6). This means that out of the available gauging stations, any eight or more stations (Density > 175 km^2/station) would lead to average rainfall values which has a < 10% deviation. A threshold density of any 8 stations from the available 12 stations would lead to average annual rainfall of Ellagawa watershed with a deviation <10% in the average value. Though the average annual rainfall values reach a consistent value beyond the said threshold station density, it may not be reflecting the actual rainfall experienced by the watershed. If the geographic distribution of available gauging stations is non uniform and the stations are located far apart, then the threshold may attach a higher weightage to one or more stations. Any adjustments as a corrective measure would require fresh installations at closer intervals.

The possibility of higher weightage allocation due to geographic location was investigated by comparing the spatial averaging weights for each gauging station combination. Thiessen weights that were assigned to each station for each station combination is shown in Figure 5-7 and Figure 5-8. Figure 5-8 is to emphasize the weight distribution when the station configuration density is greater than the threshold of 175 km^2/station. Consistently high weights assigned to Pelmadulla, Kuruvita (Keragala) and Nivithigala stations (Figure 5-8) points to the influence due to the geometry of existing gauging station locations. Thiessen weights comparison with each station combination also shows that the stations Halwatura, USKvalley, Hanwella, and Maussakelle (stations which are outside the catchment) have < 0.05 weight when the station numbers are increased to and above the threshold.

The RO option assumes that with greater station densities, there is a greater chance of capturing the actual spatial distribution. Accordingly, the areal average rainfall of the catchment would be approximately 3211.48 which is the value from a 10-station ($140km^2$/station) combination with a 2% deviation. The average rainfall from a 5-station combination (typical selection) is 3,319.83 mm/year with a 48% deviation (Table 5-4).

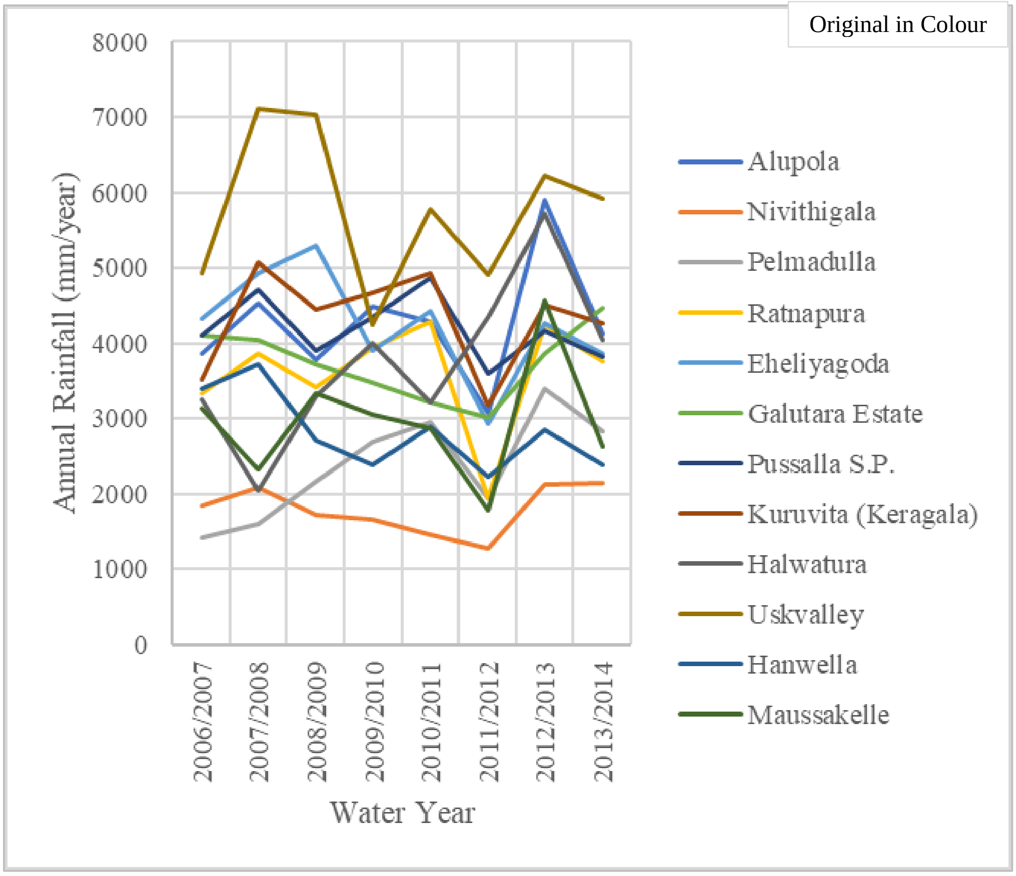

Figure 5-4:Water yearly variation of rainfall at each station

Original in Colour

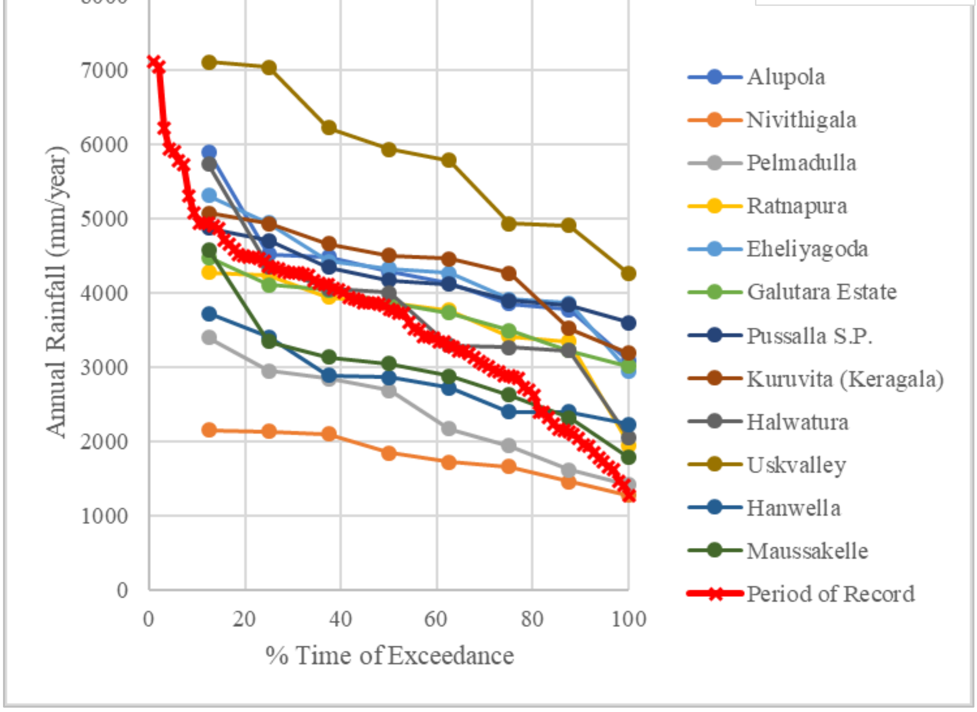

Figure 5-5: Water yearly rainfall and time of exceedance at each station

Original in Colour

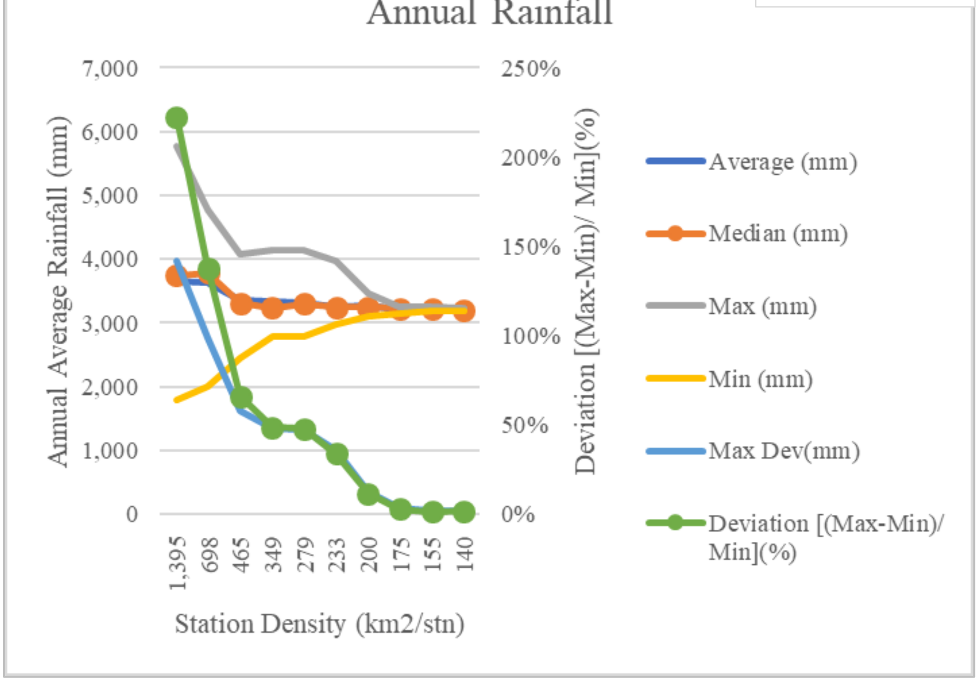

Figure 5-6: Variation of average annual rainfall over the study period for each station density

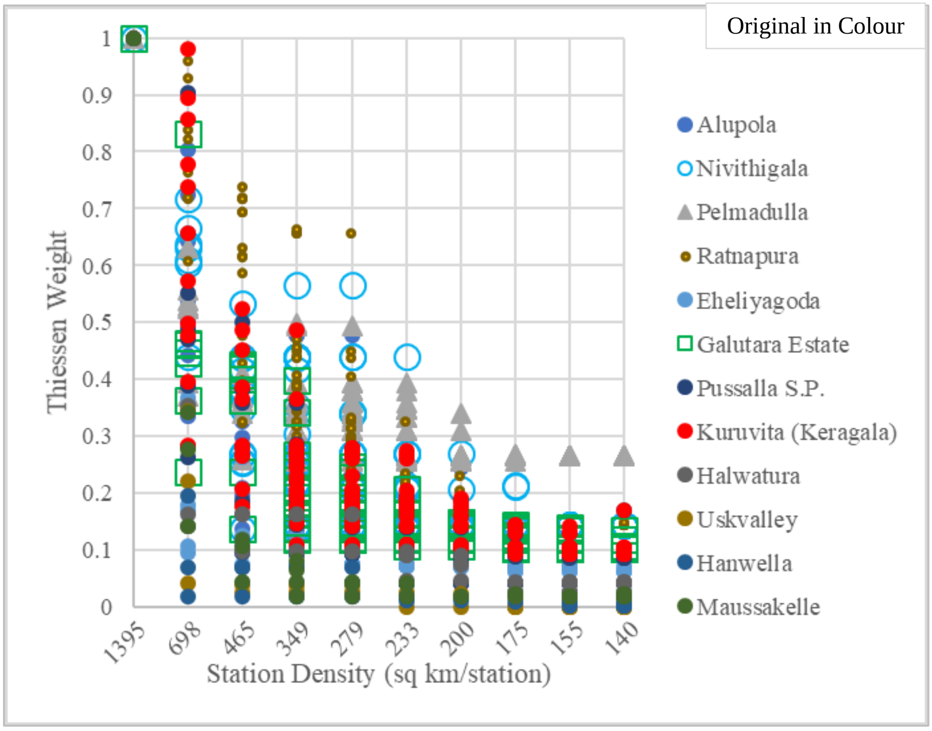

Figure 5-7: Distribution of Thiessen weights for each station combination

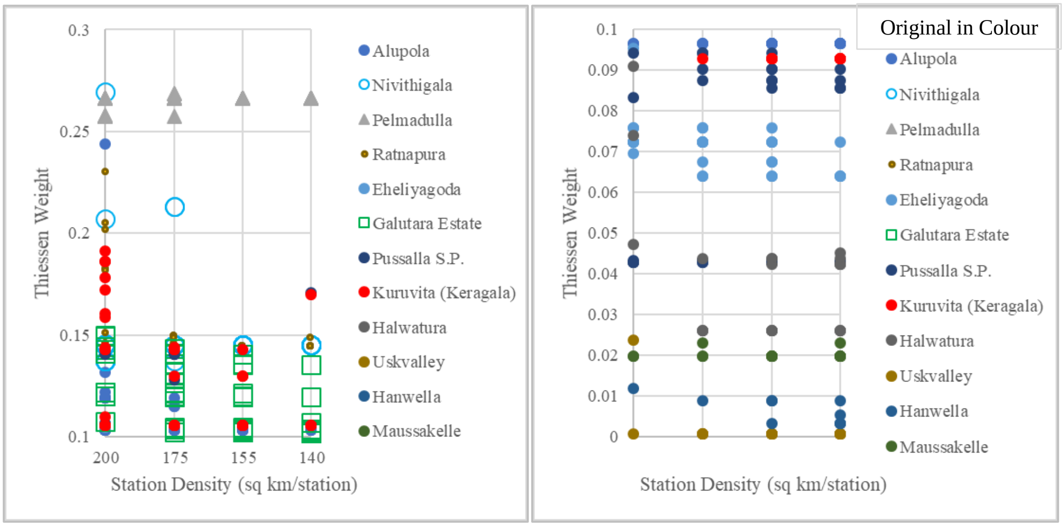

Figure 5-8: Distribution of Thiessen Weights for Density greater than 200 km^2/station

5.2.1.2 Maha Season (North-East Monsoon)

The average of watershed Maha season rainfall values computed by taking the average from Thiessen average values corresponding to each station combination show that the median values vary between 1297 and 1446 mm/season/year (Table 5-4 and Figure

5-11). Maha Season rainfall over the period has a wide variability ranging from 535 mm/year at Ratnapura to 3903 mm/year at Halwathura. Distribution of Rainfall in the project area with respect to each water year and % time of exceedance in Figure 5-9 and Figure 5-10 reflect the yearly variation and the frequency of occurrence. The variation of Maha season rainfall for all station configurations are shown in Figure C - 4.

The PoR duration curve shows that the rainfall variation between 20% and 80% of the time is between 1849 and 899 mm respectively (Figure 5-10). Similar to annual rainfall, the Maha season results for each combination show that the percentage deviation from any combination of rain gauges become less than 10% only with a station configuration denser than 175 km^2/station (Figure 5-11 and Table 5-4). Therefore, a threshold density of any 8 stations from the available 12 stations would lead to average Maha season rainfall of Ellagawa watershed with a deviation <10%. The average Maha season rainfall from a 10-stations combination is 1297.36 mm/year with a 2% deviation (Table 5-4).

Table 5-2: Seasonal rainfall - Maha Season

Rainfall Maha Season (mm/season) / Station	**2006/ 2007**	**2007/ 2008**	**2008/ 2009**	**2009/ 2010**	**2010/ 2011**	**2011/ 2012**	**2012/ 2013**	**2013/ 2014**
Alupola	1698.5	2397.2	1503.6	1659.6	1789.7	1849.8	2470.8	1816.3
Nivithigala	781	869	615	573.5	869	561	882.8	898.8
Pelmadulla	583.98	732.5	735.5	822.8	1441.6	886.5	1647.5	1294.5
Rathnapura	1258.6	1347.9	1211.2	1329.1	2118.1	535	2002	1121
Eheliyagoda	2043	1732.5	2003	1451.9	1835	1175.3	1977	1136
Galutara Estate	1848	1518.1	1285.7	1322	1498	1252	1712.2	1247.8
Pussalla S.P.	1716	1720	1575	1446.6	2092.8	1327.9	1830.3	1148.7
Kuruvita (Keragala)	1646	1715.9	1681.1	1350.7	2319.1	1043.6	1973	1172.8
Halwatura	1658.9	795.5	1391.1	1325	1307	1341.3	3903	1056.1
Uskvalley	2089.6	2200.1	2703.5	2174.3	2671.6	2385	2902.5	2050.4
Hanwella	1689.2	1607	1401.2	793.4	1399.1	1028.8	1436.2	714.2
Maussakelle	1111.8	823.9	952.1	939.3	1399.6	728.2	1412.5	553.1

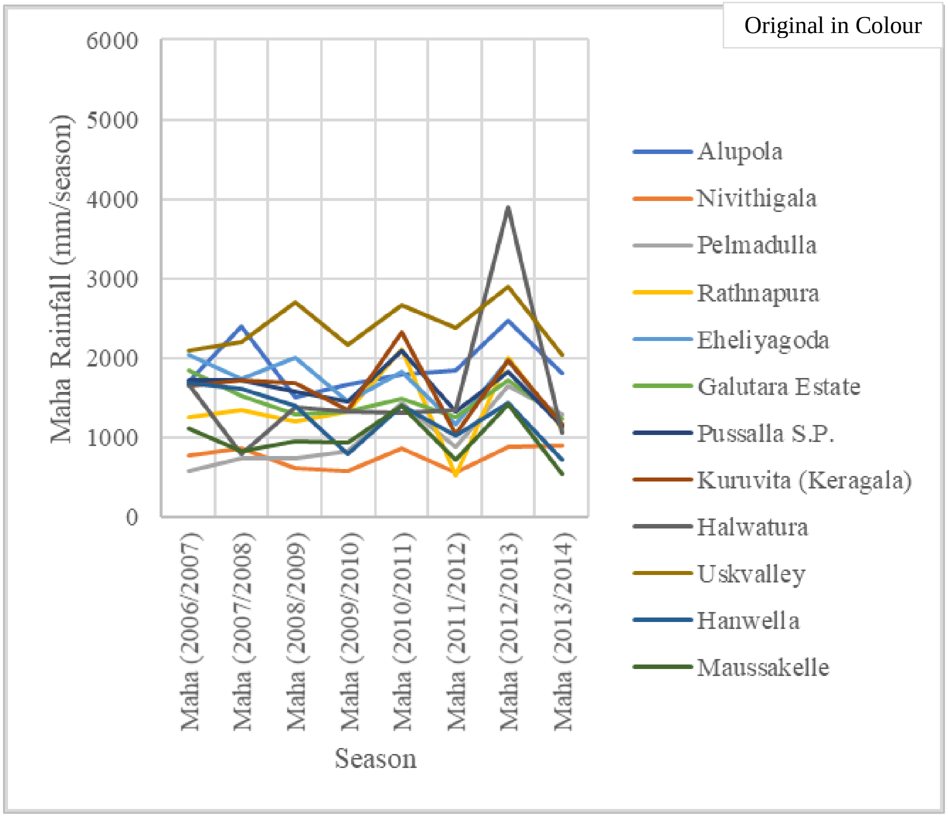

Figure 5-9: Distribution of Rainfall – Maha Season

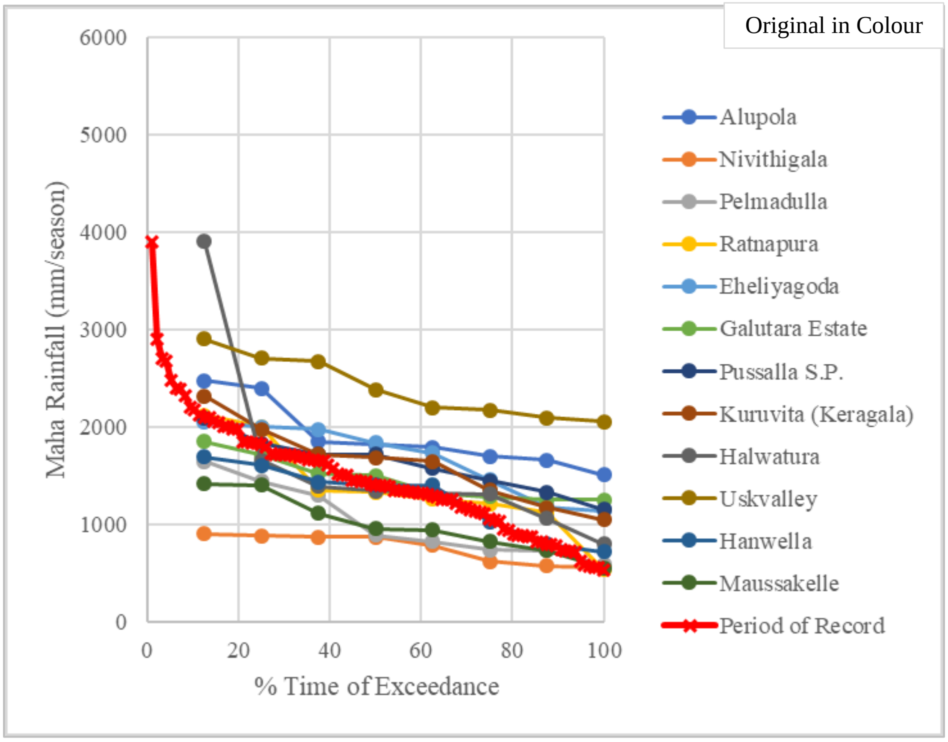

Figure 5-10: Distribution of Rainfall frequency of occurrence- Maha Season

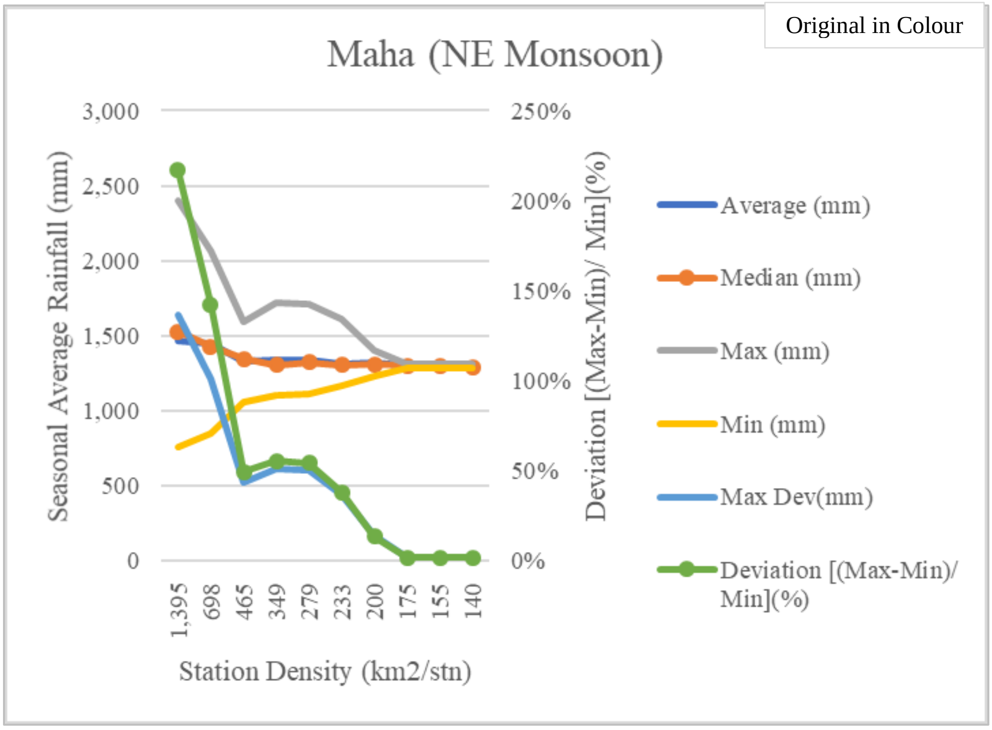

Figure 5-11:Variation of Average Maha Rainfall over Entire Period for Each Station Density

5.2.1.3 Yala Season (North-East Monsoon)

Yala season data over the study period shows that rainfall has a wide variability ranging from 586 mm/year at Nivithigala to 4908 mm/year at Uskvalley. Distribution of rainfall in the project area with respect to each water year and % time of exceedance in Figure 5-12 and Figure 5-13 reflect the yearly variation and the frequency of occurrence. The period of record duration curve shows that the rainfall variation between 20% and 80% of the time is between 2780 and 1474 mm respectively (Figure 5-13). The average Yala season rainfall values of watershed computed by averaging Thiessen average values corresponding to each station combination show that the mean values vary between 1914 and 2182 mm/season (Table 5-4 and Figure 5-14).

Similar to the annual and Maha season rainfall values, the Yala season results for each combination show that the percentage deviation from any combination of rain gauges become less than 10% only with a station configurations denser than 175 km^2/station (Figure 5-14). The variation of Yala season rainfall for all station configurations are shown in Figure C - 4. Therefore, a threshold density of any 8 stations from the available 12 stations would lead to average Yala season rainfall of Ellagawa watershed with a deviation <10%. Similar to the reasoning in the case of annual rainfall, the Yala season rainfall for the catchment was computed by taking the value for 12 stations. The average Yala season rainfall from a 10-station combination is 1914.12 mm/year with a 2% deviation (Table 5-4).

Table 5-3: Seasonal rainfall - Yala Season

Station \ **Rainfall Yala Season (mm/season)**	**2006/ 2007**	**2007/ 2008**	**2008/ 2009**	**2009/ 2010**	**2010/ 2011**	**2011/ 2012**	**2012/ 2013**	**2013/ 2014**
Alupola	2154.1	2122.6	2268.9	2822.7	2494.3	1229.8	3428.9	2316
Nivithigala	1057	1224.5	1107	1080	585.73	712	1250.1	1246.7
Pelmadulla	831.5	877.8	1433.5	1864.7	1510	1055	1745.5	1547.2
Rathnapura	2086.8	2507.6	2197.9	2611.5	2158.7	1411	2234	2641
Eheliyagoda	2280.5	3206	3300.6	2457	2586	1762	2284	2727
Galutara Estate	2255.7	2517	2441	2167	1723.5	1755	2150.4	3228.4
Pussalla S.P.	2398	2983	2317.7	2897.2	2780.1	2272.8	2337.4	2682.8
Kuruvita (Keragala)	1874.1	3355.9	2774.5	3311.2	2608.8	2138.4	2527.8	3094.2
Halwatura	1607.6	1245.6	1900.7	2675.5	1910.5	3009.5	1824	2998.2
Uskvalley	2840.2	4908	4336.4	2080.6	3108.5	2521	3321	3879
Hanwella	1710.4	2115.1	1316.7	1605.1	1490.6	1195.1	1424.1	1681.1
Maussakelle	2020.9	1494.6	2387.2	2107.3	1474	1049.5	3165	2071.3

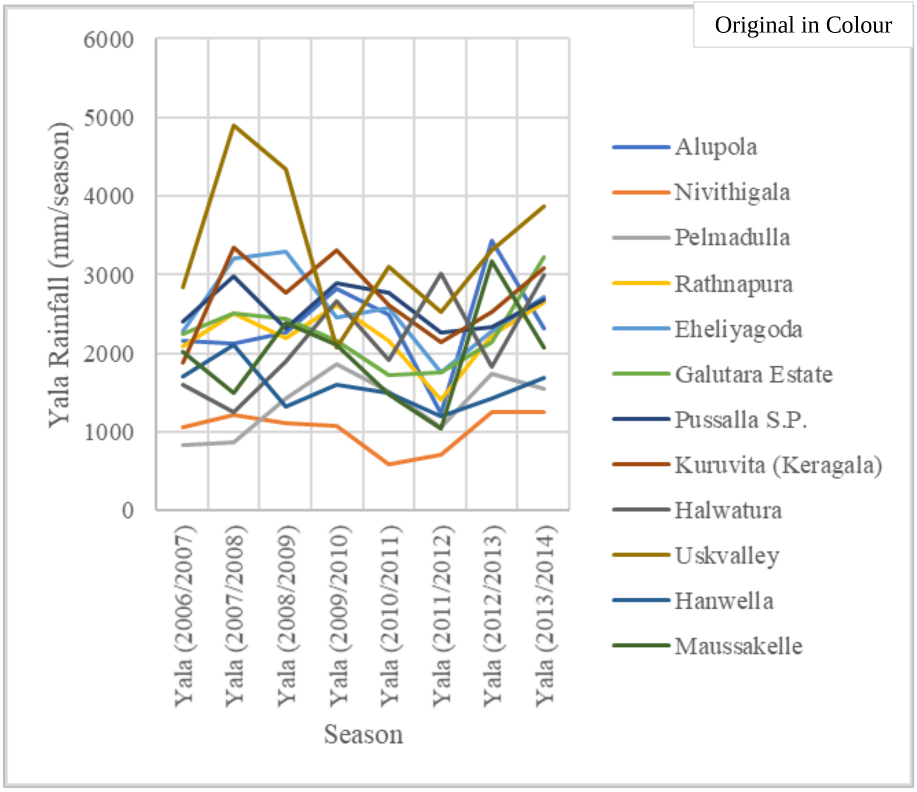

Figure 5-12: Distribution of rainfall – Yala season

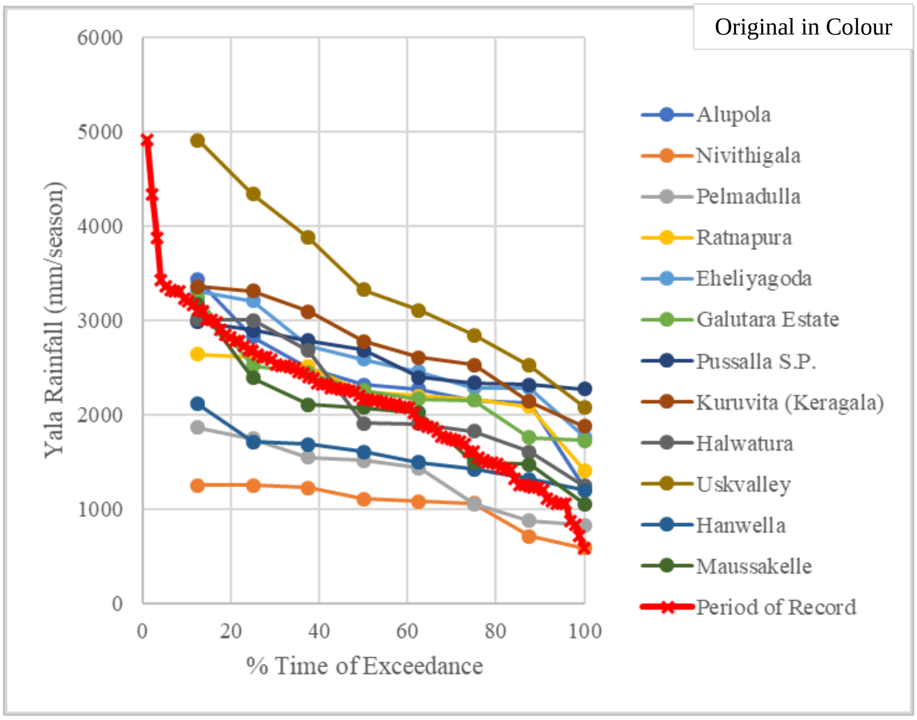

Figure 5-13: Distribution of rainfall frequency of occurrence- Yala Season

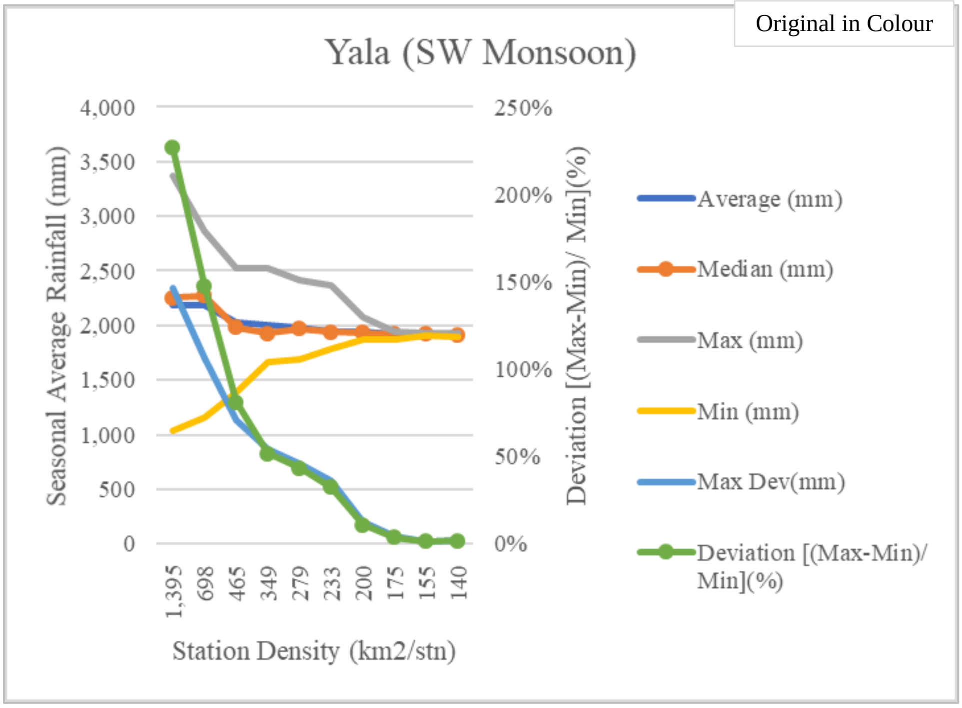

Figure 5-14: Variation of average Yala rainfall over entire period for each station density

5.2.1.4 Each Month

Average observed monthly rainfall in each year over the study period is shown in Figure 5-15. Each station reflected a high spatial and a temporal variability. Variation of rainfall magnitude over the years showed a non-uniform temporal variation when each geographic location was compared. Gauged data for each month behaved similar to the annual and seasonal rainfall. Graphs showing the variation and the % time of exceedance are in ANNEX C - Figure C - 5 to Figure C - 16.

December, January, February and March are the driest months while August and September were also relatively dry. Most stations have experienced two relatively dry years while a few (Eheliyagoda S.P, Alupola) showed that only the 2009 and 2012 has been with lower rainfall. Halwatura, Uskvally and Kuruvita (Keragala) showed the highest variability of rainfall over the years.

Table 5-4: Annual and Seasonal Rainfall with Statistical Indicators for Varying Station Density

Selected Number of Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Station Density (km^2/station)	**1,395**	**698**	**465**	**349**	**279**	**233**	**200**	**175**	**155**	**140**
Number of Combinations	**12**	**40**	**34**	**61**	**50**	**32**	**17**	**13**	**14**	**10**
Inside only Combination Number	**8**	**28**	**22**	**45**	**38**	**20**	**8**	**1**	**-**	**-**
Outside only Combination Number	**4**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Annual Rainfall										
Annual Rainfall - Average (mm)	3,651.33	3,628.72	3,366.33	3,346.01	3,319.83	3,255.53	3,264.76	3,215.04	3,224.34	3,211.48
Annual Rainfall - Median (mm)	3,741.96	3,783.16	3,310.16	3,236.61	3,302.58	3,249.91	3,247.05	3,221.98	3,222.82	3,207.72
Annual Rainfall - Max (mm)	5,771.46	4,774.76	4,083.81	4,138.83	4,134.69	3,981.63	3,462.45	3,249.04	3,244.95	3,240.84
Annual Rainfall - Min (mm)	1,789.14	2,006.22	2,456.59	2,782.65	2,795.98	2,971.77	3,101.91	3,152.31	3,193.37	3,179.76
Annual Rainfall - Max Dev(mm)	3,982.32	2,768.54	1,627.22	1,356.18	1,338.70	1,009.86	360.54	96.73	51.58	61.08
Annual Rainfall - Deviation [(Max-Min)/Min] (%)	223%	138%	66%	49%	48%	34%	12%	3%	2%	2%
Annual Rainfall - Std Dev (mm)	1,054.08	650.50	464.49	407.00	280.74	197.63	84.21	30.25	16.98	20.00
Maha (NE Monsoon)										
Maha (NE Monsoon) - Average (mm)	1,469.22	1,446.31	1,334.06	1,344.34	1,336.24	1,308.87	1,317.46	1,300.37	1,301.51	1,297.36
Maha (NE Monsoon) - Median (mm)	1,528.86	1,426.61	1,348.98	1,304.85	1,324.56	1,306.83	1,312.25	1,302.53	1,302.86	1,294.60
Maha (NE Monsoon) - Max (mm)	2,397.13	2,069.66	1,590.81	1,716.30	1,715.51	1,612.82	1,400.94	1,311.12	1,311.99	1,311.90
Maha (NE Monsoon) - Min (mm)	756.26	853.08	1,062.97	1,103.14	1,110.71	1,168.65	1,234.32	1,285.89	1,285.08	1,285.95
Maha (NE Monsoon) - Max Dev(mm)	1,640.86	1,216.59	527.84	613.16	604.80	444.17	166.61	25.23	26.91	25.95
Maha (NE Monsoon) - Deviation [(Max-Min)/Min] (%)	217%	143%	50%	56%	54%	38%	13%	2%	2%	2%
Maha (NE Monsoon) - Std Dev (mm)	440.83	265.07	164.93	169.53	119.77	87.87	37.39	9.89	9.25	9.44
Yala (SW Monsoon)										
Yala (SW Monsoon) - Average (mm)	2,182.12	2,182.41	2,032.27	2,001.67	1,983.59	1,946.65	1,947.30	1,914.66	1,922.82	1,914.12
Yala (SW Monsoon) - Median (mm)	2,255.41	2,276.00	1,986.07	1,925.77	1,972.58	1,940.49	1,937.44	1,920.12	1,921.57	1,913.65
Yala (SW Monsoon) - Max (mm)	3,374.34	2,857.54	2,527.77	2,523.72	2,419.18	2,368.81	2,071.53	1,938.86	1,934.86	1,928.94
Yala (SW Monsoon) - Min (mm)	1,032.88	1,153.14	1,393.61	1,661.25	1,685.28	1,785.80	1,867.59	1,865.49	1,907.92	1,891.08
Yala (SW Monsoon) - Max Dev(mm)	2,341.46	1,704.39	1,134.15	862.47	733.90	583.01	203.95	73.37	26.93	37.86
Yala (SW Monsoon) - Deviation [(Max-Min)/Min] (%)	227%	148%	81%	52%	44%	33%	11%	4%	1%	2%
Yala (SW Monsoon) - Std Dev (mm)	638.30	407.43	307.25	242.69	164.53	111.57	48.36	22.22	8.64	11.54

However, the percentage deviation from any combination of rain gauges become less than 10% only with a station configuration denser than 175 km^2/station (Figure C - 17).

Similar to the reasoning in the case of annual rainfall, monthly rainfall for the catchment was computed by taking the value for 12 stations. Accordingly, the areal average rainfall of the Ellagawa watershed for each month are shown in Table C - 2. The average monthly rainfall from a 10-station combination with 1% - 7% deviations are shown in the same table.

Graph of maximum deviation against station density (Figure C - 17) indicated that at a density greater than 175 km^2/station, the maximum deviation for any month falls between 7% and 1%.

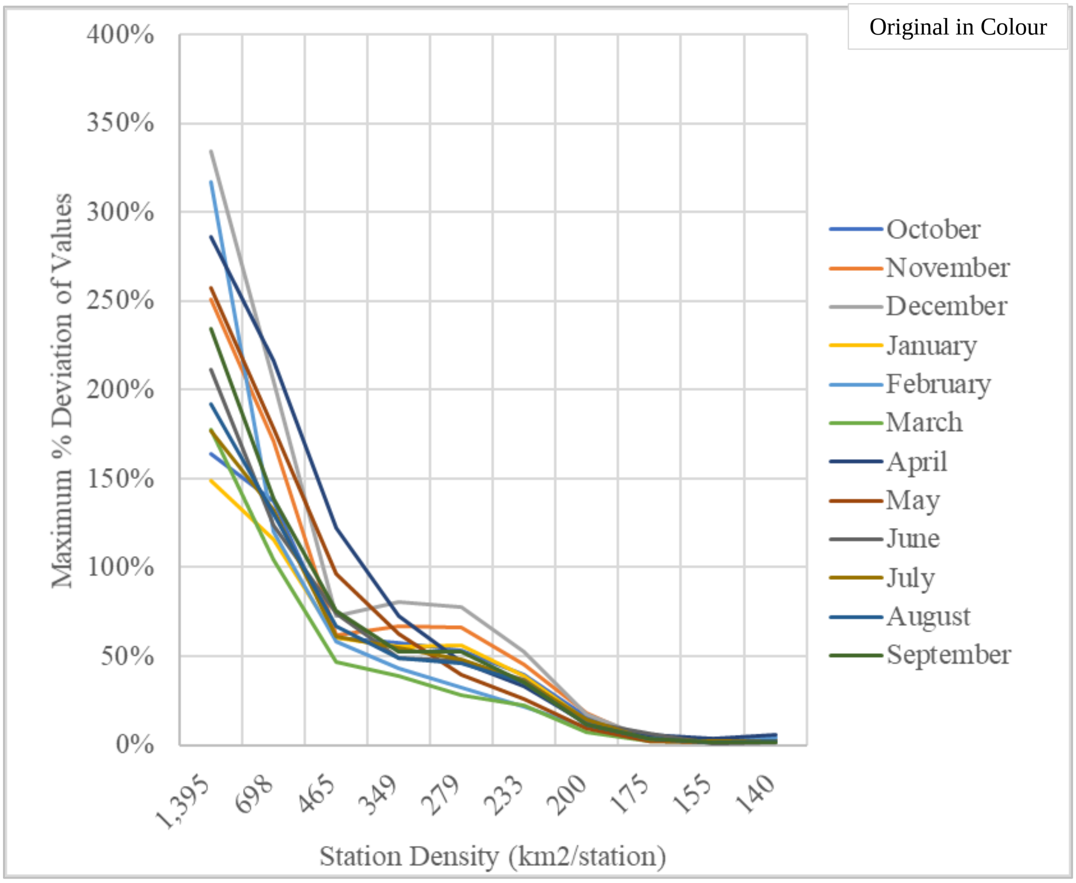

Figure 5-15: Maximum Deviation of Average Rainfall in Each Month (2006/7 -2013/14)

5.2.2 Rainfall-Runoff Option 1 (RR Option 1)

The influence of station number for rainfall spatial averaging was then further tested, with an application of hydrological model.

As detailed previously in section 3.1.3, RR option was divided into two sections to seek better understanding from the point of view of a practicing water manager. Initially it was assumed that a water manager had received an already calibrated and verified monthly water balance model (a typical model) for the concerned watershed, and the present requirement is to apply the model with the same parameters but with a change in rainfall input stations. In this sudy the two parameter model proposed by Xiong and Guo (1999) was adapted for evaluation of the rainfall varying the station density. The model is already calibrated and verified for best performance but with alternate data (Dissanayake, 2017; Sharifi, 2015). As explained in Dissanayake (2017) the model performs satisfactory level of 0.7668 MRAE in data disparity conditions, while performing far better in no data disparity conditions. With the aim of finding data responses of model to verify the different density rainfall in different spatial variation the same model was used. c and Sc parameters of the typical model were 2.07 and 1496 respectively. The RR option-1 evaluated the response of typical model and its calibrated and verified parameters to the areal rainfall from each station combination.

5.2.2.1 Establishing the Typical Model

The typical two parameter monthly water balance model available for the watershed manager had used rainfall data of five stations distributed over the watershed (Figure 5-16).

The five stations and data durations used in the work by Dissanayake (2017), and the data of typical model used as the reference for this work are in Table 5-5. Using the typical rainfall station configuration as a reference, the 8-year data period by Dissanayake (2017) was used to calibrate the typical setting.

Observed and estimated outflow hydrographs, flow duration curves, annual water balance and MRAE values are shown in the Figure 5-17, Figure 5-18, Figure 5-19 and

Table 5-5. The hydrographs, and flow duration curves indicated that the high and low flow matching were weaker than the intermediate flow estimation which was very good.

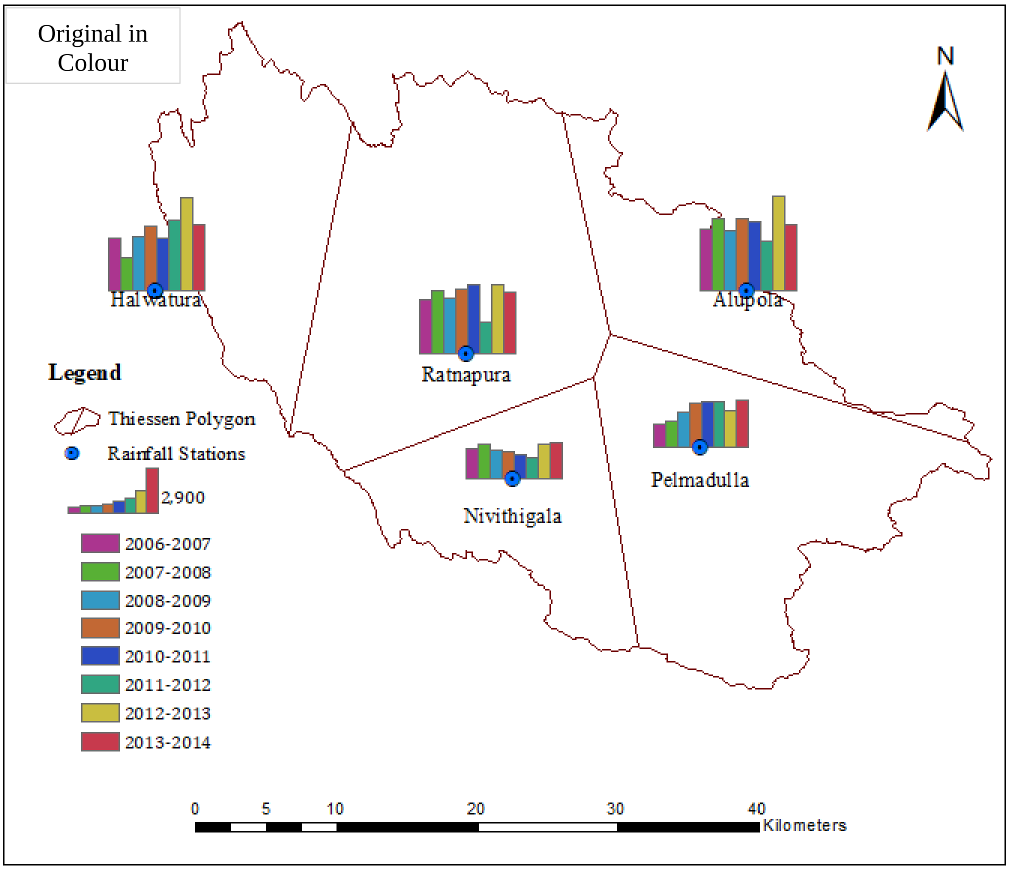

Figure 5-16: Rainfall stations configuration layout of the typical model (Dissanayake, 2017)

Table 5-5: Typical model references for the Typical Rainfall Station Configuration

Parameters, Performance and Data		
Parameter c		2.07
Parameter SC		1,496.10
Initial Soil Moisture		381.00
Model Warmup Period (cycles)		5 cycles
MRAE (Objective Function)	Overall Hydrograph	0.4214
	Flow Duration Curve	0.2018
	High flow (< 20%)	0.1203
	Intermediate flow (20% - 60%)	0.0731
	Low flow (> 60%)	0.3746
Data Duration (Water year)		2006/7 – 2013/14

Original in Colour

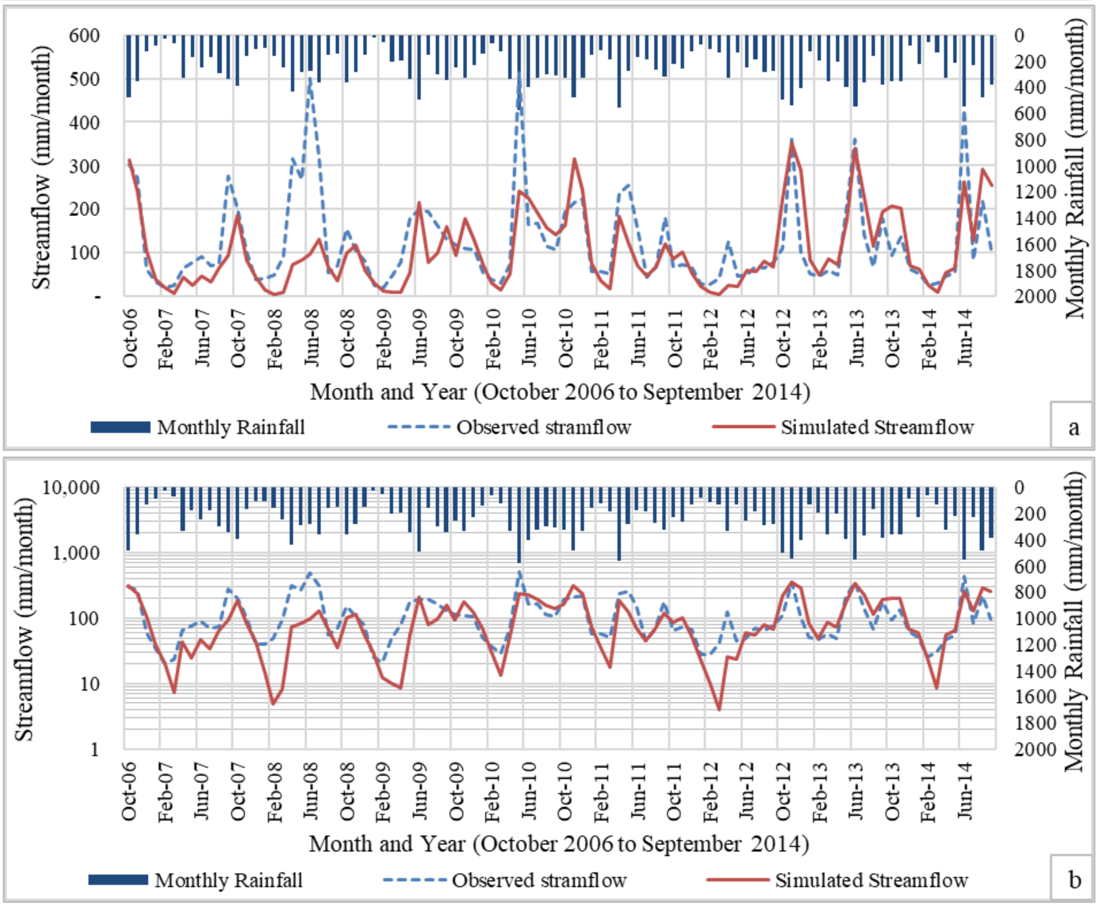

Figure 5-17: Hydrograph of Typical Model (Normal plot - a; semi log plot - b)

Original in Colour

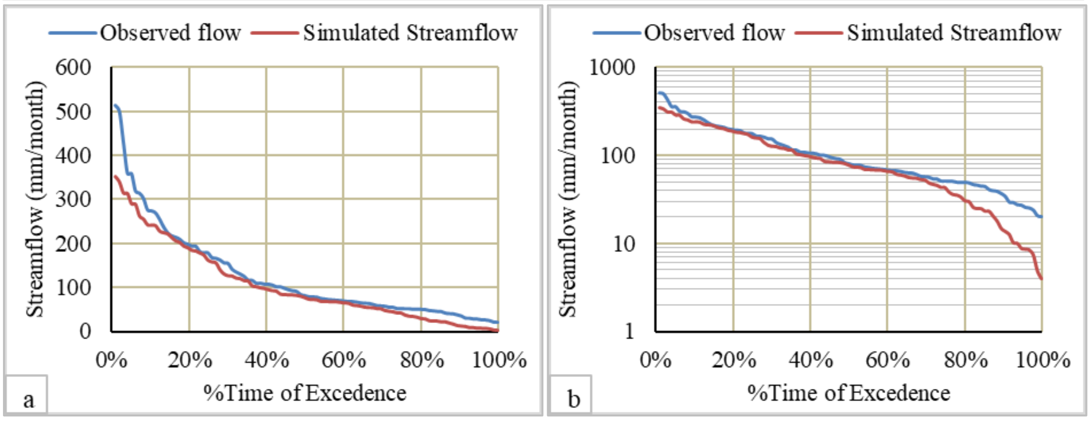

Figure 5-18: Duration Curve of Typical Model (Normal plot-a; Semi log plot-b)

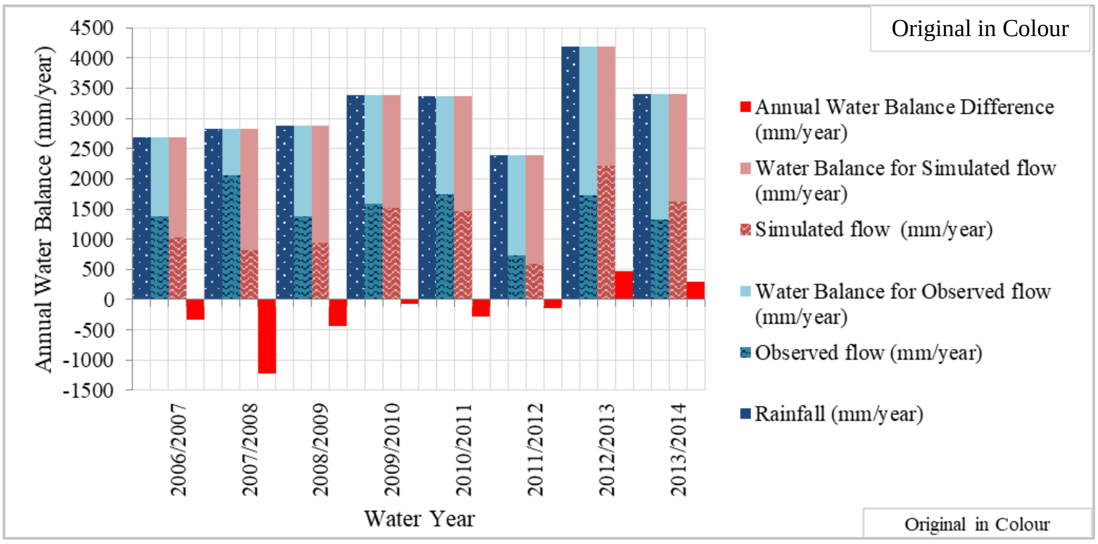

Figure 5-19: Annual Water Balance for the Typical Configuration

5.2.2.2 Comparison

Watershed average rainfall computed from the set of gauging station combinations ranging from 1395 km^2/station to 140 km^2/station were used as the input for the typical watershed model.

Streamflow hydrographs and flow duration curve matching for each station combination are shown in ANNEX D - Figure D - 1 to Figure D - 8. The figures indicate the hydrograph matching for all combinations corresponding to each selected number of stations. In these figures the observed hydrographs, the best performing hydrograph for the particular station combinations, and the best of all station combinations are highlighted.

Flow duration curves also highlight the observed and best performing cases. Minimum MRAE values of hydrographs and Flow duration matching for each station combination are in Table 5-6. Variation of MRAE values for each input are shown in the Figure 5-20, Figure 5-21, Figure 5-27, Figure 5-28, Figure 5-29 and Table D - 1.

Overall streamflow hydrograph, Flow duration curves, water balance, high, intermediate and lowflow, for all gauging station density options, reflected the same behavior shown by Thiessen averaged rainfall in RO option. Gauging station density higher than the threshold density of 175 km^2/station (8 stations) indicated that the

MRAE values reaching consistent values (Figure 5-20). MRAE plots of high, intermediate and low flows indicate the magnitudes of MRAE at consistent performances.

Table 5-6: Best performing station configurations for hydrographs and flow duration curves and corresponding MRAE - RR1 Option

Station Density (km^2/station)	**Comparison Hydrograph**		**Comparison Flow Duration Curve**	
	MRAE	**Station Configuration**	**MRAE**	**Station Configuration**
1395	0.4948	1St-C11	0.2930	1St-C4
698	0.3876	2St-C21	0.1685	2St-C21
465	0.3795	3St-C18	0.1470	3St-C1
349	0.3562	4St-C14	0.1486	4St-C2
279	0.3498	5St-C11	0.1506	5St-C36
233	0.3593	6St-C30	0.1517	6St-C21
200	0.3707	7St-C8	0.1516	7St-C10
175	0.3693	8St-C11	0.1570	8St-C7
155	0.3766	9St-C3	0.1565	9St-C15
140	0.3765	10St-C3	0.1576	10St-C5

Table 5-7: Best performing station configurations for different flow types and corresponding MRAE - RR1 Option

Station Density (km^2/station)	**Comparison High Flows**		**Comparison Intermediate Flows**		**Comparison Low flows**	
	Station Configuration	**MRAE**	**Station Configuration**	**MRAE**	**Station Configuration**	**MRAE**
1395	1St-C4	0.4036	1St-C11	0.5156	1St-C11	0.4831
698	2St-C1	0.0745	2St-C11	0.0519	2St-C12	0.2429
465	3St-C15	0.0665	3St-C18	0.0495	3St-C1	0.2239
349	4St-C18	0.0699	4St-C43	0.0402	4St-C34	0.2000
279	5St-C35	0.0690	5St-C43	0.0375	5St-C6	0.2038
233	6St-C20	0.0737	6St-C21	0.0291	6St-C10	0.1977
200	7St-C16	0.0854	7St-C10	0.0274	7St-C6	0.2021
175	8St-C2	0.1141	8St-C7	0.0434	8St-C10	0.2889
155	9St-C4	0.1145	9St-C14	0.0405	9St-C15	0.2876
140	10St-C2	0.1206	10St-C10	0.0379	10St-C2	0.2893

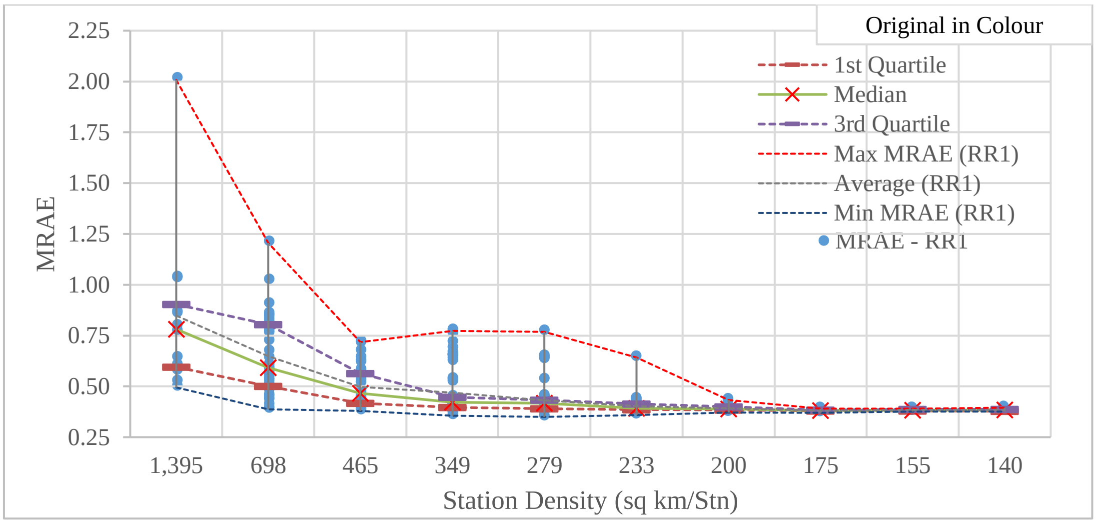

Figure 5-20: Overall Hydrograph matching performances in different densities

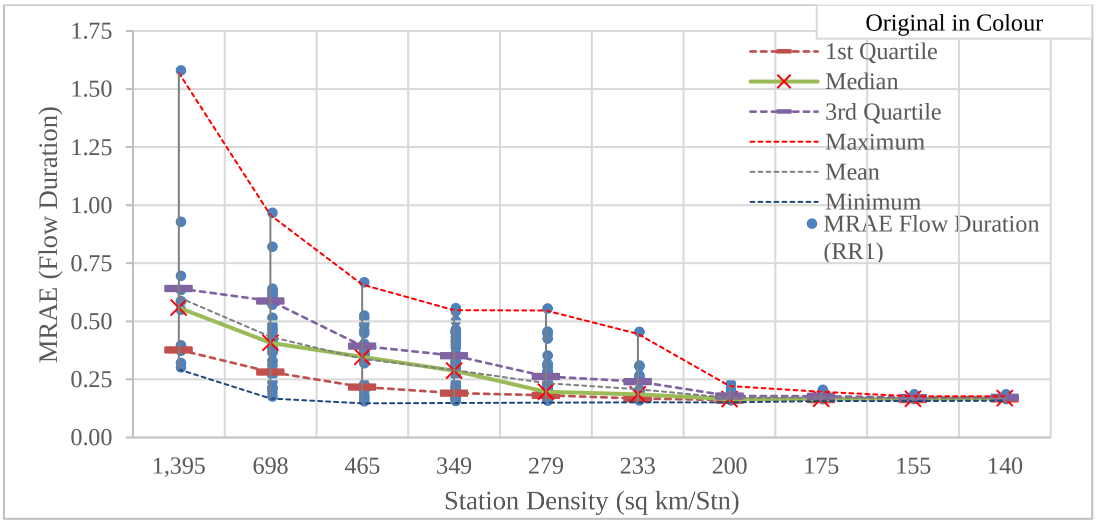

Figure 5-21: Flow Duration Curve matching performances in different densities

Intermediate flows showed the best fitting which is followed by the high flows. Lowflow matching which was relatively poor has caused the overall MRAE value to reflect an average performance level. The observed annual streamflow values showed that even at the consistent rainfall density values, the streamflow estimation error was approximately 200 mm/annum, which is approximately an error of 8%.

At the consistent rainfall density overestimation in Maha season was 40 mm/season, while underestimation Yala season was approximately 180mm/season.

Variability of MRAE values for densities less than 175km^2/station were significant with each gauging station combination. This shows that even with the same station configuration, an already calibrated model with less than consistent station densities may perform differently and most likely with poorer results.

Table 5-8: Best performing station configurations for relative absolute water balance and corresponding %RAE - RR1 Option

Station Density (km^2/station)	Comparison Annual Absolute Water Balance		Comparison Maha Absolute Water Balance		Comparison Yala Absolute Water Balance	
	Station Configuration	**%RAE**	**Station Configuration**	**%RAE**	**Station Configuration**	**%RAE**
1395	1St-C4	12.6%	1St-C11	5.1%	1St-C9	3.9%
698	2St-C1	3.4%	2St-C20	1.3%	2St-C36	7.0%
465	3St-C1	1.7%	3St-C17	0.5%	3St-C4	1.9%
349	4St-C32	0.3%	4St-C3	0.8%	4St-C9	1.3%
279	5St-C23	0.5%	5St-C46	0.7%	5St-C20	0.4%
233	6St-C10	1.5%	6St-C31	1.7%	6St-C15	2.3%
200	7St-C6	2.4%	7St-C8	2.8%	7St-C7	2.7%
175	8St-C2	7.4%	8St-C13	3.0%	8St-C2	16.1%
155	9St-C4	7.5%	9St-C11	3.5%	9St-C2	16.6%
140	10St-C2	7.8%	10St-C7	3.6%	10St-C2	17.4%

It can be noted that, the same model and the calibrated parameters would provide closer matching model estimations when the rainfall gauging density is greater than the threshold value of 175 km^2/station. This result shows that if the areal average rainfall is computed by using a denser network than the 175 km^2/station, then there is a greater likelihood for a pre calibrated model to display a consistent and relatively acceptable performance (Table 5-9).

Minimum error values (either MRAE or %RAE) for each gauging station density with respect to a particular flow category, indicate the best streamflow matching that could be achieved by a particular station density (Figure 5-34, Table D - 1). In case of overall hydrograph matching, the minimum MRAE value of 0.3498 was with a combination of 5 stations and at a density of 279 km^2/station. Minimum MRAE for overall flow duration curve is 0.1470 and the station density is 465 km^2/station.

In the case of low flows, all station combinations 4,5,6 and 7 with respective densities 349, 279, 233 and 199 km^2/station showed an approximate minimum MRAE value of 0.20. Best high flow matching was with a three-station combination (465 km^2/station) in which the MRAE values reached a minimum value of 0.0665. Comparison of the three flow components showed that intermediate flows fitted better than the others. In case of intermediate flow, the lowest MRAE value of 0.0274 was with a combination of 7 gauging stations (199 km^2/station). Even though station configurations denser than 175 km^2/station showed consistent MRAE values for any station combination, the best streamflow component fitting was with specific station configurations having much lesser densities (Figure 5-35, Figure 5-36, Table 5-9 and Table 5-10). Therefore, the effect of rainfall spatial variability appears to smoothen out with very high station densities that leads to consistent outputs.

Table 5-9: Hydrograph matching MRAE Variation in RR1

Station Density (km^2 per station)	**Maximum MRAE**	**Average MRAE**	**Minimum MRAE**	**1st Quartile**	**Median**	**3rd Quartile**	**% Deviation**	**Standard Deviation**
1395	2.0071	0.8480	0.4948	0.5951	0.7812	0.9032	306%	0.41
698	1.2053	0.6480	0.3876	0.5007	0.5916	0.8039	211%	0.19
465	0.7172	0.4979	0.3795	0.4168	0.4662	0.5629	89%	0.10
349	0.7728	0.4684	0.3562	0.3969	0.4212	0.4473	117%	0.11
279	0.7683	0.4316	0.3498	0.3905	0.4163	0.4323	120%	0.08
233	0.6420	0.4036	0.3593	0.3863	0.3915	0.4138	79%	0.05
200	0.4331	0.3920	0.3707	0.3832	0.3887	0.3996	17%	0.02
175	0.3905	0.3809	0.3693	0.3789	0.3812	0.3836	6%	0.01
155	0.3905	0.3832	0.3766	0.3793	0.3827	0.3867	4%	0.00
140	0.3947	0.3839	0.3765	0.3781	0.3843	0.3869	5%	0.01

Though the behavior of the overall MRAE of the hydrographs show that there is a minimum value at a station density of 279 km^2/station, the FDC matching shows that the minimum is at 465 km^2/station. However the RAE value decreases to the minimum with the increase of station density up to 465 km^2/station and then slight increment showing a consistent RAE variation (Table 5-14). The % RAE minimum value decreases (number increasing but performance decrease) with the increase of station density only after a threshold density of 349 km^2/station for annual 465 km^2/station for Maha and 279 km^2/station for Yala.

Table 5-10: Flow Duration Curve matching performance (MRAE) Variation in different densities (RR1)

Station Density (km^2 per station)	Maximum	Mean	Minimum	1st Quartile	Median	3rd Quartile	% Deviation	Standard Deviation
1395	1.57	0.60	0.2930	0.38	0.56	0.64	436%	0.35
698	0.96	0.43	0.1685	0.28	0.41	0.59	468%	0.18
465	0.66	0.34	0.1470	0.22	0.35	0.39	348%	0.12
349	0.55	0.29	0.1486	0.19	0.29	0.35	269%	0.11
279	0.55	0.23	0.1506	0.18	0.20	0.26	263%	0.09
233	0.45	0.21	0.1517	0.17	0.19	0.24	194%	0.06
200	0.22	0.17	0.1516	0.16	0.17	0.18	46%	0.02
175	0.20	0.17	0.1570	0.16	0.17	0.18	25%	0.01
155	0.18	0.17	0.1565	0.16	0.17	0.17	14%	0.01
140	0.18	0.17	0.1576	0.17	0.17	0.17	12%	0.01

Table 5-11: High flows matching performance (MRAE) Variation in different densities (RR1)

Station Density (km^2 per station)	1st Quartile	Median	3rd Quartile	Maximum	Mean	Minimum	% Deviation	Standard Deviation
1395	0.48	0.53	0.67	1.31	0.63	0.4036	224%	0.25
698	0.20	0.31	0.44	0.79	0.33	0.0745	954%	0.17
465	0.17	0.25	0.30	0.52	0.25	0.0665	678%	0.11
349	0.11	0.21	0.29	0.39	0.21	0.0699	455%	0.10
279	0.10	0.12	0.18	0.38	0.16	0.0690	451%	0.08
233	0.10	0.12	0.18	0.32	0.14	0.0737	339%	0.06
200	0.10	0.11	0.12	0.18	0.12	0.0854	110%	0.02
175	0.13	0.13	0.14	0.17	0.14	0.1141	53%	0.02
155	0.12	0.13	0.13	0.14	0.13	0.1145	26%	0.01
140	0.13	0.13	0.14	0.16	0.14	0.1206	31%	0.01

Table 5-12: Intermediate flows matching performance (MRAE) Variation in different densities (RR1)

Station Density (km^2 per station)	1st Quartile	Median	3rd Quartile	Maximum	Mean	Minimum	% Deviation	Standard Deviation
1395	0.58	0.89	1.04	1.98	0.91	0.5156	284%	1395
698	0.31	0.52	0.77	1.24	0.51	0.0519	2284%	698
465	0.14	0.35	0.47	0.77	0.33	0.0495	1456%	465
349	0.10	0.18	0.30	0.77	0.26	0.0402	1816%	349
279	0.09	0.16	0.20	0.77	0.19	0.0375	1951%	279
233	0.07	0.10	0.17	0.65	0.13	0.0291	2116%	233
200	0.05	0.07	0.09	0.21	0.08	0.0274	669%	200
175	0.05	0.07	0.07	0.07	0.06	0.0434	70%	175
155	0.05	0.06	0.06	0.07	0.06	0.0405	66%	155
140	0.04	0.04	0.05	0.07	0.05	0.0379	76%	140

Table 5-13: Low flows matching performance (MRAE) Variation in different densities (RR1)

Station Density (km^2 per station)	1st Quartile	Median	3rd Quartile	Maximum	Mean	Minimum	% Deviation	Standard Deviation
1395	0.63	0.76	0.93	2.38	0.89	0.4831	393%	1395
698	0.30	0.35	0.43	0.82	0.40	0.2429	237%	698
465	0.28	0.33	0.50	0.81	0.39	0.2239	262%	465
349	0.28	0.35	0.46	0.57	0.37	0.2000	187%	349
279	0.24	0.29	0.40	0.57	0.32	0.2038	178%	279
233	0.26	0.31	0.40	0.47	0.32	0.1977	136%	233
200	0.27	0.29	0.30	0.39	0.29	0.2021	92%	200
175	0.29	0.29	0.32	0.33	0.30	0.2889	16%	175
155	0.29	0.29	0.31	0.32	0.30	0.2876	11%	155
140	0.31	0.31	0.32	0.32	0.31	0.2893	10%	140

Table 5-14: %RAE for water balance - Variation in RR1

Station Density (km^2 per station)	1st Quartile	Median	3rd Quartile	Maximum	Mean	Minimum	% Deviation	Standard Deviation
1395	20.7%	31.4%	38.9%	437.0%	67.8%	12.6%	3372%	1.18
698	17.2%	24.2%	32.9%	231.1%	32.9%	3.4%	6705%	0.37
465	13.3%	18.4%	27.5%	89.7%	23.0%	1.7%	5034%	0.18
349	7.4%	20.6%	25.6%	43.2%	17.7%	0.3%	12528%	0.11
279	3.3%	8.1%	17.4%	41.8%	11.5%	0.5%	8600%	0.10
233	4.0%	7.5%	17.9%	25.5%	10.5%	1.5%	1568%	0.08
200	5.4%	7.4%	8.2%	16.3%	7.3%	2.4%	570%	0.03
175	8.4%	9.0%	10.1%	13.4%	9.4%	7.4%	83%	0.02
155	7.9%	8.8%	9.2%	10.7%	8.8%	7.5%	42%	0.01
140	9.2%	9.8%	10.4%	11.5%	9.7%	7.8%	47%	0.01

5.2.2.3 Water Balance

Water Balance Errors for station configurations denser than 175 km^2/station were compared with the best overall streamflow hydrographs, Overall flow duration curve, and absolute water balance error values are shown in Figure 5-35, Figure 5-36 and Figure 5-37.

Though the least MRAE showed as 0.3498 with the density of 279 km^2/station, the water balance is poor. The minimum water balance error of 6.5 mm with the density of 349 km^2/station reached a MRAE of 0.4328, which is above the 10% of consistent MRAE average. All the results of water balance are shown in Table D - 1.

Comparison of streamflow hydrographs and rainfall hyetographs indicated there are mismatches of Thiessen rainfall with the observed streamflow and that can be the cause of variation in water balance error in different station selection.

In the minimum MRAE of flow duration (typical) and high flow are 0.1470 and 0.0665 with the station density of 465 km^2/station provided 32.44 mm and 42.96 mm water balance error which are considerably good water balance error values compared to the hydrograph matching MRAE. For intermediate flow, minimum MRAE is 0.0274 at the density of 199 km^2/station while the low flow minimum MRAE (0.1977) is at the station density of 233 km^2/station. However, the water balance error of intermediate flow is 142.25 mm and low flow is 29.48 mm which are better than the consistent water balance error.

5.2.2.4 Station Layouts

The layout for the minimum Overall MRAE indicate that the corresponding five stations are as in Figure 5-22. The best fitting High, Intermediate and Low flow gauging station combinations are shown in Figure 5-24, Figure 5-25 and Figure 5-26. Figure 5-23 shows the best flow duration curve matching combination. The best performance values of the five station combinations are in Table 5-15. Station weight comparisons for these four cases are in Table 5-16.

Table 5-15: Best performances in streamflow estimations with typical station number

Category	**MRAE/%RAE**
Best matching Hydrograph - MRAE Overall **(5c11)**	0.3498
Best matching Flow Duration Curve - MRAE Flow Duration **(5c36)**	0.1506
Best matching High flows - MRAE Flow Duration **(5c35)**	0.0690
Best matching Intermediate flows - MRAE Flow Duration **(5c43)**	0.0375
Best matching Low flows - MRAE Flow Duration **(5c6)**	0.2038
Best performance in Water Balance - %RAE **(5c23)**	0.5%

Comparison of five station Minimum MRAE values of overall hydrograph matching, flow duration, high flow, intermediate flow and low flow with that of typical model showed that, there are one or more stations which contributed by more than the average Thiessen weight (0.2) to result the minimum of any MRAE. Pelmadulla, and Ratnapura are the most contributing (57-70%) stations for the weights except for low flow condition. However, for low flow conditions Alupola and Nivithigala provided 51% of the weights, while Ratnapura supporting with a low Thiessen weight. The minimum Water balance error indicated above average Thiessen weights for Alupola, Nivithigala and Ratnapura providing more than 70% of the weights.

Table 5-16: Station weight comparisons for best performing five stations configurations

Station	**Minimum MRAE Overall** (5c11)	**Minimum MRAE Flow Duration** (5c36)	**Minimum MRAE High flow** (5c35)	**Minimum MRAE Intermediate flow** (5c43)	**Minimum MRAE Low flow** (5c6)	**Minimum Relative Water Balance Error** (5c23)
Alupola				0.11	0.24	0.25
Nivithigala	0.14			0.15	0.27	0.27
Pelmadulla	0.34	0.39	0.39	0.27		
Ratnapura	0.24	0.26	0.26	0.44	0.15	0.21
Eheliyagoda S.P.	0.10		0.08			0.13
Galutara Estate		0.14	0.12		0.15	0.14
Pussalla S.P.	0.19	0.09				
Kuruvita (Keragala)		0.11	0.15		0.19	
Halwatura						
Uskvalley				0.04		
Hanwella						
Maussakelle						

According to the above comparison, the Ratnapura station contributed as a common station to obtain the minimum MRAE while showing influences of Pelmadulla, Nivithigala and Alupola having above average Thiessen weights.

Results indicated that there were other influential stations contributing to different flow categories. This hints the need of a composite station combination for matching various hydrograph components.

Assuming equal weightage for (the fitting of) each flow characteristic, weights were computed for each station in the 279 km^2/ station (5 Station) configurations. The analysis to determine the most preferred five stations indicated that Rathnapura, Pelmadulla, Nivithigala, Kuruvita (Keragala), Galutara Estate were having respective weights as, 0.343, 0.31, 0.114, 0.13 and 0.103. The heaviest contributions for the streamflow magnitudes are because of the gauged data at Ratnapura and Pelmadulla. The weights of other two stations are approximately 10%.

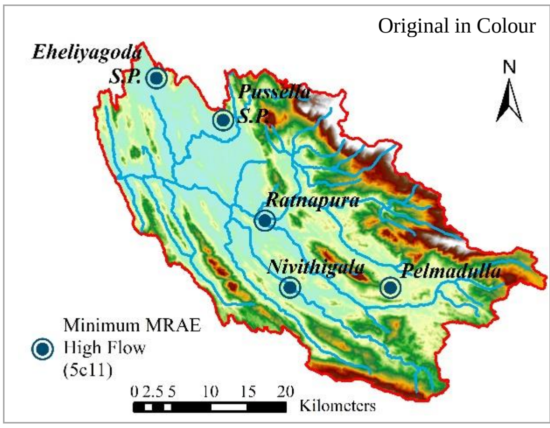

Figure 5-22: Best Hydrograph matching 5 stations (279 km²/station)

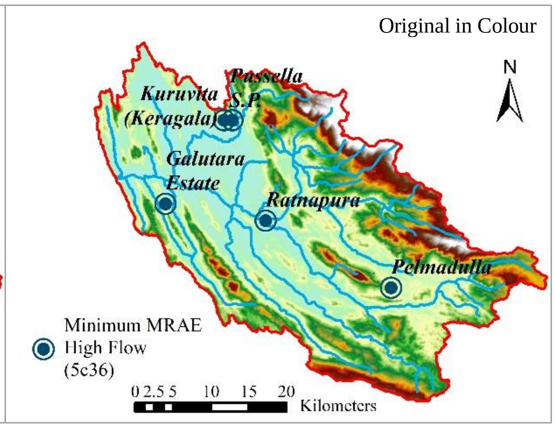

Figure 5-23: Best flow duration curve matching 5 stations (279 km²/station)

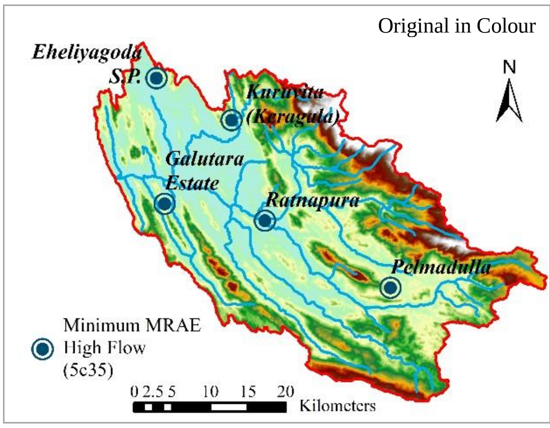

Figure 5-24: Best High flows matching 5 stations (279 km²/station)

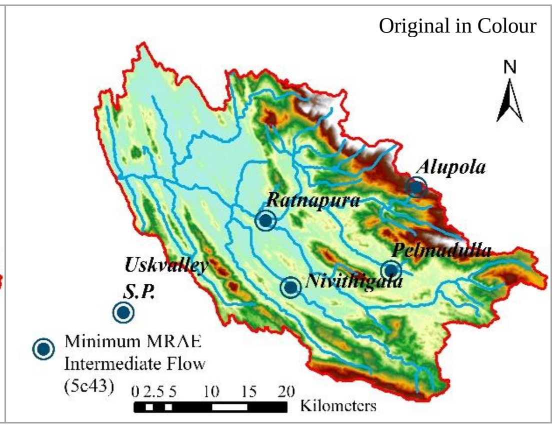

Figure 5-25: Best Intermediate flows matching 5 stations (279 km²/station)

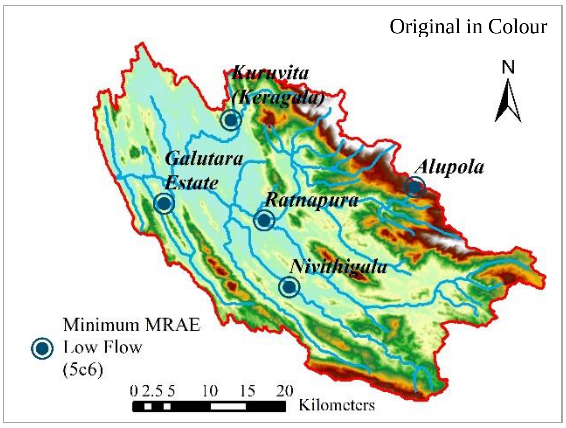

Figure 5-26: Best flow duration curve matching 5 stations (279 km²/station)

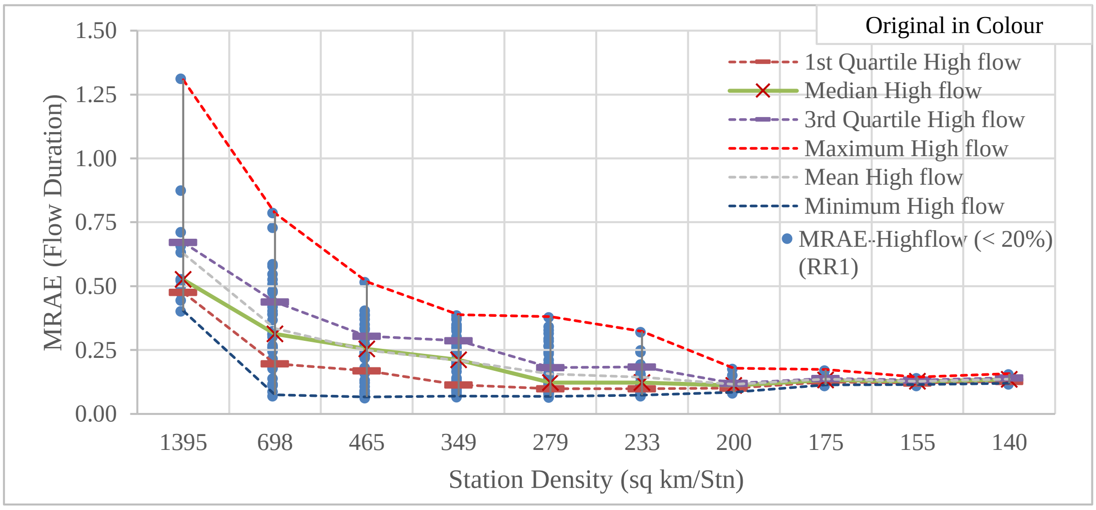

Figure 5-27: High flow matching for performances in different densities

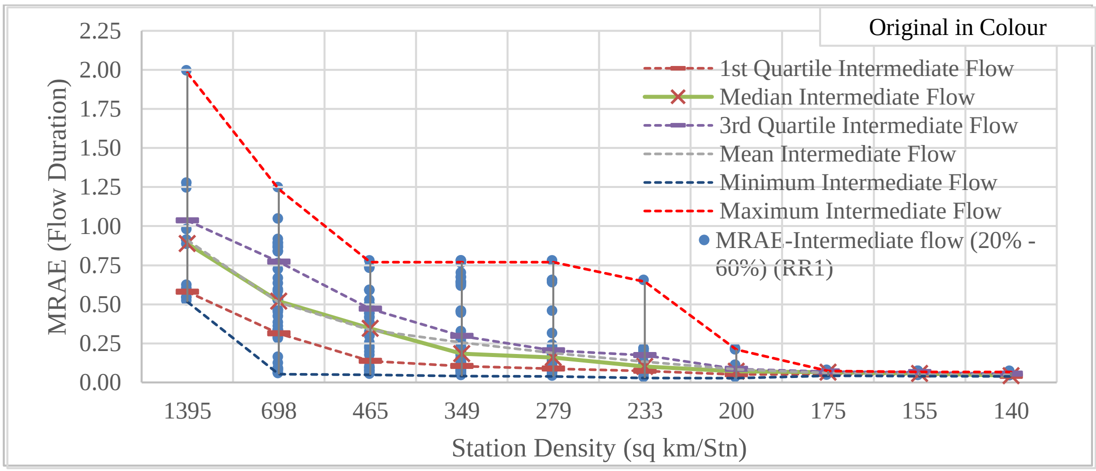

Figure 5-28: Intermediate flow matching performances in different densities

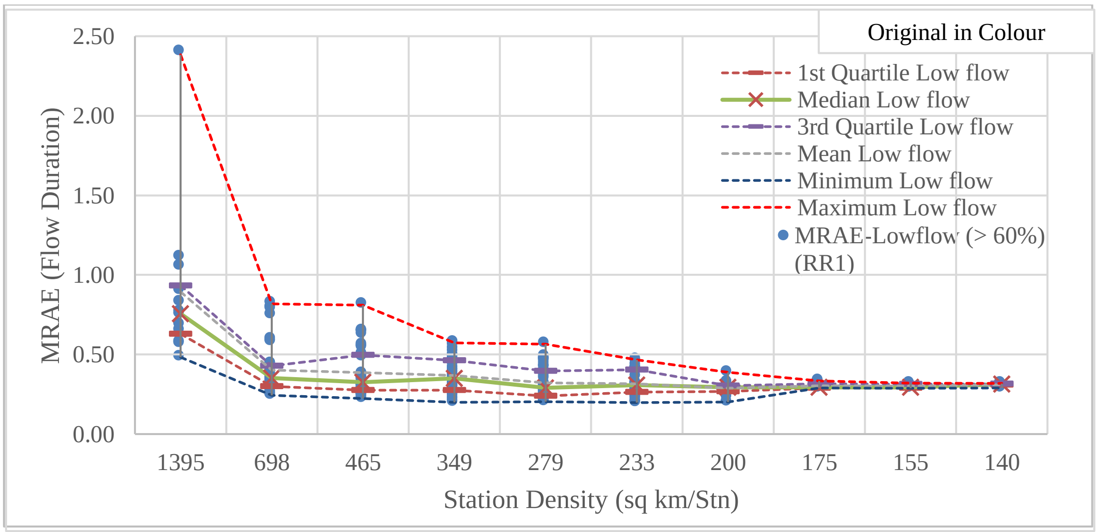

Figure 5-29: Low Flow Matching performances in different Densities

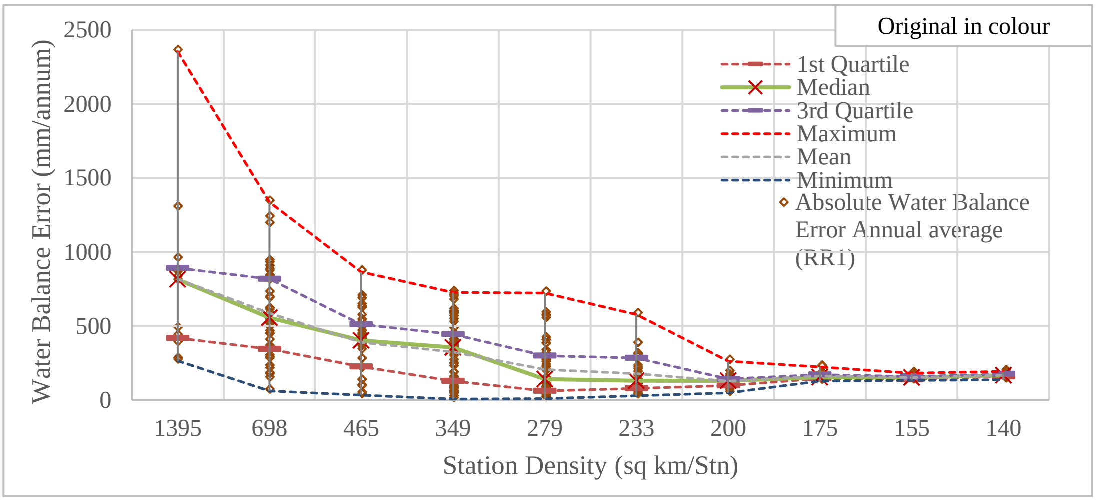

Figure 5-30: Annual Absolute Water Balance error variation in different Densities

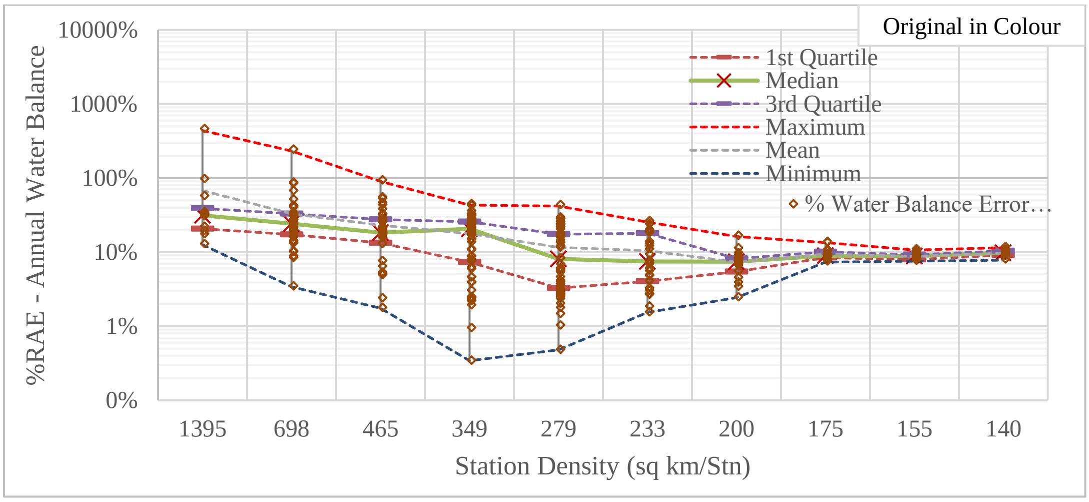

Figure 5-31: Comparison of Estimated % Annul absolute water balance error

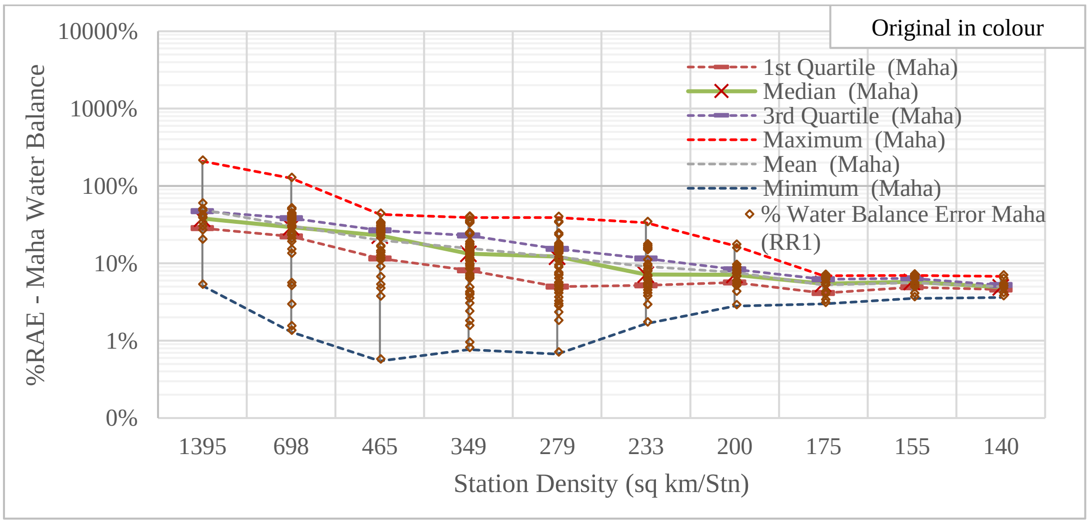

Figure 5-32: Comparison of Estimated % Maha absolute water balance error

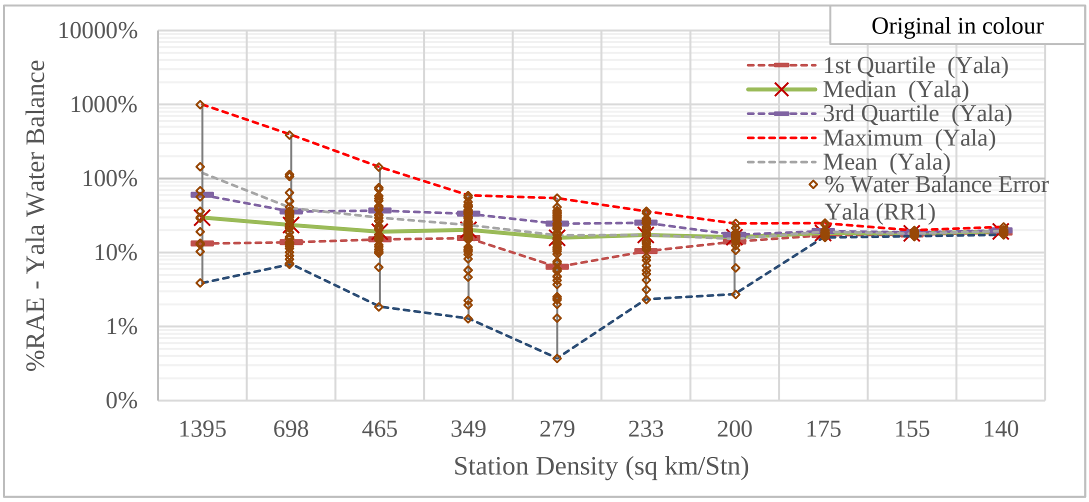

Figure 5-33: Comparison of Estimated % Yala absolute water balance error

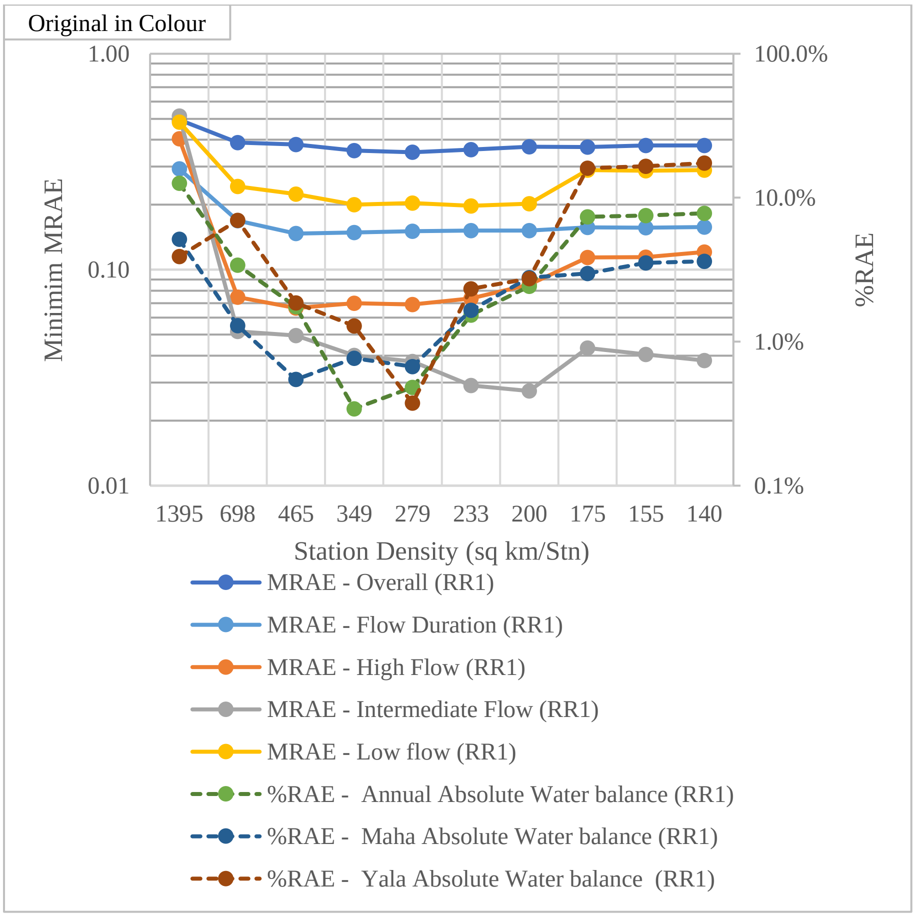

Figure 5-34: Best performance values (MRAE/%RAE) for Each Gauging Station Density

Comparison of hydrographs for consistent setting, corresponding FDC curve matching and Water balance error are in Figure 5-35, Figure 5-36 and Figure 5-37. The consistent matching curves do not fit very well to the observed but all together all curves follow a similar pattern/variation with showing less deviation. It is clearly noted that there is a good match of peaks not with the magnitude but in timing.

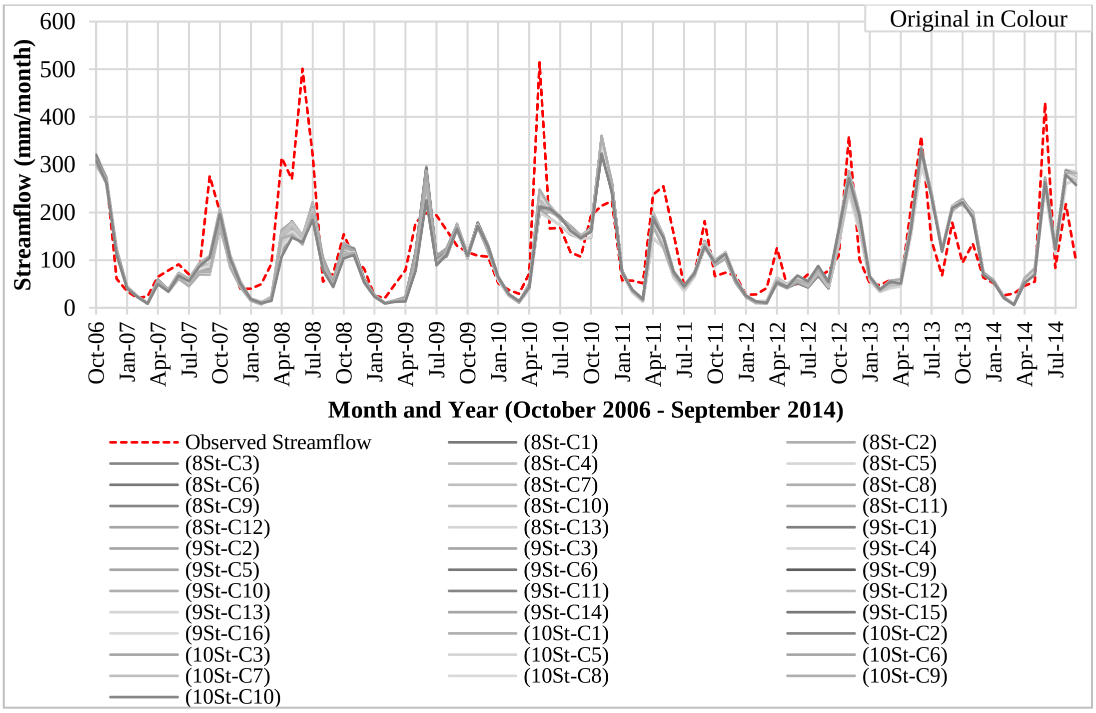

Figure 5-35: Hydrographs (RR1) with consistent configurations

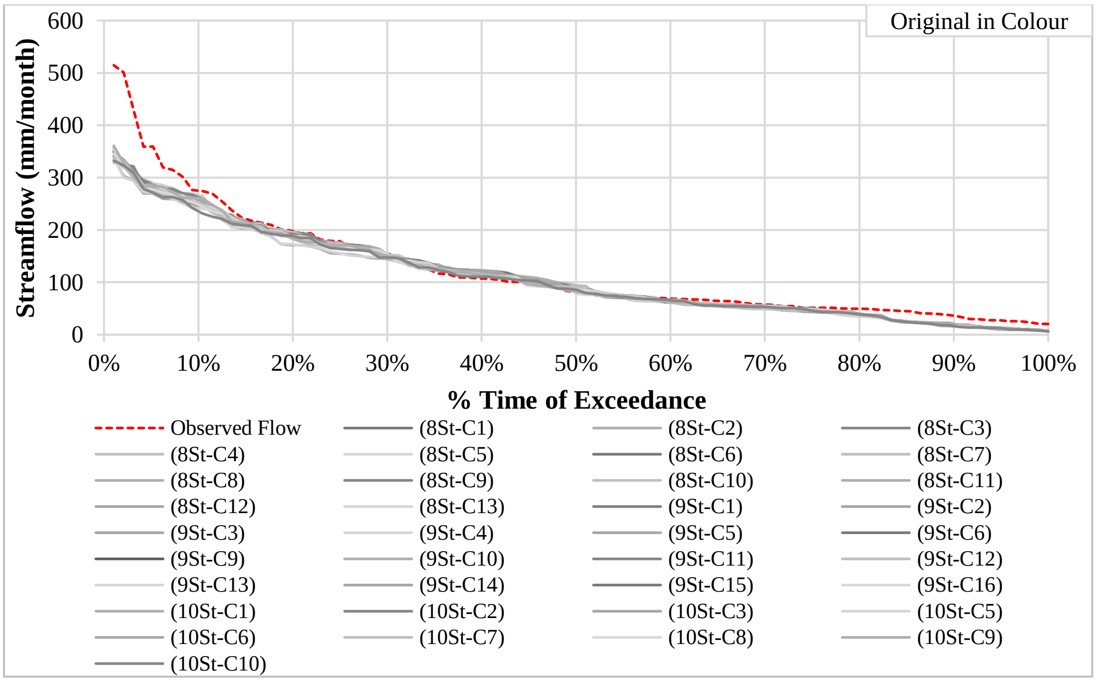

Figure 5-36: FD curves (RR1) for consistent configurations

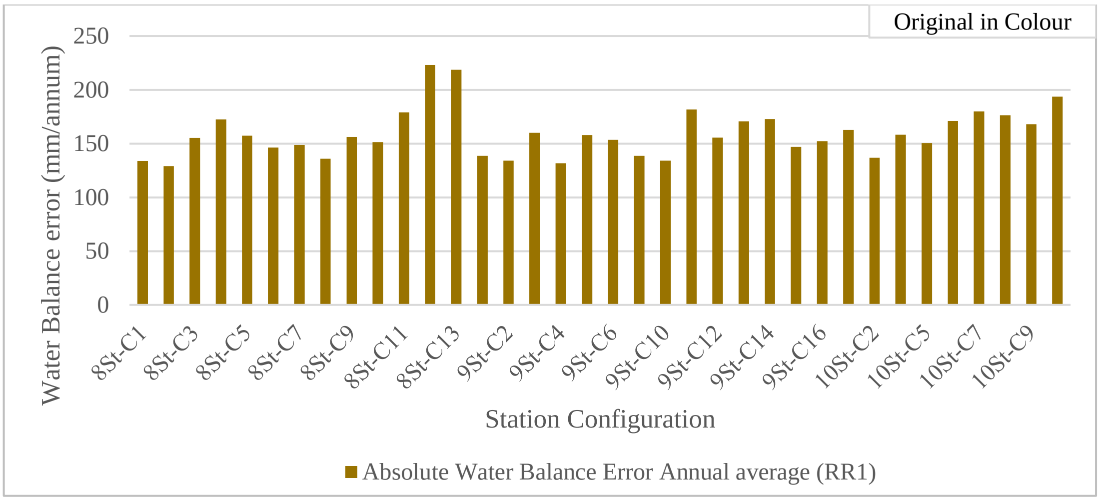

Figure 5-37: Annual Absolute WB error (RR1) with consistent configurations

The consistent flow duration curves show a good match of intermediate flows. However, it doesn't show a close match with high and low flows. The consistent densities are highlight that they are not good enough to capture the high or low flows with the typical model.

Though there are fluctuations in the matching of different configurations, a significant variation in water balance cannot be in consistent densities. Deviation of water balance estimates at the consistent densities between 75 to 225 mm/year

Comparison of best overall matching hydrographs and FDC are shown in Figure 5-38, Figure 5-39 and Table 5-6. The best performing streamflow hydrographs at each density consideration are highlighted in the figures. One-station per catchment (1395km^2/station) hydrograph indicates the worst matching when compared with other best fitting hydrographs at the different station number selected to calculate input rainfall.

Comparisons of best high, intermediate and low flow FDC for each configuration are in Figure 5-39, Figure 5-40, Figure 5-41, Figure 5-42, Table 5-6 and Table 5-7. Similar to the hydrograph matching, all above the mentioned figures and tables indicated that the behavior of one station performance is worse than the other station configurations.

Comparisons of best % RAE in water balance for annual, Maha and Yala seasons are in Figure 5-43 and Table 5-8. The minimum water balance error values for annual, Maha and Yala seasons were obtained in mid-level densities. Error increases with increasing station density but reaches a consistent value after 175 km^2/station.

All best performing station configuration in each performance condition are not equal and thus, water managers can select the station configuration depending on the required performance category.

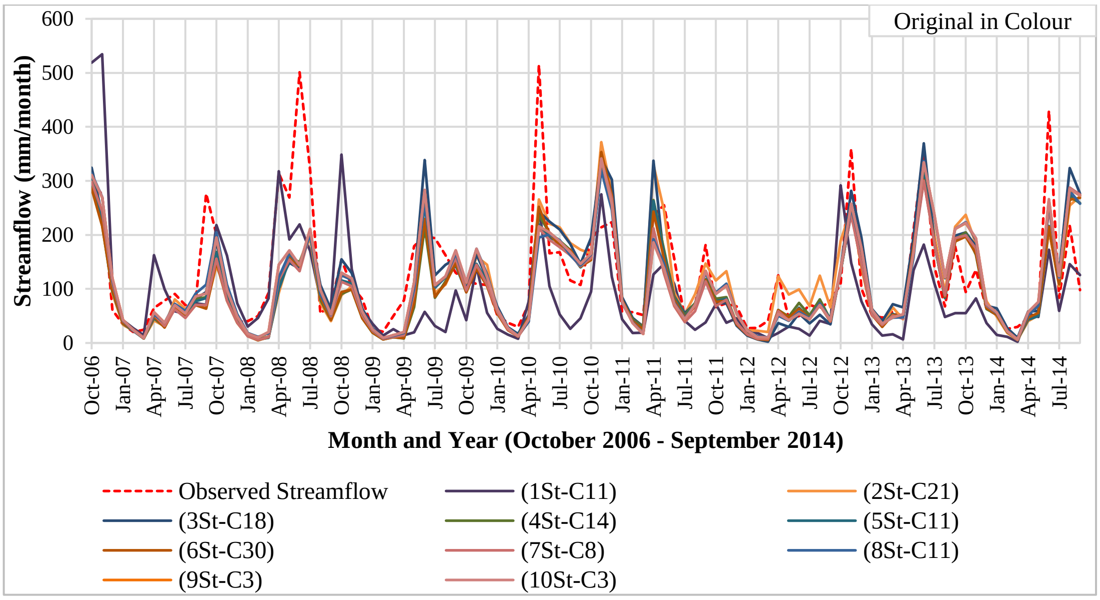

Figure 5-38 : Best overall matching MRAE in different station configurations

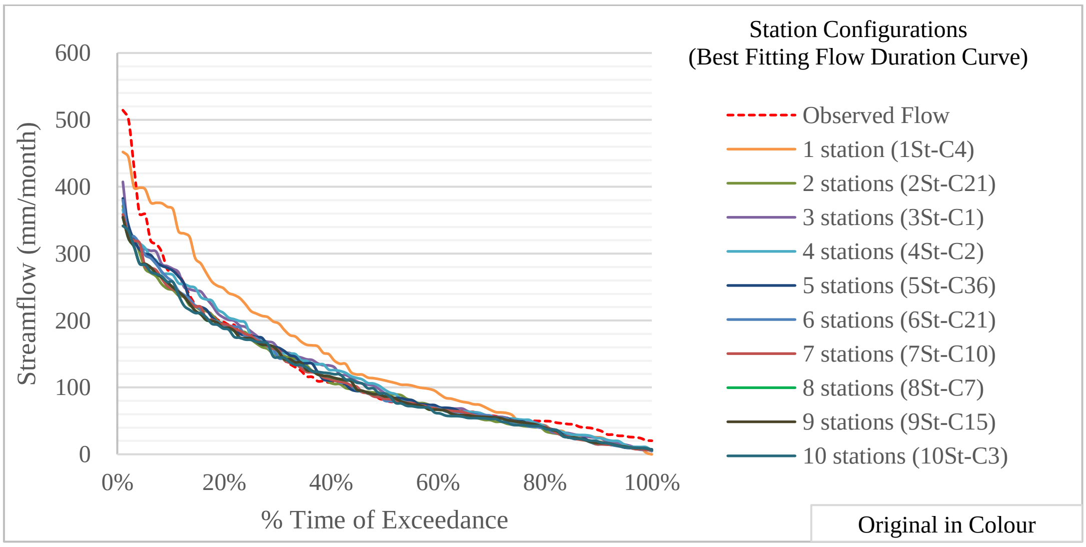

Figure 5-39: Best matching Flow duration curve for different station configurations

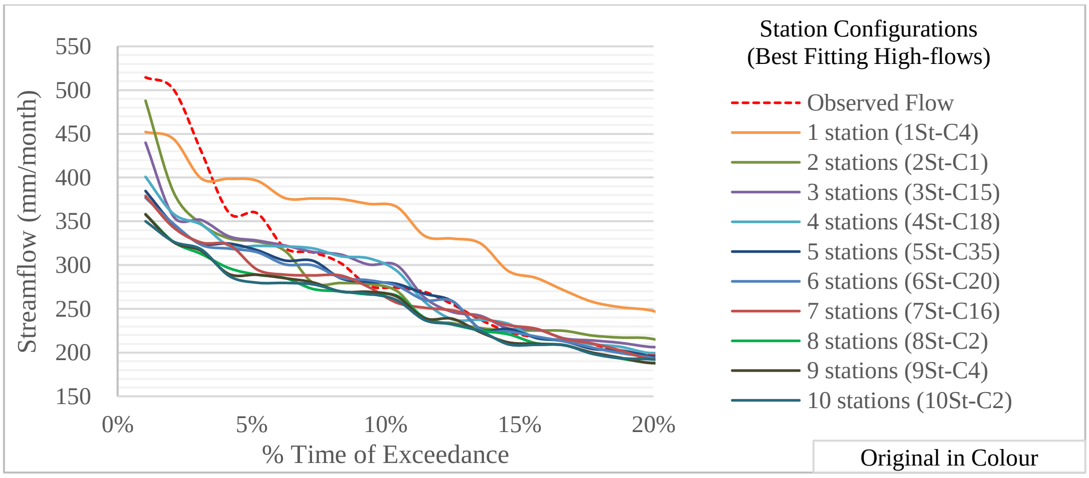

Figure 5-40: Best matching high-flow in different station configurations

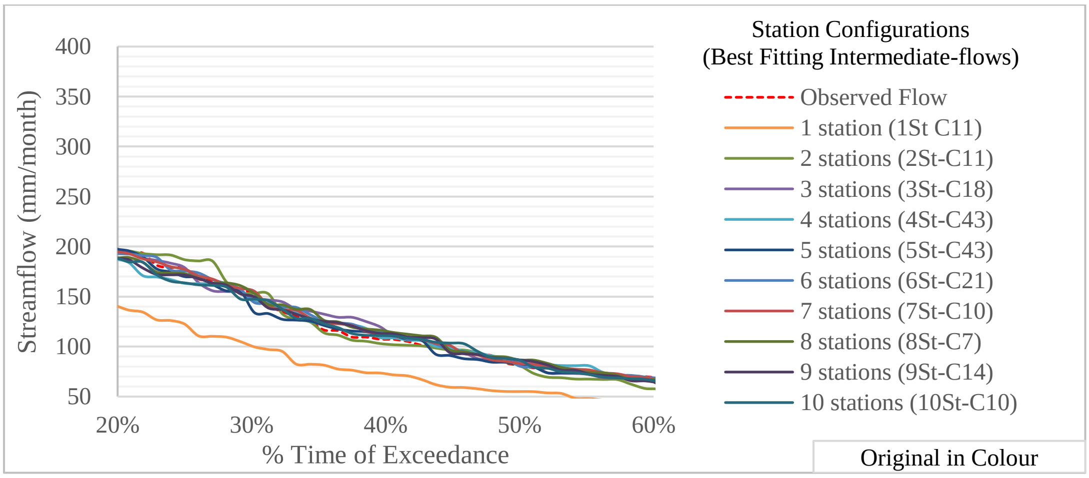

Figure 5-41: Best matching intermediate-flow in different station configurations

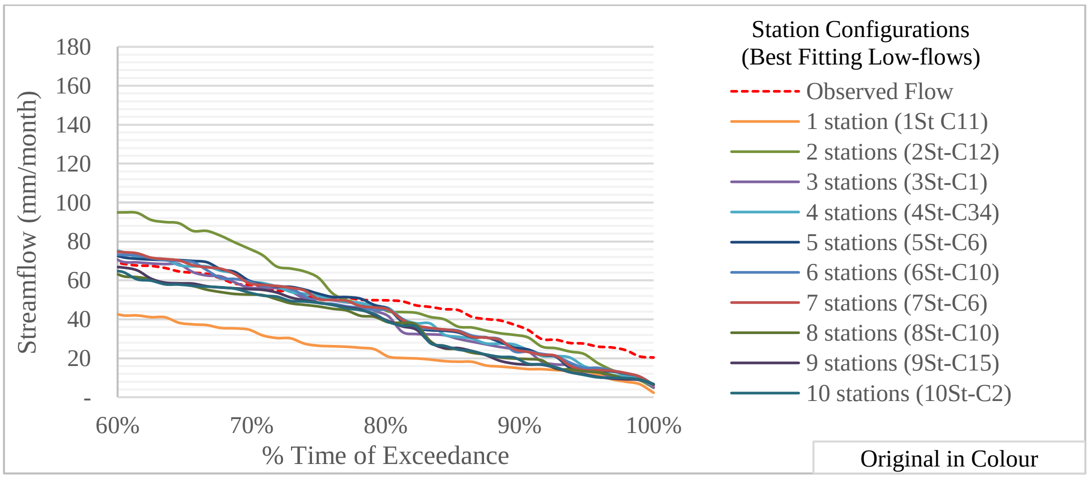

Figure 5-42: best matching low-flow in different station configurations

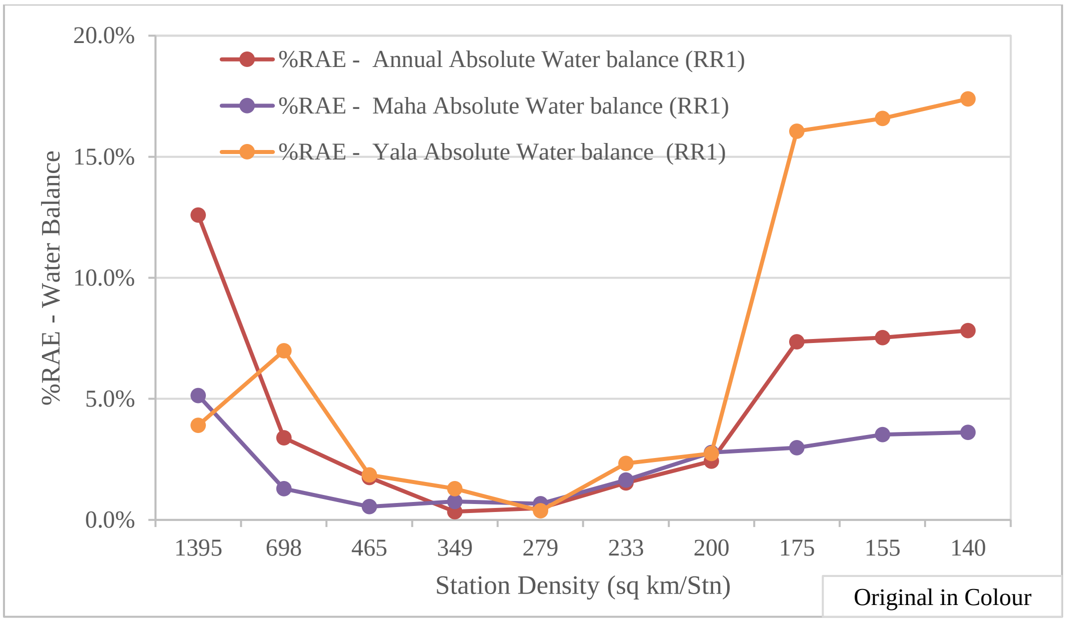

Figure 5-43: best %RAE for water balance in different station configurations

5.2.3 Rainfall-Runoff Option 2 (RR Option 2)

A spreadsheet and its built-in optimization tool were used to develop and calibrate the parameters of the two-parameter monthly water balance model that was used in the RR1 option. A combination of the built-in optimization tool and a trial and error selection of initial parameters was used for the identification of the set of parameters with the minimum MRAE. Graphical outputs were also observed to ascertain a global parameter search.

Model calibrations evaluated the streamflow hydrographs (Figure 5-44), flow duration curves (Figure 5-45), annual water balance, high flow (Figure 5-46) intermediate flow (Figure 5-47) and low flow estimations (Figure 5-48) with the use of MRAE as the numerical indicator. All results are in ANNEX E - Table E - 1.

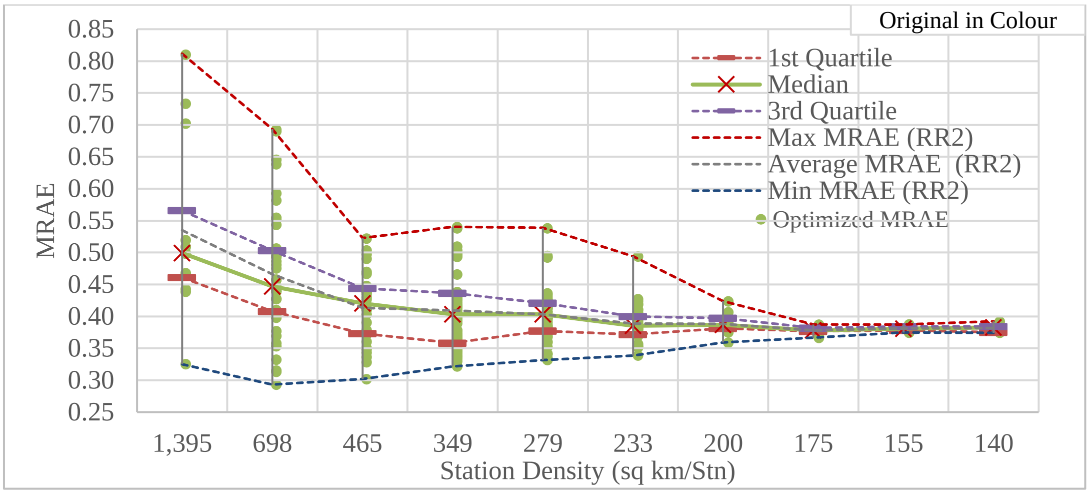

Figure 5-44: Overall MRAE – Hydrograph matching - RR Option 2

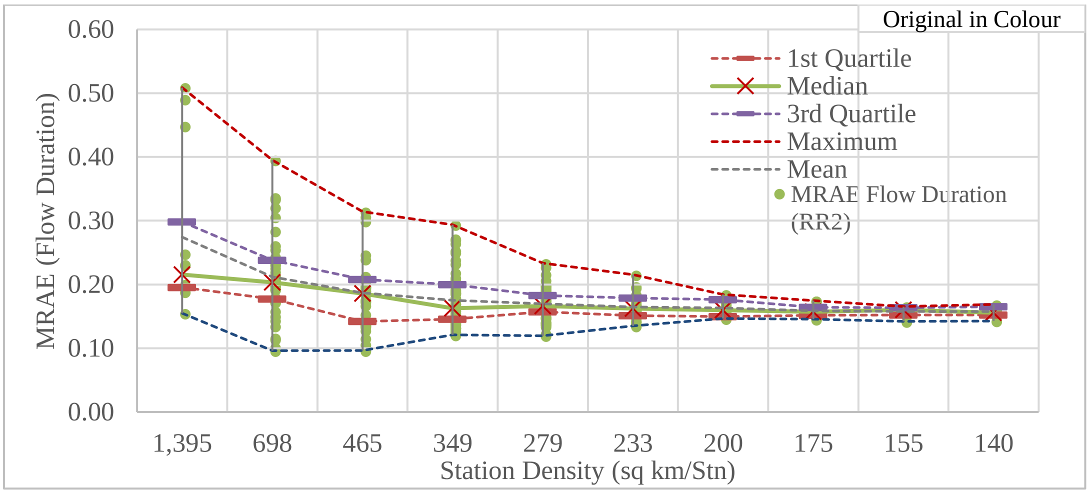

Figure 5-45: Flow Duration Curve matching MRAE – RR2

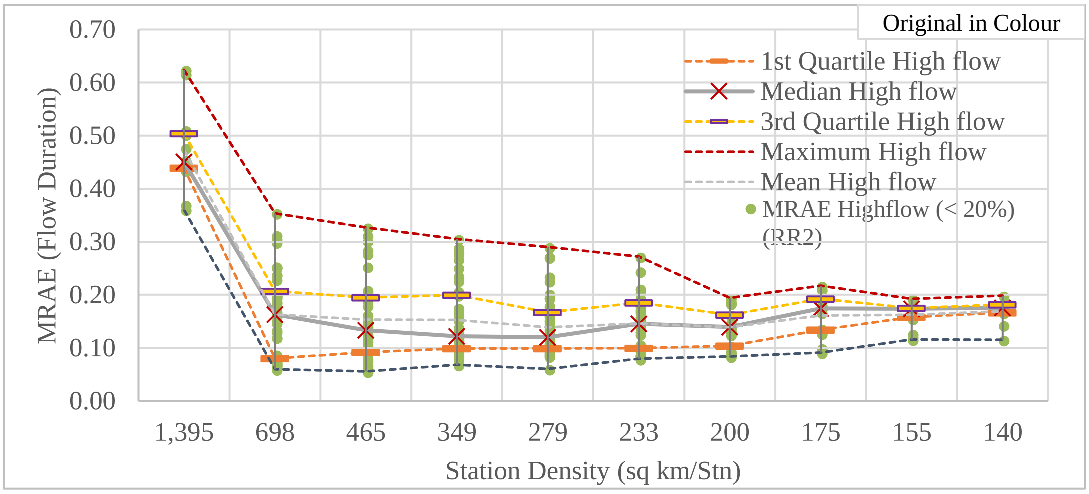

Figure 5-46: High flow - Flow Duration Curve matching MRAE – RR2

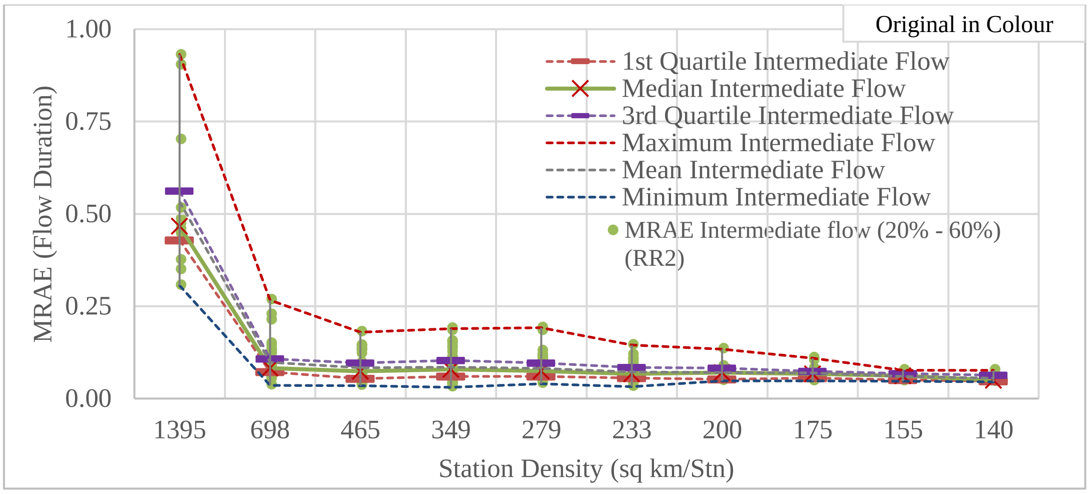

Figure 5-47: Intermediate- flow - Flow Duration Curve matching MRAE – RR2

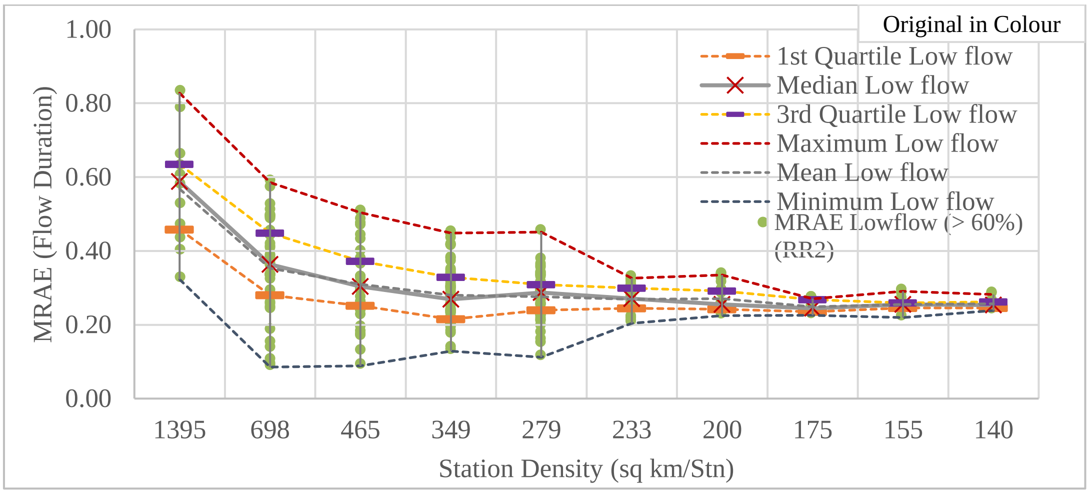

Figure 5-48: Low flow - Flow Duration Curve matching MRAE – RR2

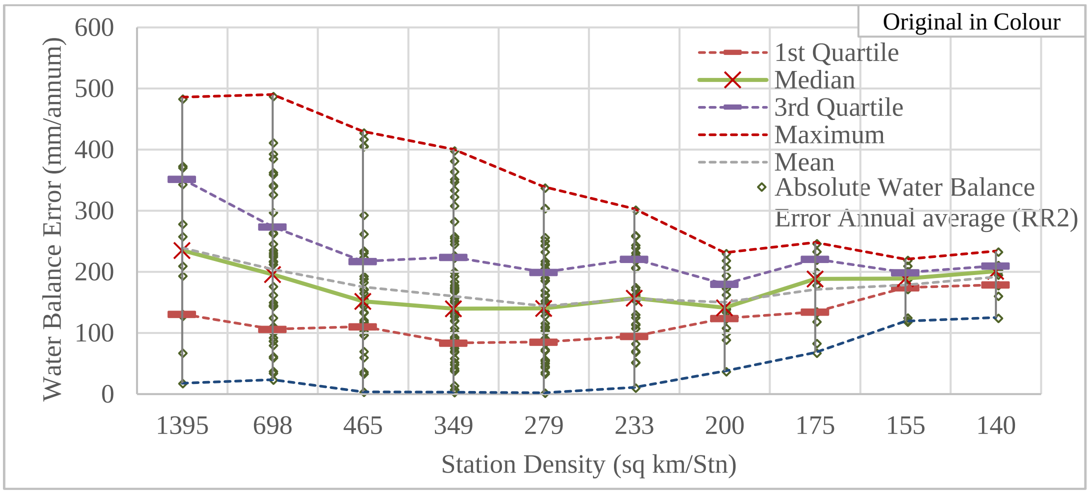

Figure 5-49: Annual Water balance Error -RR2

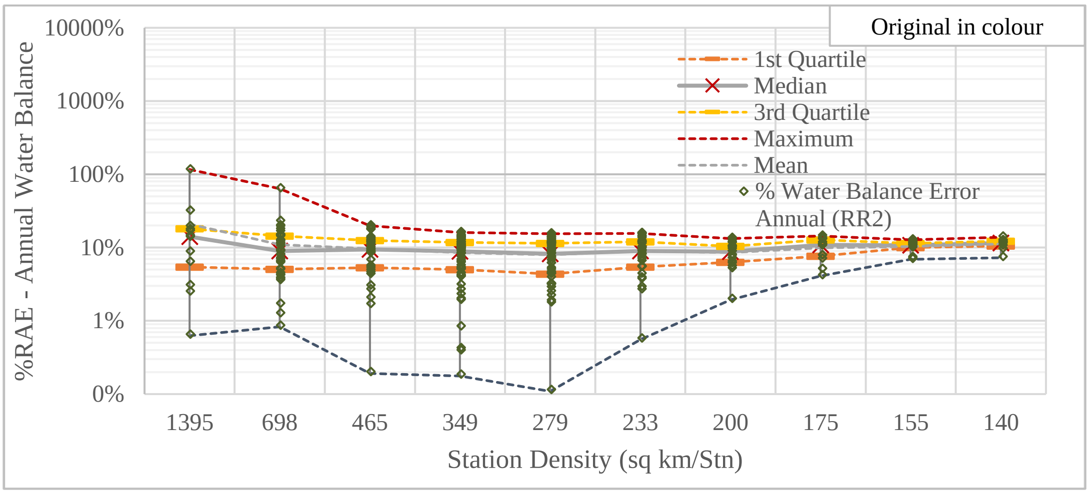

Figure 5-50: Annual % RAE - Water balance -RR2

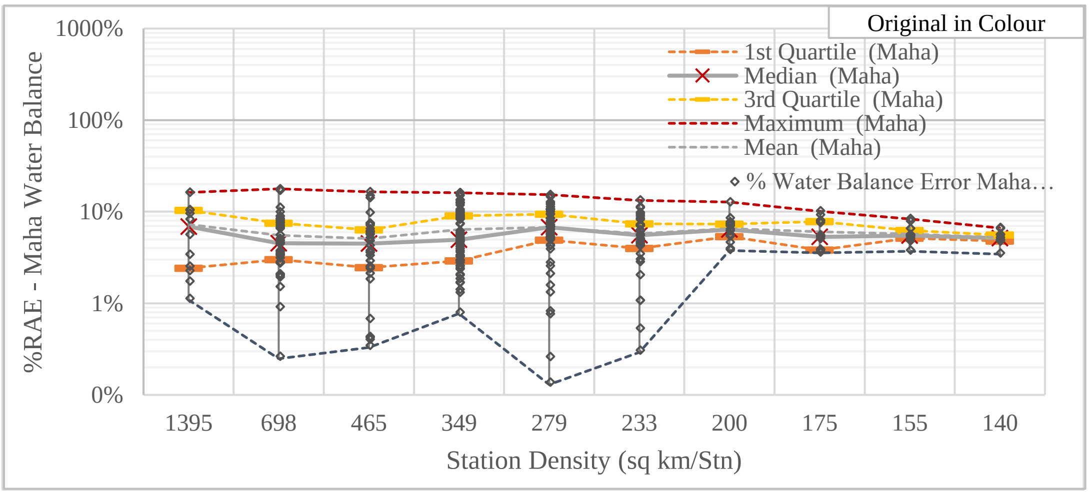

Figure 5-51: Maha % RAE - Water balance -RR2

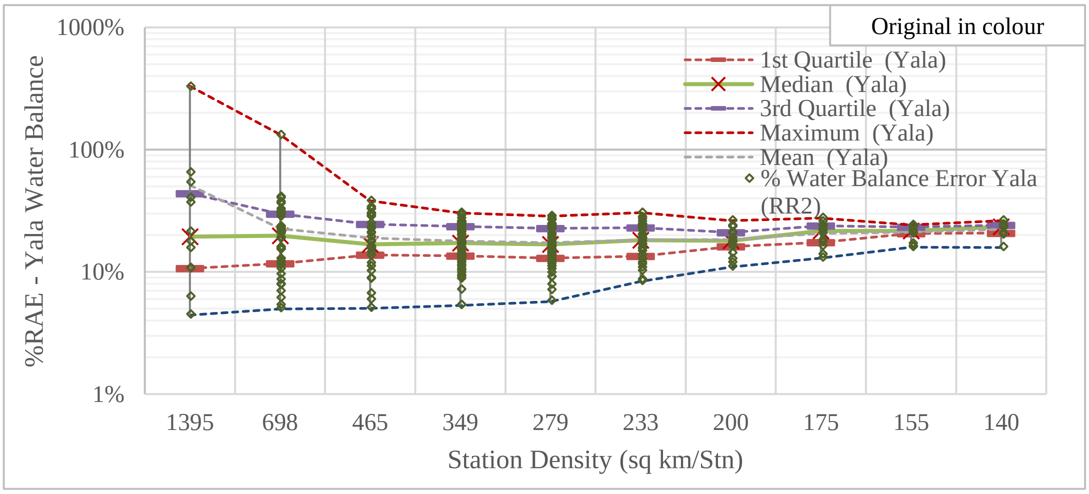

Figure 5-52: Yala % RAE - Water balance -RR2

5.2.3.1 Consistent Model Estimates

The estimated streamflow indicated that the consistent matching with any station combination could be observed only with a station configuration denser than 175km^2/station. This consistency was similar to the RO and RR1 options. The performance of the model with consistent station densities are as shown in Figure 5-54 and Figure 5-55. Comparison of Flow duration curve, indicated mismatches in high flows and lower values in low flow consideration. But the intermediate flows show a slightly good matching than the high and low flows (Figure 5-60, Figure 5-61 and Figure 5-62) show the MRAE values corresponding to the consistent flow matching.

At consistent gauging station densities, all hydrographs behave similarly, showing a MRAE variation 0.3668-0.3923 (Table E - 1). The Curve matching also shows drastic variations in August 2007 to August 2008 period with the observed streamflow (Figure 5-54). The highflow behavior in the year 2008 and 2010 2012 and 2014 showed a significant mismatch both in magnitude and timing while the low flow showed a greater mismatch in the time of occurrent.

Water balance and %water balance error graph in the consistent range of densities show that absolute water balance error is less than 250 mm (15%) (Figure 5-53 and Figure 5-56). MRAE values of consistent station combinations have very little deviation between each other, but water balance error values show a consistency at the consistent MRAE showing 4-14% water balance variation except for a few combinations (Figure 5-56).

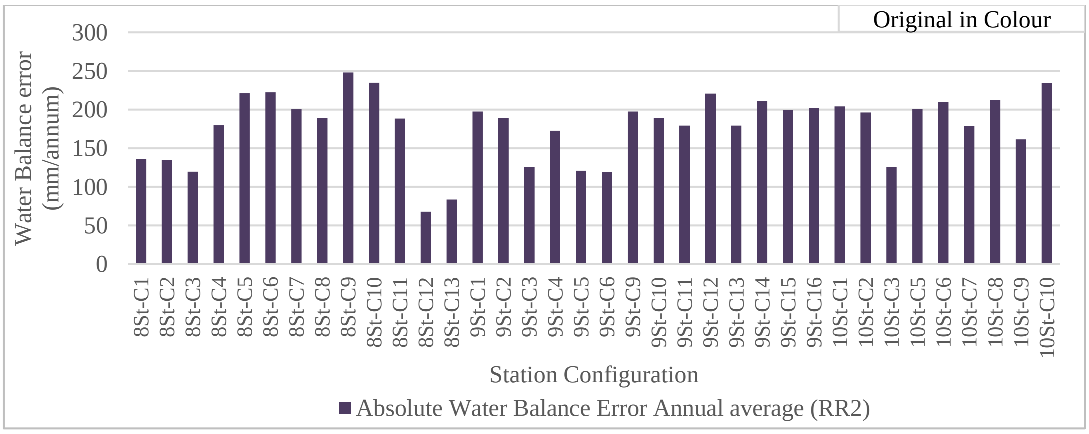

Figure 5-53: Water balance error at station densities with consistent MRAE

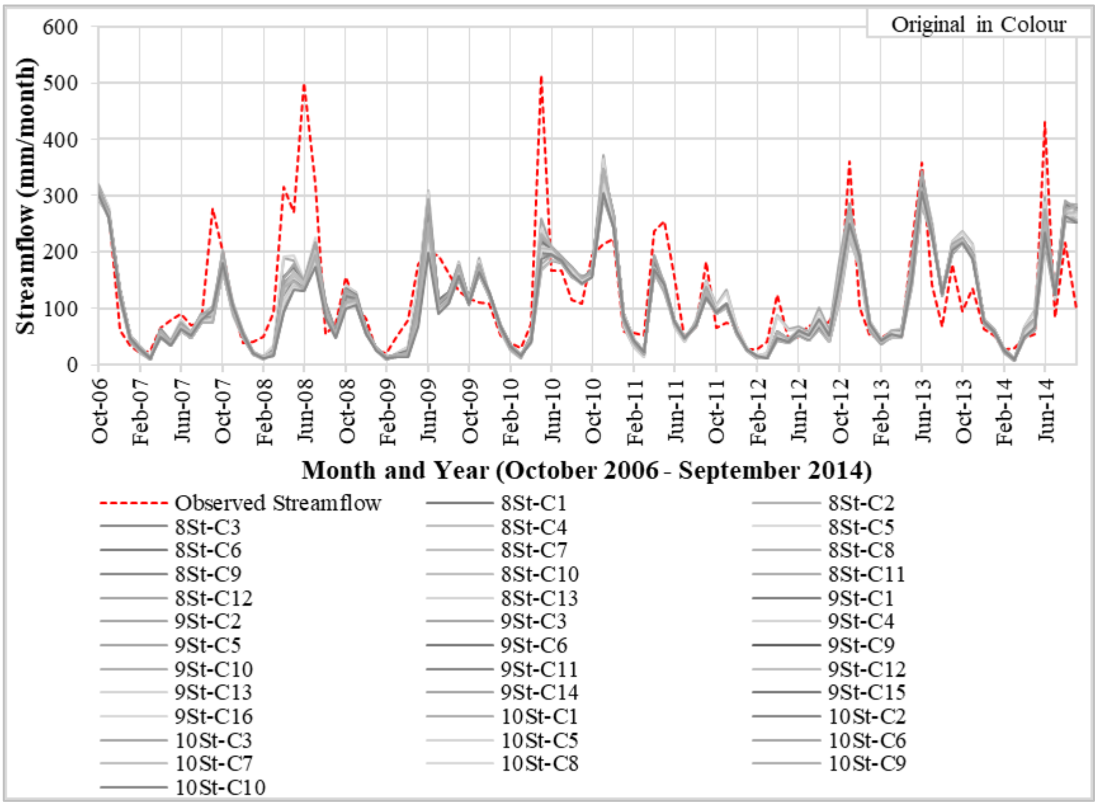

Figure 5-54: Hydrographs with Consistent Overall MRAE – RR2

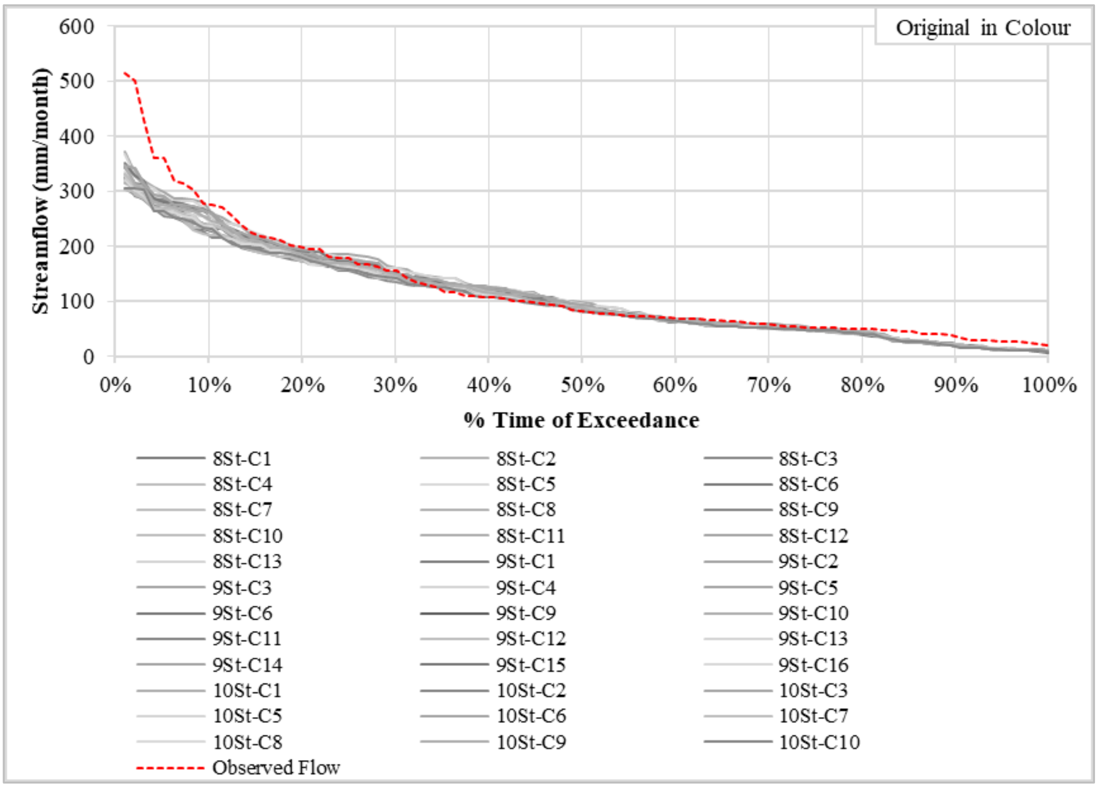

Figure 5-55: Flow duration curves with Consistent MRAE – RR2

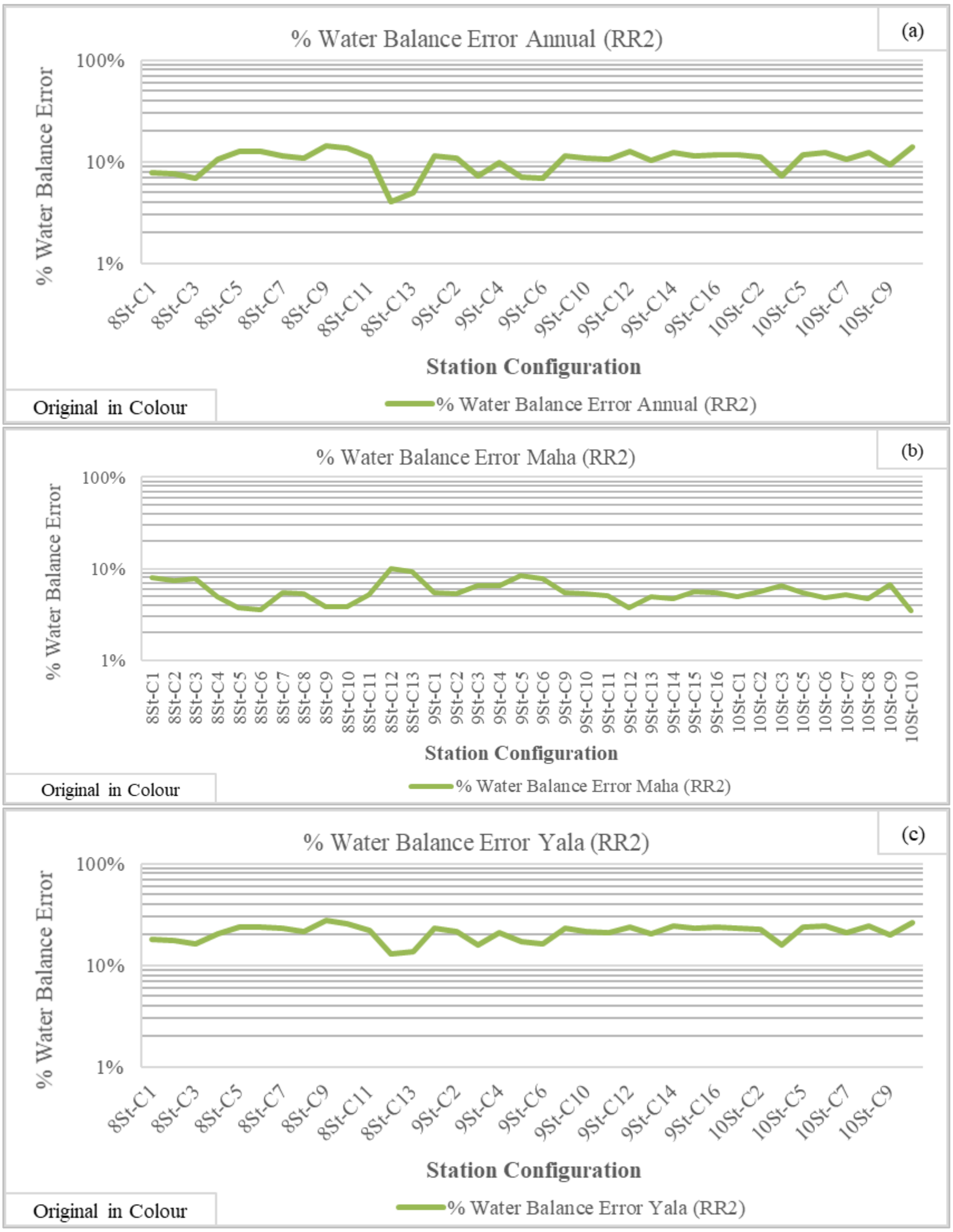

Figure 5-56: % RAE for Water Balance in consistent densities, Annual, Maha and Yala - RR2

Table 5-17: Best curve fitting station configurations and corresponding MRAE values

Station Density (km^2/station)	Comparison Hydrographs		Comparison Flow Duration Curves		Comparison High Flow		Comparison Intermediate Flow		Comparison Low flow	
	Station Configuration	MRAE	Station Configuration	MRAE	Station Configuration	MRAE	Station Configuration	MRAE	Station Configuration	MRAE
1395	1St-C2	0.3252	1St-C2	0.1549	1St-C4	0.3602	1St-C2	0.3058	1St-C2	0.3230
698	2St-C16	0.2931	2St-C16	0.0963	2St-C25	0.0597	2St-C19	0.0357	2St-C16	0.0853
465	3St-C13	0.3017	3St-C8	0.0966	3St-C34	0.0556	3St-C16	0.0351	3St-C8	0.0887
349	4St-C37	0.3217	4St-C39	0.1210	4St-C19	0.0683	4St-C60	0.0304	4St-C30	0.1288
279	5St-C31	0.3316	5St-C14	0.1197	5St-C37	0.0603	5St-C42	0.0397	5St-C14	0.1118
233	6St-C18	0.3387	6St-C27	0.1350	6St-C3	0.0793	6St-C25	0.0323	6St-C18	0.2036
200	7St-C8	0.3591	7St-C8	0.1464	7St-C15	0.0841	7St-C17	0.0476	7St-C5	0.2244
175	8St-C11	0.3668	8St-C1	0.1455	8St-C12	0.0909	8St-C6	0.0474	8St-C3	0.2259
155	9St-C3	0.3748	9St-C5	0.1422	9St-C3	0.1159	9St-C14	0.0470	9St-C5	0.2192
140	10St-C10	0.3744	10St-C9	0.1429	10St-C3	0.1153	10St-C10	0.0453	10St-C9	0.2387

Table 5-18: Best performing station configurations and corresponding % RAE of water balance

Station Density (km^2/station)	Comparison Water Balance - Annual		Comparison Water Balance -Maha		Comparison Water Balance - Yala	
	Station Configuration	%RAE	Station Configuration	%RAE	Station Configuration	%RAE
1395	1St-C8	0.6%	1St-C3	1.1%	1St-C8	4.4%
698	2St-C28	0.8%	2St-C12	0.2%	2St-C28	5.0%
465	3St-C9	0.2%	3St-C27	0.3%	3St-C36	5.0%
349	4St-C33	0.2%	4St-C14	0.8%	4St-C57	5.3%
279	5St-C22	0.1%	5St-C11	0.1%	5St-C21	5.7%
233	6St-C11	0.6%	6St-C31	0.3%	6St-C22	8.4%
200	7St-C6	1.9%	7St-C4	3.8%	7St-C6	11.0%
175	8St-C12	4.1%	8St-C6	3.6%	8St-C12	13.0%
155	9St-C6	6.9%	9St-C12	3.7%	9St-C3	15.9%
140	10St-C3	7.3%	10St-C10	3.5%	10St-C3	15.9%

5.2.3.2 Best Model Performance and Station Density

Details corresponding to the best fitting streamflow estimations and the water balance comparisons are shown in Table 5-17 and Table 5-18 with the performance indicators of MRAE and % Water Balance (%RAE). Combination of 2 stations (Nivithigala and Eheliyagoda – 2St-C16) with the density of 698 km^2/station shows the best performance in overall hydrograph matching, overall flow duration matching and in low flow matching while the 3 stations combination (3St-C34) with the density of 465km^2/station for high flow and 4 stations combination (4St-C60) with the density of 349 km^2/station is the best for intermediate flow matching.

The water balance error comparison indicates that 5 stations with the density of 279km^2/station shows the minimum in annually and in Maha season for % Relative Absolute Error, but the results are in different combinations. The behavior of Yala water balance is minimum with only one station (Kuruvita - Keragala) selection at 1395 km^2/station density.

The most noteworthy result of the RR2 option is the behavior of the best fitting streamflow estimations for each of the gauging station combinations. The best fitting result of each station combination is shown as the Minimum value in the Figure 5-57. These values showed that the best streamflow estimations improved with different gauging station densities. This indicates that there are some stations which have a greater influence on a particular characteristic of the watershed streamflow. These results shown in the Table 5-17 and Table 5-18 reflect that the 698 km^2/station is the most prominent density while 465 km^2/station is better for high flow estimations and 349 km^2/station is the best station density for intermediate flow estimations.

The comparative evaluation of the best fit hydrographs and flow duration curves are in the Figure 5-58 and Figure 5-59. High, intermediate and low-flow matching curves are in Figure 5-60, Figure 5-61, and Figure 5-62. In general, the best streamflow estimations for each station combination showed that the highflow matching has improved but remained poorly matched in the case of year 2008, 2010 and 2014. The low flows showed a significant improvement (having a MRAE range: 0.0853-0.2387).

The gauging station distribution and the Thiessen polygons corresponding to the best fitting streamflow estimations are shown in Figure 5-65.

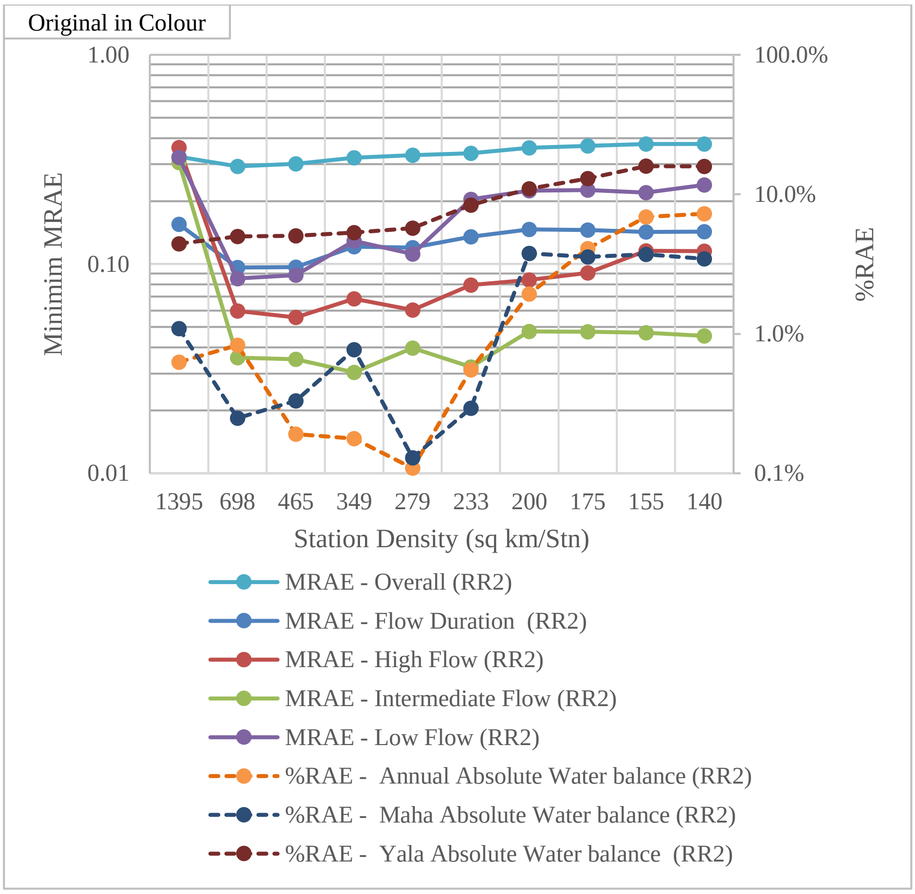

Figure 5-57: Behaviour of the best fitting streamflow estimations for each of the station densities

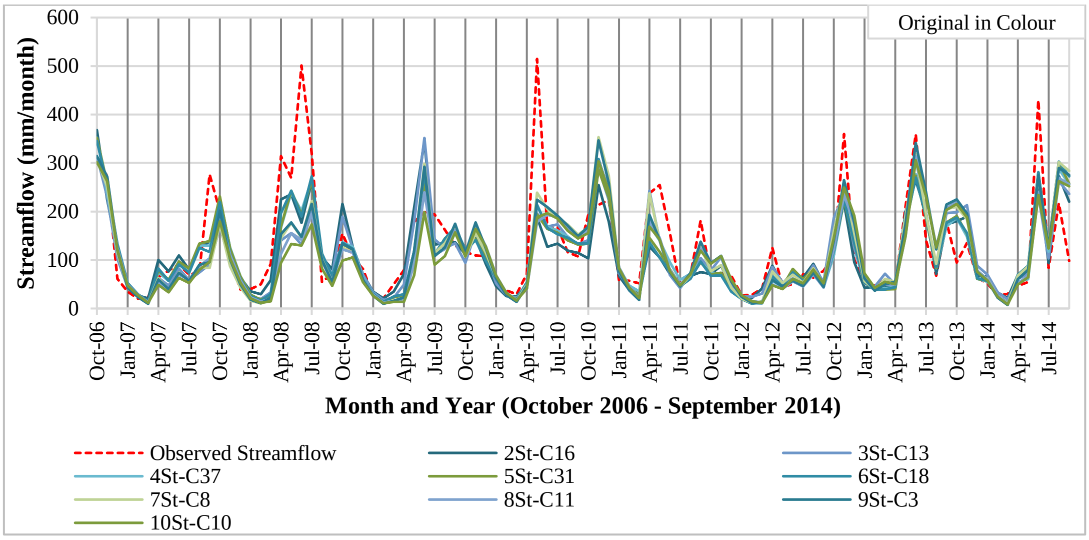

Figure 5-58: Minimum overall MRAE at different station number selection

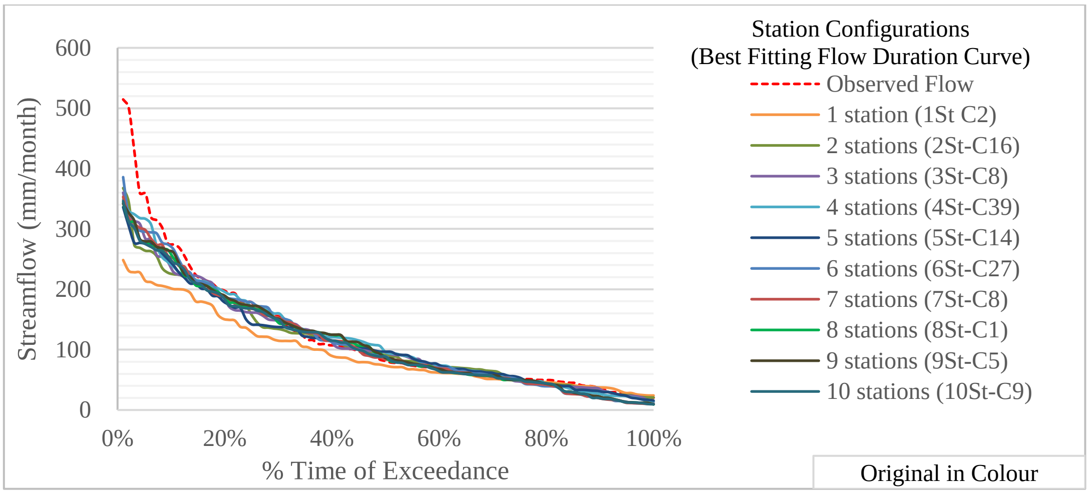

Figure 5-59: Minimum MRAE Flow Duration at different station number selection – RR2

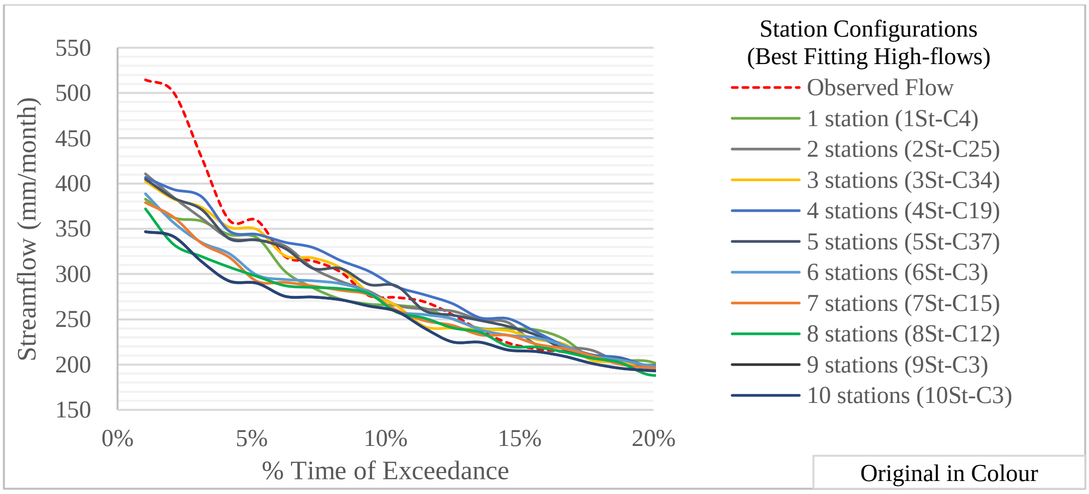

Figure 5-60: Minimum MRAE at High-flow in Flow Duration at different station number selection -RR2

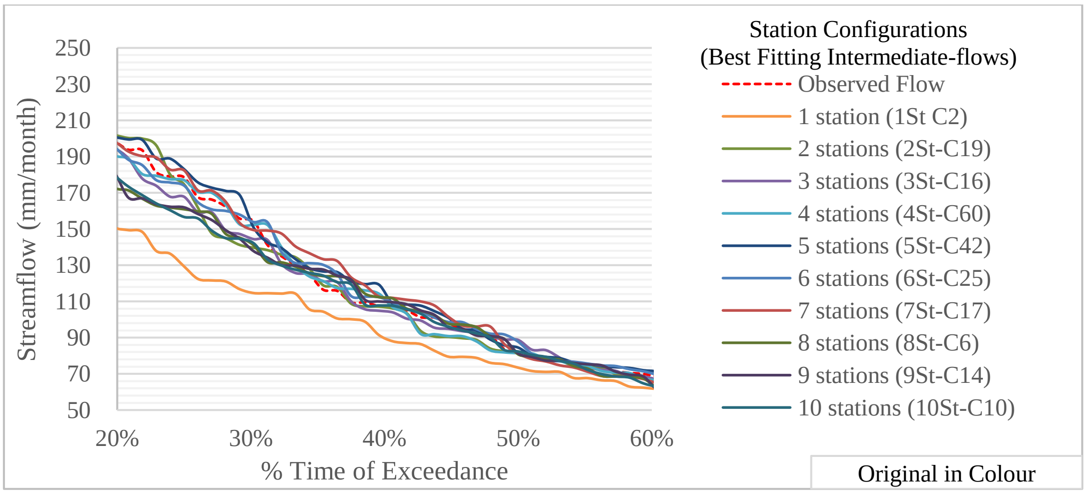

Figure 5-61: MRAE at Intermediate-flow in Flow Duration at different station number selection -RR2

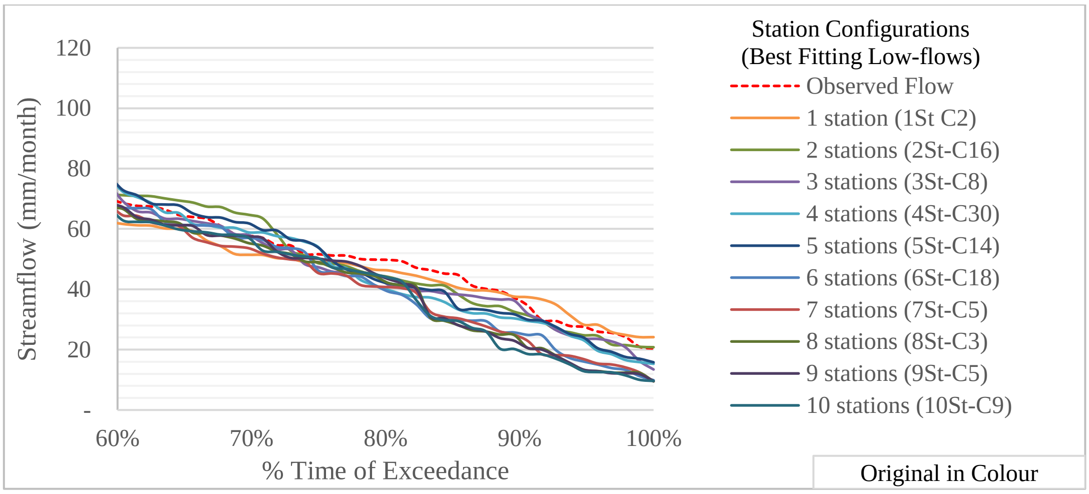

Figure 5-62: Minimum MRAE at Low-flow in Flow Duration at different station number selection -RR2

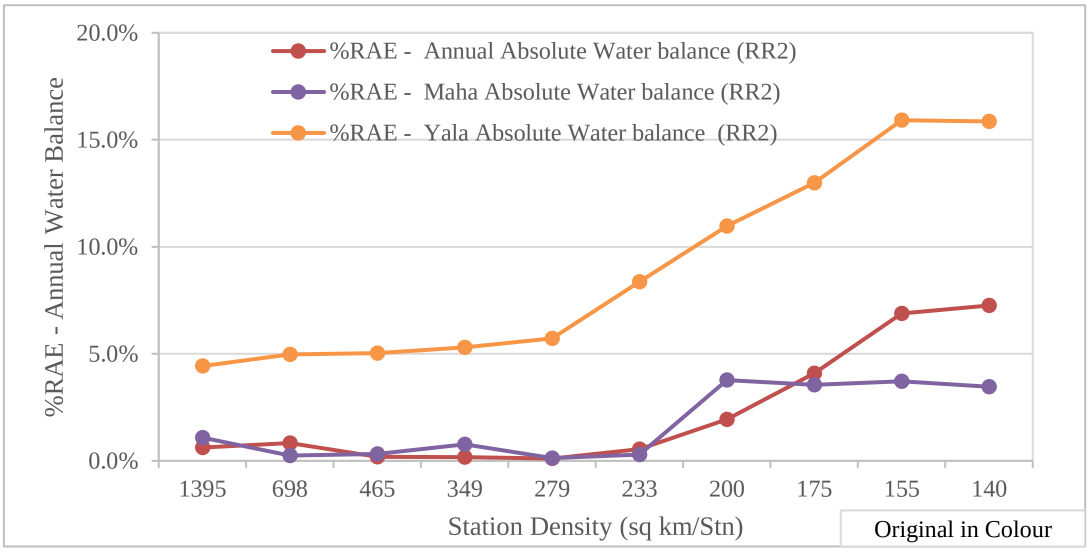

Figure 5-63: Minimum %RAE Water balance in annual, Maha and Yala at different station densities – RR2

5.2.3.3 Best Station Layouts

Gauging station density and configuration that produced the best fitting streamflow hydrograph (Figure 5-58), flow duration curve (Figure 5-59), High-flows (Figure 5-60), Intermediate flow (Figure 5-61), Lowflow (Figure 5-62) and Annual Water Balance (Figure 5-63) indicate that there are gauging stations with a greater influence on the observed streamflow. The gauging station weights corresponding to each configuration are in the Table 5-19.

Thiessen weights for each station combination shows that the most contributing stations are Nivithigala Ratnapura and Eheliyagoda for the overall hydrograph, flow duration curve and high flow matching. In case of water balance, Alupola, nivithigala and Ratnapura were most contributing. In case of lowflows Nivithigala is most contributing.

It was noted that the stations Halwatura, Uskvalley, Hanwella and Maussakele, had no influence in the estimation of key characteristics. These stations and responses are shown in the Table 5-19. The stations with low influence are located outside of the catchment boundary and the areal extent contribution for Thiessen weights are minimal.

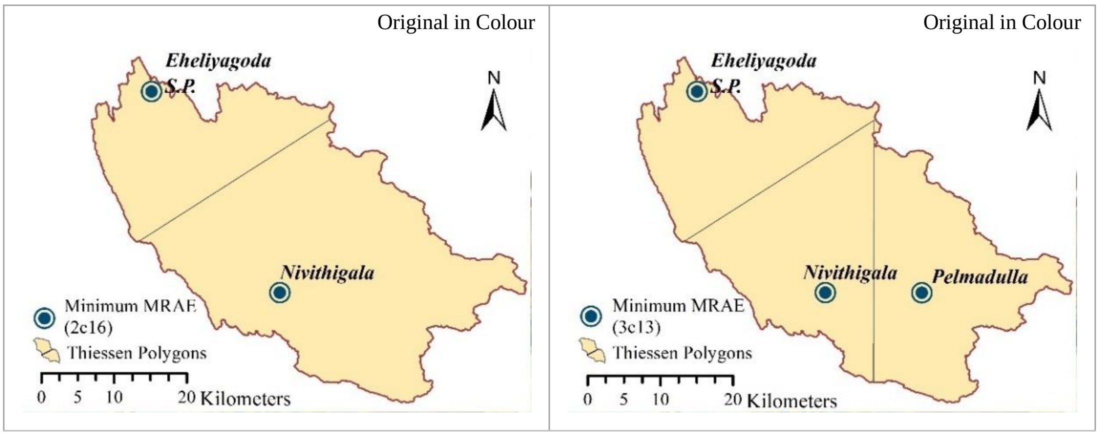

Figure 5-64: Best streamflow matching station combinations (2-3 stations selection) - RR2

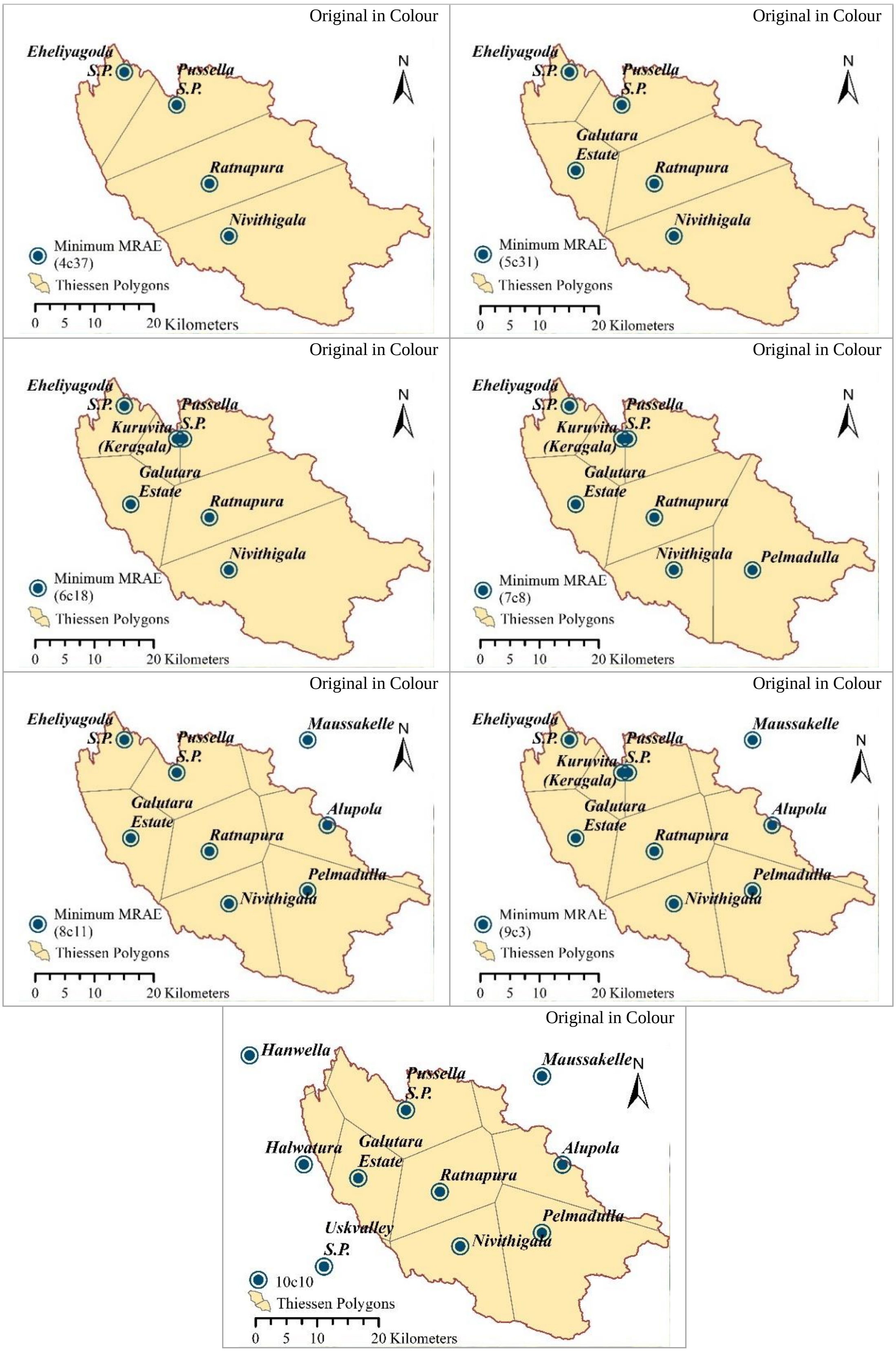

Figure 5-65: Best streamflow matching station combinations (4-10 stations selection) - RR2

Table 5-19 - Gauging station weights corresponding to hydrograph components

	Best fitting hydrograph	Best fitting Flow Duration curve	Best fitting High flows	Best fitting Intermediate	Best fitting Low flows	Minimum Water Balance Error	Sum of Thiessen Weights	Influencing flow considerations (No)	Weighted Influence	% Importance
Density (km²/station)	**698**	**698**	**465**	**349**	**698**	**279**				
Combination / **Station**	***2c16***	***2c16***	***3c34***	***4c60***	***2c16***	***5c22***				
Alupola	-	-	-	-	-	0.25	0.25	1.00	0.25	1.13
Nivithigala	0.72	0.72	-	0.15	0.72	0.27	2.57	5.00	12.85	58.64
Pelmadulla	-	-	-	0.35	-	-	0.35	1.00	0.35	1.58
Rathnapura	-	-	0.69	0.47	-	0.21	1.37	3.00	4.11	18.76
Eheliyagoda S.P.	0.28	0.28	-	-	0.28	0.10	0.94	4.00	3.76	17.19
Galutara Estate	-	-	-	-	-	-	-	-	-	-
Pussalla S.P.	-	-	-	-	-	0.18	0.18	1.00	0.18	0.83
Kuruvita (Keragala)	-	-	0.28	-	-	-	0.28	1.00	0.28	1.28
Halwatura	-	-	-	-	-	-	-	-	-	-
Uskvalley	-	-	0.03	0.04	-	-	0.07	2.00	0.13	0.61
Hanwella	-	-	-	-	-	-	-	-	-	-
Maussakelle	-	-	-	-	-	-	-	-	-	-

Importance of each station was computed by considering the influence on each flow category. A weight was assigned to indicate the number of times a particular station had contributed to the 6 evaluation criteria that considered variety of hydrograph components (Table 5-19). This indicated that Nivithigala, Ratnapura and Eheliyagoda respectively were contributing 5, 3 and 4 times out of 6 hydrograph categories. The weighted influence was computed by using the equation 3.

$$\text{Weighted influence} = (\text{Sum of Thiessen Weights in best fitting}) \times (\text{Influensing Count}) \quad \ldots\ldots\ldots\ldots \quad 3$$

Results from the RR2 option indicated that though high station densities enable achievement of consistent model performances, the spatial variability of watershed rainfall does not get reflected even with a station density as high as 140 km^2/station. High station densities appear to average the information from highly contributing gauging stations and this happens with a dense station network having stations within the watershed.

Table 5-20:Thiessen weights for all minimum MRAE and %RAE combinations in different densities

	Station Density (km^2/Station)	Station Configuration	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda S.P.	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
Comparison hydrographs (RR2)	1395	1St-C2	-	1.00	-	-	-	-	-	-	-	-	-	-
	698	2St-C16	-	0.72	-	-	0.28	-	-	-	-	-	-	-
	465	3St-C13	-	0.35	0.37	-	0.28	-	-	-	-	-	-	-
	349	4St-C37	-	0.44	-	0.28	0.10	-	0.19	-	-	-	-	-
	279	5St-C31	-	0.44	-	0.22	0.07	0.12	0.15	-	-	-	-	-
	233	6St-C18	-	0.44	-	0.22	0.07	0.12	0.04	0.11	-	-	-	-
	200	7St-C8	-	0.14	0.34	0.18	0.07	0.12	0.04	0.11	-	-	-	-
	175	8St-C11	0.10	0.15	0.27	0.15	0.07	0.12	0.13	-	-	-	-	0.02
	155	9St-C3	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.09	-	-	-	0.02
	140	10St-C10	0.10	0.15	0.27	0.15	-	0.10	0.17	-	0.04	0.001	0.003	0.02
Comparison Flow Duration curves (RR2)	1395	1St-C2	-	1.00	-	-	-	-	-	-	-	-	-	-
	698	2St-C16	-	0.72	-	-	0.28	-	-	-	-	-	-	-
	465	3St-C8	0.21	0.53	0.26	-	-	-	-	-	-	-	-	-
	349	4St-C39	-	0.26	0.37	-	0.16	0.21	-	-	-	-	-	-
	279	5St-C14	-	0.57	-	-	0.07	0.14	0.04	0.18	-	-	-	-
	233	6St-C27	-	0.15	0.35	0.16	-	0.14	-	0.19	-	-	0.01	-
	200	7St-C8	-	0.14	0.34	0.18	0.07	0.12	0.04	0.11	-	-	-	-
	175	8St-C1	0.10	0.15	0.27	0.14	0.07	0.10	-	0.14	0.03	-	-	-
	155	9St-C5	0.10	0.15	0.27	0.14	0.07	0.10	-	0.13	0.03	-	-	0.02
	140	10St-C9	0.10	0.15	0.27	0.14	-	0.11	-	0.17	0.05	0.001	0.005	0.02
Comparison High flow (RR2)	1395	1St-C4	-	-	-	1.00	-	-	-	-	-	-	-	-
	698	2St-C25	-	-	-	0.82	0.18	-	-	-	-	-	-	-
	465	3St-C34	-	-	-	0.69	-	-	-	0.28	-	0.03	-	-
	349	4St-C19	-	-	-	0.66	0.08	0.12	-	0.15	-	-	-	-
	279	5St-C37	-	-	-	0.66	0.07	0.12	0.04	0.11	-	-	-	-
	233	6St-C3	0.12	0.14	0.26	0.21	0.11	-	-	0.17	-	-	-	-
	200	7St-C15	0.10	0.15	0.27	0.21	0.11	-	-	0.16	-	-	-	0.02
	175	8St-C12	0.11	0.21	0.27	-	0.06	0.13	0.04	0.14	0.03	-	-	-
	155	9St-C3	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.09	-	-	-	0.02
	140	10St-C3	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.09	-	0.001	-	0.02
Comparison Intermediate flows (RR2)	1395	1St-C2	-	1.00	-	-	-	-	-	-	-	-	-	-
	698	2St-C19	-	-	0.39	0.61	-	-	-	-	-	-	-	-
	465	3St-C16	-	-	0.39	0.32	-	-	0.28	-	-	-	-	-
	349	4St-C60	-	0.15	0.35	0.47	-	-	-	-	-	0.04	-	-
	279	5St-C42	0.11	0.15	0.27	0.40	-	-	-	-	-	-	0.07	-
	233	6St-C25	-	0.15	0.35	0.16	-	0.11	-	0.19	0.05	-	-	-
	200	7St-C17	0.10	0.15	0.27	0.18	0.07	-	-	0.16	0.07	-	-	-
	175	8St-C6	0.10	0.15	0.27	0.14	-	0.14	0.09	0.11	-	0.001	-	-
	155	9St-C14	0.10	0.15	0.27	0.14	-	0.10	0.09	0.09	0.04	-	-	0.02
	140	10St-C10	0.10	0.15	0.27	0.15	-	0.10	0.17	-	0.04	0.001	0.003	0.02
Comparison Low flows (RR2)	1395	1St-C2	-	1.00	-	-	-	-	-	-	-	-	-	-
	698	2St-C16	-	0.72	-	-	0.28	-	-	-	-	-	-	-
	465	3St-C8	0.21	0.53	0.26	-	-	-	-	-	-	-	-	-
	349	4St-C30	-	0.57	-	-	-	0.16	0.09	0.18	-	-	-	-
	279	5St-C14	-	0.57	-	-	0.07	0.14	0.04	0.18	-	-	-	-
	233	6St-C18	-	0.44	-	0.22	0.07	0.12	0.04	0.11	-	-	-	-
	200	7St-C5	0.13	0.21	0.26	-	0.07	0.14	0.04	0.14	-	-	-	-
	175	8St-C3	0.10	0.15	0.27	0.14	0.08	0.12	-	0.13	-	-	-	0.02
	155	9St-C5	0.10	0.15	0.27	0.14	0.07	0.10	-	0.13	0.03	-	-	0.02
	140	10St-C9	0.10	0.15	0.27	0.14	-	0.11	-	0.17	0.05	0.001	0.005	0.02

5.2.3.4 Best Hydrograph Estimation

The station configuration for the best hydrograph estimation is same for the best flow duration curve matching and it is shown in Figure 5-72 and comparison of best matching monthly hydrographs, duration curves, water balance, high, intermediate and low flow with the observed streamflow are in the Figure 5-66, Figure 5-67, Figure 5-68, Figure 5-69, Figure 5-70 and Figure 5-71.

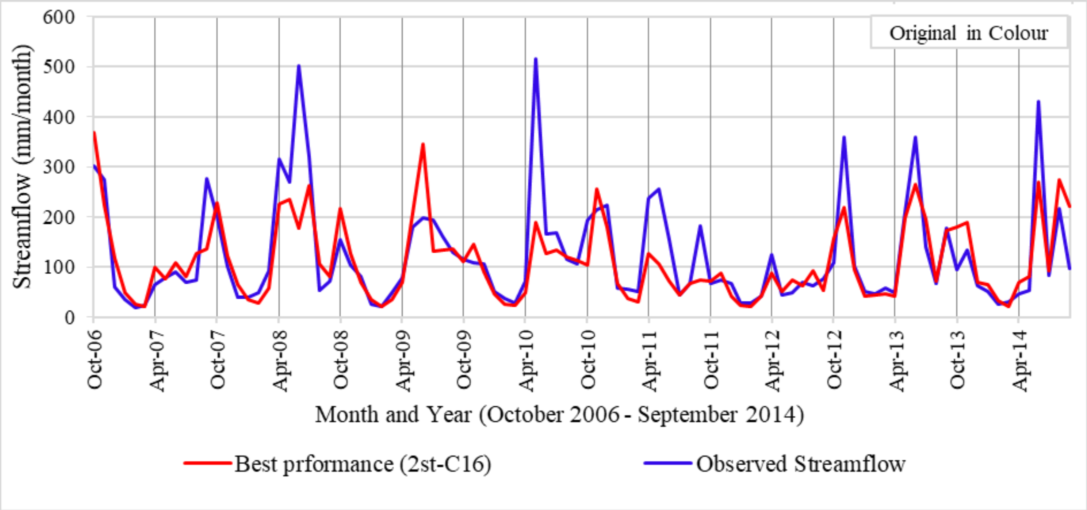

Figure 5-66: Overall best fitting hydrograph– 2St-C16 (RR2)

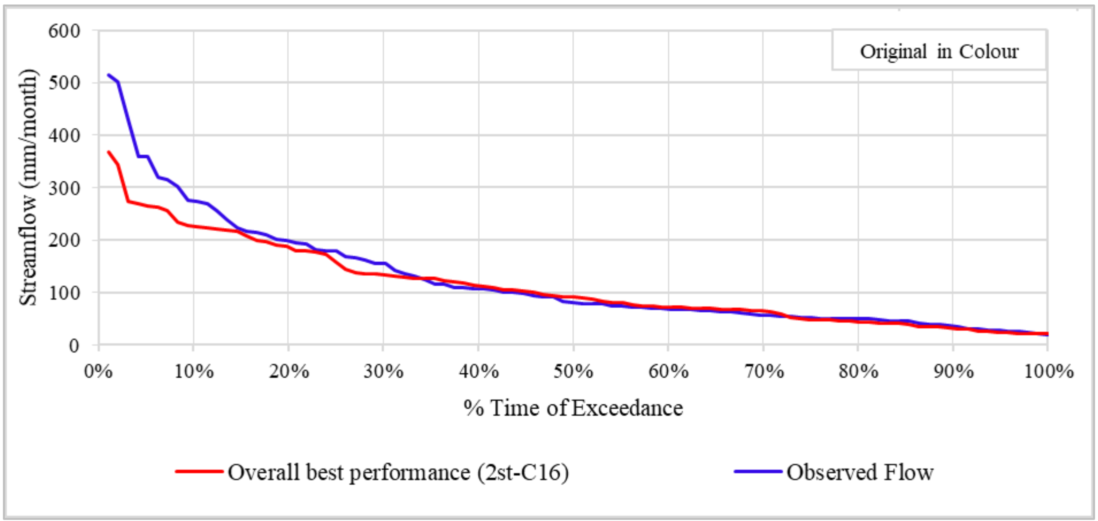

Figure 5-67: Overall best fitting flow duration curve – 2St-C16 (RR2)

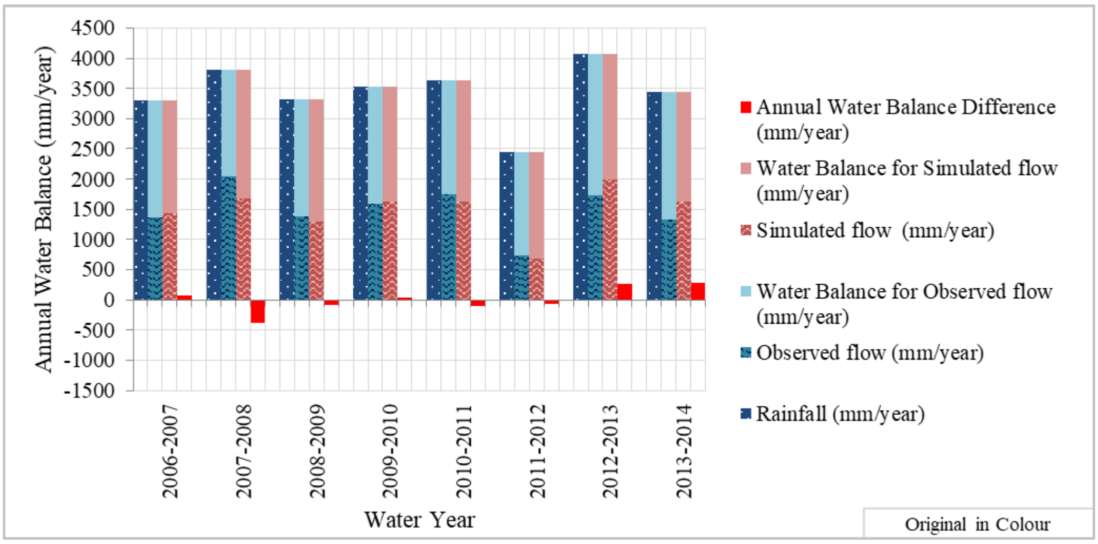

Figure 5-68: Overall least Annual Water Balance error – 5St-C22 (RR2)

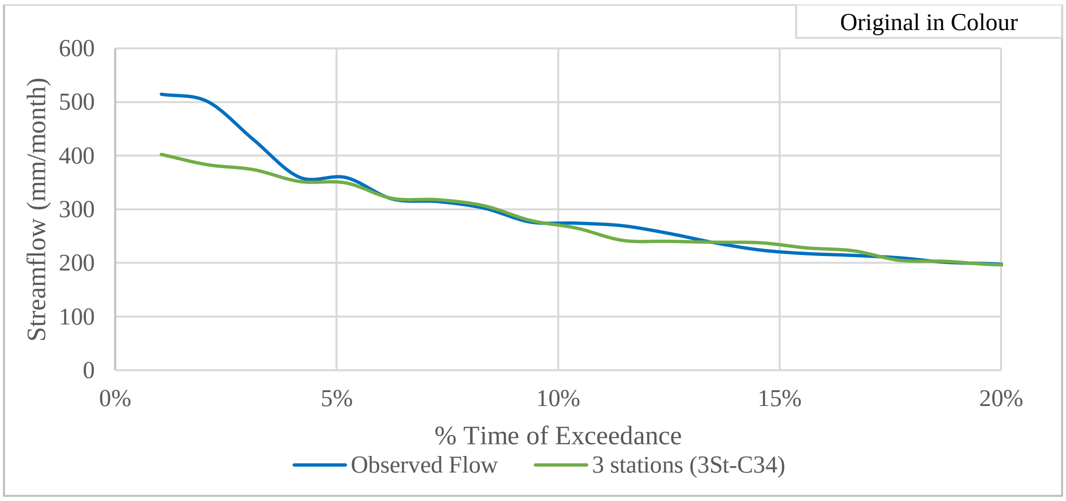

Figure 5-69: Best fitting curve for High-flow

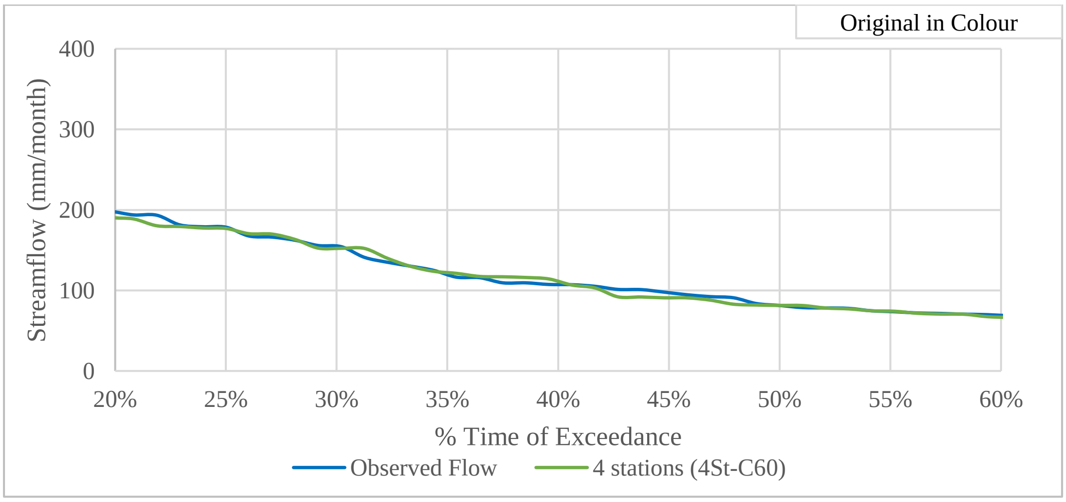

Figure 5-70: Best fitting curve for Intermediate-flow

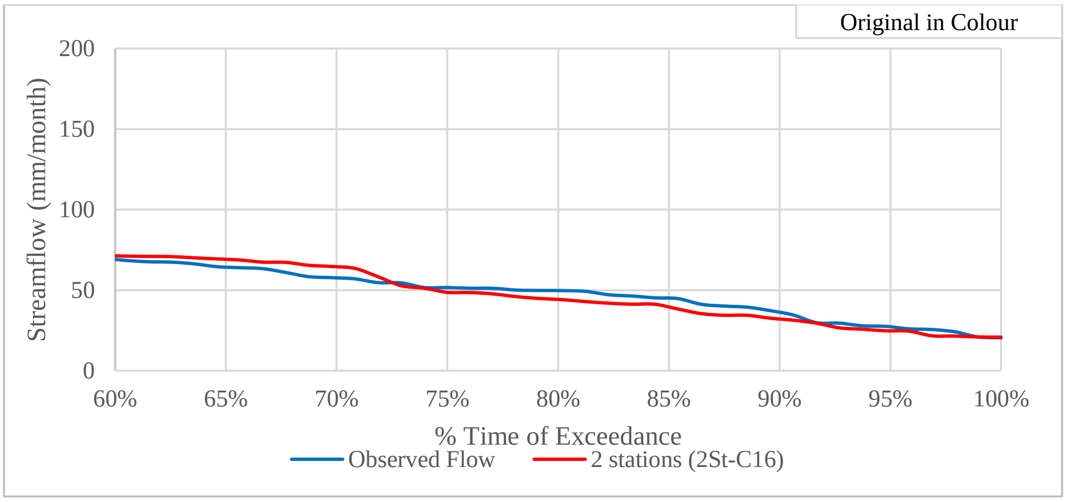

Figure 5-71: Best fitting curve for Low-flow

Hydrographs show that the high observed streamflow in the water years 2008, 2010 and 2014 had not been satisfactorily estimated by the model. This could be either due to a rainfall or streamflow error, or due to deficiencies in the model or the method of optimization. Other than the above, the hydrographs show excellent matching in both intermediate and low flows, and this is also shown in the flow duration curve matching. The seasonal streamflow matching is shown in the Figure 5-73. These results indicate very good matching in Maha season and satisfactory matching in Yala season. The Yala season results indicated the poor high flow estimations in some years probably due to data deficiencies.

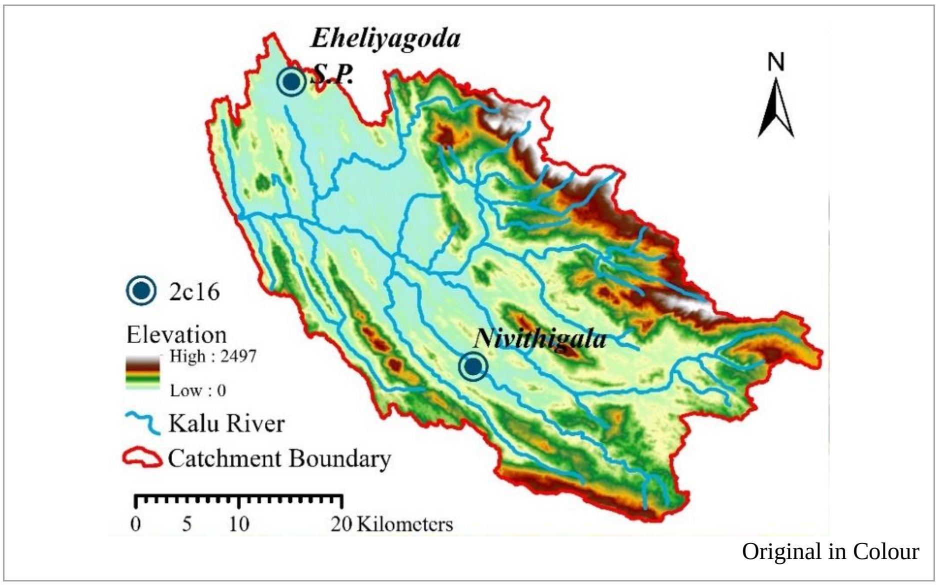

Figure 5-72: The station configuration for the best hydrograph estimation

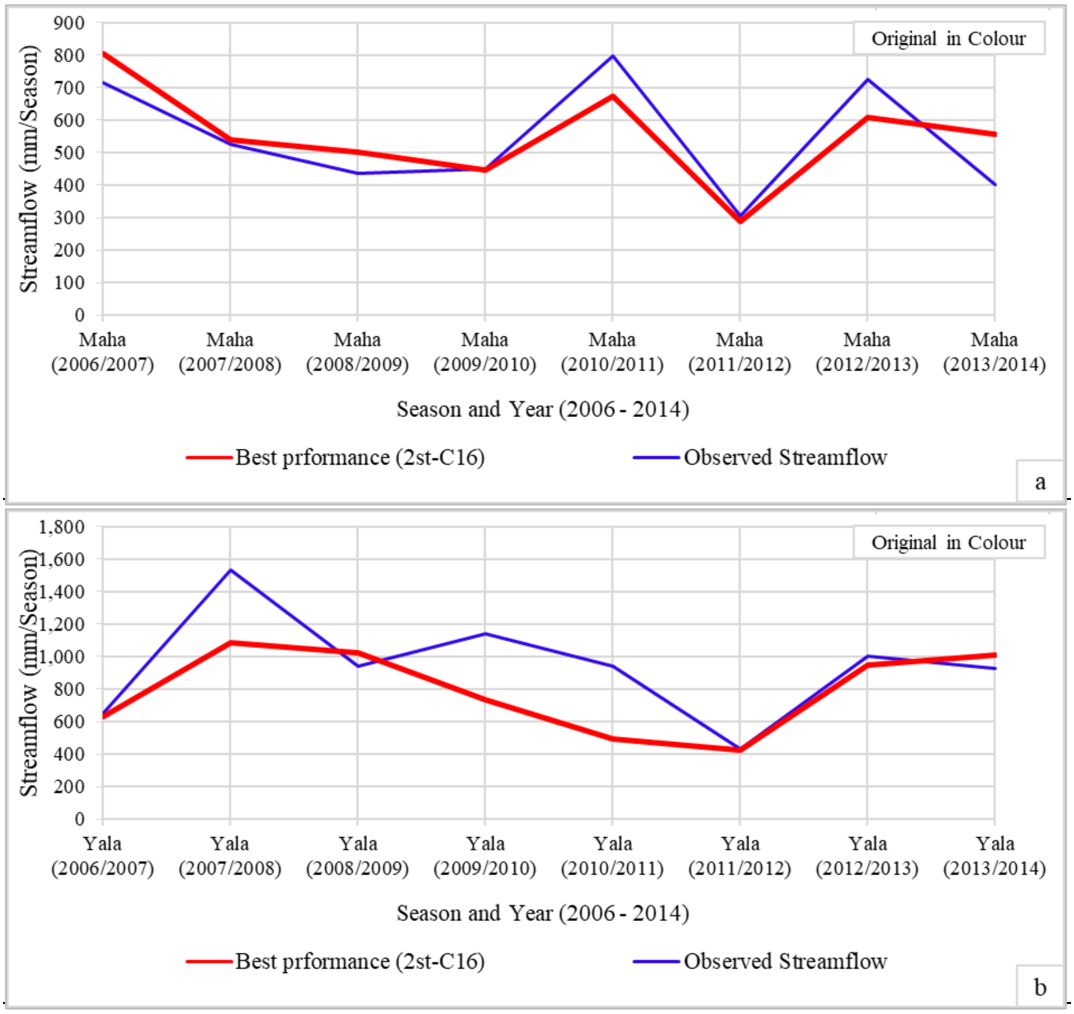

Figure 5-73: Seasonal streamflow variation of best performing station configuration (a – Maha Season; b – Yala season)

5.2.3.5 Model Parameters

Optimized model parameters corresponding to RR Option 2 are shown in the Figure 5-74 and Figure 5-75 and in Table 5-21 and Table 5-22. Since the model parameters were optimized by minimizing the objective function to achieve at the best monthly streamflow values. Therefore, the comparison of parameters was done with the result corresponding to minimum MRAE values of overall hydrographs and the flow duration curves. The respective C and the Sc values are 1.29 and 937.32 for the best matching hydrographs and the flow duration curves and gauging station density is 698km^2/station. These values are well within the literature reported values for the two-parameter monthly water balance model. The best Typical model was with a gauging density of 279 km^2/station. In this case the C and Sc values are 2.07 and 1496.10 respectively. In the work by Dissanayake (2017) the C and Sc values are 1.29 and 827.84 respectively.

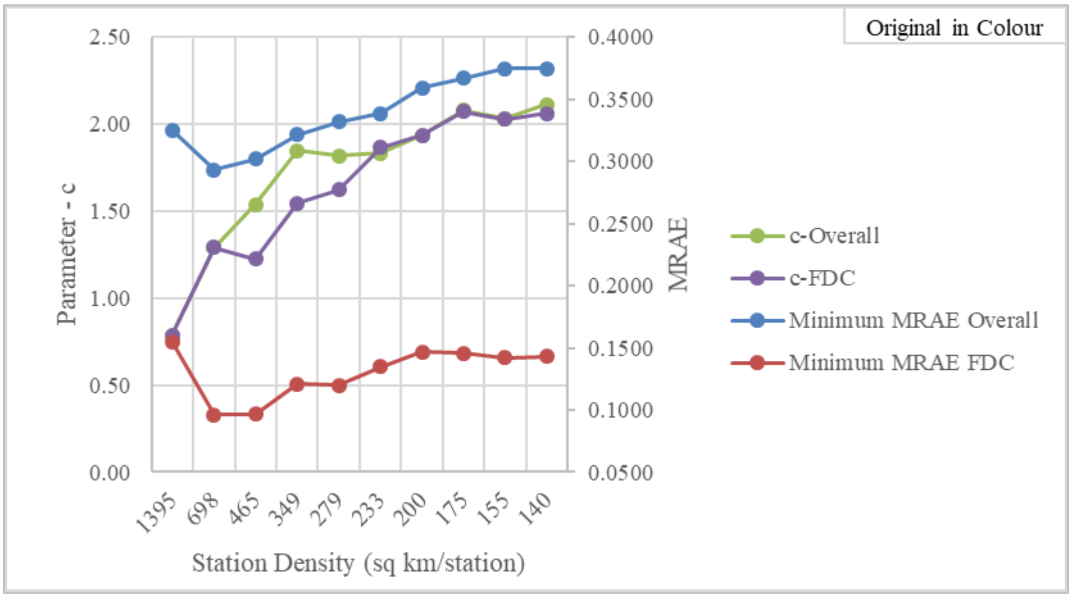

Figure 5-74: c and SC parameter variation in best matching hydrographs in different densities

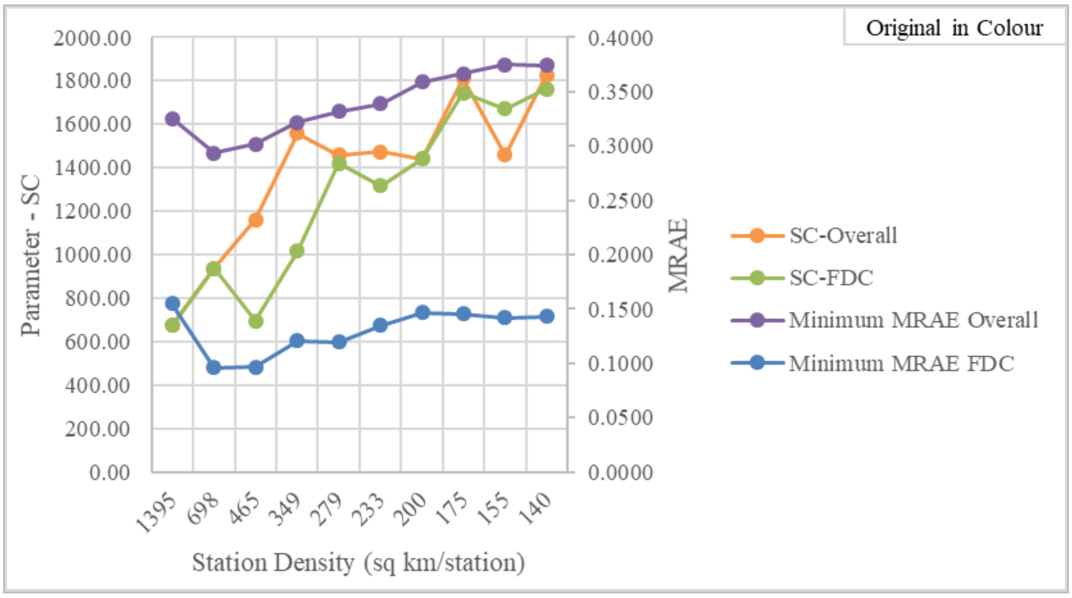

Figure 5-75: c and SC parameter variation in best matching flow duration curves in different densities

Table 5-21: c parameter variation of best matching hydrographs for different station densities

Station Density (km2 per station)	c-Overall	c-FDC	c-high flow	c-Intermediate flow	c-low flow	c-water balance	Minimum MRAE Overall	Minimum MRAE FDC
1395	0.79	0.79	2.53	0.79	0.79	3.13	0.3252	0.1549
698	1.29	1.29	2.58	1.98	1.29	3.12	0.2931	0.0963
465	1.54	1.23	2.69	2.19	1.23	1.97	0.3017	0.0966
349	1.85	1.54	2.56	1.83	1.64	2.00	0.3217	0.1210
279	1.82	1.62	2.59	1.83	1.62	2.12	0.3316	0.1197
233	1.83	1.86	2.07	1.89	1.83	2.14	0.3387	0.1350
200	1.94	1.94	2.02	2.07	2.08	2.16	0.3591	0.1464
175	2.08	2.07	1.90	2.15	2.03	1.90	0.3668	0.1455
155	2.03	2.03	2.03	2.11	2.03	2.03	0.3748	0.1422
140	2.11	2.06	2.03	2.11	2.06	2.03	0.3744	0.1429

Table 5-22: SC parameter variation of best matching flow duration curves for different station densities

Station Density (km2 per station)	SC-Overall	SC-FDC	SC-high flow	SC-Intermediate flow	SC-low flow	SC-water balance	Minimum MRAE Overall	Minimum MRAE FDC
1395	672.94	672.94	1945.48	672.94	672.94	3768.41	0.3252	0.1549
698	937.32	937.32	1857.79	1426.93	937.32	3695.42	0.2931	0.0963
465	1160.44	695.85	2271.01	2069.94	695.85	1287.65	0.3017	0.0966
349	1559.99	1017.67	1780.46	1183.77	1415.05	1266.79	0.3217	0.1210
279	1457.35	1419.52	1872.32	1173.92	1419.52	1531.32	0.3316	0.1197
233	1474.12	1315.51	1355.88	1371.60	1474.12	1338.02	0.3387	0.1350
200	1441.39	1441.39	1337.39	1377.60	1857.51	1472.92	0.3591	0.1464
175	1813.44	1744.73	1214.01	1955.33	1657.31	1214.01	0.3668	0.1455
155	1457.47	1671.72	1457.47	1919.91	1671.72	1659.66	0.3748	0.1422
140	1827.14	1762.53	1455.99	1827.14	1762.53	1455.99	0.3744	0.1429

5.3 Influence of Spatial Interpolation methods

5.3.1 General

As indicated in the section on methodology the computations were carried out to compare the spatial interpolation methods. The 5 and 8 station configurations used for the comparison are in Figure 5-76 to Figure 5-79 and Figure 5-80 to Figure 5-83 respectively.

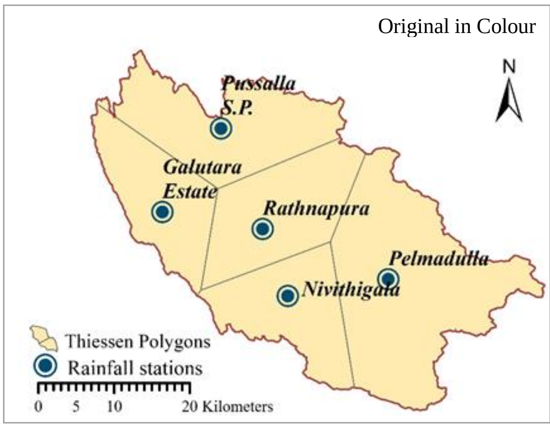

Figure 5-76: All stations inside the catchment (5 stations)

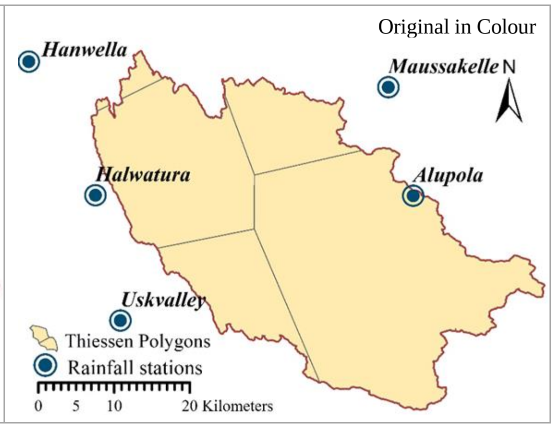

Figure 5-77: Maximum stations outside the catchment (5 stations)

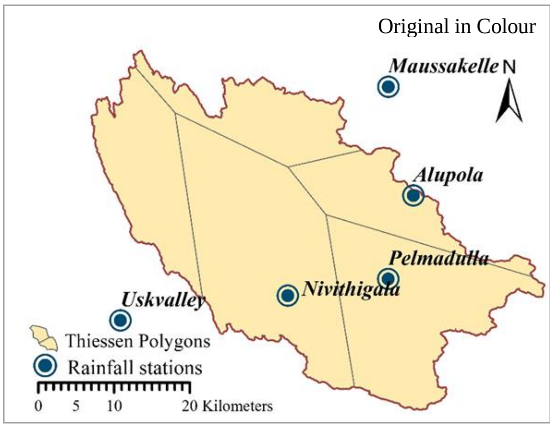

Figure 5-78: Most stations at the upstream of the catchment (5 stations)

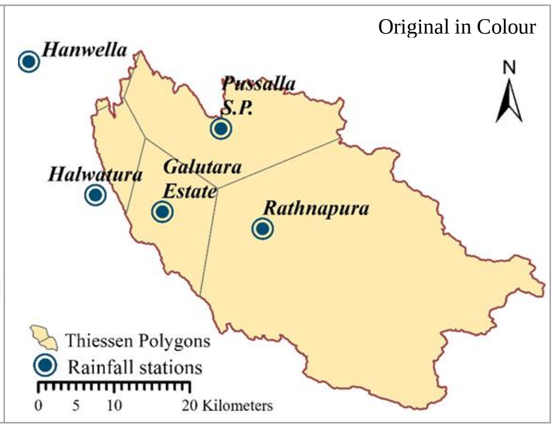

Figure 5-79: Most stations at the downstream of the catchment (5 stations)

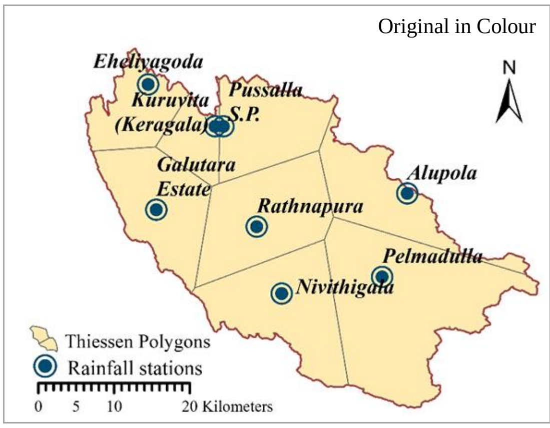

Figure 5-80: All stations inside the catchment (8 stations)

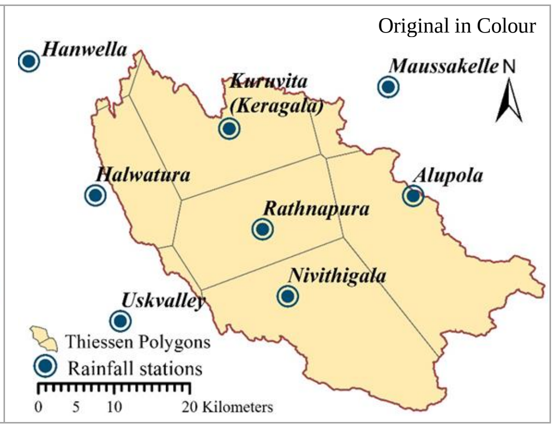

Figure 5-81: Maximum stations outside the catchment (8 stations)

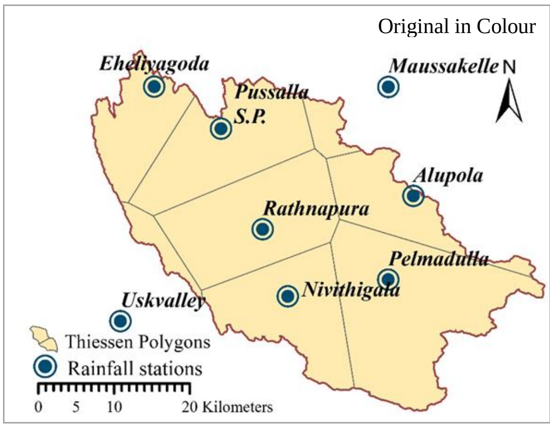

Figure 5-82: Most stations at the upstream of the catchment (8 stations)

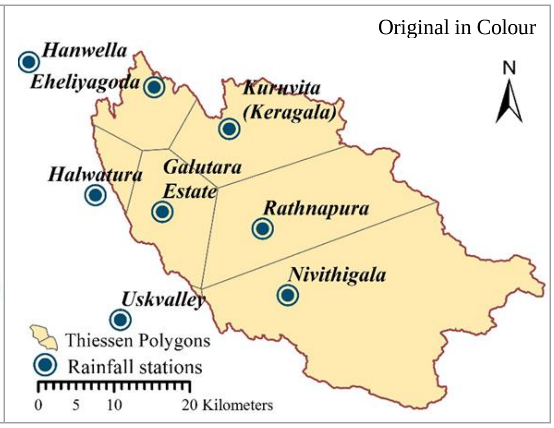

Figure 5-83: Most stations at the downstream of the catchment (8 stations)

The Thiessen weights corresponding to each case are showing Table 5-23.

The spatial averages in each method were computed by using GIS models. In case of different station selections, the GIS model computed a rainfall surface over the catchment area as shown in Figure 5-84.

Using the GIS models of ArcGIS Model Builder 96 monthly rainfall surfaces were developed for each method. Figure 5-84 shows the spatial variation of rainfall in the months of January 2010 computed by seven different interpolation methods use for this comparative study. According to the results it indicated that both the Spline methods generates negative rainfall for the most upstream edges (south and south-eastern edges). Spline 1 shows more negative values than Spline 2.

Table 5-23: Thiessen weights of station configurations for spatial averaging method evaluation

Rain Gauging Stations	5 Station Configurations				8 Station Configurations			
	All inside	Maximum outside	Upstream	Downstream	All inside	Maximum outside	Upstream	Downstream
Alupola		0.53	0.11		0.10	0.24	0.10	
Nivithigala	0.15		0.34		0.15	0.27	0.15	0.44
Pelmadulla	0.35		0.27		0.27		0.27	
Rathnapura	0.17			0.66	0.14	0.18	0.19	0.22
Eheliyagoda S.P.					0.07		0.10	0.07
Galutara Estate	0.14			0.10	0.12			0.10
Pussalla S.P.	0.20			0.19	0.04		0.16	
Kuruvita (Keragala)					0.11	0.19		0.15
Halwatura		0.25		0.04		0.09		0.03
Uskvalley		0.11	0.16			0.009	0.02	0.001
Hanwella		0.01		0.003		0.005		
Maussakelle		0.10	0.12			0.02	0.02	

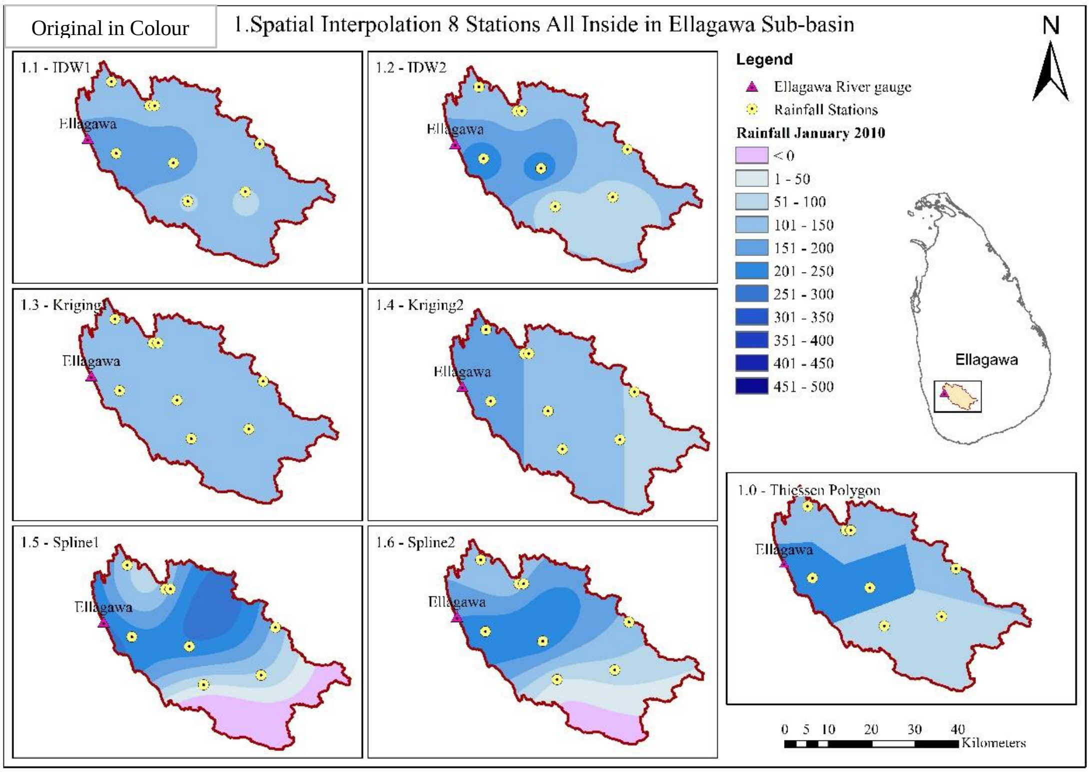

Figure 5-84: Rainfall surface over the catchment - Example: 8 stations inside the catchment selection on January 2010

These rainfall inputs were then used to calibrate the 2-parameter model for each configuration. Summary of the rainfall inputs from the selected averaging methods were aggregated to annual, seasonal and monthly temporal resolutions.

5.3.2 Annual Areal Rainfall

Annual average areal rainfall variation of Ellagawa watershed over the entire study period is in Figure 5-85. The average values and deviation between each configuration for each interpolation method is in ANNEX G - Table G - 1.

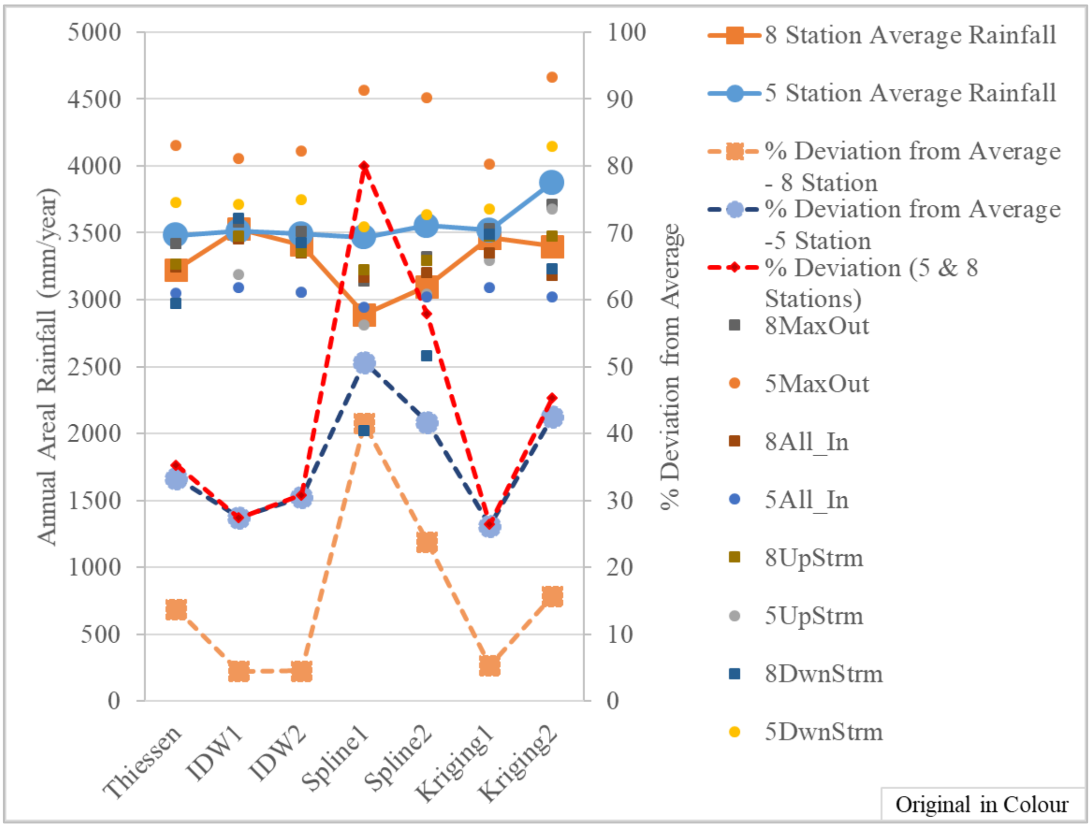

Figure 5-85: Average Annual rainfall variation

Annual average rainfall value range from 5 station (279 km^2/station) and 8 station (175km^2/station) configurations varied as 2808 – 4667mm/year and 2024 – 3712mm/year for respective configurations.

Maximum deviation of rainfall value for each method and for each configuration was computed. The percentage deviation from the average of each configuration was also computed.

Each method showed considerable deviation of annual rainfall value from various station configurations having the same density. In the annual values the 279km^2/station density (5-station) showed a higher deviation with 175 km^2/station density (8-station) in case of all spatial averaging methods.

For both station densities, highest % deviation was identified by Spline-1 method while both IDW methods and Kriging 1 method showed low deviation values. However for the 279 km^2/station density (5 station), rainfall from various methods had a relatively small difference between them while for the density of 175 km^2/station (8 station) in between differences are higher.

5.3.3 Maha Season Rainfall

Maha season average areal rainfall variation of Ellagawa watershed over the entire study period is in Figure 5-86. The values and deviation between each configuration for each interpolation method is in ANNEX G - Table G - 2.

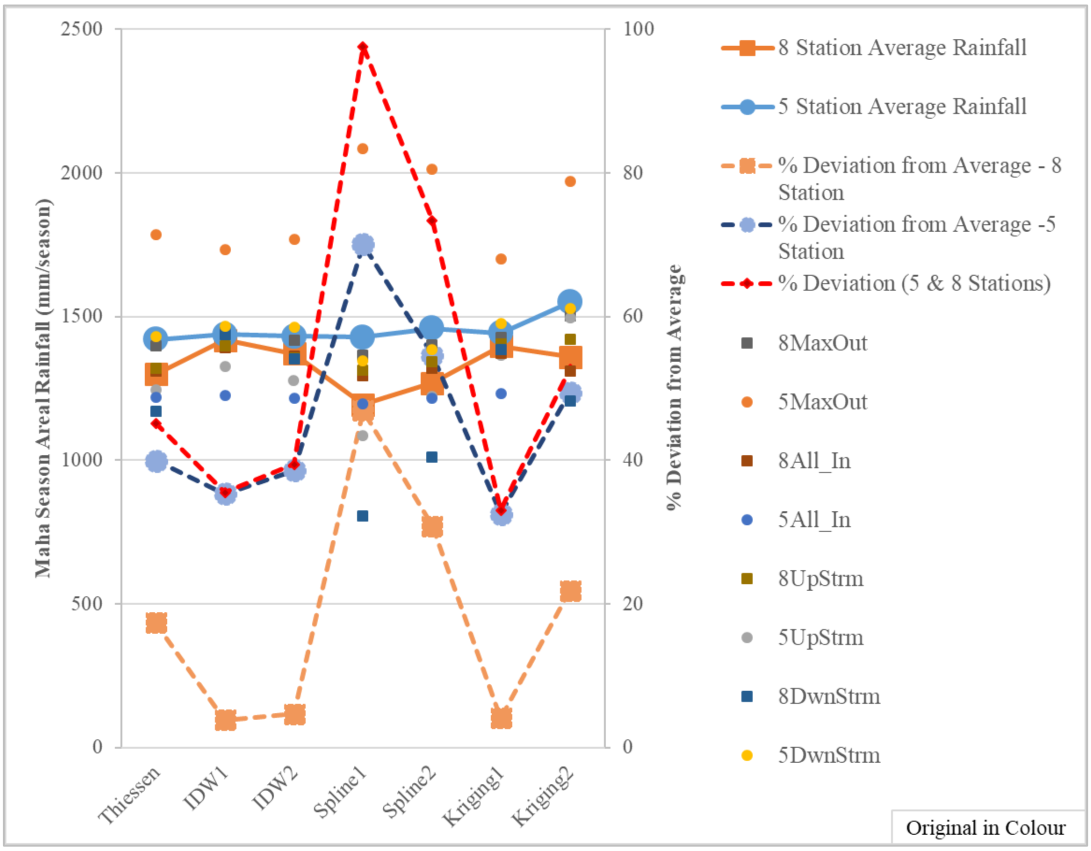

Figure 5-86: Average Maha season rainfall variation

Maha season average rainfall value range from 5 station (279 km^2/station) and 8 station (175 km^2/station) configurations varied as 1084 – 2084 mm/season and 806 – 1502 mm/season for respective configurations.

Similar to the annual rainfall, maximum deviation of rainfall value for each method and for each configuration and the percentage deviation from average of each configuration were computed. For both station densities, highest % deviation was identified by Spline-1 method while IDW and Kriging 1 methods showed low deviation values. However a significant reduction in % deviation from average is identified for the density of 175 km^2/station (8 station) than the density of 279km^2/station (5 station).

5.3.4 Yala Season Rainfall

Yala season average areal rainfall variation of Ellagawa watershed over the entire study period is in Figure 5-87. The values and deviation between each configuration for each interpolation method is in ANNEX G - Table G - 3.

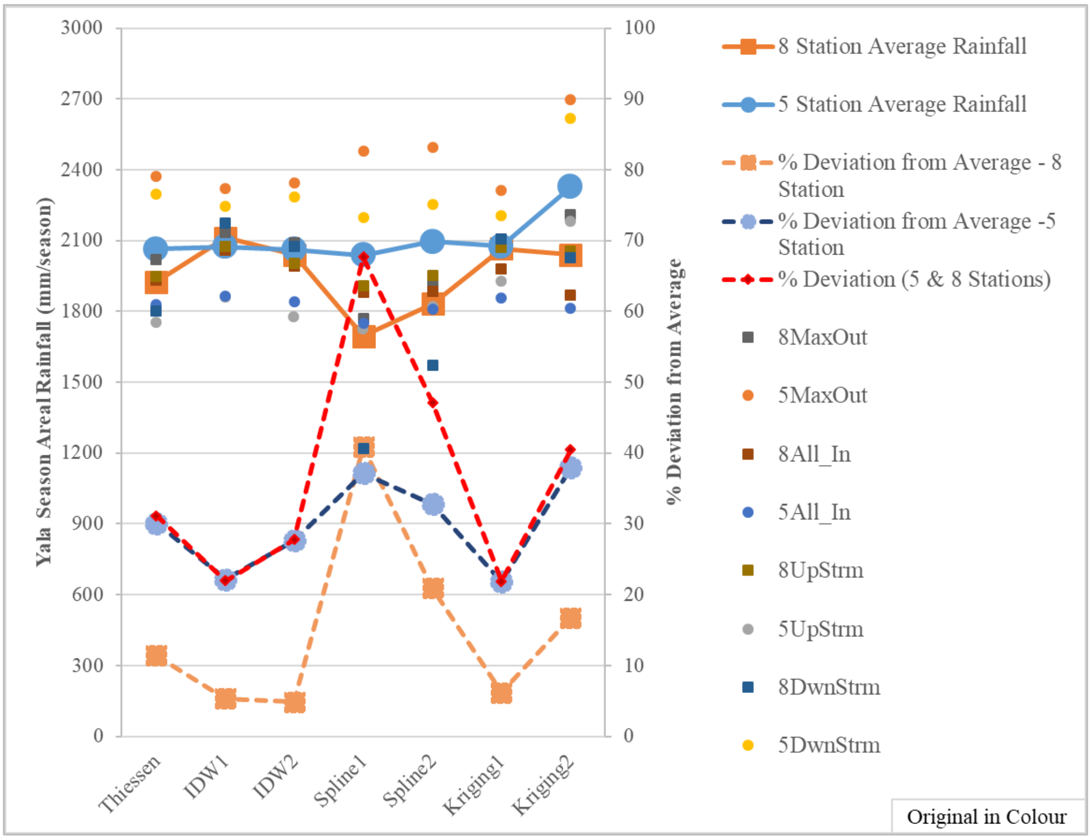

Figure 5-87: Average Yala season rainfall variation

Yala season average rainfall value range from 5 station (279 km^2/station) and 8 station (175 km^2/station) configurations varied as 1724 – 2696 mm/season and 1218 – 2211 mm/season for respective configurations.

Similar to the annual and Maha seasonal rainfall, maximum deviation of rainfall value for each method and for each configuration and the percentage deviation from average of each configuration were computed. For both station densities, highest deviation and % deviation was identified by Spline-1 method while Kriging 1 method showed lowest deviation values. Behavior of the variation of deviation is similar in both the Spline methods but different with the other methods as same as for annual and Maha season.

5.3.5 Watershed Response

5.3.5.1 General

Evaluation of the suitability of areal averaging method was done by comparing the runoff response resulted from each rainfall input. As described in the section on methodology the RR option calibrated the 2 Parameter model for each areal rainfall monthly time series derived using the 8 selected methods and for the station configurations corresponding to the density 279 km^2/station (5 station) and 175km^2/station (8 station).

Streamflow hydrograph matching was compared by computing the MRAE for the overall hydrographs, Flow duration curves, High, intermediate, low flows and annual water balance. Evaluation of high, intermediate and low flows was done by segmenting the flow duration curve using the % time of exceedance. High and low flow thresholds were taken as 20% and 60% time of exceedance respectively (Wijesekera, 2018). The flow occurring with a % time of exceedance between the thresholds were categorized as intermediate flows. Variation of MRAE in case of both station densities and corresponding comparative station configurations are discussed below.

5.3.5.2 Overall Hydrograph Comparison

Variation of MRAE corresponding to overall Hydrograph matching with rainfall input from the selected spatial interpolation methods are in Figure 5-88 and Figure 5-89. The summary of MRAE results are in Table 5-24.

Similar to the rainfall deviation Spline method shows the highest deviation in the MRAE. Compared to other configurations, when maximum stations outside the catchment (when 5 stations selected) shows highest streamflow estimation error. The minimum MRAE also obtained when 8 stations selected from most downstream of the catchment and with Spline tension method (Figure 5-88). However MRAE minimum shows a very little deviation when compared with each spatial averaging method.

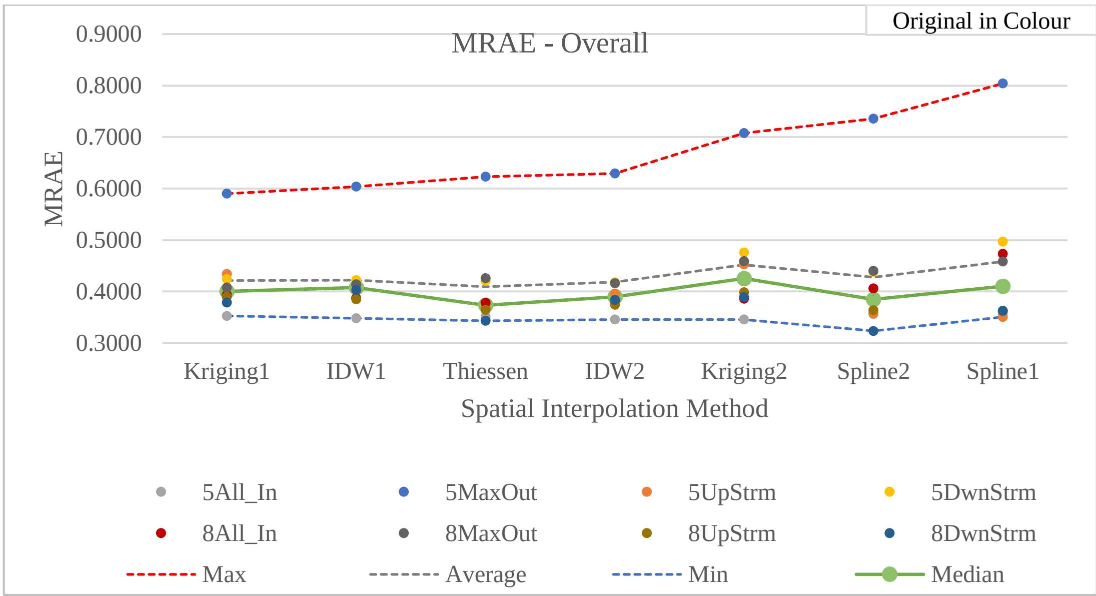

Figure 5-88: Behaviour of Streamflow hydrograph matching MRAE Variation for different station configuration

The maximum mismatching is when the station density is 279 km^2/station (5 station) and for the station layout when all stations are outside or close to the boundary of watershed. Minimum MRAE values which demonstrated the cases of best fit hydrographs, were mostly with 279 km^2/station density (5 station) and when all stations are within the watershed.

Comparison of average MRAE values from station layouts corresponding to both densities reveal that for both gauging station densities the overall hydrograph matching is not sensitive to a particular spatial averaging method (Figure 5-88).

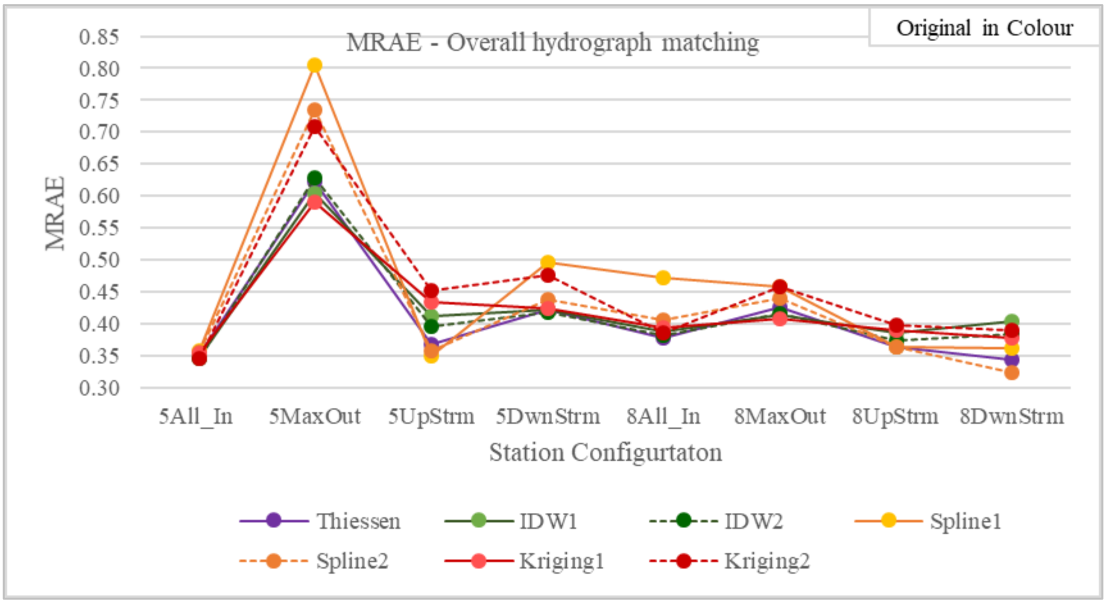

Figure 5-89: Behaviour of Streamflow hydrograph matching MRAE in different spatial interpolation methods

Table 5-24: Summary of Streamflow hydrograph matching MRAE

MRAE - Overall	**Kriging1**	**IDW1**	**Thiessen**	**IDW2**	**Kriging2**	**Spline2**	**Spline1**
5All_In	0.3525	0.3478	0.3511	0.3454	0.3455	0.3563	0.3579
5MaxOut	0.5900	0.6036	0.6231	0.6292	0.7076	0.7353	0.8039
5UpStrm	0.4336	0.4123	0.3683	0.3957	0.4522	0.3574	0.3504
5DwnStrm	0.4239	0.4220	0.4207	0.4176	0.4753	0.4378	0.4964
8All_In	0.3933	0.3868	0.3780	0.3823	0.3856	0.4058	0.4728
8MaxOut	0.4074	0.4138	0.4259	0.4159	0.4586	0.4401	0.4581
8UpStrm	0.3895	0.3849	0.3642	0.3739	0.3985	0.3633	0.3625
8DwnStrm	0.3781	0.4028	0.3428	0.3835	0.3888	0.3233	0.3622
Max	0.59	0.60	0.62	0.63	0.71	0.74	0.80
Average	0.42	0.42	0.41	0.42	0.45	0.43	0.46
Min	0.35	0.35	0.34	0.35	0.35	0.32	0.35
Median	0.40	0.41	0.37	0.39	0.43	0.38	0.41
Deviation	**0.24**	**0.26**	**0.28**	**0.28**	**0.36**	**0.41**	**0.45**

The same insensitivity could be seen with respect to the station layouts other than when all stations were outside in the case of 279 km^2/station density (5 station) (Figure 5-89).

5.3.5.3 Flow Duration Curve Comparison

MRAE with respect to flow duration curve matching are shown in Figure 5-90 and Table 5-25. In this too, the average model performance was quite similar irrespective of the method of spatial averaging except for the maximum error scenario which was when the station density was 279 km^2/station density (5 station) and all stations were outside the boundary.

In general, the spatial averaging method appears relatively insensitive for both gauging station densities.

5.3.5.4 Comparison of Flow Categories

Comparison of the effect areal averaging rainfall from the selected computing methods with the high flow (Figure 5-91, Table 5-26) intermediate flow (Figure 5-92, Table 5-27) and low flow (Figure 5-93, Table 5-28) also show that except for the all stations outside scenario the rest indicate a very low effect on the streamflow matching. Therefore, the order of magnitude of these differences were evaluated by computing water balance.

5.3.5.5 Water Balance Comparison

Comparison of percentage estimation error of water balance corresponding to each spatial averaging method is shown in Figure 5-94 and Table 5-29.

Results indicated a similar small deviation for Thiessen, both Kriging methods, both IDW methods and Spline tension methods. However, Spline regularized method shows an exceptionally high deviation of approximately 60%, while the deviation of others varies between 8 and 16%.

Table 5-25: Summary of Flow duration curve matching MRAE

MRAE FDC	Kriging1	IDW1	IDW2	Thiessen	Spline1	Spline2	Kriging2
5All_In	0.1381	0.1429	0.1416	0.1432	0.1366	0.1292	0.1633
5MaxOut	0.1562	0.1521	0.2000	0.2666	0.3306	0.3206	0.3760
5UpStrm	0.1540	0.1492	0.1505	0.1391	0.1228	0.1262	0.1693
5DwnStrm	0.1590	0.1599	0.1611	0.2050	0.2419	0.2184	0.2091
8All_In	0.1525	0.1549	0.1552	0.1644	0.2210	0.1523	0.1535
8MaxOut	0.1569	0.1474	0.1597	0.1662	0.1125	0.1298	0.1793
8UpStrm	0.1778	0.1829	0.1635	0.1495	0.1362	0.1536	0.1522
8DwnStrm	0.1487	0.1490	0.1524	0.1366	0.1679	0.1018	0.1529
Max	0.18	0.18	0.20	0.27	0.33	0.32	0.38
Average	0.16	0.15	0.16	0.17	0.18	0.17	0.19
Min	0.14	0.14	0.14	0.14	0.11	0.10	0.15
Median	0.16	0.15	0.16	0.16	0.15	0.14	0.17
Deviation	**0.04**	**0.04**	**0.06**	**0.13**	**0.22**	**0.22**	**0.22**

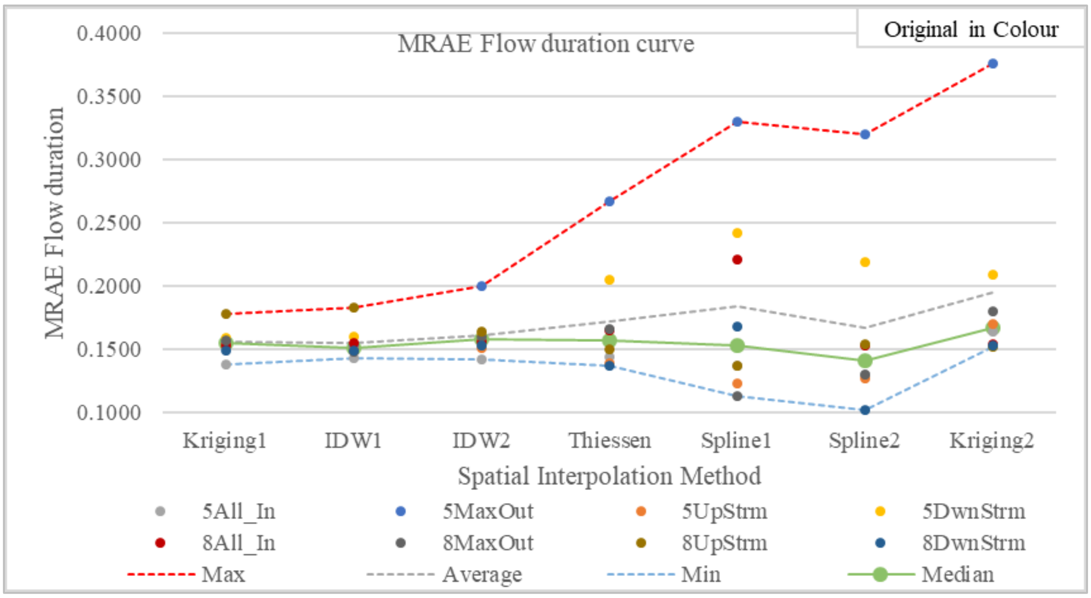

Figure 5-90: Flow Duration Curve fitting MRAE variation

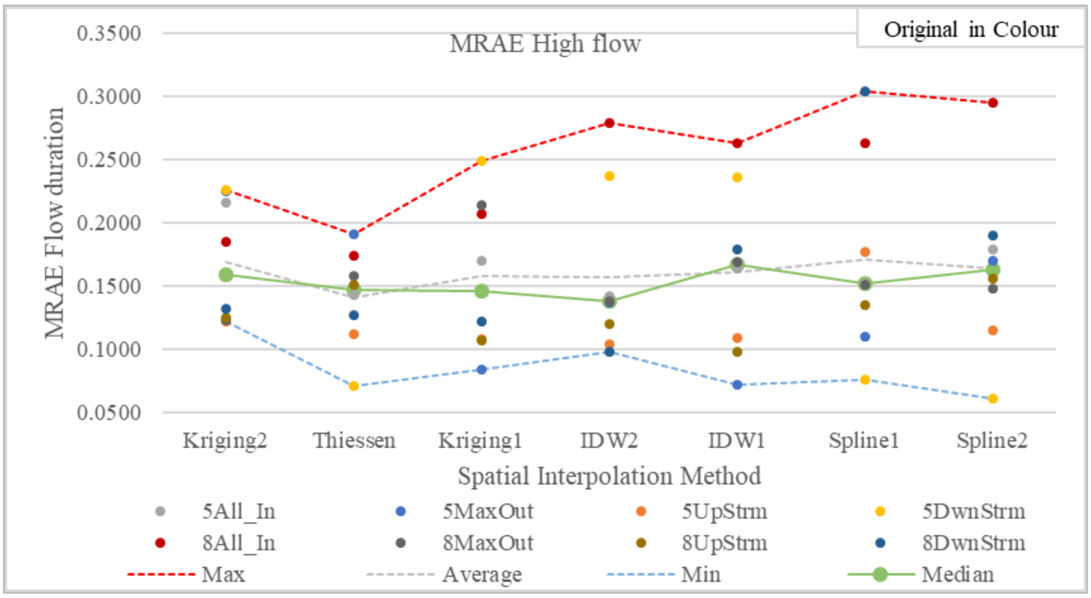

Figure 5-91: MRAE variation for high flows

Table 5-26: Summary of High flow MRAE

MRAE HF	Kriging2	Thiessen	Kriging1	IDW2	IDW1	Spline1	Spline2
5All_In	0.2156	0.1429	0.1702	0.1423	0.1637	0.1519	0.1791
5MaxOut	0.2249	0.1906	0.0836	0.1367	0.0714	0.1098	0.1703
5UpStrm	0.1220	0.1120	0.1079	0.1034	0.1090	0.1774	0.1150
5DwnStrm	0.2265	0.0704	0.2489	0.2368	0.2362	0.0756	0.0605
8All_In	0.1851	0.1740	0.2074	0.2787	0.2632	0.2627	0.2952
8MaxOut	0.1230	0.1580	0.2137	0.1380	0.1692	0.1512	0.1473
8UpStrm	0.1252	0.1507	0.1067	0.1197	0.0977	0.1351	0.1560
8DwnStrm	0.1317	0.1270	0.1215	0.0975	0.1788	0.3041	0.1902
Max	0.23	0.19	0.25	0.28	0.26	0.30	0.30
Average	0.17	0.14	0.16	0.16	0.16	0.17	0.16
Min	0.12	0.07	0.08	0.10	0.07	0.08	0.06
Median	0.16	0.15	0.15	0.14	0.17	0.15	0.16
Deviation	**0.10**	**0.12**	**0.17**	**0.18**	**0.19**	**0.23**	**0.23**

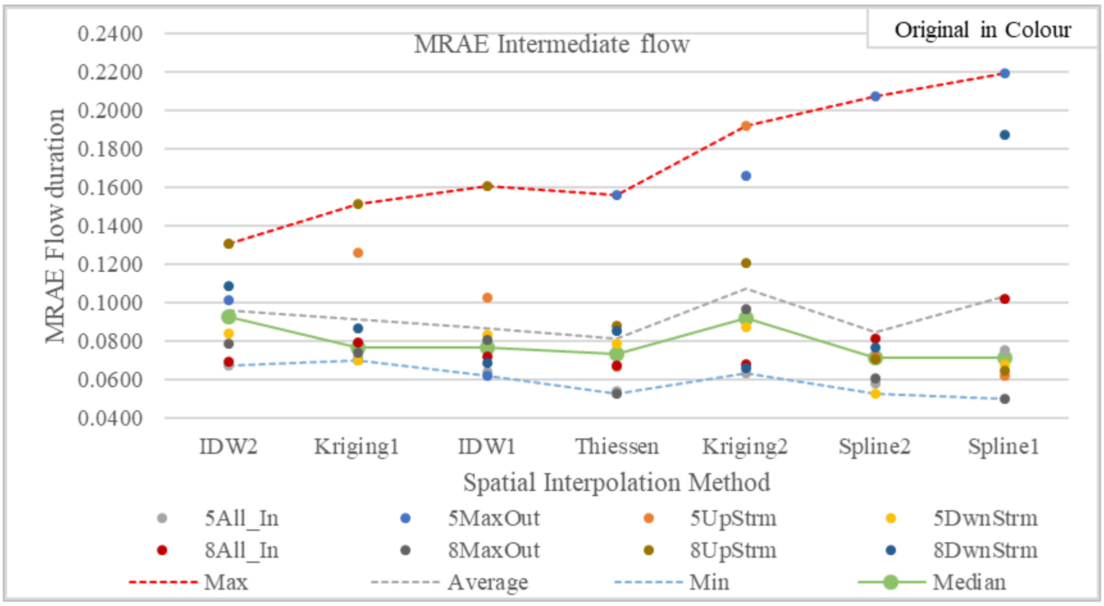

Figure 5-92: MRAE variation for intermediate flows

Table 5-27: Summary of Intermediate flow MRAE

MRAE IMF	IDW2	Kriging1	IDW1	Thiessen	Kriging2	Spline2	Spline1
5All_In	0.0670	0.0709	0.0639	0.0535	0.0629	0.0578	0.0750
5MaxOut	0.1011	0.0699	0.0619	0.1561	0.1662	0.2078	0.2195
5UpStrm	0.1303	0.1261	0.1025	0.0666	0.1924	0.0721	0.0620
5DwnStrm	0.0835	0.0698	0.0831	0.0784	0.0869	0.0522	0.0679
8All_In	0.0689	0.0793	0.0718	0.0672	0.0677	0.0813	0.1021
8MaxOut	0.0788	0.0741	0.0805	0.0524	0.0968	0.0606	0.0496
8UpStrm	0.1303	0.1516	0.1607	0.0878	0.1204	0.0703	0.0645
8DwnStrm	0.1083	0.0864	0.0686	0.0850	0.0660	0.0763	0.1874
Max	0.13	0.15	0.16	0.16	0.19	0.21	0.22
Average	0.10	0.09	0.09	0.08	0.11	0.08	0.10
Min	0.07	0.07	0.06	0.05	0.06	0.05	0.05
Median	0.09	0.08	0.08	0.07	0.09	0.07	0.07
Deviation	**0.06**	**0.08**	**0.10**	**0.10**	**0.13**	**0.16**	**0.17**

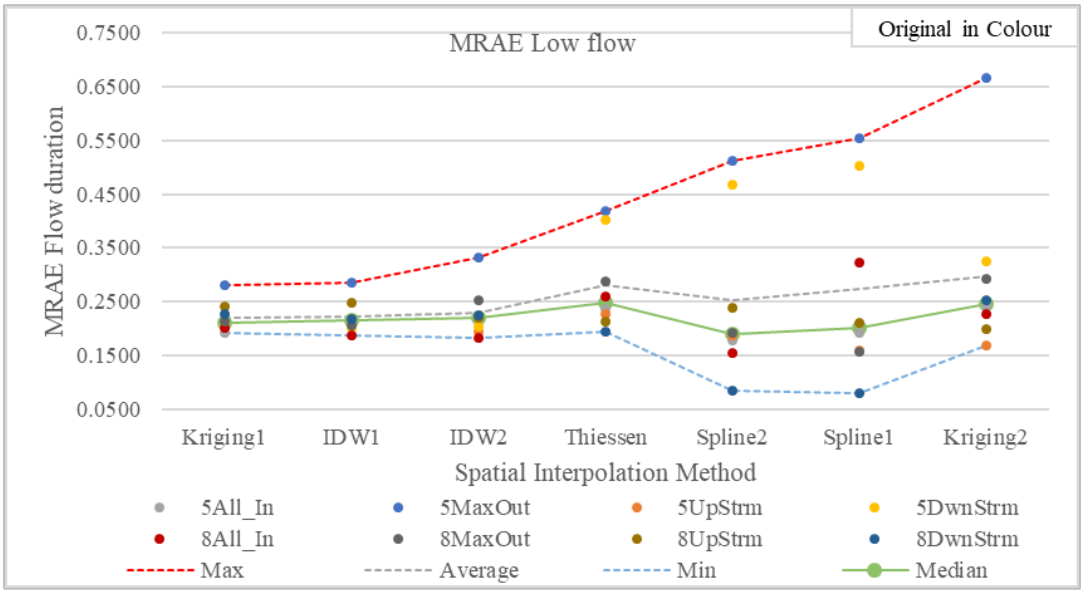

Figure 5-93: MRAE variation for low flows

Table 5-28: Summary of Low flow MRAE

MRAE LF	**Kriging1**	**IDW1**	**IDW2**	**Thiessen**	**Spline2**	**Spline1**	**Kriging2**
5All_In	0.1910	0.2135	0.2177	0.2354	0.1776	0.1923	0.2402
5MaxOut	0.2810	0.2851	0.3331	0.4181	0.5115	0.5551	0.6670
5UpStrm	0.2058	0.2171	0.1948	0.2270	0.1875	0.1579	0.1692
5DwnStrm	0.2056	0.2007	0.2028	0.4023	0.4680	0.5038	0.3257
8All_In	0.2003	0.1861	0.1821	0.2594	0.1537	0.3223	0.2258
8MaxOut	0.2136	0.2052	0.2536	0.2871	0.1920	0.1576	0.2920
8UpStrm	0.2402	0.2482	0.2196	0.2122	0.2380	0.2103	0.1982
8DwnStrm	0.2261	0.2167	0.2252	0.1942	0.0838	0.0797	0.2526
Max	0.28	0.29	0.33	0.42	0.51	0.56	0.67
Average	0.22	0.22	0.23	0.28	0.25	0.27	0.30
Min	0.19	0.19	0.18	0.19	0.08	0.08	0.17
Median	0.21	0.22	0.22	0.25	0.19	0.20	0.25
Deviation	**0.09**	**0.10**	**0.15**	**0.22**	**0.43**	**0.48**	**0.50**

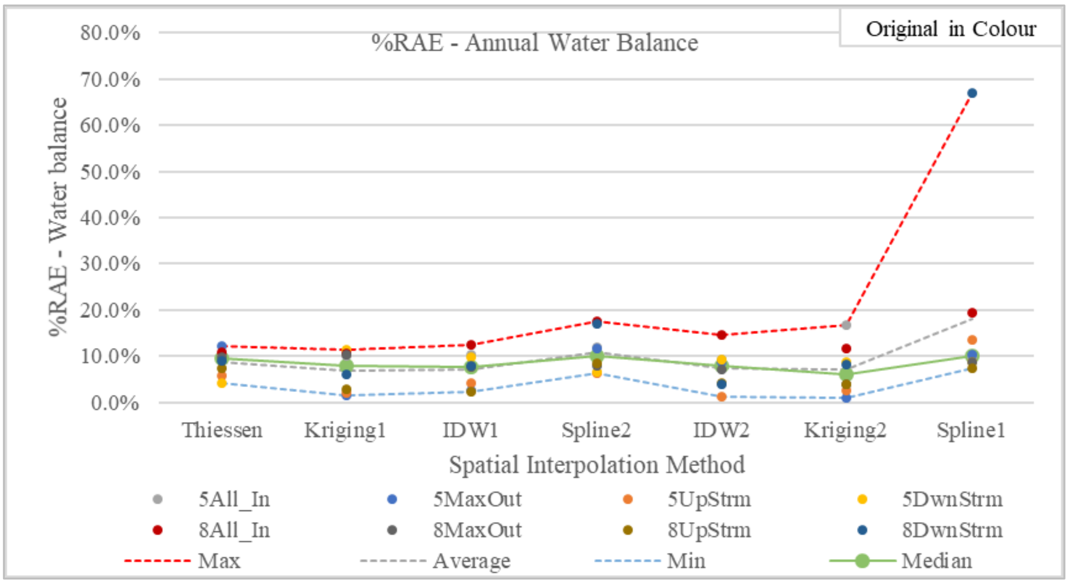

Figure 5-94: Behaviour of %RAE variation for Water Balance

Table 5-29: Summary of %RAE variation for Water Balance

%RAE - Annual Water Balance	**Thiessen**	**Kriging1**	**IDW1**	**Spline2**	**IDW2**	**Kriging2**	**Spline1**
5All_In	9.9%	10.0%	10.3%	11.8%	9.2%	16.6%	9.7%
5MaxOut	12.2%	1.5%	2.5%	11.7%	8.7%	1.0%	10.3%
5UpStrm	5.8%	2.1%	4.2%	6.3%	1.2%	2.6%	13.5%
5DwnStrm	4.2%	11.3%	9.7%	6.6%	9.4%	8.6%	8.7%
8All_In	10.8%	10.6%	12.4%	17.6%	14.6%	11.7%	19.5%
8MaxOut	9.9%	10.3%	7.6%	8.0%	7.0%	3.9%	8.7%
8UpStrm	7.4%	2.9%	2.2%	8.4%	4.3%	3.8%	7.4%
8DwnStrm	9.1%	6.1%	7.8%	16.9%	3.8%	8.3%	67.1%
Max	12.2%	11.3%	12.4%	17.6%	14.6%	16.6%	67.1%
Average	8.7%	6.8%	7.1%	10.9%	7.3%	7.1%	18.1%
Min	4.2%	1.5%	2.2%	6.3%	1.2%	1.0%	7.4%
Median	9.5%	8.0%	7.7%	10.1%	7.8%	6.1%	10.0%
Deviation	8.02%	9.76%	10.21%	11.34%	13.39%	15.62%	59.65%

5.3.5.6 Comparison of Magnitudes

The magnitude of average streamflow estimation difference over the study period for each type of input are shown in Figure 5-95 and Figure 5-96. Average streamflow values for annual seasonal and monthly in each station configurations are in ANNEX G - Table G - 4.

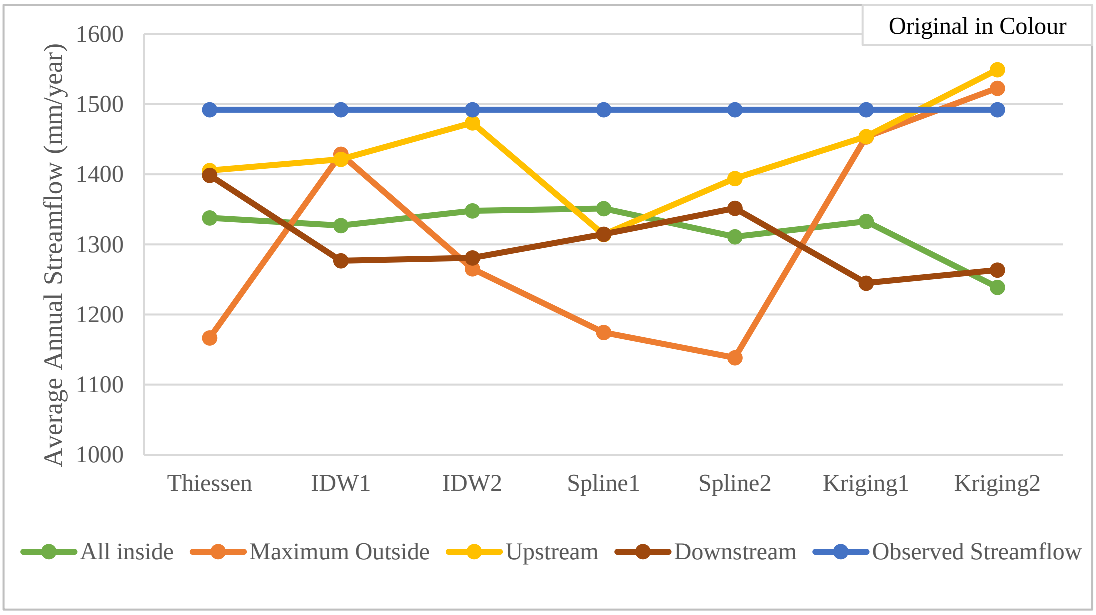

Figure 5-95: Annual average streamflow variation for 5 station configurations

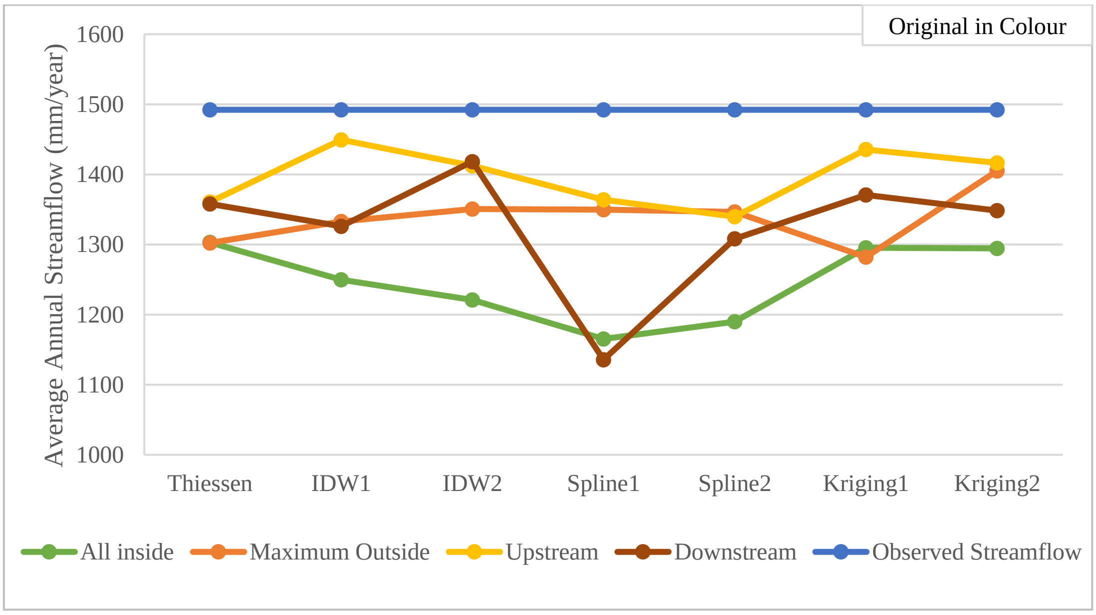

Figure 5-96: Annual average streamflow variation for 8 station configurations

5.3.6 Rainfall Processing Time (RT)

The evaluation of processing times indicated that lowest time-consuming method is Thiessen polygon method while the highest time consumption methods are Kriging methods. The time required to process the rainfall surfaces varies with the processing computers performance, a model development time result estimation time etc., thus the values in Table 5-30 are indicative only.

Computations of time for IDW, Spline and Kriging was done with the help of built in function of ArcGIS Model Builder. Time for Thiessen method using MS Excel assumed a manual methodology.

A preferential rank for the spatial averaging method was given by considering the total time requirements for surface creation and data stacking actions

5.3.7 Parameter Variation

Parameter variation during model calibration for each rainfall input are shown in Figure 5-97 and Figure 5-98. The average parameter value variation for each method are shown in Table 5-31.

Table 5-30: Processing times for all rainfall surfaces

Time (seconds)	**IDW1**	**IDW2**	**Spline1**	**Spline2**	**Kriging1**	**Kriging2**	**Thiessen**
Create surfaces	794.01	768.67	935.01	834.89	1638.74	1842.91	12.83
Total time for Stacking	858.89	860.17	857.44	848.20	855.36	867.04	96.02
Total time	1652.90	1628.84	1792.45	1683.09	2494.10	2709.95	108.85
Total time (minutes)	***27.55***	***27.15***	***29.87***	***28.05***	***41.57***	***45.17***	***1.81***
Rank	***3***	***2***	***5***	***4***	***6***	***7***	***1***

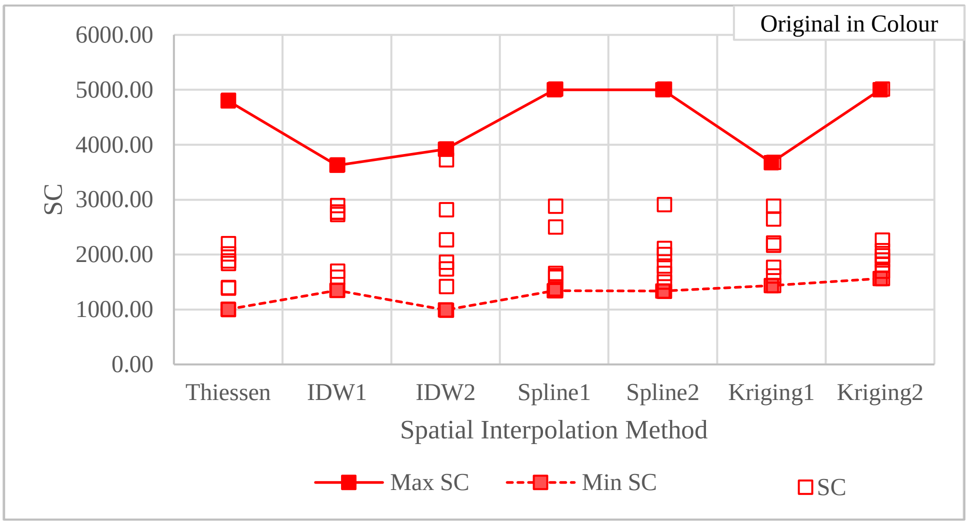

Figure 5-97: Parameter SC variation in different spatial interpolation methods

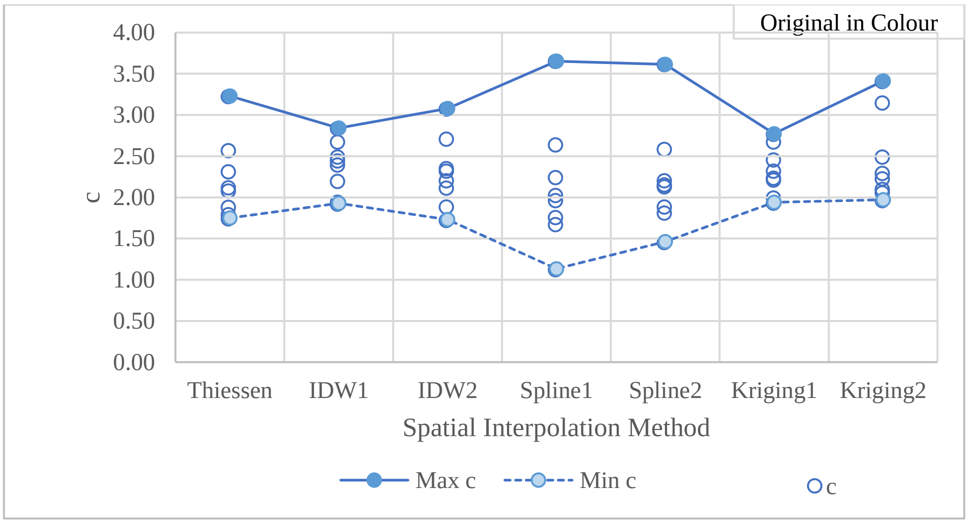

Figure 5-98: Parameter c variation in different spatial interpolation methods

Table 5-31: Parameter c and SC variation in each spatial interpolation methods

Spatial Interpolation Method	**c**			**SC**		
	Max c	**Avg c**	**Min c**	**Max SC**	**Avg SC**	**Min SC**
Thiessen	3.23	2.22	1.75	4798.61	2065.61	1003.17
IDW1	2.84	2.37	1.93	3623.82	2426.40	1349.46
IDW2	3.08	2.30	1.73	3917.00	2340.95	991.70
Spline1	3.65	2.14	1.13	5000.00	2244.80	1342.36
Spline2	3.62	2.24	1.46	5000.00	2287.48	1335.33
Kriging1	2.77	2.33	1.94	3672.92	2298.15	1436.77
Kriging2	3.41	2.47	1.97	5000.00	2285.48	1564.53

6 DISCUSSION

6.1 State of art Rain Gauge Selection

The comprehensive review of guidelines, textbooks and reviewed publications revealed that there are many gaps with regards to the gauging station selection. This research was mainly to capture the station density that should be adhered to when computing areal average rainfall of a watershed. Determination of station density requires the fulfillment of many other attributes to ensure that rainfall stations are contributing to the watershed rainfall.

With respect to the computation of station density, none of the literature clearly indicated the specifics about the location of stations. A researcher attempting to identify the number of stations would like to ascertain the distribution and proximity of stations to the concerned watershed. The next is the proximity of one station to another. Though there are a few literature on these aspects, it is important to provide a clear guidance for water management practitioners to appropriately select the gauging stations.

The other important factor is the lack of importance given to ensure the publication of rainfall gauging station number, distribution, method of selection etc., in reviewed publications and other important documents. Such information is vital for the study of the representativeness of rainfall input and the constraints faced not only when planning and design of water infrastructures, but also when making policy decisions. The rain-gauge density and distribution corresponding to catchment size, climate, topography etc., needs more attention for better watershed modelling work.

In practice, where there is a need for ungauged watersheds to be modelled, one requires the determination of appropriate station density. On the other hand, the most rational option for gauging station selection is the rainfall input for a watershed model to reproduce streamflows.

Recognizing the above mentioned factors as the key requirements, the present work contributed to the identification of gauging stations by considering rainfall only option, rainfall-runoff modelling option and then comparing station layouts.

6.2 State of art Spatial Averaging Method

Advances in GIS computational methods has given rise to many spatial data interpolation methods. The review of literature carried out for the present work revealed that though there are many methods for areal averaging of spatial data, the recommendations with respect to rainfall vary widely. Literature revealed that the influence of a method may vary depending on the station density, station layout, rainfall extremes and spatial distribution. The literature review in this study did not lead to a clear recommendation. However, most of the literature had used the Thiessen averaging method. The present work selected the mostly practiced spatial averaging methods to make a contribution towards the knowledgebase on areal averaging method for rainfall data.

6.3 Gauging Station Selection

Evaluation of state of art revealed that there is a lack of guidance to determine the adequacy of the number of stations and that mostly used methodology is Thiessen averaging method.

Station selection for this study was done by satisfying the recommendations in the WMO guide No.168, Indian Standard: 4987 and considering current practices for Kalu basin. After considering, conclusion in the study of Sangamon River, Illinois (Chow, 1978), density with one station per catchment was also considered to analyze the uncertainties which were noted by Faurès et al. (1995) and MacKenzie et al. (2007).

Rainfall stations for this study were selected from within the catchment and outside the catchment. Main consideration of the selections was limitation of data availability. Stations with more than 10% of missing were not considered for the analysis. Maintaining the uniform spatial variation, eight stations within the catchment and four stations outside the catchment were selected to find combinations with different density. Out of four stations which are outside the catchment, two belongs to Kalu basin and other two belongs to Kelani Basin. The least missing data period (5%) was selected by filling the gaps with neighbouring stations to obtained a reliable analysis. Though outside stations were selected, the influence reflected by Thiessen weights were minimal except for the gauging station Halwatura.

6.4 Station Density- Rainfall Only Option

6.4.1 General

In this investigation 12 gauging stations in the Kalu river basin fitting to many configurations were used to study the areal average rainfall of Ellagawa watershed. This was the most dense station set that was available due to constraints such as missing data and proximity to watershed. Ellagawa watershed in the wet zone of Sri Lanka, receiving rain from North-East and South-West monsoons revealed that the areal average rainfall value converges to a consistent value with increasing station density, irrespective of the station layout. Results showed that beyond a threshold density of 175 km^2/station the deviation of annual average rainfall value becomes less than 3%. Also, the deviation of seasonal and monthly values decreases beyond 2, 4 and 3% percentages for Maha, Yala and Monthly averages for any of the configurations when the stations are denser than 175 km^2/station.

6.5 Influence of Station Density

6.5.1 Rainfall Only Option

6.5.1.1 Rainfall variation in density variation

The annual average rainfall varies from approximately 5771 to 1789 for 1 to 10 station densities in 2006 to 2013 water years. Classification of rainfall from 1500 – 5771mm with incrementing equal classes of 500mm upto 5000mm with >5000mm indicated that variations of 3000-3500mm for 2007, 2008, 2009, 2010 and 2013, 2500-3000mm for 2006, 2000-2500mm for 2011 and 3500-4000mm for 2012 with 100% probability in which 8 station or more station selection for their configuration. Though the rainfall varies in different years, in different configurations with 8 stations or above, the deviation showed a consistency in each year compared to when less than 8 stations were selected. Analysis of seasonal and monthly rainfall also indicated the similar pattern of consistency in the selection of 8 or more stations with low variation.

6.5.1.2 Measurements of Deviations

A simple deviation classification with a probabilistic analysis of deviation measures was considered to evaluate the sensitivity of deviation. The sensitivity of rainfall measures was obtained through a simple index, i.e. deviation of the rainfall estimates with respect to the minimum of density category. The deviation of rainfall with respect to the minimum of density consideration varied 223% to 2% in 1 to 10 station consideration in average annual and seasonal while showing a consistency at 8 station selection or above at 3%. The annual average deviations were 12% and 34% when 7 (200 km^2/station) and 6 (233 km^2/station) stations selected.

Further analysis of deviation classification was considered to obtained the probability of each deviation classification (Table C - 1). The plot of probability vs deviation classification vs station density configuration (Figure 6-1) explained that deviation varies in high ranges if lesser stations were selected and the least deviations 0-0.1with 100% probability can be obtained if 175 km^2/station density or high-density considerations. As the same pattern resulted in annual, seasonal and monthly analysis of deviation, it proves that 175 km^2/station density would be the lowest density considerations with least deviated rainfall in one density configuration. Therefore 8 station density or the one station per 175 km^2 can be recommended for high accuracy requirements if there is no other spatial variation. Also, the degree of matching of deviation plots would be helpful for the modelers to make decisions when selection of the densities for model applications. Thus, the degree of matching of the deviation is recommended for all modelers to make decisions in water resources management. By comparison of plots of deviations, the probability of accuracy can be estimated before any results obtained.

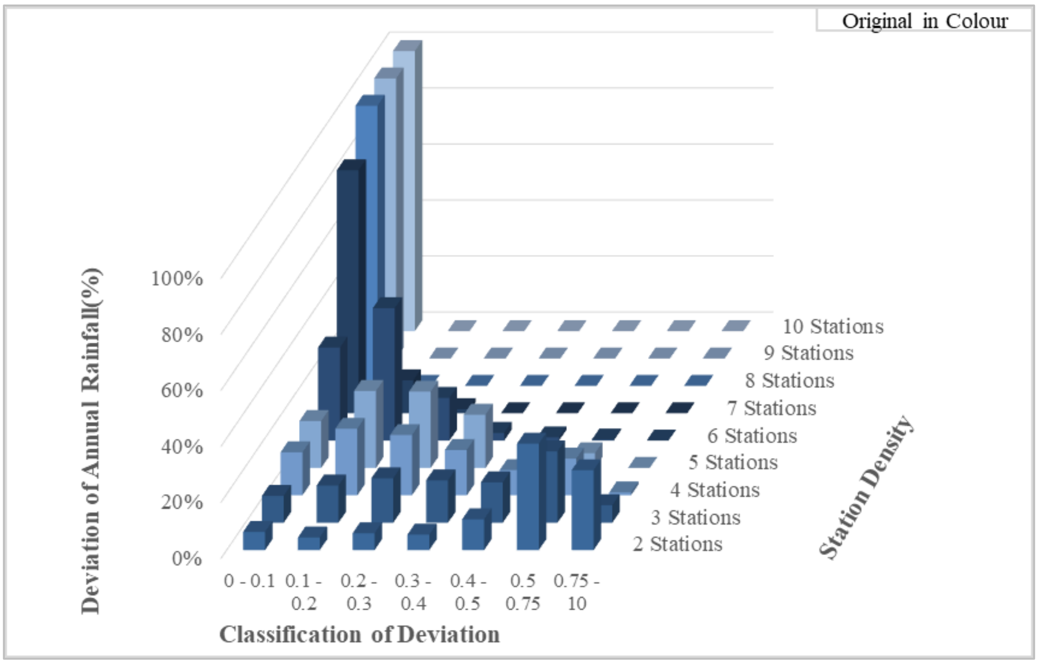

Figure 6-1: The plot of probability vs deviation classification

6.5.2 Rainfall-Runoff Option 1

The typical model performed consistently with a rainfall input from a denser network than 175km^2/station. Model performed satisfactorily for many the other configurations. The c and SC parameters of typical model, showed the convergence of overall MRAE to 0.39-0.37 from eight or more stations. Therefore, eight stations are satisfactory to represent catchment areal rainfall reinforcing the 100% probability of occurrence and resulting a 0.38 average MRAE for streamflow estimations. As the station density evaluation was done by comparing the outputs from the model, the influence of data disparities does not play a role in the resulted threshold value of station density. In this comparison, the optimised parameters of the typical configuration were also kept constant for the comparison of model response to the input data.

6.5.2.1 Comparison of Model Responses

The comparison of % deviation {[(maximum – minimum)/ minimum] x 100%} results (Table 6-1) also indicated that the typical model responded with little variation when the station density was beyond the threshold. Comparative analysis further revealed that results with station combinations ranging from 279 - 200 km^2/station density also showed a wide variation of MRAE with respect to overall hydrograph, flow duration, high, intermediate and low flows but the station density of 175 km^2/station and above settled to deliver consistent model performances.

Table 6-1: The comparison of % deviation results (RR1)

Station Density (km^2 per station)	MRAE Overall	MRAE - FDC	MRAE - High Flow	MRAE - Intermediate Flow	MRAE - Low Flow	Annual Absolute Water Balance Error
1395	306%	436%	224%	284%	393%	3372%
698	211%	468%	954%	2284%	237%	6705%
465	89%	348%	678%	1456%	262%	5034%
349	117%	269%	455%	1816%	187%	12528%
279	120%	263%	451%	1951%	178%	8600%
233	79%	194%	339%	2116%	136%	1568%
200	17%	46%	110%	669%	92%	570%
175	6%	25%	53%	70%	16%	83%
155	4%	14%	26%	66%	11%	42%
140	5%	12%	31%	76%	10%	47%

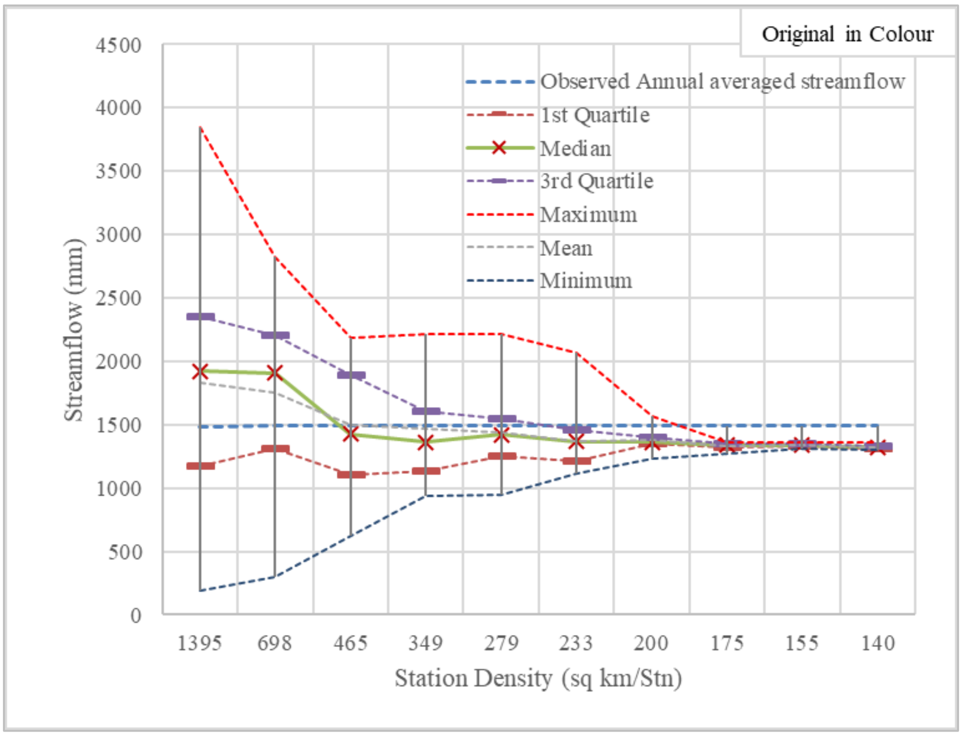

Figure 6-2: Annual Average Streamflow estimations

Plotting the annual streamflow results obtained using the typical model parameters from two parameters model also indicated that with increasing station density, it reaches a consistent annual streamflow at the density of 175 km^2/station. However, the estimation results showed an underestimation of streamflow when compared with observed flow even after reaching the consistent level.

The model performance by MRAE for overall hydrograph, flow duration curve, high, intermediate and low flows matching illustrated that the high density is not always representing the catchment rainfall as best fitting can be found even at lesser densities such as 5 stations (279 km^2/station) were selected. Though the configurations with the density of 279 km^2/station satisfied the recommendation of WMO-NO.168 (2008) and IS:4987 (1994), the best fit the two-parameter model did not always perform well with different rain gauging station configurations. MRAE deviation as high as 120% for 279 km^2/station shows this behaviour.

Comparison of model performance indicated that best fitting is varied with the evaluated performance objective, i.e. hydrograph matching, flow duration curve matching, flow types matching etc. Analysis of best fitting streamflow estimations highlighted that MRAE varies from 200 – 465 km^2/station (Table 6-2) for different streamflow characteristics. However minimum MRAE values for different densities reach consistent level beyond 175 km^2/station.

Table 6-2: Analysis of best fitting streamflow estimations -RR1

Station Density (km^2/station)	**Minimum MRAE Overall (RR1)**	**Minimum MRAE - Flow Duration (RR1)**	**Minimum MRAE - High Flow (RR1)**	**Minimum MRAE - Intermediate Flow (RR1)**	**Minimum MRAE - Low flow (RR1)**
1395	0.4948	0.2930	0.4036	0.5156	0.4831
698	0.3876	0.1685	0.0745	0.0519	0.2429
465	0.3795	0.1470	0.0665	0.0495	0.2239
349	0.3562	0.1486	0.0699	0.0402	0.2000
279	0.3498	0.1506	0.0690	0.0375	0.2038
233	0.3593	0.1517	0.0737	0.0291	0.1977
200	0.3707	0.1516	0.0854	0.0274	0.2021
175	0.3693	0.1570	0.1141	0.0434	0.2889
155	0.3766	0.1565	0.1145	0.0405	0.2876
140	0.3765	0.1576	0.1206	0.0379	0.2893

6.5.3 Rainfall-Runoff Option 2

Station configurations demonstrating best hydrograph, FDC, high, intermediate and low flow matching MRAE behaviour with typical model were selected for a detailed evaluation and in each of these cases, the model was re-calibrated. Optimisation results of model recalibration was not subjected to validation because the present study aimed at evaluating a long rainfall input for the capability to estimate watershed streamflow.

Recalibration results showed that a station configuration with a density of 698km^2/station is the best configuration (2c16) reflecting minimum MRAE values for hydrograph, FDC and low flow matching. However, MRAE minimum for high and intermediate flows were at 465 and 349 km^2/station respectively (Table 6-3).

Table 6-3: Analysis of best fitting streamflow estimations -RR2

Station Density (km^2/station)	**Minimum MRAE Overall (RR2)**	**Minimum MRAE-Flow Duration (RR2)**	**Minimum MRAE-High Flow (RR2)**	**Minimum MRAE - Intermediate Flow (RR2)**	**Minimum MRAE-Low flow (RR2)**
1395	0.3252	0.1549	0.3602	0.3058	0.3230
698	0.2931	0.0963	0.0597	0.0357	0.0853
465	0.3017	0.0966	0.0556	0.0351	0.0887
349	0.3217	0.1210	0.0683	0.0304	0.1288
279	0.3316	0.1197	0.0603	0.0397	0.1118
233	0.3387	0.1350	0.0793	0.0323	0.2036
200	0.3591	0.1464	0.0841	0.0476	0.2244
175	0.3668	0.1455	0.0909	0.0474	0.2259
155	0.3748	0.1422	0.1159	0.0470	0.2192
140	0.3744	0.1429	0.1153	0.0453	0.2387

Though the minimum MRAE values were obtained at lower densities, a consistent MRAE values for all streamflow characteristics started beyond denser values than 200-175 km^2/station and higher. Thus, a threshold station density of 175 km^2/station is the optimum density to obtain consistent streamflow estimations.

Furthermore, optimization of model parameters at each station configuration indicated that with MRAE improvement from 24% - 0% with the change of parameters. c and SC varied from 47%-0% and 240%-0% respectively. The high rate of change at parameters contributing to high MRAE changes, is an evidence to the model sensitivity to c and SC parameters. Values indicated that similar to the pattern of MRAE, the parameters had shown a convergence with increasing number of stations.

Evaluation of model performance with model re-calibration depicts that a few cases with low density gauging stations provide best streamflow estimations. Even though, a highly consistent matching could be achieved with increasing station densities, the high densities did not appear as the best rainfall reflecting watershed response.

6.5.4 Comparison of Rainfall-Runoff Options

6.5.4.1 Behavior of MRAE

The behavior of overall MRAE in RR1 and RR2 is shown in Figure 6-3 and Figure 6-4. By MRAE variation with hydrograph matching indicates that model performance with RR2 option is better than with RR1. However, the consistent model performance for both RR1 and RR2 is with same gauging station density.

MRAE for overall hydrograph and flow duration curve matching and high, intermediate and low flow matching also show a behavior similar to overall hydrograph (Figure 6-5 and Figure 6-6). In the consistent performance range of station densities, MRAE of RR1 was lower than RR2 for high and intermediate flows. It was reversal in case of flow duration and low flow matching.

6.5.4.2 Behavior of Water Balance

In case of both RR1 and RR2, RAE% values of Annual, Maha and Yala seasons showed a similarity of convergence at higher station densities and the consistency beyond 175 km^2/station. Annual and Maha season RR2 values showed a better error values than the case of Yala season and beyond threshold station densities.

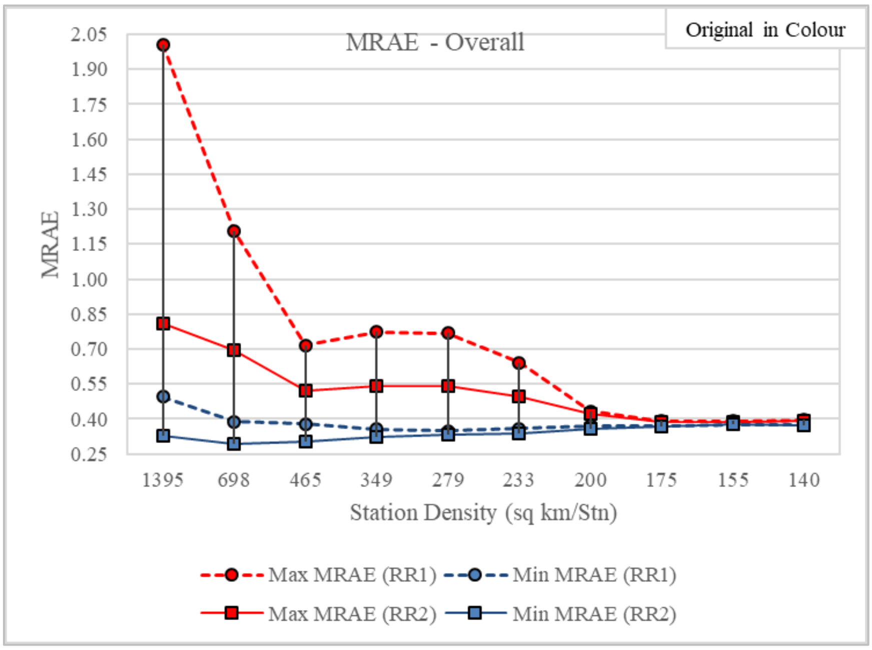

Figure 6-3: Comparison of MRAE-Overall (Normal plot)

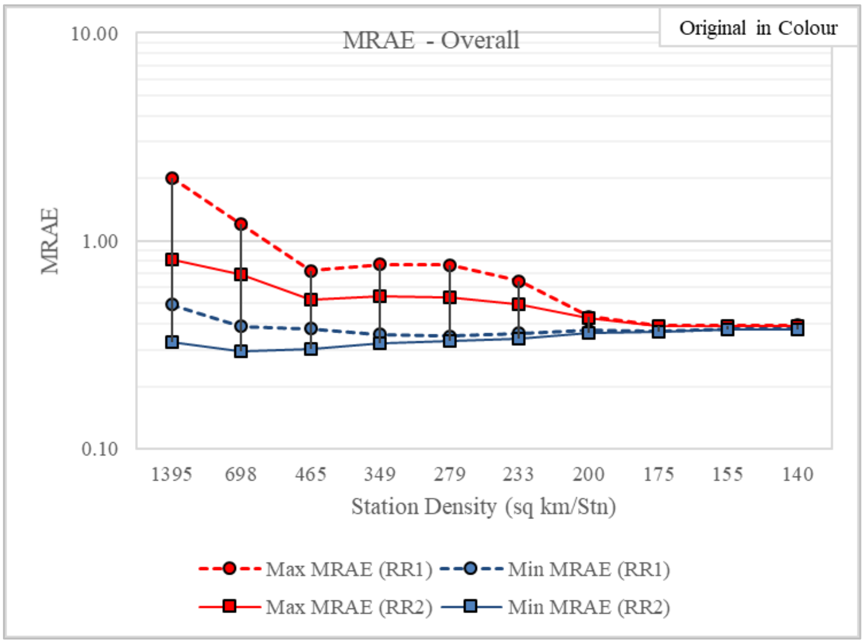

Figure 6-4: Comparison of MRAE-Overall (Semi-log plot)

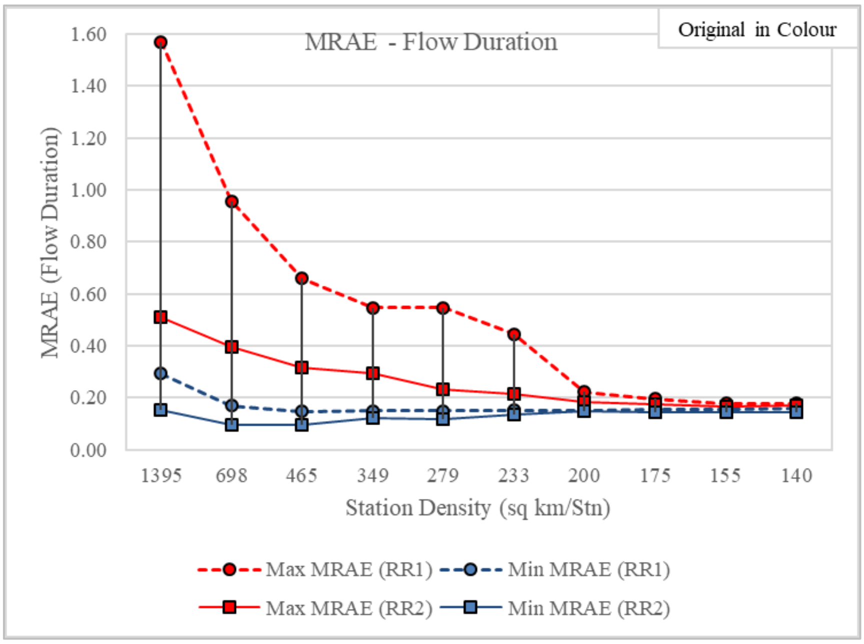

Figure 6-5: Comparison of MRAE - Flow Duration (Normal plot)

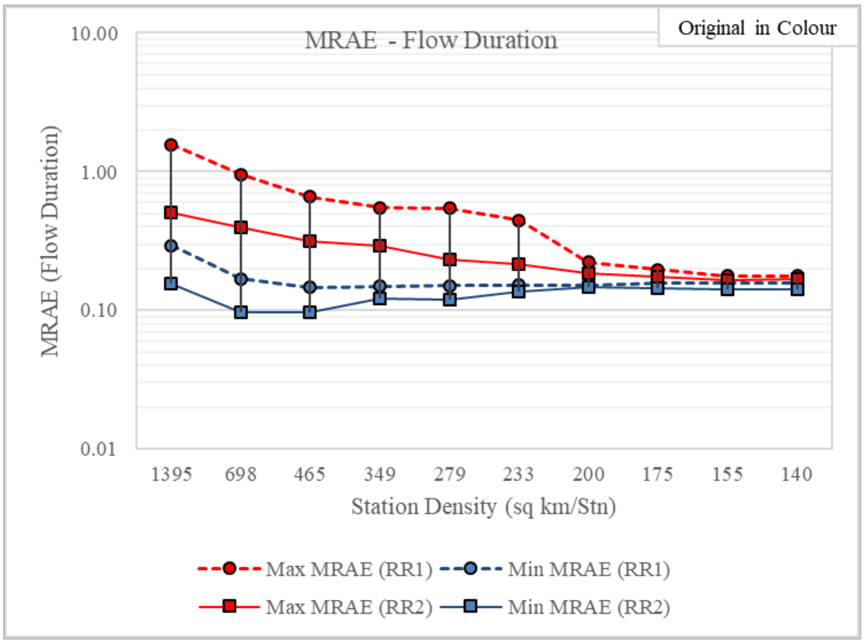

Figure 6-6: Comparison of MRAE - Flow Duration (Semi-log plot)

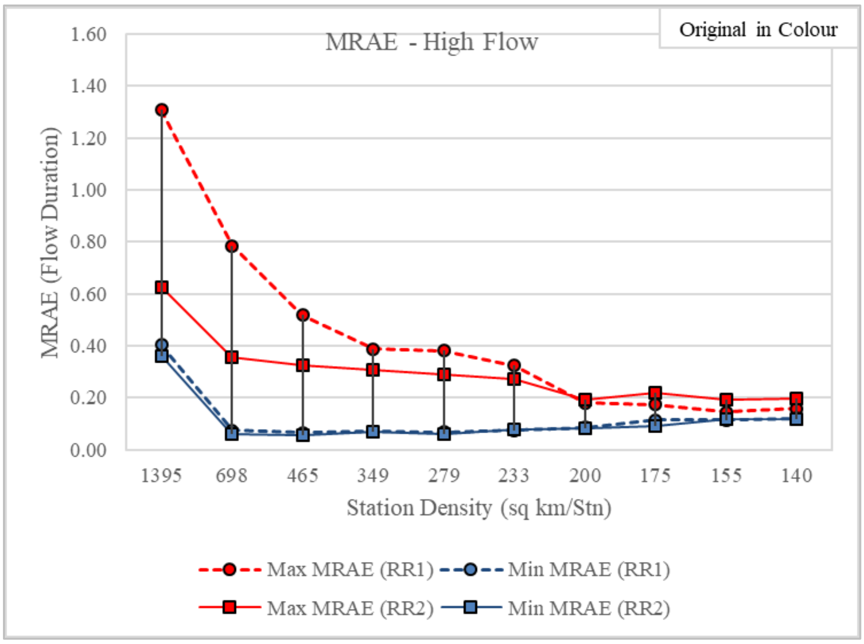

Figure 6-7: Comparison of MRAE – High Flow (Normal plot)

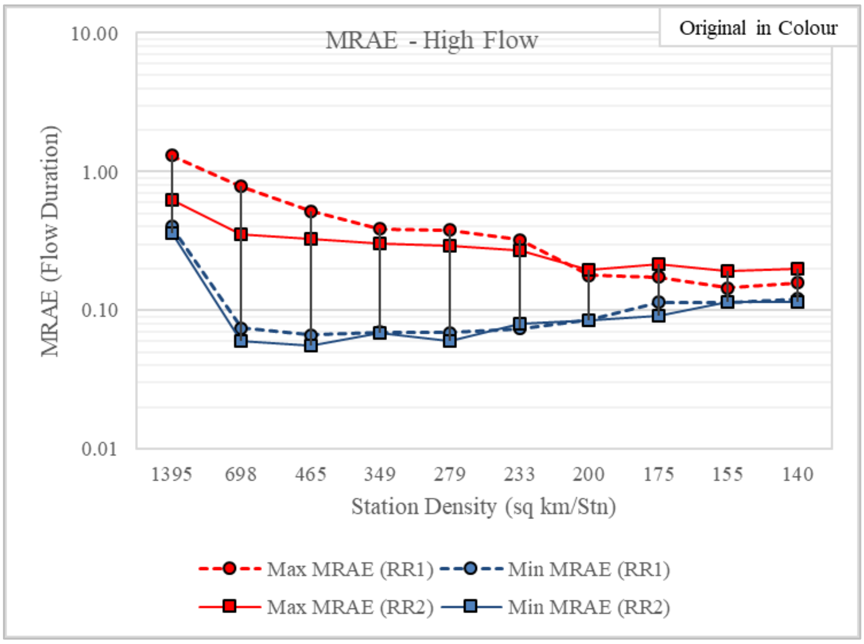

Figure 6-8: Comparison of MRAE – High Flow (Semi-log plot)

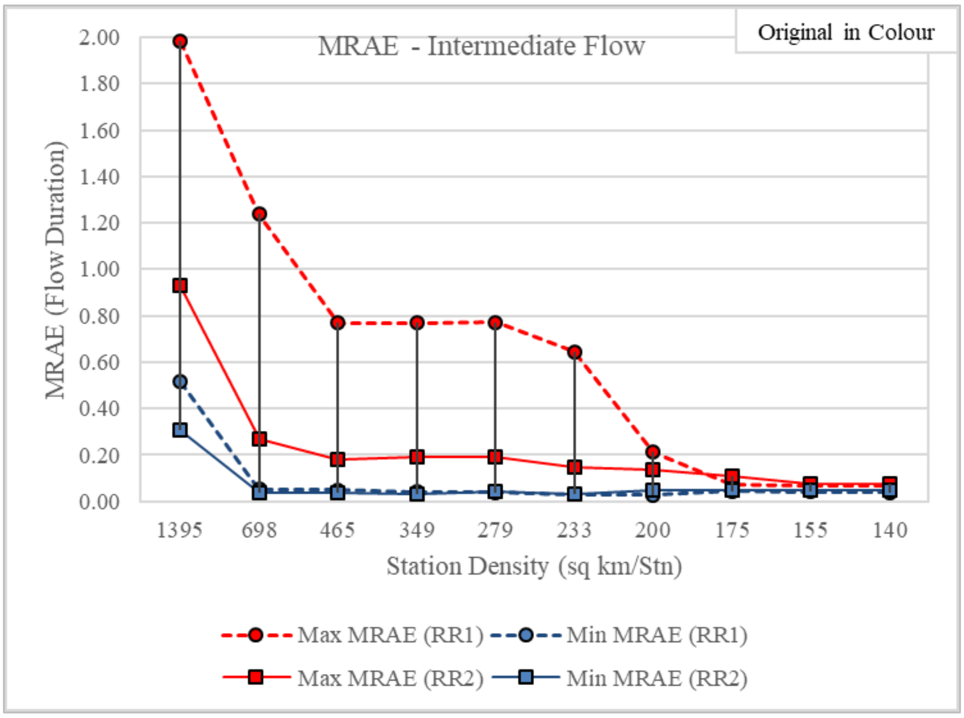

Figure 6-9: Comparison of MRAE – Intermediate Flow (Normal plot)

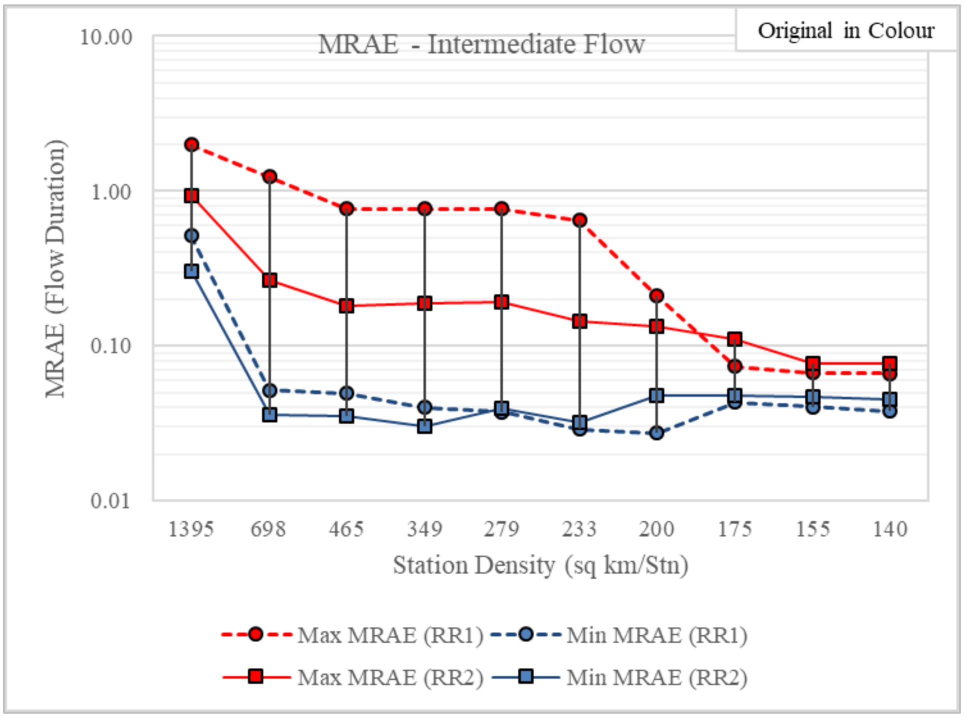

Figure 6-10: Comparison of MRAE – Intermediate Flow (Semi-log plot-b)

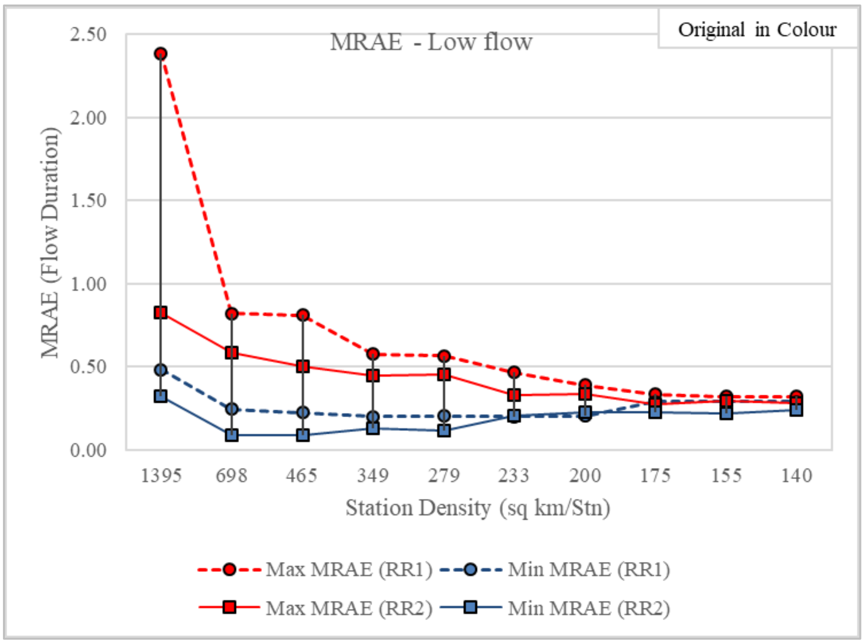

Figure 6-11: Comparison of MRAE – Low Flow (Normal plot)

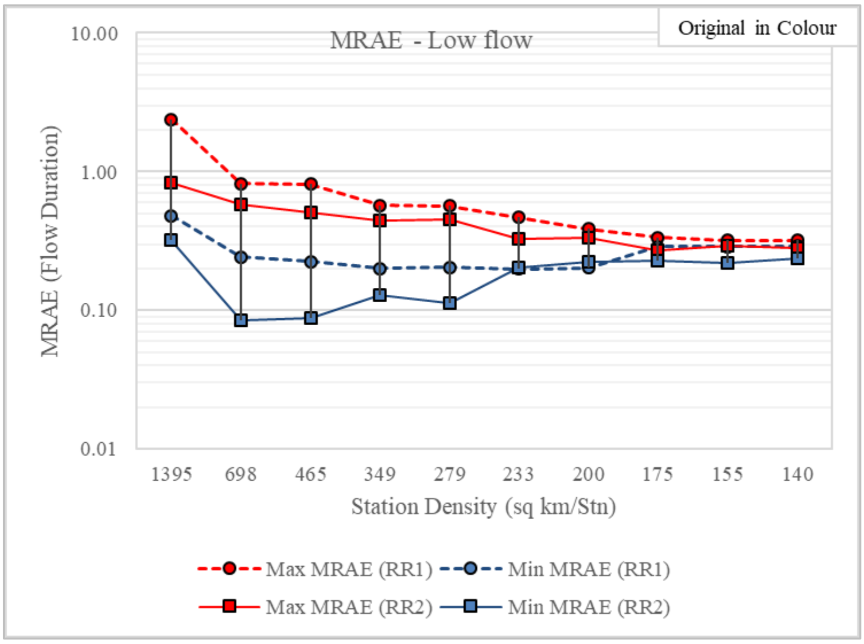

Figure 6-12: Comparison of MRAE – Low Flow (Semi-log plot)

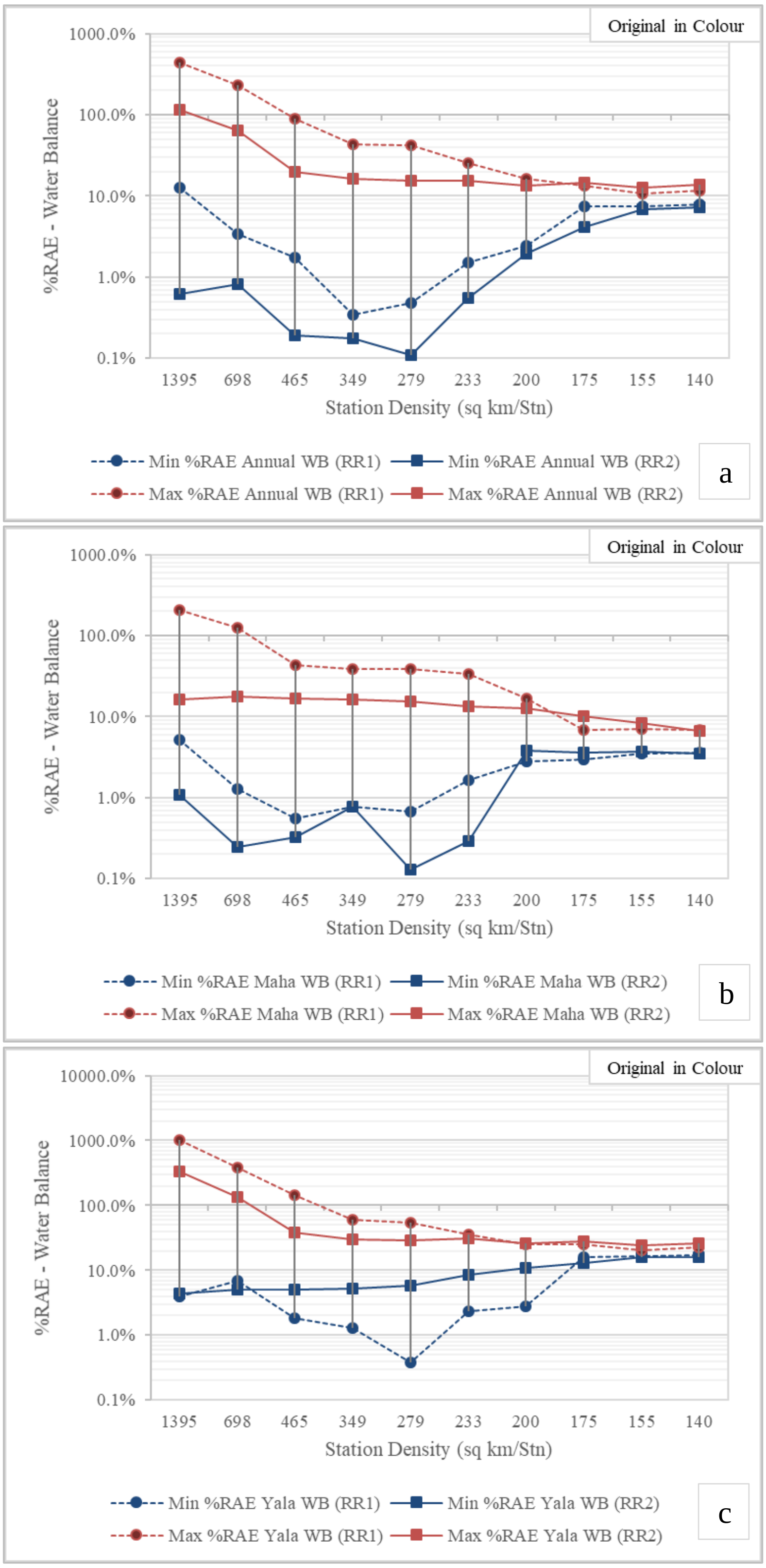

Figure 6-13: Comparison of %RAE Water Balance Semi-log plot (Annual-a, Maha-b and Yala-c)

6.6 Station Influence on Areal Rainfall

Station influence on watershed streamflow response was compared by evaluating the Thiessen weights of corresponding to the best matching station layouts under each evaluating flow characteristic. ANNEX F - Table F - 1 shows the comparison of Thiessen weights separately for RR1 and RR2 options. ANNEX F - Table F - 2 shows the combined comparison of weights for RR1 and RR2 options. Both tables show the notation corresponding to each station layout (Figure 5-64 and Figure 5-65)

Evaluation of the contribution from a station was done by summing up to value of weight in each case, averaging by the number of occurrences and then by taking the percentage weight by considering all stations used for the comparative evaluation. In case of both RR1 and RR2 options station Nivithigala was highlighted with respective weights of 34.1% and 73.1%. Combined evaluation also showed a 55% weight for Nivithigala.

Second important contribution for watershed streamflow has been form the Ratnapura rainfall station. Ratnapura showed respective influences of 34% and 23.4% for RR1 and RR2 cases. Ratnapura combined influence is 30.2%.

Eheliyagoda station ranked 3 in terms of combined contribution to Ellagawa streamflow. This station showed respective influence values of 5% and 21.4 for RR1 and RR2 options but the combined influence is high at 13.3%.

The other rainfall stations also showed a mixed response between RR1 and RR2 options similar to Eheliyagoda station. Alupola, Pelmadulla and Kuruvita (Keragala) are the other gauging stations with significant influence on watershed streamflow.

This evaluation showed that by using results of this evaluation a watershed manager can focus on the most contributing gauging stations for better quality data collection. Furthermore, this study clearly shows that watershed rainfall is best represented with the inclusion of Nivithigala, Ratnapura and Eheliyagoda gauging stations. Hence, the present study clearly indicates that it is prudent to commence watershed modelling with a consistent rainfall station density and then carryout optimisation of gauging station weights to capture the best rainfall streamflow model parameters for water resources estimation.

6.7 Evaluation of Spatial Interpolation Method

6.7.1 Rainfall Variation

Average rainfall values of 5 station layouts shared a higher value when compared with the 8 station averages. Also, the variation of values between the methods were less significant in the case of 8 station layouts.

Comparison of average annual rainfall estimates illustrated that for most of the time Regularized Spline method provides the lowest rainfall estimations, while Universal Kriging estimates the highest rainfalls. Though it is felt that the rainfall estimations for a particular station configuration would be similar in most of the cases, the values indicated that a deviation of approximately 250mm. The analysis also illustrated that in some of the months, rainfall estimates by Spline method resulted in negative values and thus a correction is required when estimating the streamflow from those negative rainfall.

6.7.2 Watershed Response

Watershed response comparison was carried out with MRAE as the indicator. The spatial averaging method evaluations looked at the comparison of observed and modelled overall hydrograph, flow duration curve and water balance for two key gauging station densities.

The results obtained for the Ellagawa watershed were separated to reflect the MRAE values with the variation of station density, station layouts and the type of averaging method. Figure 6-15 and Figure 6-16 highlight that at both station densities when most stations were outside the boundary, then the watershed responses has been relatively poor. In case of the lower density value, the MRAE value of this case is noticeably poor with all interpolation methods. Figure 6-17 and Figure 6-18 indicate that no significant pattern in flow duration curve fitting MRAE in any interpolation method, However maximum stations outside with low density (5 stations) highlight relatively worst performances in few interpolation methods. However, in case of water balance (Figure 6-19 and Figure 6-20) the % RAE value does not indicate a pattern corresponding to a particular station layout.

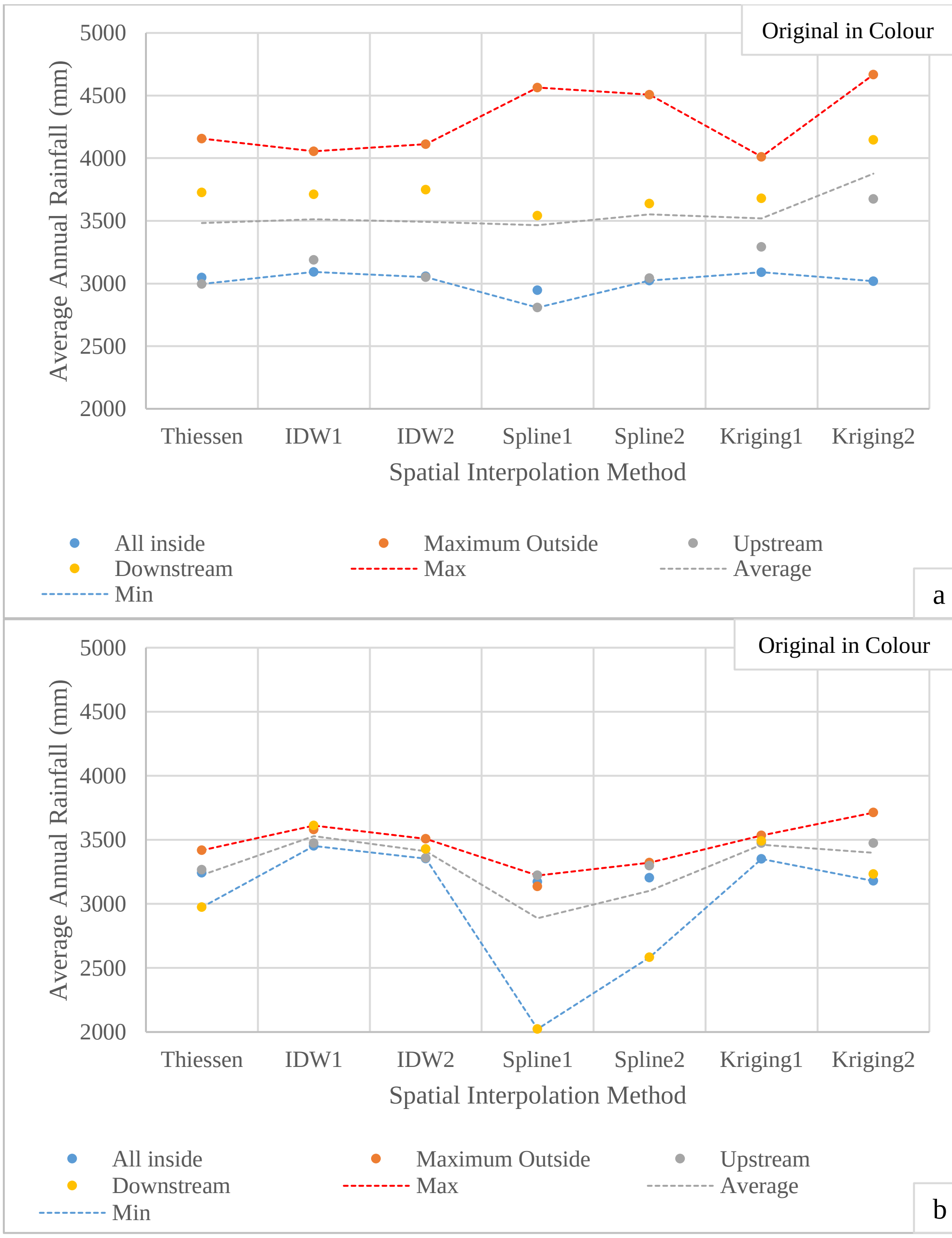

Figure 6-14: Rainfall estimations for 5 (a) and 8 (b) stations configurations

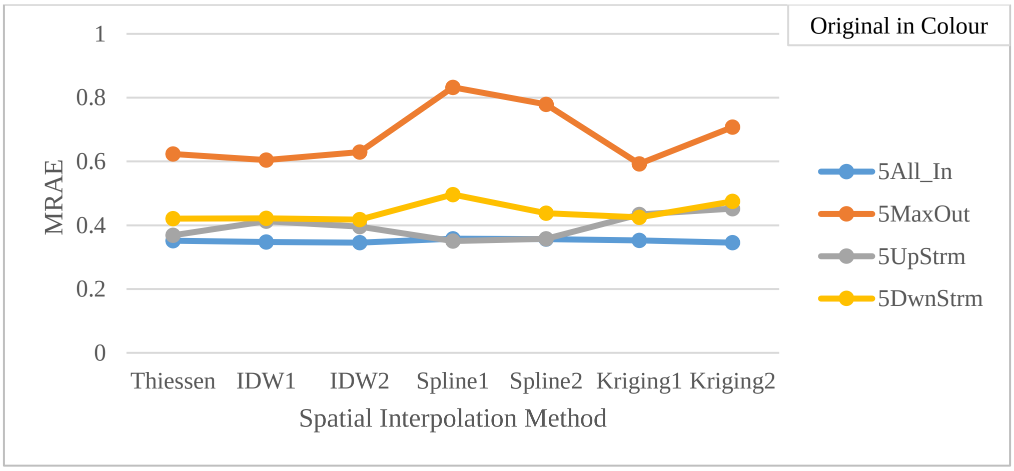

Figure 6-15: MRAE variation for different 5 stations configurations

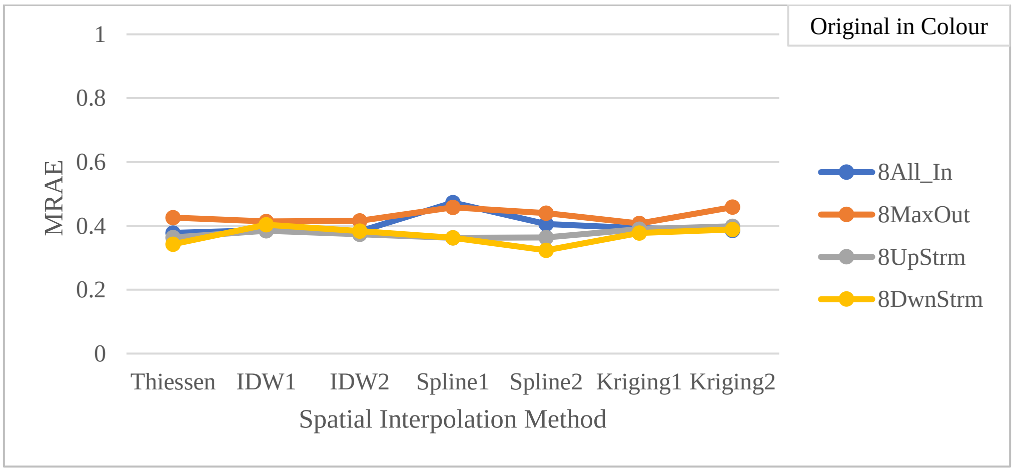

Figure 6-16: MRAE variation for different 8 stations configurations

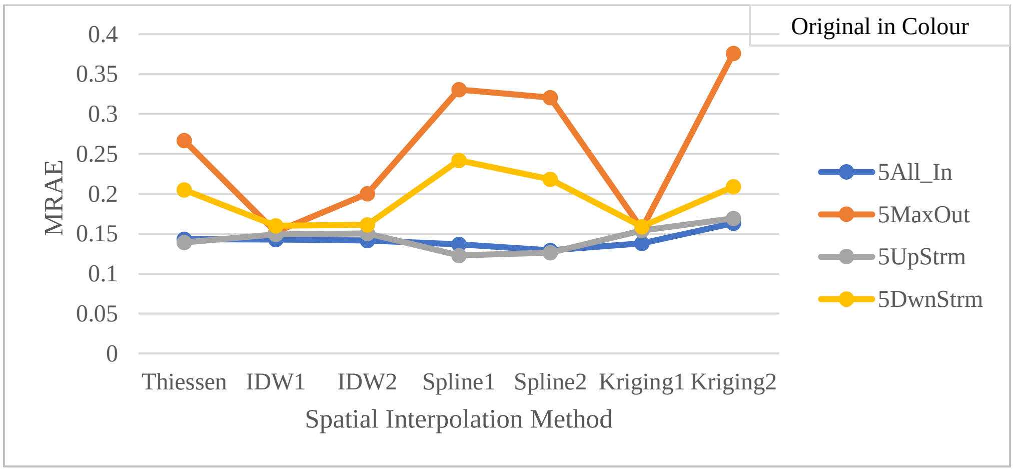

Figure 6-17: Flow Duration Curve fitting MRAE variation for different 5 stations configurations

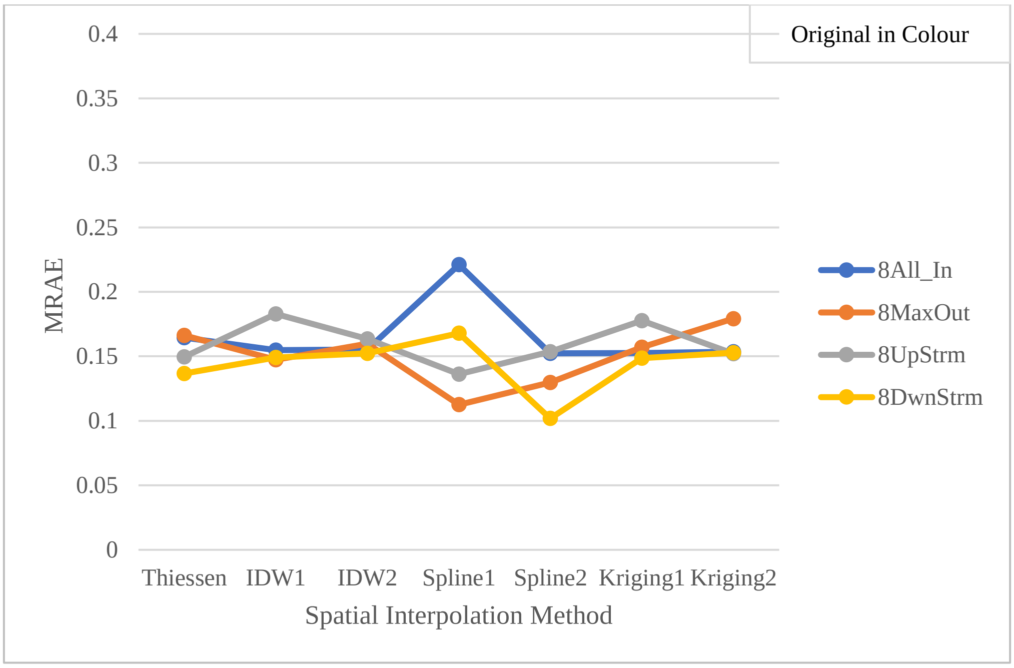

Figure 6-18: Flow Duration Curve fitting MRAE variation for different 8 stations configurations

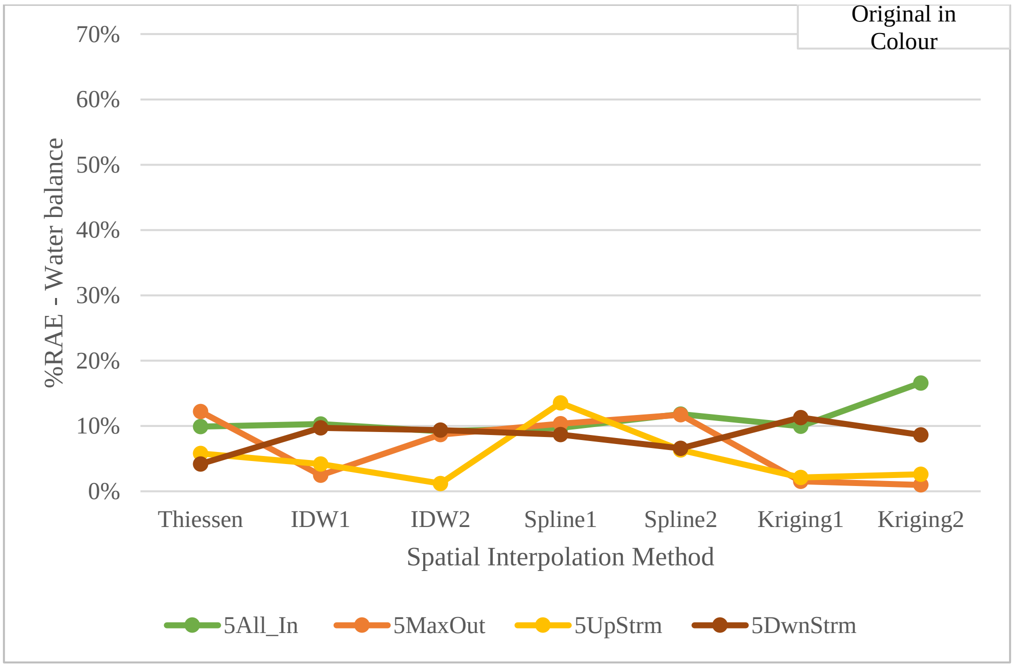

Figure 6-19: % RAE of Annual water balance variation for different 5 stations configurations

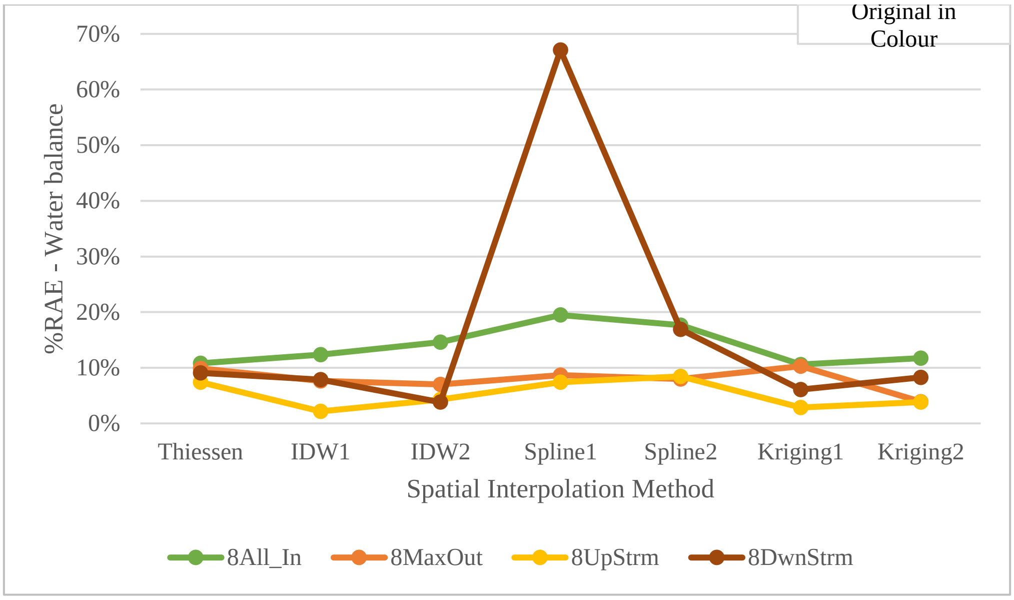

Figure 6-20: % RAE of Annual water balance variation for different 8 stations configurations

The magnitude of water quantity indicated that very low estimations in Spline methods for annual and seasonal showing a pattern. However, annual and Yala season show an under estimation, while Maha season show an over estimation in streamflow estimations for average values at both densities (5 and 8 stations) and all configurations (Figure 6-21 and Figure 6-22). Since having over estimation with lowest magnitude of water quantity, however the Spline 1 method indicated good performance in Maha season.

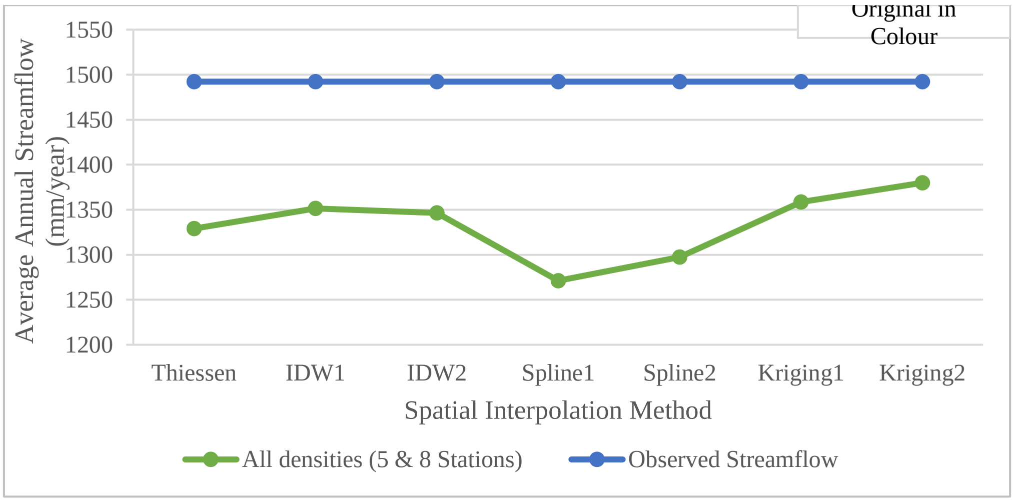

Figure 6-21: Average annual streamflow variation for different interpolation methods

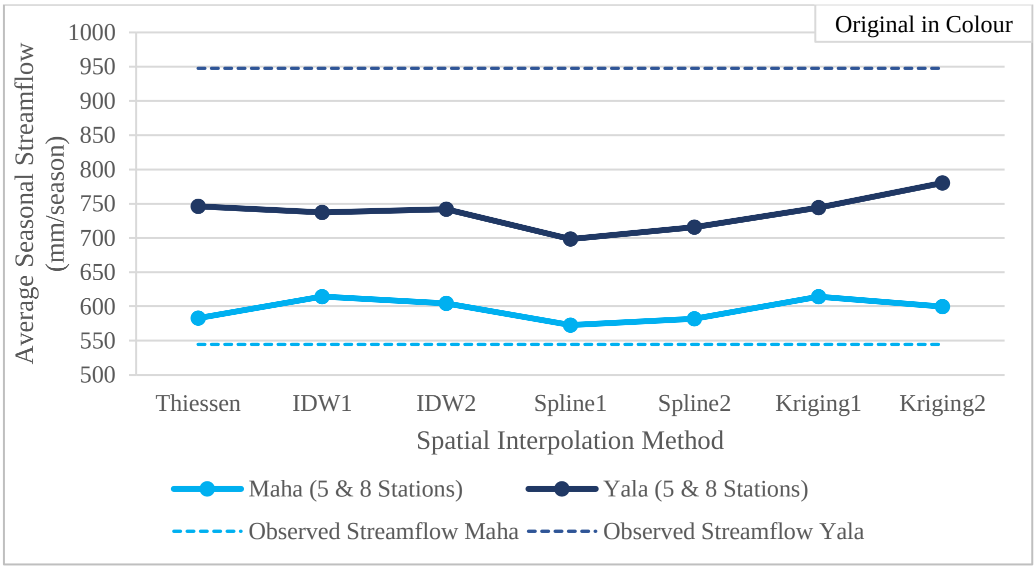

Figure 6-22: Average annual streamflow variation for different interpolation methods

The most noteworthy results from the watershed comparison is that except for "5 station density - maximum stations outside" case, the MRAE values of hydrographs and FDC for all averaging methods and for all layouts vary around 0.4 for 279km^2/station density (5 stations) and around 0.15 for the threshold station density of 175 km^2/station (8 stations). The higher variation of MRAE between layouts is shown when Spline and Kriging methods are used to compute areal average rainfall. The % RAE of annual water balance also show a similarity in the inconsistencies between layouts but error values for all methods are around 10%. The magnitude of average error in annual terms is 112-221 mm for a total of 1492 mm; in seasonal terms the Maha average error is 28-70mm for a total of 545mm; the Yala average error is 167-249mm for a total of 948mm; in monthly scale the average error is 30-32mm for a monthly average of 122mm.

The results of the comparison similar to the station density studies show that 8 station density in general would lead to better hydrograph responses, without a significant difference between areal averaging method. However, Thiessen and both IDW methods provide consistent results. Reason for the IDW methods to perform similar would be probably because of the high station density values.

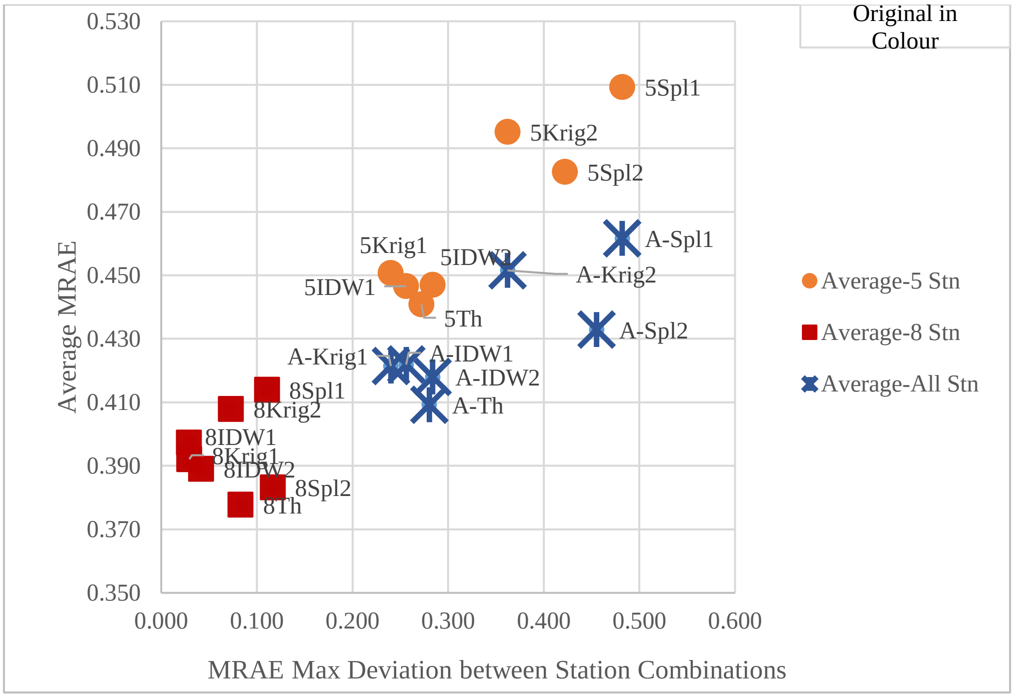

Figure 6-23: Maximum deviation for different station configurations

6.7.3 Evaluation of Deviations

Variation of maximum deviation of MRAE against average MRAE of a particular set of station combinations and for the two different station densities are shown in Figure 6-23. This analysis of deviation also reflected conclusions other watershed response evaluations from another point of view. It shows the high deviations are always with Spline method. As all methods showed a very small deviation with respect to its average all the methods can be used to estimate the areal average rainfall, in this watershed and with similar station densities.

6.7.4 Processing Time

The processing time taken for the creation for all rainfall surfaces highlighted that the Kriging methods required more time than the other methods. Considering only the time consumption, undoubtably the best method is Thiessen method.

In this analysis in the computation of Areal averages, the gauged data were assigned a weightage without considering the watershed response. In other words, this work evaluated the capability of an areal averaging method with predetermined gauging station weights. Therefore if a method wishes to provide the gauging station weights also to respond according to watershed hydrology, then the time and resource consumption for the spatial averaging methods would increase exponentially. The temporal resolution used for the present work is monthly. Based on the experience from this study, it is certain that the time requirement for a daily rainfall analysis using interpolation methods other than the Thiessen would increase exponentially. Therefore the time taken for computations together with the relative difference in performance should be considered for a rational selection of an areal averaging method.

6.7.5 Influencing Factors

The influencing factors related to the selection of an areal averaging method are the reliability of the rainfall estimate and the resource consumption for computations. The present work reflected that there is a threshold station density for the determination of areal rainfall for consistent water resources estimation. The station layout comparison indicated that at this station density, the performance does not significantly deviate with the station layout. Therefore at this threshold or higher densities, the areal averaging method selection requires the assigning of a higher weightage to computational resource requirement.

However, the RR option computations revealed that a few stations had largely contributed to the Ellagawa watershed streamflow. In this analysis it was also shown that higher densities smoothen the sensitivity of watershed response. Therefore in future, watershed managers who strive for better water resources management in water scarce situations would require to identify, and use only the contributing rainfall gauging stations. When water managers and modelers are working with less station densities, the areal averaging methods may act differently and hence require investigation.

After evaluating the state of art and considering the outputs from the executed case study, the Thiessen average method and a threshold station density of 175 km^2/station is the best option for Ellagawa watershed. It is recommended to perform similar case study using a variety of watershed sizes, climatic conditions and temporal resolutions.

7 CONCLUSIONS

1. As at present there is a lack of guidance on the selection of rain gauge distribution and on the method of computing areal average rainfall for water resources management at watershed scale. Among the prevailing literature, Thiessen averaging is the most popular method.

2. Computation of areal average rainfall of Ellagawa watershed with Thiessen method indicated that consistent areal rainfall values can be obtained with any station layout with a gauging station network denser than 175 km^2/station.

3. Maximum deviation of areal rainfall estimation at threshold gauging density is 3% in case of annual and Maha season estimations, 2% in Yala season estimation and 7% in case of monthly estimation.

4. Consistently satisfactory streamflow hydrograph matching with a two-parameter monthly water balance model was achieved at a threshold gauging density of 175 km^2/station with a 6% maximum deviation in value with any station layout.

5. Two parameter model estimated the best matching streamflow hydrographs at a gauging station density of 698 km^2/station, and demonstrated a very good MRAE of 0.2961 which shows that the two rainfall stations namely Nivithigala and Eheliyagoda S.P. are the most representative of

6. Thiessen weights of Nivithigala Ratnapura and Eheliyagoda gauging stations amounting to 37.69, 20.51 and 9.02 show that they are the stations mostly influencing the matching of hydrographs of Ellagawa watershed.

7. In case of Ellagawa, Thiessen method is the best areal averaging method for water resources assessment using any station layout and a gauging station configuration density better than 175 km^2/station.

8. Monthly evaluations of this study show that parameter optimisation of watershed models should commence with a consistent rainfall station density and Thiessen method computation, followed by optimisation of rainfall station weights to capture best model parameters.

8 RECOMMENDATIONS

It is recommended to perform similar case studies using a variety of watershed sizes, climatic conditions and temporal resolutions. It is also recommended to further study on areal averaging methods for less station densities in order to manage data scarce situations.

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ANNEX A - DATA AND DATA CHECKING

Data

Table A - 1: Data – Rainfall

Month	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
Oct-06	500.7	292	207.86	560.9	923	638	744	641.4	898	856.5	771.8	487.8
Nov-06	629.7	203	245.47	358.6	554	663	472	452.8	446.7	620.4	671.1	328.2
Dec-06	203.8	144	65.61	153.7	174	210.5	141	241	109.2	219.3	95.1	111.5
Jan-07	103.9	58	35.23	91.6	107	163	145	153.4	138	70.5	116.1	68
Feb-07	106.9	37	0.23	9	43	2	16	0	34	125.5	6.1	45.4
Mar-07	153.5	47	29.58	84.8	242	171.5	198	157.4	33	197.4	29	70.9
Apr-07	397.5	215	170.4	460	518	463	482	580.9	384.5	625.7	543.2	542.5
May-07	289.5	99	66	208.5	383	288	354	255	227	631.8	249.2	172.8
Jun-07	291	178	203.7	320.9	339	288.5	435	360.7	183.1	321.7	151.1	300.8
Jul-07	248.9	123	92.7	245.2	265	313.7	335	213.8	123	326.8	212.6	257.1
Aug-07	439.8	204	89.1	443	407	427	434	399.3	305	383.3	274.3	254.1
Sep-07	487.4	238	209.6	409.2	368.5	475.5	358	64.4	385	550.9	280	493.6
Oct-07	696.9	258	204.4	509	535.5	471.5	518	542.9	325	505.5	465	326.6
Nov-07	335.6	119	67.3	178.3	384.5	250.6	391	219.8	193	233.9	296.8	195.6
Dec-07	234.2	101	43.5	145	104	153	112	67	41	383.8	124.6	34.5
Jan-08	272.3	95	95.6	51.4	125.5	114	116	175	66.5	160	50.7	46
Feb-08	338.8	98	145.9	177.8	264	315	273	225.7	61	370.9	315.7	60.7
Mar-08	519.4	198	175.8	286.4	319	214	310	485.5	109	546	354.2	160.5
Apr-08	590.4	332	254.5	650.8	669	595	691	1036.6	259.9	1073.6	645.7	475.3
May-08	355.24	250	113.5	503	633	592	734	603.5	130.4	981.8	344.5	198.5
Jun-08	336.43	206	134.6	387.3	427	328	501	447.3	293.2	1219.2	397.4	248
Jul-08	422.4	282	209.2	557	705	575.5	658	793.3	243.5	734.4	345.2	335.8
Aug-08	235.4	64.5	92	214.9	400	211.5	165	312.6	149.6	427.2	162.4	109
Sep-08	182.7	90	74	194.6	372	215	234	162.6	169	471.8	219.9	128
Oct-08	584.7	214	256.5	400.9	781	393.5	409	471.7	404.5	628.4	667	320.3
Nov-08	362.7	116	143.1	312.7	390	290.5	415	416.7	507	1071.6	203.9	244
Dec-08	196.5	77	112	146.7	265	179	150	159.7	251.6	239.7	141.8	135.3
Jan-09	34.8	14	41.2	22.2	137	48	128	70	5	39.8	12.3	50.5
Feb-09	28.7	79	74	57.8	63	40.7	37	92.1	8	120.8	100.9	46.8
Mar-09	296.2	115	108.7	270.9	367	334	436	470.9	215	603.2	275.3	155.2

Table A – 1: Page - 2

Month	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
Apr-09	349	117	146.2	188.5	541	299	271	316.4	212.5	416.9	162.1	233
May-09	487	242	315.5	414.7	672	382	444	626.5	181	482.8	191.2	750.8
Jun-09	494.6	270	395.5	627.7	895	584	543	705.6	563	931	288.6	454.3
Jul-09	105.3	91	137.2	168.3	519	319	239	223.3	231.2	639.1	153.2	242.4
Aug-09	301.9	203	201.9	451.5	356.9	418.5	411.5	406.6	232.9	967	154.8	252
Sep-09	531.1	184	237.2	347.2	316.7	438.5	409.2	496.1	480.1	899.6	366.8	454.7
Oct-09	411.4	187	159.5	330	*****	357	384.9	349.3	174	432.6	158.1	375.7
Nov-09	631	109.5	244	280.7	*****	309	360.6	347	523	657.7	345.9	246.9
Dec-09	317.6	80	190.5	215.4	*****	283	358.1	247.6	366	333.1	77.3	136.1
Jan-10	133.6	54	61	233.6	109	226	130.2	149.8	167	303.4	55.2	32.9
Feb-10	48.2	37	36.8	111.9	30	62	41.3	146.5	31	234.4	17.2	13
Mar-10	117.8	106	131	157.5	170.8	85	171.5	110.5	64	213.1	139.7	134.7
Apr-10	425.9	152	193.6	438.3	314.7	272	421.7	613.2	439.5	327.4	421.6	244.8
May-10	623.7	290	469.5	658.5	626.3	438	793.3	997.7	785.9	926.1	554.4	444.6
Jun-10	611.6	178	382.6	451.5	327	415	395.8	359.2	363.2	366.8	200.8	396.1
Jul-10	429.5	146	298	367.4	445	346.5	433.1	376.7	361.2	360.8	129.2	403.2
Aug-10	383.9	192	308.5	385.5	272	256.5	366.2	477.3	153	51.3	33.6	445.1
Sep-10	348.1	122	212.5	310.3	472	439	*****	487.1	572.7	48.2	265.5	173.5
Oct-10	476.4	119	302	436.6	369	358	322.2	333.6	211	105.9	314	309.7
Nov-10	569.9	306	434.6	540.3	524	497	673.5	925.3	523.5	975.5	486.4	329
Dec-10	267.5	139	295	469.7	473	338	445.3	560.3	328.5	811.4	153.8	314.1
Jan-11	167.1	110	125	205.1	144	155	162.8	195.6	129	380.3	125	249.5
Feb-11	124.5	70	129	174.3	126	108	192.2	77.1	32	165	67.9	134.3
Mar-11	184.3	125	156	292.1	199	42	296.8	227.2	83	233.5	*****	63
Apr-11	463.46	116.3	666	731.7	837	483	773.1	708.6	505	1203	460.6	258.3
May-11	530.4	78	172.5	272	563	245	702.5	538.2	433.8	666.5	359.1	386.5
Jun-11	170.5	86	38.3	283	282	173	284.5	291.6	227.5	224	238.9	170.4
Jul-11	297.7	86	129	248	175	123.5	226.9	202.6	139	*****	80.4	218.4
Aug-11	476.5	141	236	259	328	265	376.4	371.9	276.2	415	137.8	184.7
Sep-11	555.7	78.43	268.2	365	401	434	416.7	495.9	329	461	213.8	255.7
Oct-11	555.7	114	139	167	321	179	406.1	299.3	299.6	549	301.6	168
Nov-11	489.5	137	256.5	129	*****	340	321.3	254.2	440.7	418.1	107.8	255.7
Dec-11	413.6	44	78	44	80	245	119.5	110.2	211.5	437.4	206	57.5
Jan-12	167.9	21	99	47	19	43	17.5	21.1	65.5	43.8	92.5	40.5
Feb-12	53.3	67	163	68	216	149	220.5	76.2	198	543.1	181.1	89.2

Table A – 1: Page - 3

Month	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
Mar-12	169.8	178	151	80	218	296	243	282.6	126	393.6	139.8	117.3
Apr-12	155.2	165	297	407	508	462	696.7	800	497	622	259	251.5
May-12	269	43	96.5	136	189	115	267.6	236.2	156	196	185.9	24.3
Jun-12	47.8	119	88.5	311	288	320	374.4	227.3	666.5	477	127.7	136.1
Jul-12	180	134	148	113	139	206	182.9	188.6	420	270	86.2	260.1
Aug-12	267.8	181	268.5	207	321	377	450.9	383.5	570.5	518	289.6	270.3
Sep-12	310	70	156.5	237	317	275	300.3	302.8	699.5	438	246.7	107.2
Oct-12	268.5	237	440	358	546	464	468.7	518.3	1260	657	648.1	581.9
Nov-12	855.6	262	359	641	504	410	505.8	584.8	635	783	243.3	257.1
Dec-12	673.3	55	184.5	380	323	281.5	*****	254.1	893	381.5	139.3	102.3
Jan-13	296	62	122	84	54	69.7	71.4	85	145	126	39.8	116.1
Feb-13	130.6	124	159	198	273	269.4	217.9	191.8	347	409	122.7	121.7
Mar-13	246.8	142.8	383	341	277	217.6	312.4	339	623	546	243	233.4
Apr-13	499.6	82.4	96	296	202	153.5	202.6	345.7	49	330	69.8	112.3
May-13	196.7	307.1	353.5	471	548	469	569.4	611.7	542.6	823	495.9	591.2
Jun-13	873.5	265.9	480	630	632	534.5	579	512.5	482.5	649	365.6	1106.3
Jul-13	956	262.4	279	293	368	324.5	384	446.5	274	525	228.3	524.4
Aug-13	548.3	67.8	135	109	104	178.5	131	157.8	96	299	60.5	415.5
Sep-13	354.8	264.5	402	435	430	490.4	471.4	453.6	379.9	695	204	415.3
Oct-13	634	200.7	296	365	458	418.4	501.9	461.4	363	539	201	199.5
Nov-13	585.1	280.2	400.5	255	312	307.9	218.3	270.6	375	617	276.8	140.1
Dec-13	101.2	59.2	164	29	156	97.1	88.6	121.6	63.1	230	41.8	42
Jan-14	245.5	194	225	294	104	224.2	124.7	131.9	101.3	323	89.5	66
Feb-14	133.6	41.9	53	46	53	113.8	116.9	101.3	43.3	231	3.2	16.7
Mar-14	116.9	122.8	156	132	53	86.4	98.3	86	110.4	*****	101.9	88.8
Apr-14	355.9	143.2	194.5	413	437	563.3	429.1	570.3	506	*****	375.8	402.3
May-14	246.6	164.2	186.5	198	204	478.2	226.3	299.2	305.3	553	168.4	76.9
Jun-14	633.2	328.2	355.7	662	668	*****	660.2	630.2	767.2	889	450.4	698.3
Jul-14	233.4	103.1	174	288	238	*****	237.5	267.1	293.5	402	87.7	319.5
Aug-14	406.7	286.1	326	633	679	*****	598.4	615.3	657.7	848	349.8	377.1
Sep-14	440.2	221.9	310.5	447	501	*****	531.3	712.1	468.5	681	249	197.2

No Data represent in *****

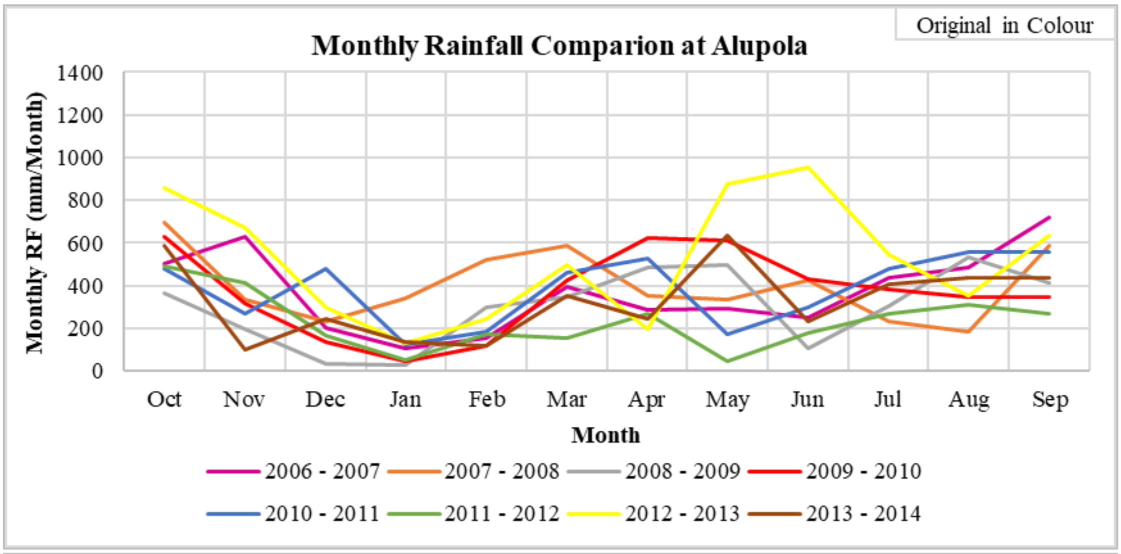
Table A - 2: Details of Rainfall Data Filling

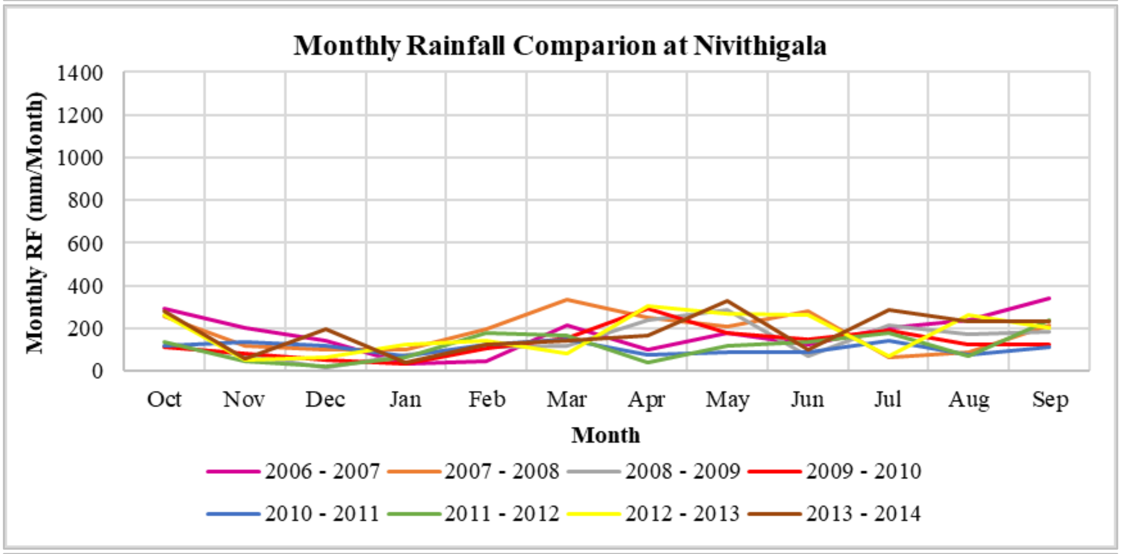
Filled Station	**Eheliyagoda S.P.** (2009 October, November, December)	**Eheliyagoda S.P.** (2011 November)	**Galatura Estate** (2014 June, July, August, September) **Uskvalley** (2011 July; 2014 March, April)	**Pussalla S.P.** (2010 September; 2012 December)	**Hanwella** (2011 March)
Month	**Kalatuwawa**	**Pussalla S.P.**	**Halwatura**	**Kuruvita (Keragala)**	**Millewa Estate**
Oct-09	341.60				
Nov-09	485.10				
Dec-09	315.40				
Sep-10				487.1	
Mar-11					252
Jul-11			139		
Nov-11		321.3			
Dec-12				254.1	
Mar-14			110.4		
Apr-14			506		
Jun-14			767.2		
Jul-14			293.5		
Aug-14			657.7		
Sep-14			468.5		

Table A - 3: Evaporation and Streamflow data

Date	Evaporation (mm)	Observed Stream flow (Q_o) (mm/month)	Date	Evaporation (mm)	Observed Stream flow (Q_o) (mm/month)
Oct-06	73.00	302.09	Oct-10	72.30	193.43
Nov-06	66.00	274.16	Nov-10	53.40	214.05
Dec-06	51.00	60.95	Dec-10	51.80	223.86
Jan-07	95.00	34.55	Jan-11	103.80	57.74
Feb-07	86.00	20.40	Feb-11	80.60	57.02
Mar-07	89.00	24.15	Mar-11	113.80	51.61
Apr-07	84.00	64.58	Apr-11	82.20	237.49
May-07	97.00	78.26	May-11	95.80	255.03
Jun-07	71.00	90.89	Jun-11	77.10	155.76
Jul-07	82.00	69.93	Jul-11	87.70	44.75
Aug-07	83.00	74.69	Aug-11	78.70	68.52
Sep-07	104.00	276.28	Sep-11	68.70	181.39
Oct-07	66.00	201.27	Oct-11	84.00	66.37
Nov-07	79.00	101.26	Nov-11	67.50	73.53
Dec-07	65.00	39.42	Dec-11	69.90	67.42
Jan-08	110.00	40.12	Jan-12	76.60	27.53
Feb-08	114.00	49.73	Feb-12	85.40	27.84
Mar-08	106.00	92.30	Mar-12	89.50	41.23
Apr-08	98.00	314.44	Apr-12	98.70	124.97
May-08	94.00	269.32	May-12	58.00	45.22
Jun-08	80.00	500.95	Jun-12	54.90	49.83
Jul-08	96.00	319.33	Jul-12	64.80	70.53
Aug-08	77.00	54.53	Aug-12	82.20	63.93
Sep-08	84.00	71.40	Sep-12	110.70	77.70
Oct-08	81.00	154.35	Oct-12	77.50	109.45
Nov-08	72.00	105.13	Nov-12	75.60	359.51
Dec-08	81.00	81.34	Dec-12	62.60	101.05
Jan-09	90.80	25.54	Jan-13	85.60	51.18
Feb-09	94.40	20.93	Feb-13	98.30	47.14
Mar-09	102.00	50.02	Mar-13	107.30	58.36
Apr-09	95.70	78.66	Apr-13	69.30	49.23
May-09	73.80	179.03	May-13	64.80	209.50
Jun-09	70.50	198.37	Jun-13	74.40	359.21
Jul-09	89.00	193.76	Jul-13	81.30	141.13
Aug-09	85.60	162.29	Aug-13	55.80	67.64
Sep-09	65.40	130.15	Sep-13	66.60	178.55
Oct-09	103.20	116.44	Oct-13	71.00	94.63
Nov-09	42.90	109.45	Nov-13	75.60	134.97
Dec-09	65.40	107.11	Dec-13	69.80	63.36
Jan-10	65.10	51.15	Jan-14	85.60	51.65
Feb-10	75.60	37.28	Feb-14	98.30	25.98
Mar-10	88.90	29.52	Mar-14	107.30	29.81
Apr-10	87.90	71.98	Apr-14	69.30	46.36
May-10	90.20	514.54	May-14	64.80	54.65
Jun-10	88.80	166.20	Jun-14	74.40	429.66
Jul-10	72.50	167.58	Jul-14	81.30	83.68
Aug-10	79.40	115.81	Aug-14	55.80	217.31
Sep-10	85.20	107.40	Sep-14	66.60	97.89

Monthly Rainfall Variation





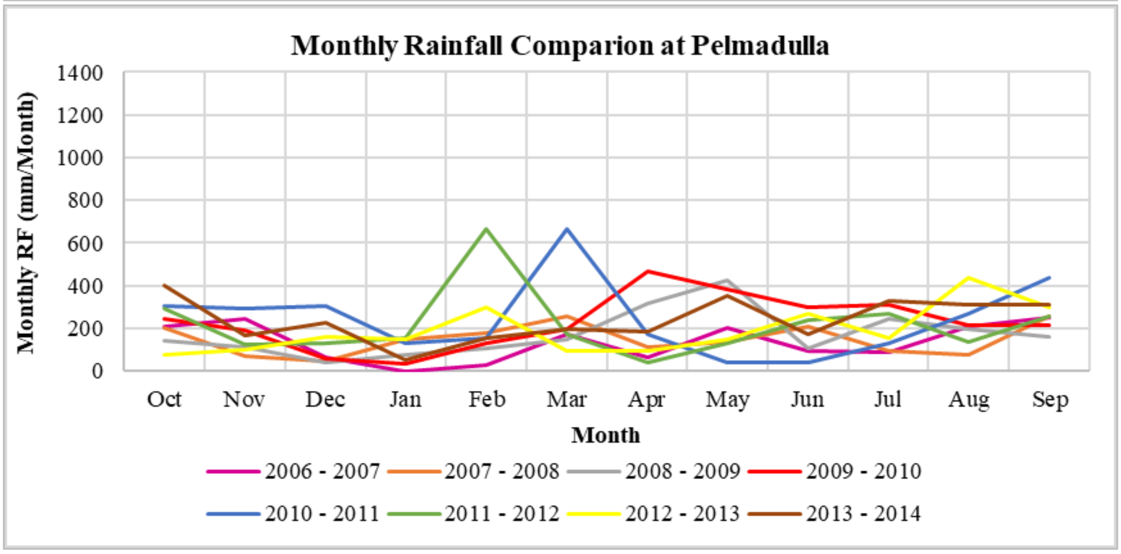


Figure A - 1: Alupola, Nivithigala and Pelmadulla Monthly Rainfall Variation

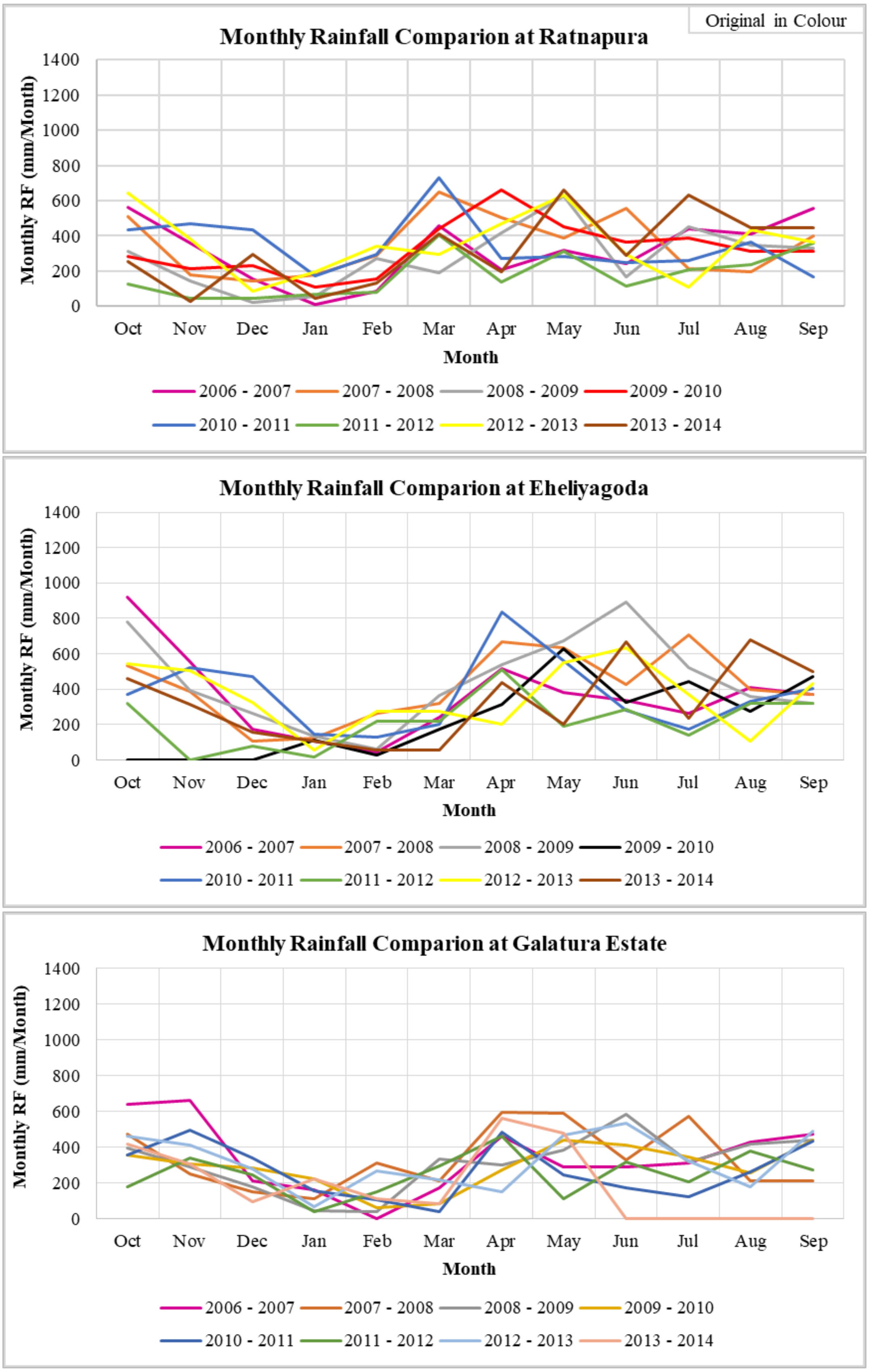


Figure A - 2: Ratnapura, Eheliyagoda and Galatura Monthly Rainfall Variation

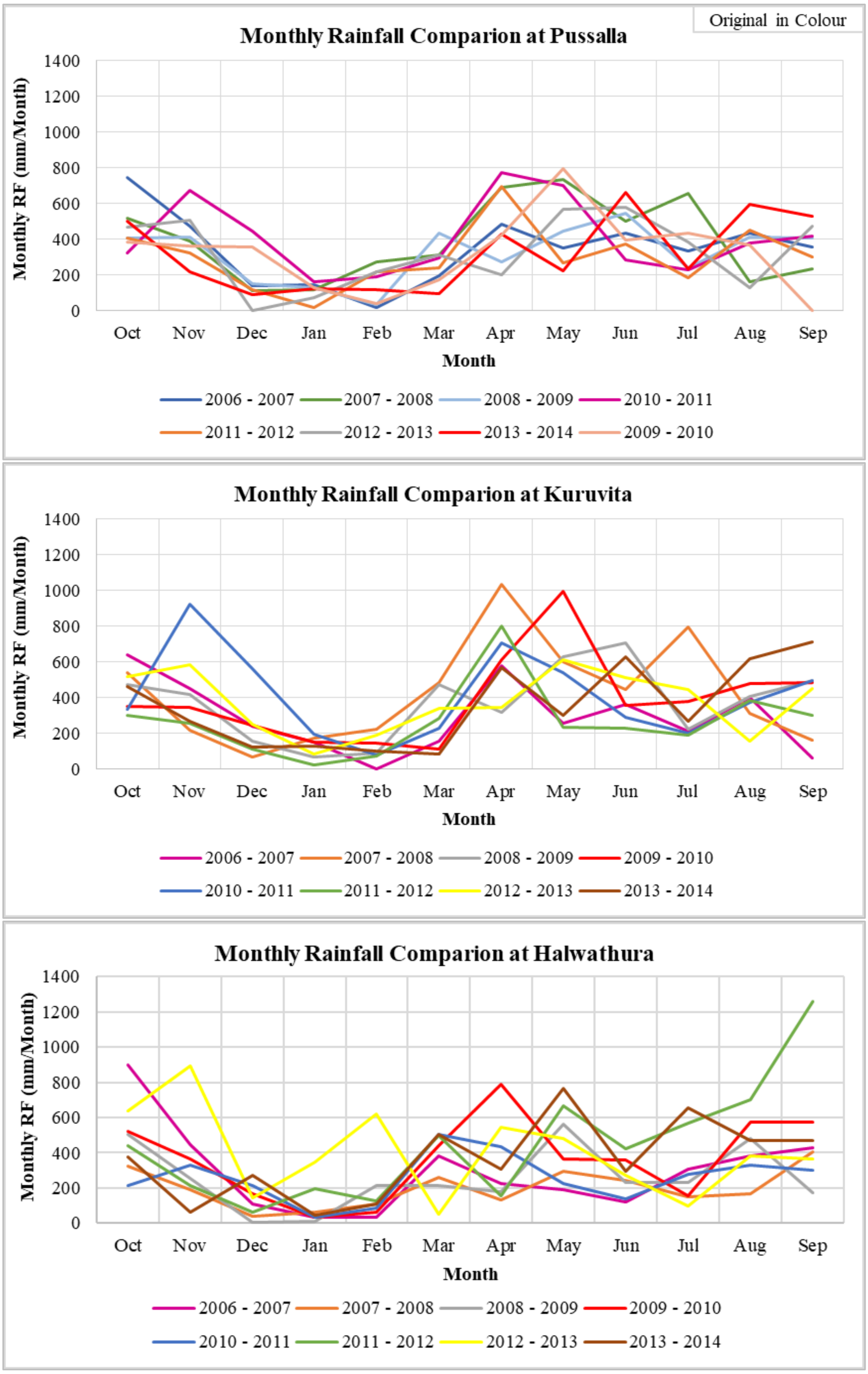


Figure A - 3: Pussalla, Kuruvite and Halwatura Monthly Rainfall Variation

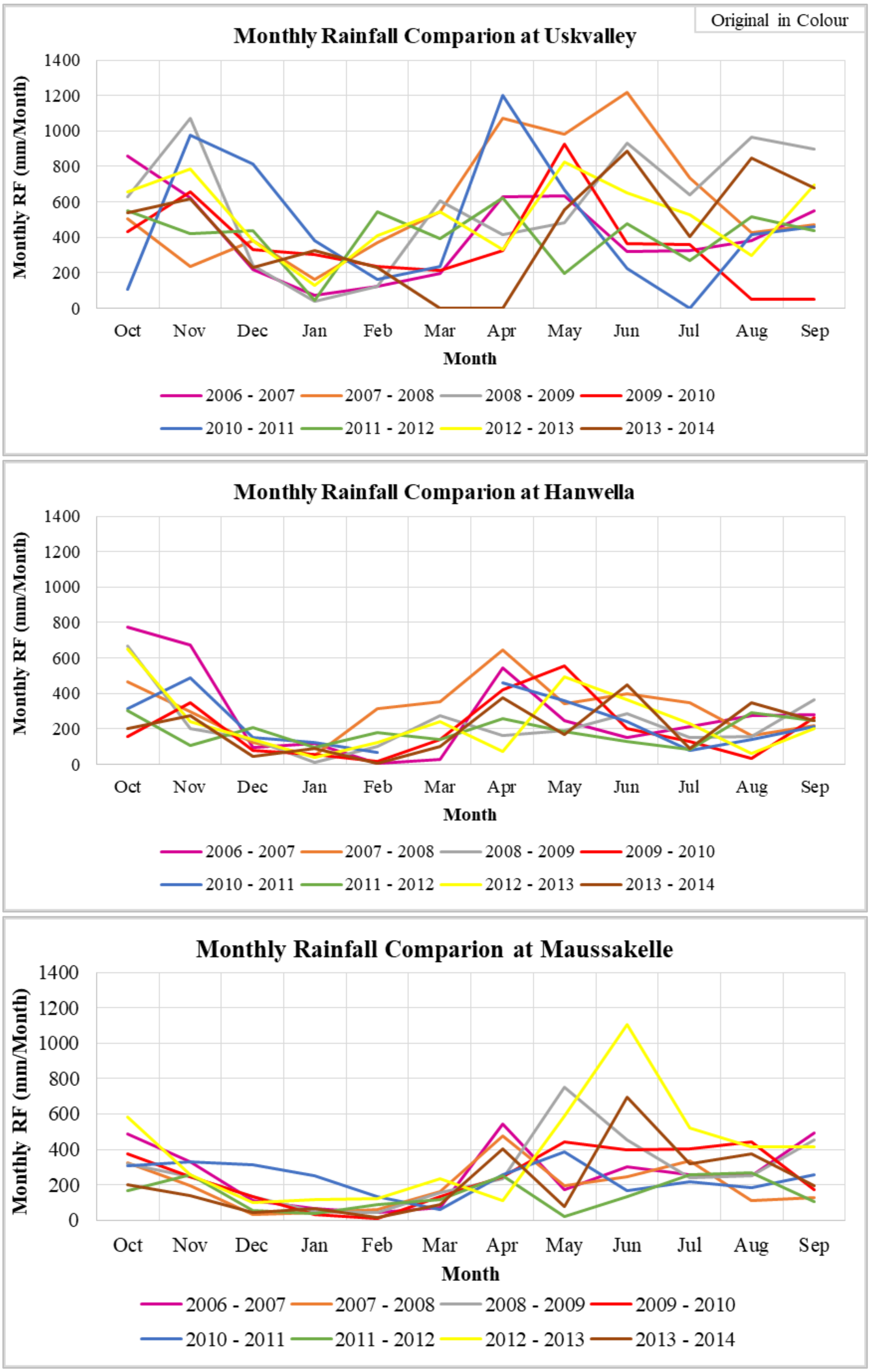


Figure A - 4: Uskvalley, Hanwella and Maussakelle Monthly Rainfall Variation

Double Mass Curve Plots

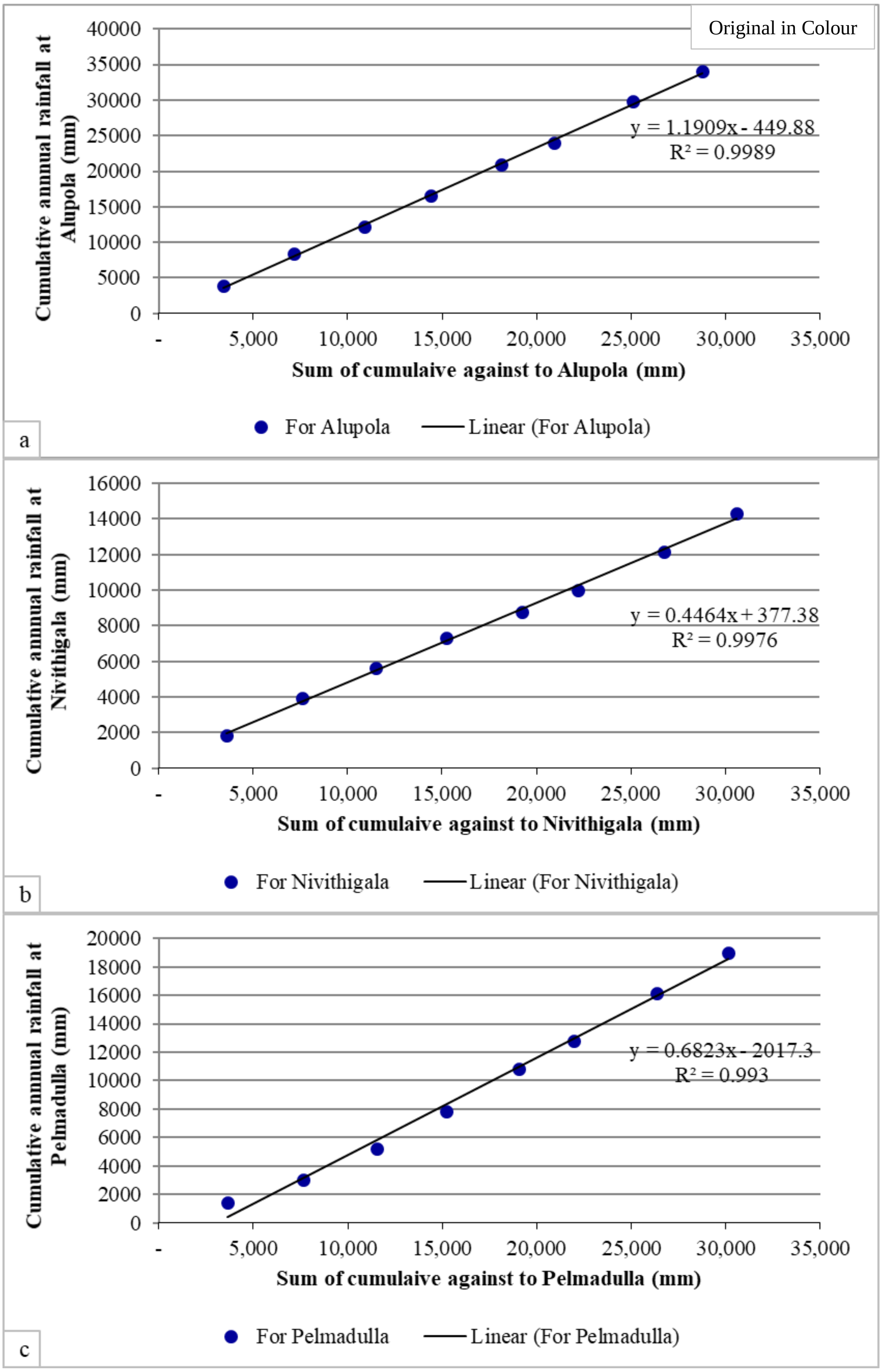


Figure A - 5: Double Mass Curves for Alupola (a), Nivithigala (b) and Pelmadulla (c)

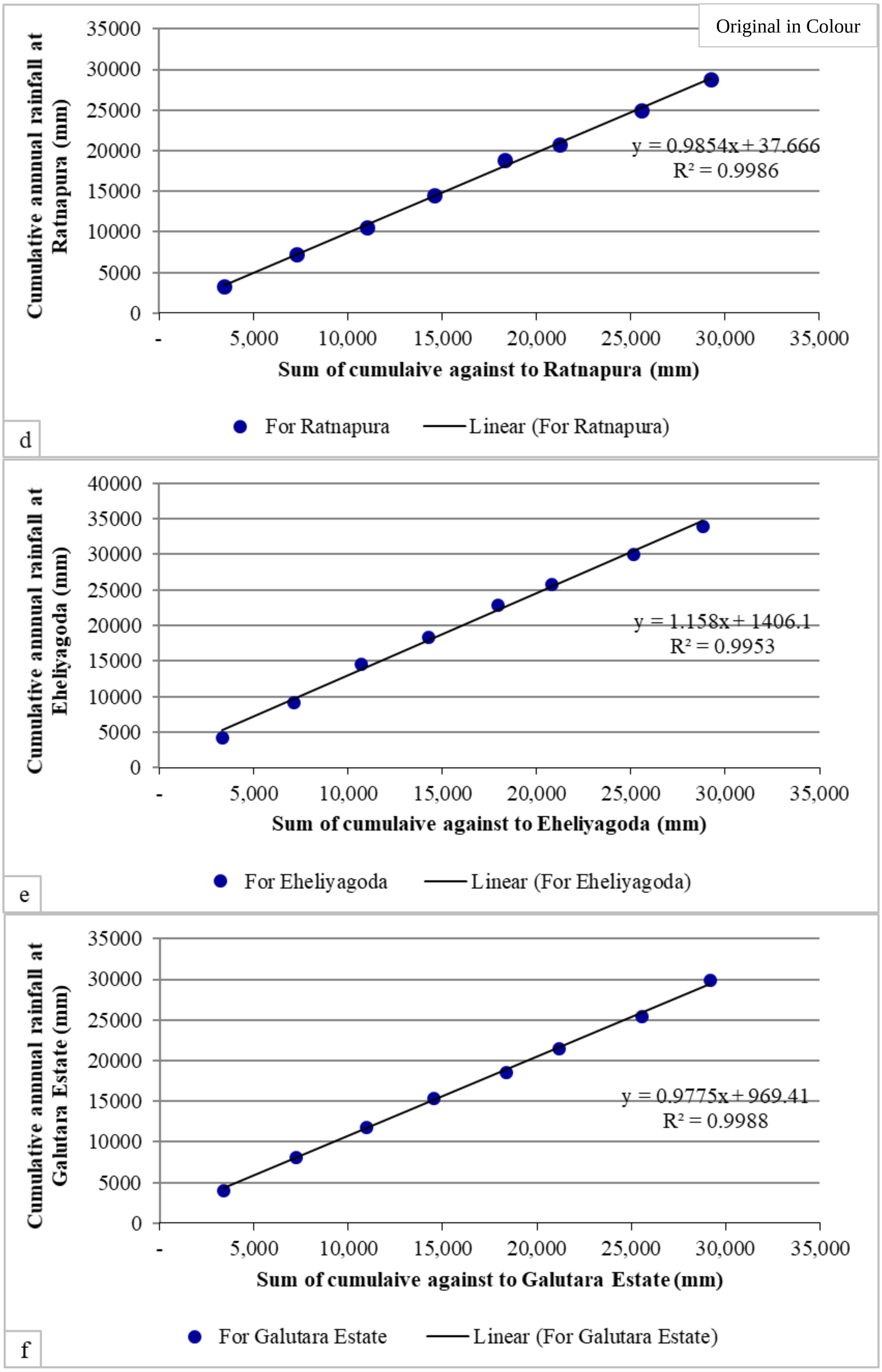


Figure A - 6: Double Mass Curves for Ratnapura (d), Eheliyagoda (e) and Galutara Estate (f)

Original in Colour

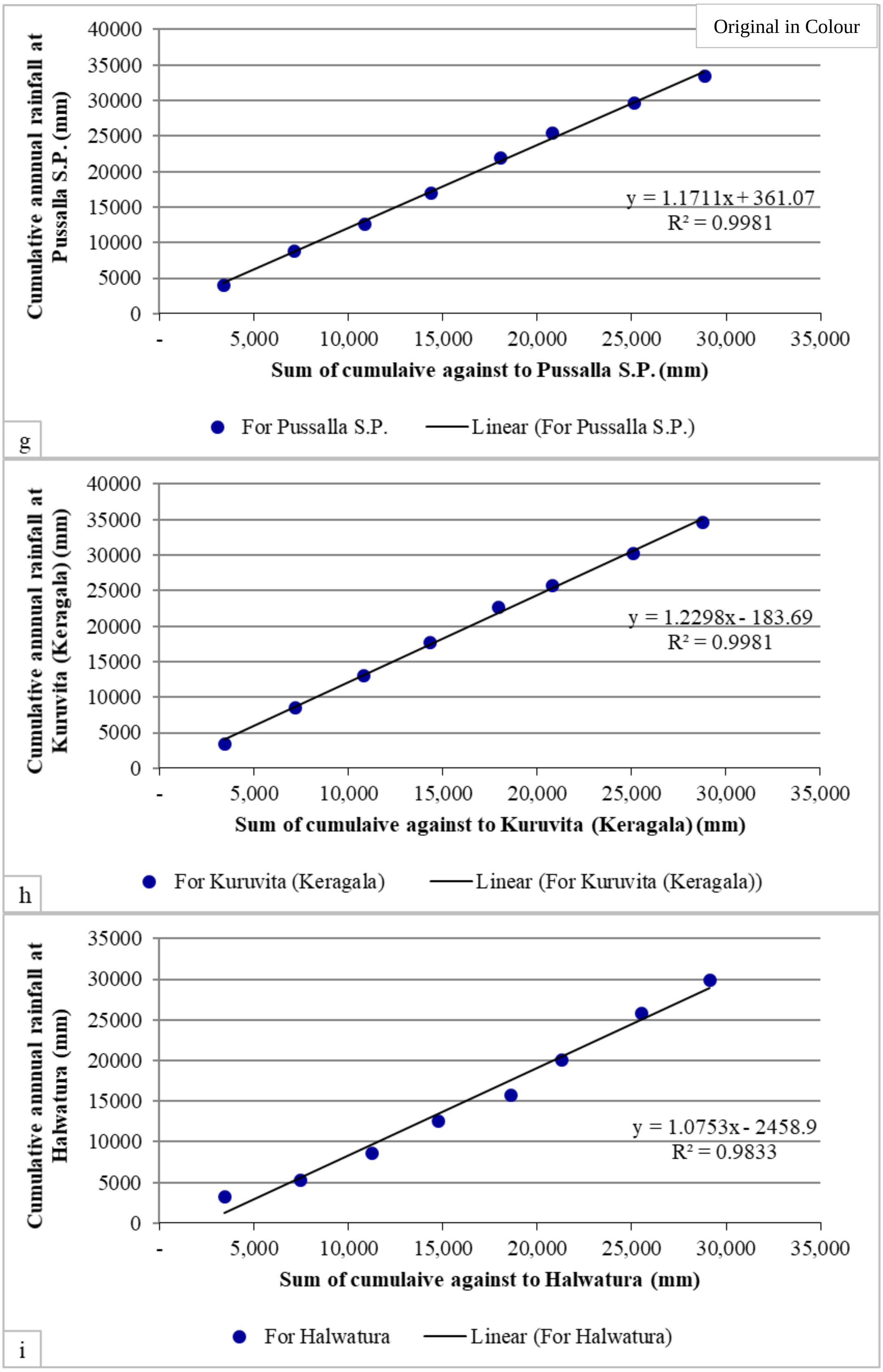


Figure A - 7: Double Mass Curves for Pussella S.P. (g), Kuruvita (Keragala) (h) and Halwatura (i)

Original in Colour

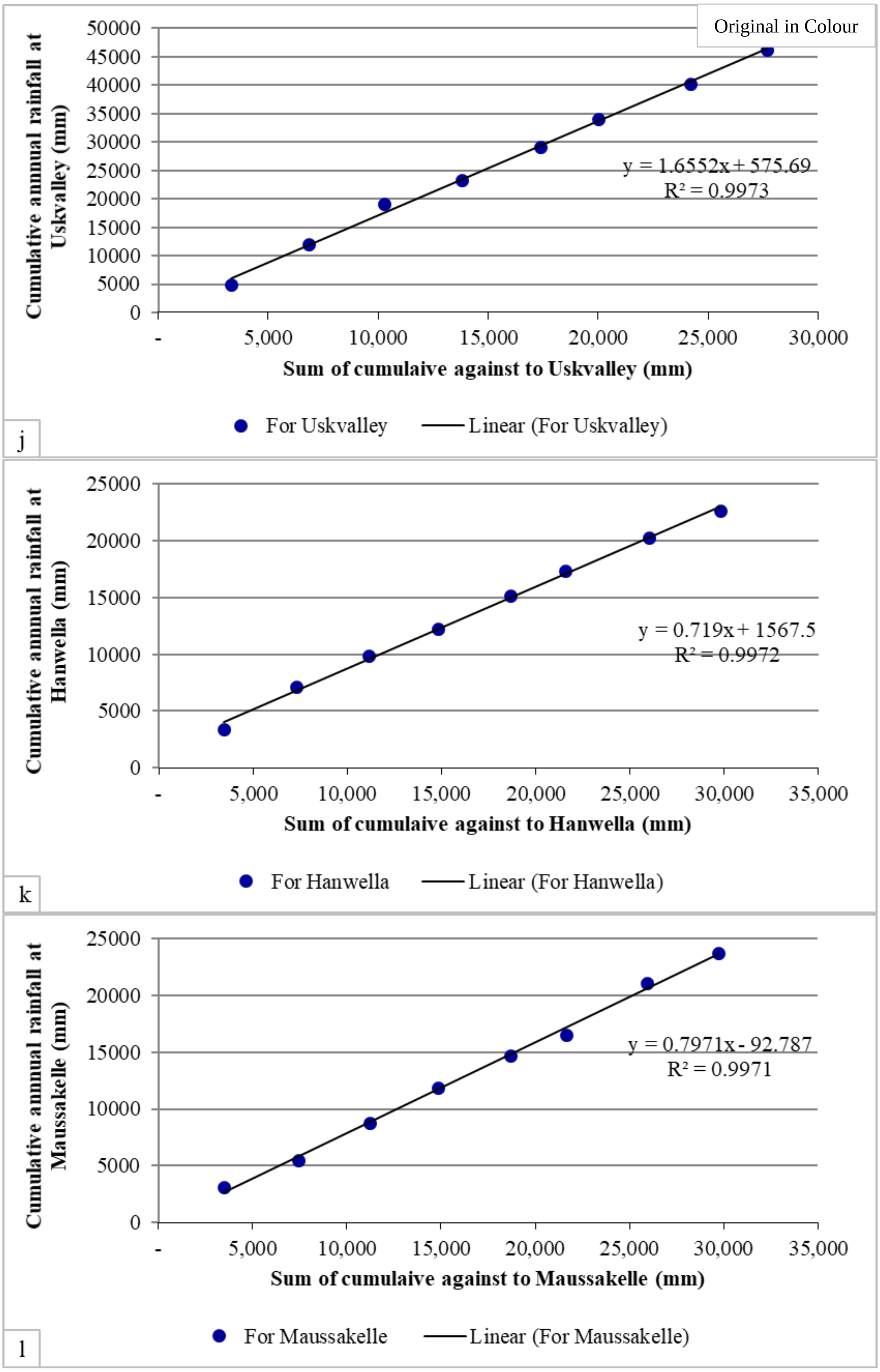


Figure A - 8: Double Mass Curve for Uskvalley (j), Hanwella (k) and Maussakelle (l)

ANNEX B - STATION COMBINATIONS

Thiessen Weights for Selected Rainfall Station Configuration

Table B - 1: Thiessen Weights for Rainfall Station Configurations

	Station Configuration **X**St-C**Y** **X** – Station Number **Y** - Configuration ID	**Alupola**	**Nivithigala**	**Pelmadulla**	**Rathnapura**	**Eheliyagoda S.P.**	**Galutara Estate**	**Pussalla S.P.**	**Kuruvita (Keragala)**	**Halwatura**	**Uskvalley**	**Hanwella**	**Maussakelle**
1	1St-C1	1.00	-	-	-	-	-	-	-	-	-	-	-
2	1St-C2	-	1.00	-	-	-	-	-	-	-	-	-	-
3	1St-C3	-	-	1.00	-	-	-	-	-	-	-	-	-
4	1St-C4	-	-	-	1.00	-	-	-	-	-	-	-	-
5	1St-C5	-	-	-	-	1.00	-	-	-	-	-	-	-
6	1St-C6	-	-	-	-	-	1.00	-	-	-	-	-	-
7	1St-C7	-	-	-	-	-	-	1.00	-	-	-	-	-
8	1St-C8	-	-	-	-	-	-	-	1.00	-	-	-	-
9	1St-C9	-	-	-	-	-	-	-	-	1.00	-	-	-
10	1St-C10	-	-	-	-	-	-	-	-	-	1.00	-	-
11	1St-C11	-	-	-	-	-	-	-	-	-	-	1.00	-
12	1St-C12	-	-	-	-	-	-	-	-	-	-	-	1.00
13	2St-C1	-	-	0.52	-	-	-	-	0.48	-	-	-	-
14	2St-C2	-	-	0.54	-	-	0.46	-	-	-	-	-	-
15	2St-C5	0.54	-	-	-	-	0.46	-	-	-	-	-	-
16	2St-C6	0.50	-	-	-	-	-	-	0.50	-	-	-	-
17	2St-C8	-	0.64	-	-	-	0.36	-	-	-	-	-	-
18	2St-C9	-	0.60	-	-	-	-	-	0.40	-	-	-	-
19	2St-C10	0.33	0.67	-	-	-	-	-	-	-	-	-	-
20	2St-C11	0.44	-	0.56	-	-	-	-	-	-	-	-	-
21	2St-C12	0.34	-	-	0.66	-	-	-	-	-	-	-	-
22	2St-C13	0.64	-	-	-	0.36	-	-	-	-	-	-	-
23	2St-C14	0.51	-	-	-	-	-	0.49	-	-	-	-	-
24	2St-C15	-	0.61	-	-	-	-	0.39	-	-	-	-	-
25	2St-C16	-	0.72	-	-	0.28	-	-	-	-	-	-	-
26	2St-C17	-	0.44	-	0.56	-	-	-	-	-	-	-	-
27	2St-C18	-	0.63	0.37	-	-	-	-	-	-	-	-	-
28	2St-C19	-	-	0.39	0.61	-	-	-	-	-	-	-	-
29	2St-C20	-	-	0.63	-	0.37	-	-	-	-	-	-	-
30	2St-C21	-	-	0.53	-	-	-	0.47	-	-	-	-	-
31	2St-C22	-	-	-	0.72	-	-	-	0.28	-	-	-	-
32	2St-C23	-	-	-	0.72	-	-	0.28	-	-	-	-	-
33	2St-C24	-	-	-	0.76	-	0.24	-	-	-	-	-	-
34	2St-C25	-	-	-	0.82	0.18	-	-	-	-	-	-	-
35	2St-C26	-	-	-	-	0.17	0.83	-	-	-	-	-	-
36	2St-C27	-	-	-	-	0.10	-	0.90	-	-	-	-	-
37	2St-C28	-	-	-	-	0.11	-	-	0.89	-	-	-	-
38	2St-C29	-	-	-	-	-	0.45	0.55	-	-	-	-	-
39	2St-C30	-	-	-	-	-	0.43	-	0.57	-	-	-	-
40	2St-C31	-	-	-	-	-	-	0.26	0.74	-	-	-	-
41	2St-C32	0.65	-	-	-	-	-	-	-	0.35	-	-	-
42	2St-C33	0.66	-	-	-	-	-	-	-	-	0.34	-	-
43	2St-C34	0.80	-	-	-	-	-	-	-	-	-	0.20	-
44	2St-C35	0.72	-	-	-	-	-	-	-	-	-	-	0.28
45	2St-C36	-	-	-	0.86	-	-	-	-	-	-	-	0.14
46	2St-C37	-	-	-	0.93	-	-	-	-	-	-	0.07	-
47	2St-C38	-	-	-	0.96	-	-	-	-	-	0.04	-	-
48	2St-C39	-	-	-	0.84	-	-	-	-	0.16	-	-	-

	Station Configuration	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda S.P.	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
49	2St-C40	-	-	-	-	-	-	-	0.86	0.14	-	-	-
50	2St-C41	-	-	-	-	-	-	-	0.78	-	0.22	-	-
51	2St-C42	-	-	-	-	-	-	-	0.98	-	-	0.02	-
52	2St-C43	-	-	-	-	-	-	-	0.66	-	-	-	0.34
53	3St-C1	0.26	0.38	-	-	-	-	-	0.37	-	-	-	-
54	3St-C3	0.20	0.38	-	-	-	0.42	-	-	-	-	-	-
55	3St-C4	0.14	-	0.41	-	-	-	-	0.45	-	-	-	-
56	3St-C5	-	0.27	0.37	-	-	0.36	-	-	-	-	-	-
57	3St-C7	-	0.25	0.36	-	-	-	-	0.39	-	-	-	-
58	3St-C8	0.21	0.53	0.26	-	-	-	-	-	-	-	-	-
59	3St-C9	0.25	0.27	-	0.48	-	-	-	-	-	-	-	-
60	3St-C10	0.30	0.44	-	-	0.26	-	-	-	-	-	-	-
61	3St-C11	0.26	0.38	-	-	-	-	0.36	-	-	-	-	-
62	3St-C12	-	0.14	0.34	0.52	-	-	-	-	-	-	-	-
63	3St-C13	-	0.35	0.37	-	0.28	-	-	-	-	-	-	-
64	3St-C14	-	0.26	0.36	-	-	-	0.38	-	-	-	-	-
65	3St-C15	-	-	0.39	0.32	-	-	-	0.28	-	-	-	-
66	3St-C16	-	-	0.39	0.32	-	-	0.28	-	-	-	-	-
67	3St-C17	-	-	0.39	0.37	-	0.24	-	-	-	-	-	-
68	3St-C18	-	-	0.39	0.43	0.18	-	-	-	-	-	-	-
69	3St-C19	-	-	-	0.74	0.13	0.14	-	-	-	-	-	-
70	3St-C20	-	-	-	0.72	0.10	-	0.19	-	-	-	-	-
71	3St-C21	-	-	-	0.72	0.11	-	-	0.18	-	-	-	-
72	3St-C22	-	-	-	-	0.08	0.40	-	0.52	-	-	-	-
73	3St-C23	-	-	-	-	0.07	0.43	0.50	-	-	-	-	-
74	3St-C24	-	-	-	-	-	0.42	0.09	0.49	-	-	-	-
75	3St-C25	0.34	-	-	0.49	-	-	-	-	0.16	-	-	-
76	3St-C26	0.34	-	-	0.62	-	-	-	-	-	0.04	-	-
77	3St-C27	0.34	-	-	0.59	-	-	-	-	-	-	0.07	-
78	3St-C28	0.33	-	-	0.63	-	-	-	-	-	-	-	0.04
79	3St-C29	-	0.42	-	0.48	-	-	-	-	-	-	-	0.11
80	3St-C30	-	0.44	-	0.49	-	-	-	-	-	-	0.07	-
81	3St-C31	-	0.44	-	0.52	-	-	-	-	-	0.04	-	-
82	3St-C32	-	0.44	-	0.40	-	-	-	-	0.16	-	-	-
83	3St-C33	-	-	-	0.69	-	-	-	0.21	0.10	-	-	-
84	3St-C34	-	-	-	0.69	-	-	-	0.28	-	0.03	-	-
85	3St-C35	-	-	-	0.72	-	-	-	0.26	-	-	0.02	-
86	3St-C36	-	-	-	0.61	-	-	-	0.27	-	-	-	0.12
87	4St-C1	0.14	-	0.38	-	-	0.24	-	0.24	-	-	-	-
88	4St-C2	0.26	0.34	-	-	-	0.17	-	0.23	-	-	-	-
89	4St-C3	0.18	0.22	0.26	-	-	0.34	-	-	-	-	-	-
90	4St-C4	0.13	0.24	0.26	-	-	-	-	0.37	-	-	-	-
91	4St-C5	-	0.14	0.34	0.28	-	0.24	-	-	-	-	-	-
92	4St-C6	-	0.14	0.34	0.24	-	-	-	0.28	-	-	-	-
93	4St-C7	-	0.22	0.36	-	-	0.17	-	0.25	-	-	-	-
94	4St-C8	0.13	-	0.31	0.32	-	0.24	-	-	-	-	-	-
95	4St-C9	0.12	-	0.31	0.29	-	-	-	0.28	-	-	-	-
96	4St-C10	0.33	-	-	0.33	-	0.15	-	0.19	-	-	-	-
97	4St-C11	0.13	0.14	0.26	0.48	-	-	-	-	-	-	-	-
98	4St-C12	0.17	0.31	0.26	-	0.26	-	-	-	-	-	-	-
99	4St-C13	0.14	0.25	0.26	-	-	-	0.36	-	-	-	-	-
100	4St-C14	-	0.14	0.34	0.24	-	-	0.28	-	-	-	-	-
101	4St-C15	-	0.14	0.34	0.34	0.18	-	-	-	-	-	-	-
102	4St-C16	-	-	0.39	0.34	0.13	0.14	-	-	-	-	-	-
103	4St-C17	-	-	0.39	0.32	0.10	-	0.19	-	-	-	-	-

	Station Configuration	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda S.P.	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
104	4St-C18	-	-	0.39	0.32	0.11	-	-	0.18	-	-	-	-
105	4St-C19	-	-	-	0.66	0.08	0.12	-	0.15	-	-	-	-
106	4St-C20	-	-	-	0.66	0.07	0.12	0.15	-	-	-	-	-
107	4St-C21	-	-	-	-	0.07	0.40	0.04	0.49	-	-	-	-
108	4St-C22	0.13	-	0.31	0.38	0.18	-	-	-	-	-	-	-
109	4St-C23	0.12	-	0.31	0.29	-	-	0.28	-	-	-	-	-
110	4St-C24	0.34	-	-	0.39	0.13	0.14	-	-	-	-	-	-
111	4St-C25	0.34	-	-	0.39	0.10	-	0.18	-	-	-	-	-
112	4St-C26	0.33	-	-	0.39	0.11	-	-	0.17	-	-	-	-
113	4St-C27	0.49	-	-	-	0.07	0.25	0.19	-	-	-	-	-
114	4St-C28	0.48	-	-	-	0.08	0.25	-	0.20	-	-	-	-
115	4St-C29	0.48	-	-	-	-	0.27	0.09	0.16	-	-	-	-
116	4St-C30	-	0.57	-	-	-	0.16	0.09	0.18	-	-	-	-
117	4St-C31	0.30	0.35	-	-	0.15	0.20	-	-	-	-	-	-
118	4St-C32	0.25	0.27	-	0.30	0.18	-	-	-	-	-	-	-
119	4St-C33	0.25	0.27	-	0.24	-	0.24	-	-	-	-	-	-
120	4St-C34	0.25	0.27	-	0.21	-	-	0.28	-	-	-	-	-
121	4St-C35	0.24	0.27	-	0.21	-	-	-	0.28	-	-	-	-
122	4St-C36	-	0.44	-	0.30	0.13	0.14	-	-	-	-	-	-
123	4St-C37	-	0.44	-	0.28	0.10	-	0.19	-	-	-	-	-
124	4St-C38	-	0.44	-	0.28	0.11	-	-	0.18	-	-	-	-
125	4St-C39	-	0.26	0.37	-	0.16	0.21	-	-	-	-	-	-
126	4St-C40	-	0.26	0.36	-	0.10	-	0.29	-	-	-	-	-
127	4St-C41	-	0.25	0.36	-	0.11	-	-	0.28	-	-	-	-
128	4St-C42	-	0.22	0.36	-	-	0.17	0.25	-	-	-	-	-
129	4St-C43	-	-	0.50	-	0.07	0.21	0.22	-	-	-	-	-
130	4St-C44	-	-	0.49	-	0.08	0.21	-	0.22	-	-	-	-
131	4St-C45	-	-	-	0.66	-	0.14	0.09	0.11	-	-	-	-
132	4St-C47	0.33	-	-	0.39	-	-	-	0.27	-	-	-	0.02
133	4St-C48	0.33	-	-	0.39	-	-	-	0.26	-	-	0.02	-
134	4St-C49	0.33	-	-	0.36	-	-	-	0.28	-	0.03	-	-
135	4St-C50	0.33	-	-	0.36	-	-	-	0.20	0.10	-	-	-
136	4St-C51	-	0.44	-	0.25	-	-	-	0.21	0.10	-	-	-
137	4St-C52	-	0.44	-	0.26	-	-	-	0.28	-	0.02	-	-
138	4St-C53	-	0.44	-	0.28	-	-	-	0.26	-	-	0.02	-
139	4St-C54	-	0.42	-	0.23	-	-	-	0.27	-	-	-	0.08
140	4St-C55	0.24	0.27	-	0.45	-	-	-	-	-	-	-	0.04
141	4St-C56	0.25	0.27	-	0.41	-	-	-	-	-	-	0.07	-
142	4St-C57	0.25	0.27	-	0.44	-	-	-	-	-	0.04	-	-
143	4St-C58	0.25	0.27	-	0.31	-	-	-	-	0.16	-	-	-
144	4St-C59	-	0.15	0.35	0.35	-	-	-	-	0.16	-	-	-
145	4St-C60	-	0.15	0.35	0.47	-	-	-	-	-	0.04	-	-
146	4St-C61	-	0.15	0.35	0.44	-	-	-	-	-	-	0.07	-
147	4St-C62	-	0.15	0.33	0.46	-	-	-	-	-	-	-	0.07
148	5St-C1	0.13	0.14	0.26	0.31	-	-	-	-	0.16	-	-	-
149	5St-C2	0.13	0.21	0.26	-	-	0.17	-	0.23	-	-	-	-
150	5St-C4	0.12	0.14	0.26	0.21	-	-	-	0.28	-	-	-	-
151	5St-C5	0.13	0.14	0.26	0.24	-	0.24	-	-	-	-	-	-
152	5St-C6	0.24	0.27	-	0.15	-	0.15	-	0.19	-	-	-	-
153	5St-C7	0.12	-	0.31	0.23	-	0.15	-	0.19	-	-	-	-
154	5St-C8	0.14	-	0.34	0.18	-	0.15	-	0.19	-	-	-	-
155	5St-C10	-	0.14	0.34	0.26	0.13	0.14	-	-	-	-	-	-
156	5St-C11	-	0.14	0.34	0.24	0.10	-	0.19	-	-	-	-	-
157	5St-C12	-	0.14	0.34	0.24	0.11	-	-	0.18	-	-	-	-
158	5St-C13	-	-	0.49	-	0.07	0.21	0.04	0.18	-	-	-	-

	Station Configuration	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda S.P.	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
159	5St-C14	-	0.57	-	-	0.07	0.14	0.04	0.18	-	-	-	-
160	5St-C15	0.48	-	-	-	0.07	0.25	0.04	0.16	-	-	-	-
161	5St-C16	0.13	0.14	0.26	0.30	0.18	-	-	-	-	-	-	-
162	5St-C17	0.12	0.14	0.26	0.21	-	-	0.28	-	-	-	-	-
163	5St-C18	0.13	-	0.31	0.30	0.13	0.14	-	-	-	-	-	-
164	5St-C19	0.12	-	0.31	0.29	0.10	-	0.18	-	-	-	-	-
165	5St-C20	0.12	-	0.31	0.29	0.11	-	-	0.17	-	-	-	-
166	5St-C21	0.24	0.27	-	0.21	0.11	-	-	0.17	-	-	-	-
167	5St-C22	0.25	0.27	-	0.21	0.10	-	0.18	-	-	-	-	-
168	5St-C23	0.25	0.27	-	0.21	0.13	0.14	-	-	-	-	-	-
169	5St-C24	0.26	0.34	-	-	0.07	0.14	0.18	-	-	-	-	-
170	5St-C25	0.26	0.34	-	-	0.08	0.15	-	0.18	-	-	-	-
171	5St-C26	0.14	-	0.38	-	0.08	0.21	-	0.20	-	-	-	-
172	5St-C27	0.14	-	0.38	-	0.07	0.21	0.19	-	-	-	-	-
173	5St-C28	0.34	-	-	0.33	0.07	0.12	0.14	-	-	-	-	-
174	5St-C29	0.33	-	-	0.33	0.08	0.12	-	0.14	-	-	-	-
175	5St-C30	-	0.44	-	0.22	0.08	0.12	-	0.15	-	-	-	-
176	5St-C31	-	0.44	-	0.22	0.07	0.12	0.15	-	-	-	-	-
177	5St-C32	-	0.22	0.36	-	0.07	0.14	0.20	-	-	-	-	-
178	5St-C33	-	0.22	0.36	-	0.08	0.15	-	0.20	-	-	-	-
179	5St-C34	-	-	0.39	0.27	0.07	0.12	0.15	-	-	-	-	-
180	5St-C35	-	-	0.39	0.26	0.08	0.12	-	0.15	-	-	-	-
181	5St-C36	-	-	0.39	0.26	-	0.14	0.09	0.11	-	-	-	-
182	5St-C37	-	-	-	0.66	0.07	0.12	0.04	0.11	-	-	-	-
183	5St-C38	0.33	-	-	0.33	-	0.14	0.09	0.11	-	-	-	-
184	5St-C39	0.14	-	0.38	-	-	0.23	0.09	0.16	-	-	-	-
185	5St-C40	0.26	0.34	-	-	-	0.16	0.09	0.14	-	-	-	-
186	5St-C41	0.10	0.15	0.27	0.45	-	-	-	-	-	-	-	0.04
187	5St-C42	0.11	0.15	0.27	0.40	-	-	-	-	-	-	0.07	-
188	5St-C43	0.11	0.15	0.27	0.44	-	-	-	-	-	0.04	-	-
189	5St-C44	0.11	0.15	0.27	0.31	-	-	-	-	0.16	-	-	-
190	5St-C45	-	0.15	0.35	0.20	-	-	-	0.21	0.10	-	-	-
191	5St-C46	-	0.15	0.35	0.20	-	-	-	0.28	-	0.02	-	-
192	5St-C47	-	0.15	0.35	0.22	-	-	-	0.26	-	-	0.02	-
193	5St-C48	-	0.15	0.33	0.21	-	-	-	0.27	-	-	-	0.04
194	5St-C49	0.10	-	0.33	0.29	-	-	-	0.27	-	-	-	0.02
195	5St-C50	0.10	-	0.33	0.29	-	-	-	0.26	-	-	0.02	-
196	5St-C51	0.10	-	0.33	0.27	-	-	-	0.28	-	0.03	-	-
197	5St-C52	0.10	-	0.33	0.27	-	-	-	0.20	0.10	-	-	-
198	6St-C1	0.13	0.14	0.26	0.21	0.13	0.14	-	-	-	-	-	-
199	6St-C2	0.12	0.14	0.26	0.21	0.10	-	0.18	-	-	-	-	-
200	6St-C3	0.12	0.14	0.26	0.21	0.11	-	-	0.17	-	-	-	-
201	6St-C4	0.12	0.14	0.26	0.15	-	0.15	-	0.19	-	-	-	-
202	6St-C5	0.12	0.14	0.26	0.15	-	0.14	0.19	-	-	-	-	-
203	6St-C6	0.12	0.14	0.26	0.20	-	-	0.18	0.11	-	-	-	-
204	6St-C7	0.14	0.21	0.26	-	0.07	0.14	0.18	-	-	-	-	-
205	6St-C8	0.13	0.21	0.26	-	0.08	0.15	-	0.18	-	-	-	-
206	6St-C9	0.13	0.21	0.26	-	-	0.16	0.09	0.14	-	-	-	-
207	6St-C10	0.25	0.27	-	0.15	0.07	0.12	0.14	-	-	-	-	-
208	6St-C11	0.24	0.27	-	0.15	0.08	0.12	-	0.14	-	-	-	-
209	6St-C12	0.24	0.27	-	0.15	-	0.14	0.09	0.11	-	-	-	-
210	6St-C13	0.12	-	0.31	0.23	-	0.14	0.09	0.11	-	-	-	-
211	6St-C14	0.12	-	0.31	0.24	0.07	0.12	0.14	-	-	-	-	-
212	6St-C15	0.12	-	0.31	0.23	0.08	0.12	-	0.14	-	-	-	-
213	6St-C16	0.14	-	0.38	-	0.07	0.21	0.04	0.16	-	-	-	-

	Station Configuration	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda S.P.	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
214	6St-C17	0.33	-	-	0.33	0.07	0.12	0.04	0.11	-	-	-	-
215	6St-C18	-	0.44	-	0.22	0.07	0.12	0.04	0.11	-	-	-	-
216	6St-C19	-	0.22	0.36	-	0.07	0.14	0.04	0.17	-	-	-	-
217	6St-C20	-	-	0.39	0.26	0.07	0.12	0.04	0.11	-	-	-	-
218	6St-C21	0.10	0.15	0.27	0.18	-	-	-	0.20	0.10	-	-	-
219	6St-C22	0.10	0.15	0.27	0.19	-	-	-	0.28	-	0.02	-	-
220	6St-C23	0.10	0.15	0.27	0.21	-	-	-	0.26	-	-	0.02	-
221	6St-C24	0.10	0.15	0.27	0.21	-	-	-	0.27	-	-	-	0.02
222	6St-C25	-	0.15	0.35	0.16	-	0.11	-	0.19	0.05	-	-	-
223	6St-C26	-	0.15	0.35	0.16	-	0.15	-	0.19	-	0.001	-	-
224	6St-C27	-	0.15	0.35	0.16	-	0.14	-	0.19	-	-	0.01	-
225	6St-C28	-	0.15	0.33	0.15	-	0.15	-	0.18	-	-	-	0.04
226	6St-C29	-	0.15	0.33	0.21	-	-	0.18	0.09	-	-	-	0.04
227	6St-C30	-	0.15	0.35	0.22	-	-	0.17	0.11	-	-	0.01	-
228	6St-C31	-	0.15	0.35	0.20	-	-	0.17	0.11	-	0.02	-	-
229	6St-C32	-	0.15	0.35	0.20	-	-	0.11	0.11	0.09	-	-	-
230	7St-C1	0.12	0.14	0.26	0.15	0.07	0.12	0.14	-	-	-	-	-
231	7St-C2	0.12	0.14	0.26	0.15	0.08	0.12	-	0.14	-	-	-	-
232	7St-C3	0.12	0.14	0.26	0.20	0.10	-	0.08	0.11	-	-	-	-
233	7St-C4	0.12	0.14	0.26	0.15	-	0.14	0.09	0.11	-	-	-	-
234	7St-C5	0.13	0.21	0.26	-	0.07	0.14	0.04	0.14	-	-	-	-
235	7St-C6	0.24	0.27	-	0.15	0.07	0.12	0.04	0.11	-	-	-	-
236	7St-C7	0.12	-	0.31	0.23	0.07	0.12	0.04	0.11	-	-	-	-
237	7St-C8	-	0.14	0.34	0.18	0.07	0.12	0.04	0.11	-	-	-	-
238	7St-C10	0.10	0.15	0.27	0.18	-	-	0.11	0.11	0.09	-	-	-
239	7St-C11	0.10	0.15	0.27	0.14	-	0.11	-	0.19	0.05	-	-	-
240	7St-C12	0.10	0.15	0.27	0.14	-	0.15	-	0.19	-	0.001	-	-
241	7St-C13	0.10	0.15	0.27	0.14	-	0.14	-	0.19	-	-	0.01	-
242	7St-C14	0.10	0.15	0.27	0.14	-	0.15	-	0.18	-	-	-	0.02
243	7St-C15	0.10	0.15	0.27	0.21	0.11	-	-	0.16	-	-	-	0.02
244	7St-C16	0.10	0.15	0.27	0.19	0.10	-	-	0.17	-	0.02	-	-
245	7St-C17	0.10	0.15	0.27	0.18	0.07	-	-	0.16	0.07	-	-	-
246	7St-C18	0.10	0.15	0.27	0.14	0.08	0.12	-	0.14	-	-	-	-
247	8St-C1	0.10	0.15	0.27	0.14	0.07	0.10	-	0.14	0.03	-	-	-
248	8St-C2	0.10	0.15	0.27	0.14	0.08	0.12	-	0.14	-	0.001	-	-
249	8St-C3	0.10	0.15	0.27	0.14	0.08	0.12	-	0.13	-	-	-	0.02
250	8St-C4	0.10	0.15	0.27	0.14	-	0.14	0.09	0.09	-	-	-	0.02
251	8St-C5	0.10	0.15	0.27	0.14	-	0.14	0.09	0.11	-	-	0.009	-
252	8St-C6	0.10	0.15	0.27	0.14	-	0.14	0.09	0.11	-	0.001	-	-
253	8St-C7	0.10	0.15	0.27	0.14	-	0.10	0.09	0.11	0.04	-	-	-
254	8St-C8	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.11	-	-	-	-
255	8St-C9	0.11	0.15	0.27	0.15	0.06	0.10	0.14	-	0.03	-	-	-
256	8St-C10	0.11	0.15	0.27	0.15	0.07	0.12	0.14	-	-	0.001	-	-
257	8St-C11	0.10	0.15	0.27	0.15	0.07	0.12	0.13	-	-	-	-	0.02
258	8St-C12	0.11	0.21	0.27	-	0.06	0.13	0.04	0.14	0.03	-	-	-
259	8St-C13	0.11	0.21	0.27	-	0.07	0.14	0.04	0.14	-	0.001	-	-
260	9St-C1	0.10	0.15	0.27	0.14	0.06	0.10	0.04	0.11	0.03	-	-	-
261	9St-C2	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.11	-	0.001	-	-
262	9St-C3	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.09	-	-	-	0.02
263	9St-C4	0.10	0.15	0.27	0.14	0.07	0.10	-	0.14	0.03	0.001	-	-
264	9St-C5	0.10	0.15	0.27	0.14	0.07	0.10	-	0.13	0.03	-	-	0.02
265	9St-C6	0.10	0.15	0.27	0.14	0.08	0.12	-	0.13	-	0.001	-	0.02
266	9St-C9	0.10	0.15	0.27	0.14	0.06	0.10	0.04	0.11	0.03	-	-	-
267	9St-C10	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.11	-	0.001	-	-
268	9St-C11	0.10	0.15	0.27	0.14	-	0.14	0.09	0.09	-	-	0.009	0.02

	Station Configuration	Alupola	Nivithigala	Pelmadulla	Rathnapura	Eheliyagoda S.P.	Galutara Estate	Pussalla S.P.	Kuruvita (Keragala)	Halwatura	Uskvalley	Hanwella	Maussakelle
269	9St-C12	0.10	0.15	0.27	0.14	-	0.14	0.09	0.11	-	0.001	0.009	-
270	9St-C13	0.10	0.15	0.27	0.14	-	0.14	0.09	0.09	-	0.001	-	0.02
271	9St-C14	0.10	0.15	0.27	0.14	-	0.10	0.09	0.09	0.04	-	-	0.02
272	9St-C15	0.10	0.15	0.27	0.14	-	0.10	0.09	0.11	0.04	0.001	-	-
273	9St-C16	0.10	0.15	0.27	0.14	-	0.10	0.09	0.11	0.04	-	0.003	-
274	10St-C1	0.10	0.15	0.27	0.14	0.06	0.10	0.04	0.09	0.03	-	-	0.02
275	10St-C2	0.10	0.15	0.27	0.14	0.06	0.10	0.04	0.11	0.03	0.001	-	-
276	10St-C3	0.10	0.15	0.27	0.14	0.07	0.12	0.04	0.09	-	0.001	-	0.02
277	10St-C4	0.10	0.15	0.27	0.14	0.06	0.10	0.04	0.11	0.03	0.001	-	-
278	10St-C5	0.10	0.15	0.27	0.14	-	0.10	0.09	0.11	0.04	0.001	0.003	-
279	10St-C6	0.10	0.15	0.27	0.14	-	0.10	0.09	0.09	0.04	0.001	-	0.02
280	10St-C7	0.10	0.15	0.27	0.14	-	0.14	0.09	0.09	-	0.001	0.009	0.02
281	10St-C8	0.10	0.15	0.27	0.14	-	0.10	0.09	0.09	0.04	-	0.003	0.02
282	10St-C9	0.10	0.15	0.27	0.14	-	0.11	-	0.17	0.05	0.001	0.005	0.02
283	10St-C10	0.10	0.15	0.27	0.15	-	0.10	0.17	-	0.04	0.001	0.003	0.02

Table B - 2: Summary of Station Combination Results (RO option)

Configuration	**Year**	**Annual rainfall (mm/year)**			**Annual Deviation** with respect to minimum	**Maha Season rainfall (mm/season)**			**Maha Deviation** with respect to minimum	**Yala Season rainfall (mm/season)**			**Yala Deviation** with respect to minimum
		Min	**Average**	**Max**		**Min**	**Average**	**Max**		**Min**	**Average**	**Max**	
2 stations	2006-2007	1681.78	3304.11	4222.81	151%	708.15	1,420.05	1,880.97	166%	973.62	1,884.06	2,389.90	145%
	2007-2008	1914.84	3902.76	5522.56	188%	818.53	1,524.18	2,329.46	185%	1,096.31	2,378.59	3,699.48	237%
	2008-2009	1887.27	3546.96	5027.66	166%	659.55	1,322.95	1,915.98	190%	1,227.72	2,224.01	3,120.24	154%
	2009-2010	2035.81	3768.99	4618.56	127%	665.68	1,273.08	1,836.49	176%	1,370.13	2,495.91	3,278.53	139%
	2010-2011	1954.09	3897.59	5116.54	155%	1,080.71	1,822.11	2,397.13	122%	927.47	2,089.75	2,761.57	198%
	2011-2012	1650.26	2688.85	3707.30	144%	546.43	1,059.34	2,033.74	272%	838.82	1,554.49	2,262.29	170%
	2012-2013	2174.90	4152.62	6010.98	131%	1,165.54	1,907.89	2,977.86	155%	1,433.27	2,346.27	3,391.82	137%
	2013-2014	2409.21	3728.20	4749.93	98%	959.91	1,240.88	1,896.76	98%	1,357.81	2,486.24	3,267.92	141%
	Average	1963.52	3623.76	4872.04	143%	853.08	1,446.31	2,069.66	143%	1,153.14	2,182.41	2,857.54	148%
3 stations	2006-2007	2151.17	3072.25	4124.77	92%	922.44	1285.45	1796.06	95%	1,228.73	1,786.79	2,328.71	90%
	2007-2008	2477.28	3570.63	4646.41	88%	1047.61	1368.77	1742.84	66%	1,323.30	2,201.86	3,008.49	127%
	2008-2009	2266.77	3261.36	4227.90	87%	832.21	1195.21	1547.11	86%	1,434.56	2,066.14	2,680.79	87%
	2009-2010	2512.60	3531.10	4150.62	65%	865.28	1187.63	1477.47	71%	1,647.31	2,343.47	2,792.79	70%
	2010-2011	2398.32	3661.32	4499.12	85%	1209.45	1760.56	2189.13	81%	1,223.75	1,919.51	2,315.01	89%
	2011-2012	1647.28	2410.22	3299.06	100%	566.51	886.14	1284.43	127%	908.87	1,423.30	2,014.63	122%
	2012-2013	2774.77	3832.58	5048.54	58%	1412.55	1809.25	2471.83	75%	1,724.45	2,159.72	2,688.59	56%
	2013-2014	2746.47	3538.44	4320.17	58%	967.59	1179.49	1397.86	44%	1,548.16	2,357.36	3,120.12	102%
	Average	2371.83	3359.74	4289.57	77%	1,062.97	1,334.06	1,590.81	50%	1,393.61	2,032.27	2,527.77	81%
4 stations	2006-2007	2423.14	3028.14	3999.82	65%	954.98	1,286.42	1,764.03	85%	1,335.67	1,741.72	2,235.79	67%
	2007-2008	2526.29	3523.87	4633.28	83%	975.20	1,396.69	1,999.12	105%	1,551.09	2,127.18	2,994.79	93%
	2008-2009	2685.02	3239.03	4202.36	57%	949.16	1,192.85	1,542.32	62%	1,711.85	2,046.18	2,660.04	55%
	2009-2010	2738.42	3493.88	4328.32	58%	915.87	1,181.71	1,519.29	66%	1,818.07	2,312.17	2,860.45	57%
	2010-2011	2695.73	3588.42	4498.99	68%	1,342.87	1,710.75	2,078.93	55%	1,335.82	1,903.95	2,424.82	82%
	2011-2012	1919.98	2493.64	3152.18	72%	668.44	963.33	1,551.10	132%	1,161.30	1,396.58	1,964.23	69%
	2012-2013	2878.04	3807.67	4992.54	65%	1,300.45	1,803.12	2,338.59	80%	1,725.56	2,185.54	2,846.15	65%
	2013-2014	3047.83	3521.53	4302.30	41%	995.19	1,219.86	1,498.05	51%	1,898.37	2,300.03	3,103.33	63%
	Average	2614.31	3351.31	4138.83	58%	1,103.14	1,344.34	1,716.30	56%	1,661.25	2,001.67	2,523.72	52%

Table B - 2: page 2

Configuration	Year	Annual rainfall (mm/year)			Annual Deviation with respect to minimum	Maha Season rainfall (mm/season)			Maha Deviation with respect to minimum	Yala Season rainfall (mm/season)			Yala Deviation with respect to minimum
5 stations	2006-2007	2486.19	2940.50	3906.44	57%	1,045.40	1,256.09	1,752.58	68%	1,409.89	1,684.41	2,187.45	55%
	2007-2008	2780.84	3424.63	4527.23	63%	1,087.50	1,357.61	1,994.14	83%	1,638.25	2,067.01	2,672.62	63%
	2008-2009	2825.22	3215.58	3986.85	41%	1,014.55	1,179.90	1,517.67	50%	1,781.05	2,035.68	2,469.18	39%
	2009-2010	2724.84	3480.72	4219.09	55%	918.86	1,167.58	1,502.71	64%	1,805.98	2,313.15	2,720.16	51%
	2010-2011	2697.62	3573.25	4257.53	59%	1,336.66	1,707.62	2,044.18	53%	1,343.90	1,906.94	2,341.86	74%
	2011-2012	2036.41	2577.80	3090.33	59%	757.04	976.46	1,501.95	98%	1,178.77	1,407.67	1,594.28	35%
	2012-2013	2989.48	3718.62	4980.42	64%	1,313.55	1,812.69	2,140.80	63%	1,725.61	2,168.06	2,839.62	65%
	2013-2014	3055.95	3519.04	4206.10	38%	1,025.07	1,231.98	1,495.06	46%	2,025.24	2,285.77	2,769.16	37%
	Average	2699.57	3306.27	4146.75	54%	1,110.71	1,336.24	1,715.51	54%	1,685.28	1,983.59	2,419.18	44%
6 stations	2006-2007	2551.31	2859.91	3727.53	46%	1,076.27	1,225.24	1,593.20	48%	1,430.25	1,634.68	2,134.32	49%
	2007-2008	2879.67	3343.30	4341.68	51%	1,094.67	1,319.62	1,800.63	64%	1,785.00	2,023.68	2,541.05	42%
	2008-2009	2889.59	3148.11	3836.80	33%	1,050.39	1,153.74	1,440.15	37%	1,823.30	1,994.37	2,396.66	31%
	2009-2010	2975.78	3413.32	4158.17	40%	1,000.90	1,135.23	1,454.57	45%	1,963.18	2,278.09	2,703.59	38%
	2010-2011	3031.16	3502.55	4257.40	41%	1,495.51	1,680.82	1,933.97	29%	1,522.40	1,867.94	2,323.43	53%
	2011-2012	2055.57	2597.03	2982.32	33%	768.39	972.52	1,193.17	55%	1,287.18	1,407.66	1,531.09	19%
	2012-2013	3056.79	3591.78	4772.46	45%	1,463.27	1,764.22	2,111.22	44%	1,832.01	2,121.04	2,661.24	45%
	2013-2014	3207.52	3466.81	4034.75	26%	1,046.54	1,219.59	1,375.64	31%	2,100.14	2,245.77	2,659.11	27%
	Average	2830.92	3240.35	4013.89	39%	1,168.65	1,308.87	1,612.82	38%	1,785.80	1,946.65	2,368.81	33%
7 stations	2006-2007	2694.43	2862.55	3275.74	22%	1,152.57	1,235.66	1,425.04	24%	1,541.86	1,626.89	1,850.70	20%
	2007-2008	3117.92	3346.37	3807.26	22%	1,176.92	1,329.73	1,577.61	34%	1,872.50	2,016.64	2,229.65	19%
	2008-2009	3022.32	3177.94	3374.23	12%	1,100.60	1,164.24	1,253.27	14%	1,889.60	2,013.71	2,144.31	13%
	2009-2010	3239.70	3415.56	3653.35	13%	1,068.32	1,139.58	1,226.69	15%	2,167.52	2,275.99	2,426.66	12%
	2010-2011	3284.96	3488.04	3783.44	15%	1,559.86	1,670.75	1,794.49	15%	1,769.80	1,863.33	2,050.28	16%
	2011-2012	2441.29	2597.46	2742.72	10%	880.39	983.79	1,082.43	23%	1,343.87	1,397.61	1,510.03	12%
	2012-2013	3252.49	3629.58	4056.70	14%	1,680.63	1,786.48	1,944.94	16%	1,962.79	2,135.52	2,289.09	17%
	2013-2014	3379.22	3479.63	3669.91	9%	1,172.85	1,229.48	1,280.46	9%	2,185.37	2,248.69	2,389.45	9%
	Average	3054.04	3249.64	3545.42	15%	1,234.32	1,317.46	1,400.94	13%	1,867.59	1,947.30	2,071.53	11%

Table B - 2: page 3

Configuration	Year	Annual rainfall (mm/year)			**Annual Deviation** with respect to minimum	Maha Season rainfall (mm/season)			**Maha Deviation** with respect to minimum	Yala Season rainfall (mm/season)			**Yala Deviation** with respect to minimum
8 stations	2006-2007	2825.62	2858.56	2915.23	3%	1,211.07	1,231.07	1,259.71	4%	1,597.63	1,627.49	1,655.51	4%
	2007-2008	3212.12	3302.28	3379.69	5%	1,287.65	1,315.40	1,351.66	5%	1,924.47	1,986.88	2,028.04	5%
	2008-2009	3051.94	3133.38	3208.33	5%	1,109.29	1,143.43	1,173.27	6%	1,926.78	1,989.94	2,040.48	6%
	2009-2010	3345.16	3375.45	3405.96	2%	1,119.84	1,130.19	1,149.81	3%	2,225.32	2,245.26	2,267.51	2%
	2010-2011	3405.00	3435.68	3481.13	2%	1,639.41	1,648.30	1,658.99	1%	1,813.85	1,835.48	1,868.91	3%
	2011-2012	2543.86	2604.60	2680.38	6%	965.20	988.52	1,005.41	4%	1,353.05	1,391.29	1,453.87	7%
	2012-2013	3531.03	3570.64	3620.53	2%	1,718.79	1,757.88	1,828.21	6%	2,097.69	2,117.00	2,144.53	2%
	2013-2014	3450.55	3474.19	3498.15	1%	1,214.08	1,227.21	1,240.84	2%	2,233.09	2,245.54	2,257.44	1%
	Average	3170.66	3219.35	3273.68	3%	1,287.44	1,305.25	1,325.72	3%	1,915.77	1,929.86	1,953.32	2%
9 stations	2006-2007	2815.74	2847.29	2878.83	2%	1,203.68	1,225.62	1,243.29	3%	1,598.36	1,621.67	1,642.07	3%
	2007-2008	3161.44	3266.61	3337.53	6%	1,265.47	1,301.36	1,326.38	5%	1,895.97	1,965.26	2,011.15	6%
	2008-2009	3034.55	3119.02	3188.59	5%	1,109.14	1,139.23	1,162.27	5%	1,922.57	1,979.79	2,036.28	6%
	2009-2010	3336.73	3366.50	3398.70	2%	1,115.52	1,126.50	1,134.69	2%	2,213.07	2,240.00	2,267.70	2%
	2010-2011	3394.92	3421.66	3446.80	2%	1,627.11	1,640.68	1,651.83	2%	1,808.86	1,829.26	1,846.19	2%
	2011-2012	2545.71	2610.65	2682.22	6%	966.21	986.40	1,001.90	4%	1,353.87	1,398.63	1,454.70	7%
	2012-2013	3523.23	3576.91	3622.72	3%	1,715.89	1,771.51	1,829.30	7%	2,095.44	2,110.77	2,127.45	2%
	2013-2014	3434.85	3459.50	3484.40	1%	1,208.28	1,220.83	1,230.27	2%	2,221.68	2,237.22	2,255.65	2%
	Average	3155.90	3208.52	3254.97	3%	1,285.08	1,301.51	1,311.99	2%	1,907.92	1,922.82	1,934.86	1%
10 stations	2006-2007	2766.13	2835.87	2868.95	4%	1,199.00	1,217.04	1,236.77	3%	1,567.14	1,618.82	1,657.65	6%
	2007-2008	3119.00	3215.99	3286.85	5%	1,262.86	1,284.55	1,305.86	3%	1,856.14	1,931.44	1,982.65	7%
	2008-2009	2978.42	3083.24	3163.26	6%	1,099.45	1,128.55	1,157.52	5%	1,878.97	1,954.69	2,015.69	7%
	2009-2010	3326.85	3360.65	3392.96	2%	1,109.32	1,123.37	1,133.69	2%	2,201.21	2,237.28	2,269.16	3%
	2010-2011	3379.24	3406.09	3436.72	2%	1,603.88	1,631.72	1,641.60	2%	1,792.30	1,822.65	1,843.87	3%
	2011-2012	2564.87	2627.94	2676.87	5%	966.58	988.21	1,010.31	5%	1,361.77	1,414.11	1,450.31	7%
	2012-2013	3525.41	3592.05	3634.80	3%	1,716.98	1,791.40	1,826.35	6%	2,087.66	2,106.02	2,120.98	2%
	2013-2014	3388.65	3443.41	3466.83	2%	1,203.47	1,214.01	1,226.23	2%	2,183.73	2,227.95	2,256.59	3%
	Average	3131.07	3195.66	3240.91	3%	1,285.95	1,297.36	1,311.90	2%	1,891.08	1,914.12	1,928.94	2%

ANNEX C - RAINFALL VARIATION (RO OPTION)

Rainfall Deviation

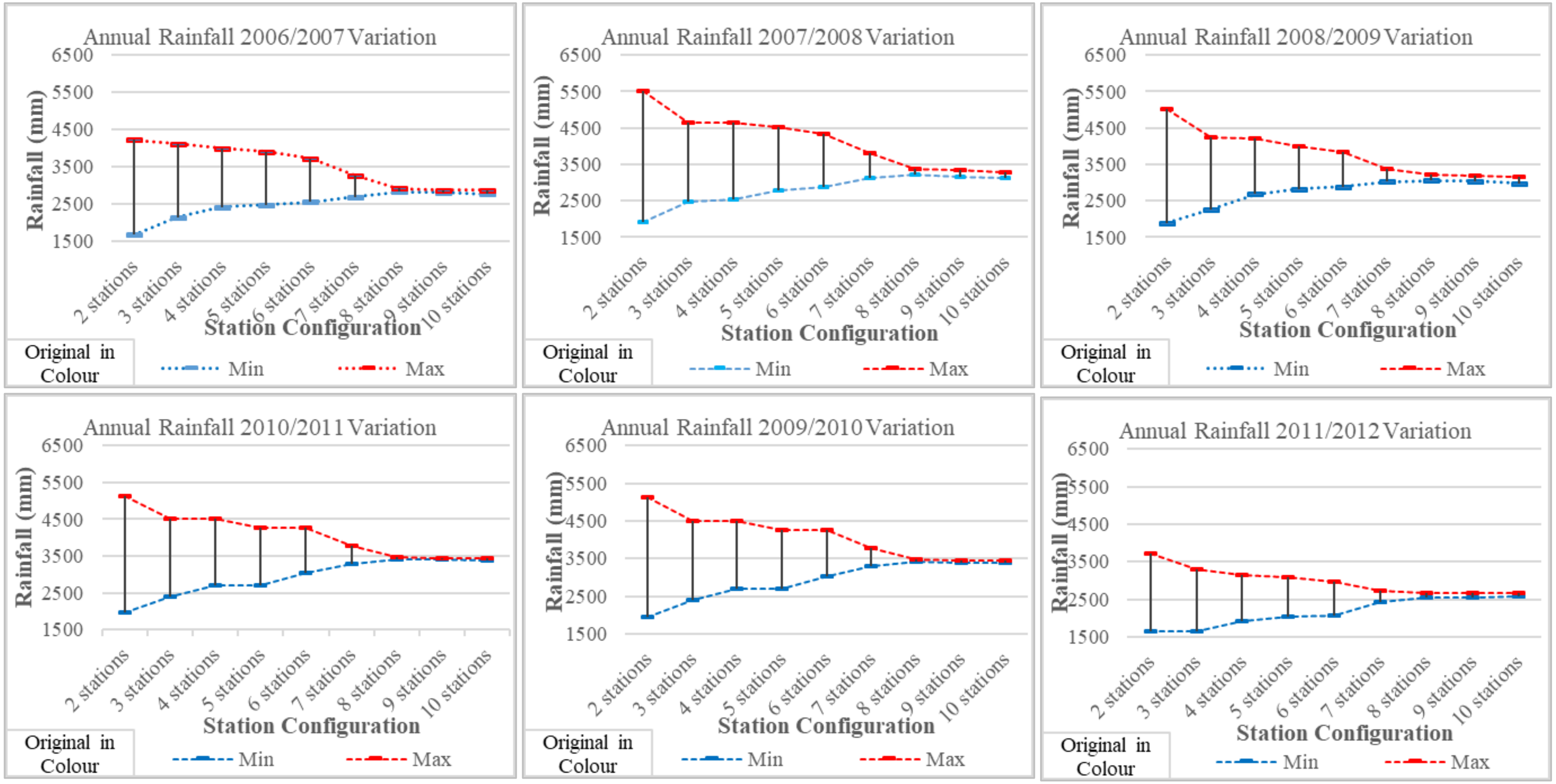


Figure C - 1: Annual rainfall variation in different station number for the catchment (Water year 2006/7 – 2011/12)

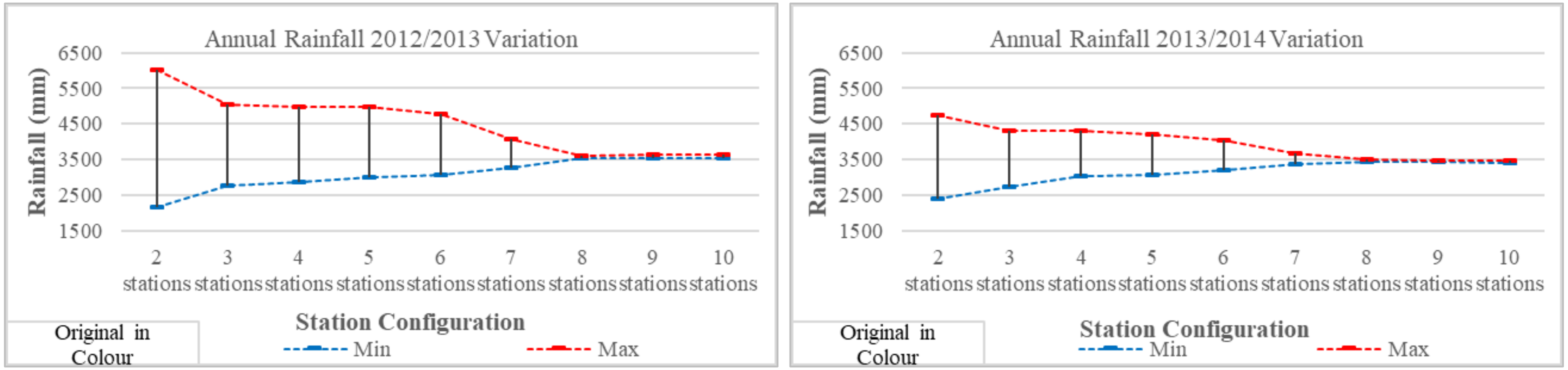


Figure C - 2: Annual rainfall variation in different station densities (Water year 2012/13 – 2013/14)

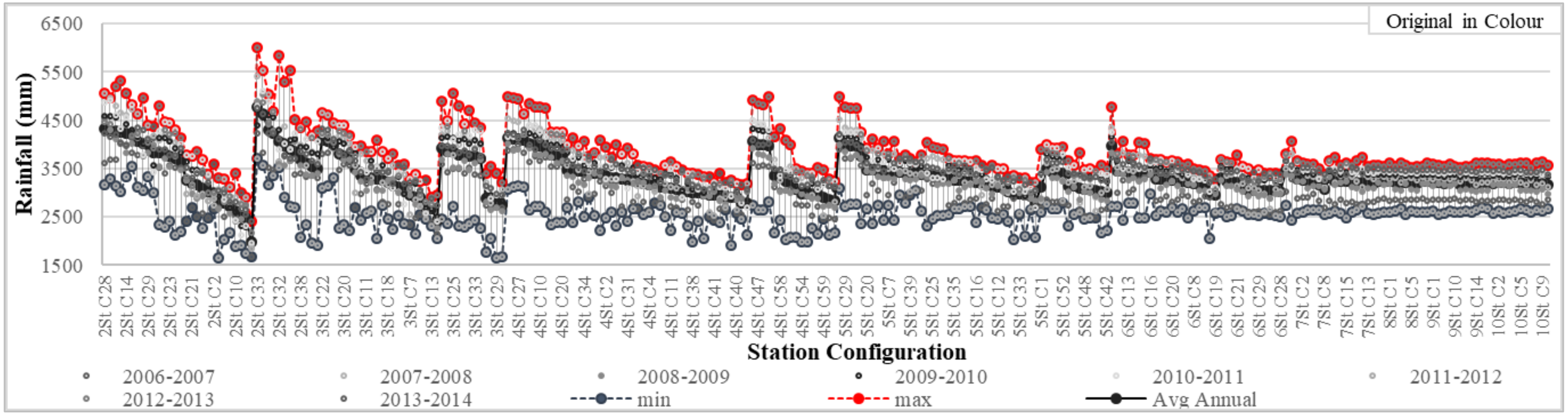


Figure C - 3: Rainfall variation for all station configurations

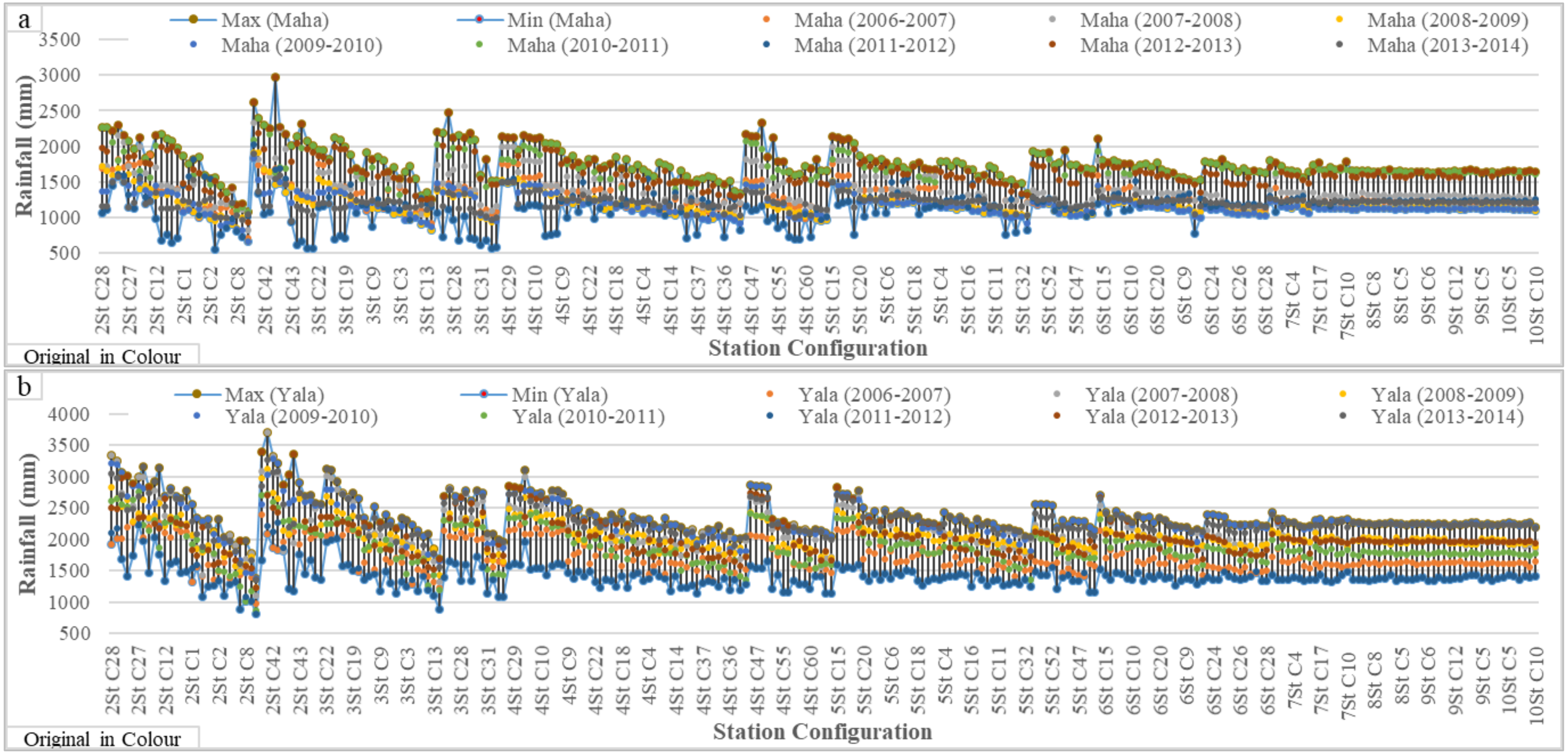


Figure C - 4: Rainfall variation in Maha (a) and Yala (b) season in different station density configuration

Table C - 1: Rainfall deviation classification

Density (km^2/station)	Deviation Class	Annual	Yala	Maha	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
698	0 - 0.1	7%	8%	10%	6%	9%	9%	9%	14%	14%	10%	9%	7%	10%	9%	8%
	0.1 - 0.2	5%	1%	5%	3%	9%	5%	12%	9%	8%	3%	9%	6%	9%	6%	5%
	0.2 - 0.3	6%	5%	10%	7%	8%	12%	7%	12%	12%	2%	9%	4%	8%	5%	5%
	0.3 - 0.4	6%	7%	7%	8%	8%	6%	14%	8%	9%	15%	8%	7%	6%	13%	9%
	0.4 - 0.5	11%	12%	9%	15%	11%	12%	9%	11%	13%	9%	7%	12%	10%	13%	17%
	0.5 - 0.75	38%	33%	30%	30%	26%	27%	29%	28%	26%	32%	27%	30%	24%	29%	31%
	0.75 - 1.0	29%	34%	28%	32%	29%	28%	20%	18%	18%	29%	30%	35%	32%	24%	24%
465	0 - 0.1	10%	7%	12%	13%	14%	11%	15%	8%	9%	9%	7%	10%	10%	10%	7%
	0.1 - 0.2	13%	10%	17%	12%	10%	4%	10%	9%	9%	2%	12%	6%	10%	7%	8%
	0.2 - 0.3	16%	10%	15%	12%	9%	17%	14%	13%	10%	8%	13%	16%	12%	9%	11%
	0.3 - 0.4	15%	17%	15%	12%	17%	9%	15%	10%	13%	8%	14%	17%	13%	17%	14%
	0.4 - 0.5	14%	12%	9%	16%	13%	16%	10%	12%	14%	17%	10%	14%	12%	18%	11%
	0.5 - 0.75	25%	30%	26%	28%	22%	28%	24%	32%	28%	31%	24%	23%	27%	20%	27%
	0.75 - 1.0	6%	14%	6%	7%	14%	15%	12%	15%	18%	24%	19%	13%	15%	19%	20%
349	0 - 0.1	15%	15%	10%	14%	12%	10%	9%	10%	7%	8%	10%	9%	9%	13%	17%
	0.1 - 0.2	24%	26%	21%	19%	14%	12%	13%	13%	10%	11%	14%	22%	20%	19%	22%
	0.2 - 0.3	22%	18%	25%	22%	20%	16%	17%	12%	14%	17%	22%	15%	19%	22%	16%
	0.3 - 0.4	16%	18%	14%	11%	13%	16%	15%	9%	21%	12%	16%	15%	16%	19%	13%
	0.4 - 0.5	9%	7%	10%	10%	13%	16%	13%	11%	14%	13%	13%	16%	12%	9%	8%
	0.5 - 0.75	13%	13%	17%	18%	20%	19%	19%	25%	20%	27%	18%	16%	19%	10%	16%
	0.75 - 1.0	1%	2%	3%	7%	8%	12%	13%	20%	14%	11%	6%	6%	5%	8%	8%
279	0 - 0.1	17%	18%	15%	22%	14%	11%	8%	13%	12%	11%	15%	18%	10%	17%	15%
	0.1 - 0.2	28%	28%	26%	24%	17%	15%	20%	16%	18%	21%	22%	31%	16%	28%	24%
	0.2 - 0.3	27%	25%	27%	21%	23%	17%	21%	11%	20%	20%	25%	16%	26%	23%	23%
	0.3 - 0.4	19%	17%	17%	11%	21%	17%	14%	14%	13%	13%	17%	13%	23%	15%	14%
	0.4 - 0.5	4%	5%	9%	7%	10%	14%	10%	18%	13%	13%	10%	12%	11%	7%	12%
	0.5 - 0.75	5%	7%	7%	12%	13%	14%	12%	21%	19%	15%	9%	9%	13%	7%	11%
	0.75 - 1.0	0%	0%	1%	2%	3%	12%	14%	8%	4%	9%	2%	3%	2%	3%	2%

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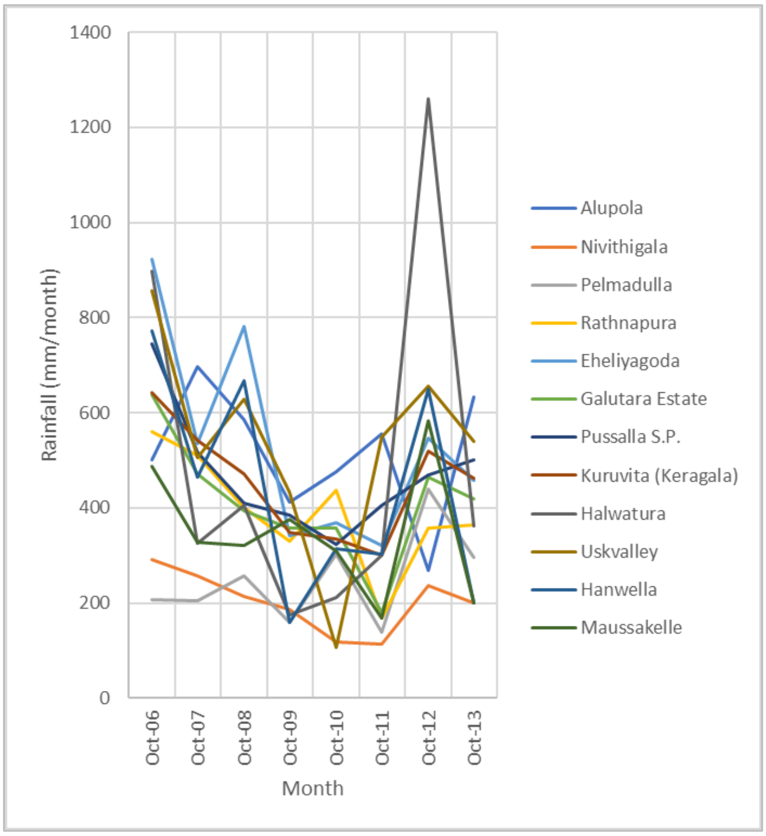
Density (km^2/station)	Deviation Class	Annual	Yala	Maha	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
233	0 - 0.1	33%	41%	28%	27%	16%	18%	26%	21%	31%	26%	25%	36%	35%	27%	38%
	0.1 - 0.2	47%	39%	41%	34%	33%	24%	27%	21%	34%	34%	35%	32%	33%	39%	31%
	0.2 - 0.3	15%	16%	21%	23%	25%	18%	12%	13%	13%	17%	23%	21%	19%	18%	16%
	0.3 - 0.4	3%	3%	5%	9%	14%	14%	12%	20%	13%	13%	11%	8%	11%	6%	9%
	0.4 - 0.5	1%	1%	4%	3%	7%	12%	6%	9%	6%	5%	5%	2%	0%	1%	4%
	0.5 - 0.75	0%	0%	1%	3%	4%	9%	11%	12%	3%	5%	1%	1%	2%	6%	2%
	0.75 - 1.0	0%	0%	0%	0%	1%	5%	5%	3%	0%	0%	0%	0%	0%	2%	0%
200	0 - 0.1	87%	87%	73%	54%	57%	40%	36%	37%	38%	46%	50%	77%	59%	64%	75%
	0.1 - 0.2	12%	13%	24%	34%	39%	26%	35%	31%	39%	38%	41%	18%	22%	21%	20%
	0.2 - 0.3	1%	1%	2%	8%	4%	18%	22%	17%	18%	14%	8%	4%	18%	4%	5%
	0.3 - 0.4	0%	0%	1%	4%	0%	5%	6%	9%	4%	2%	1%	1%	0%	7%	0%
	0.4 - 0.5	0%	0%	0%	0%	1%	7%	1%	2%	1%	0%	0%	0%	0%	4%	0%
	0.5 - 0.75	0%	0%	0%	1%	0%	1%	0%	2%	0%	1%	0%	0%	1%	1%	0%
	0.75 - 1.0	0%	0%	0%	0%	0%	1%	0%	3%	0%	0%	0%	0%	0%	0%	0%
175	0 - 0.1	100%	100%	100%	95%	97%	83%	78%	64%	76%	80%	99%	81%	81%	95%	92%
	0.1 - 0.2	0%	0%	0%	5%	3%	17%	21%	21%	24%	20%	1%	17%	19%	5%	7%
	0.2 - 0.3	0%	0%	0%	0%	0%	0%	2%	14%	0%	0%	0%	2%	0%	0%	1%
	0.3 - 0.4	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
	0.4 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.5 - 0.75	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.75 - 1.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table C-1: page 3

Density (km²/station)	Deviation Class	Annual	Yala	Maha	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
155	0 - 0.1	100%	100%	100%	100%	100%	95%	97%	93%	97%	96%	99%	97%	93%	93%	98%
	0.1 - 0.2	0%	0%	0%	0%	0%	5%	3%	7%	3%	4%	1%	3%	7%	7%	2%
	0.2 - 0.3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.3 - 0.4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.4 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.5 - 0.75	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.75 - 1.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
140	0 - 0.1	100%	100%	100%	100%	93%	83%	89%	63%	90%	84%	99%	96%	94%	91%	93%
	0.1 - 0.2	0%	0%	0%	0%	8%	18%	5%	30%	10%	16%	1%	4%	6%	5%	8%
	0.2 - 0.3	0%	0%	0%	0%	0%	0%	6%	6%	0%	0%	0%	0%	0%	4%	0%
	0.3 - 0.4	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
	0.4 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.5 - 0.75	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	0.75 - 1.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Monthly Rainfall Distribution and Frequency of Occerence



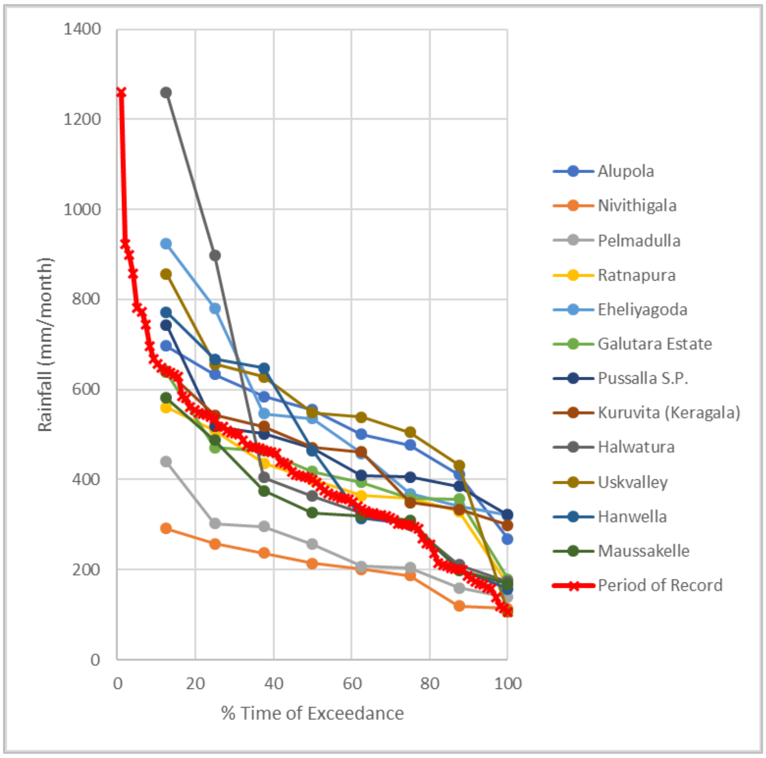


Figure C - 5: Distribution of Rainfall and Rainfall frequency of occurrence - October

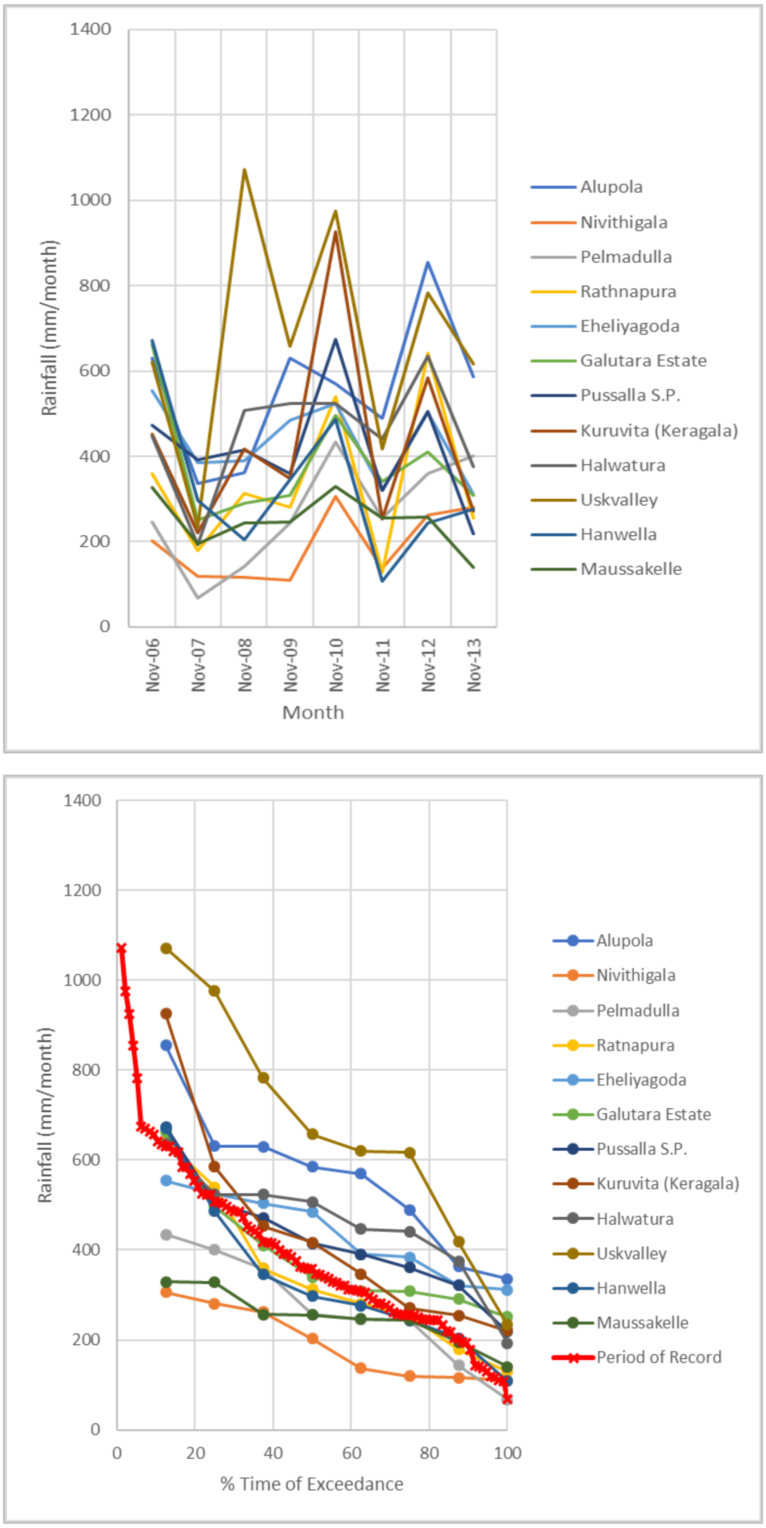


Figure C - 6: Distribution of Rainfall and Rainfall frequency of occurrence - November

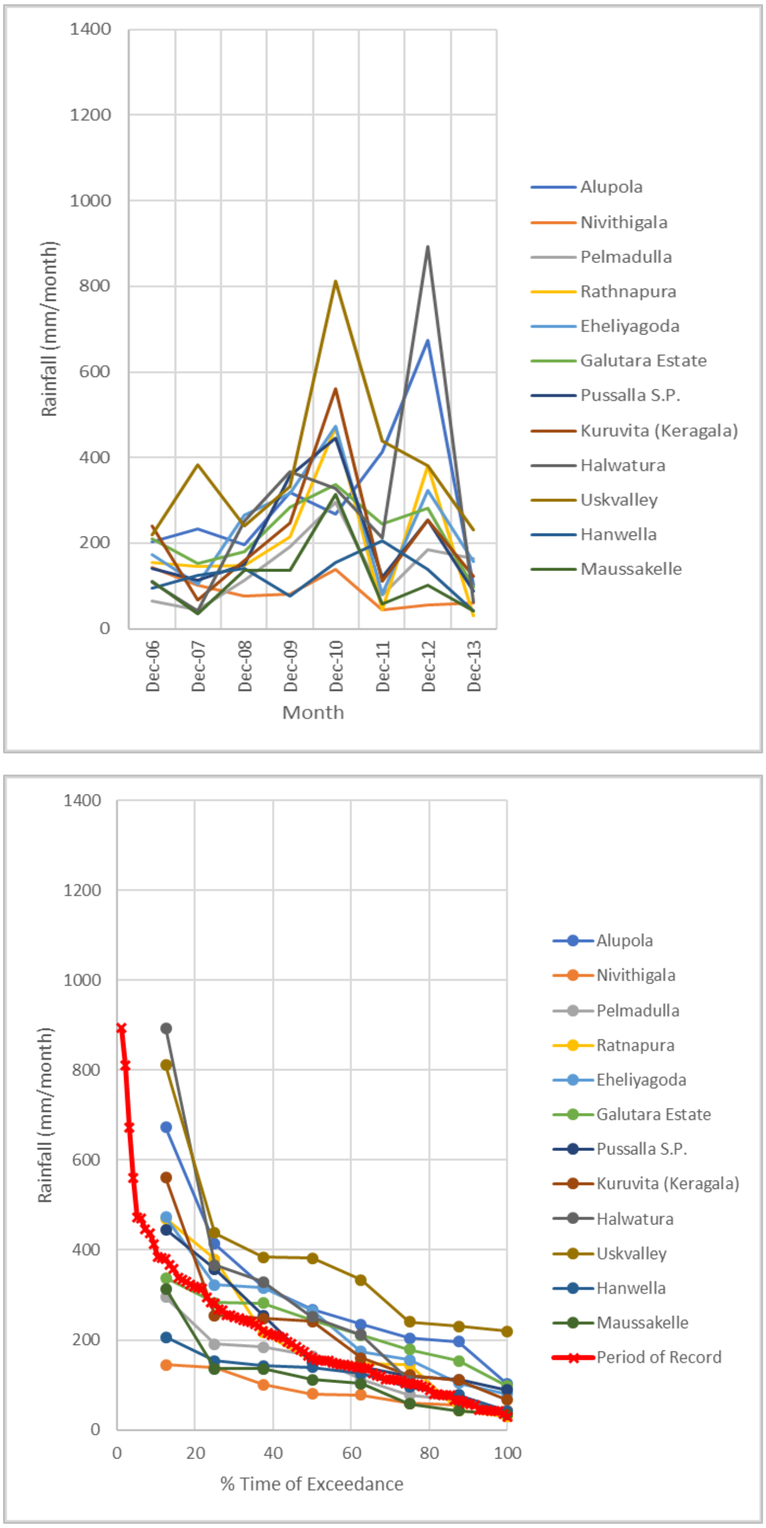
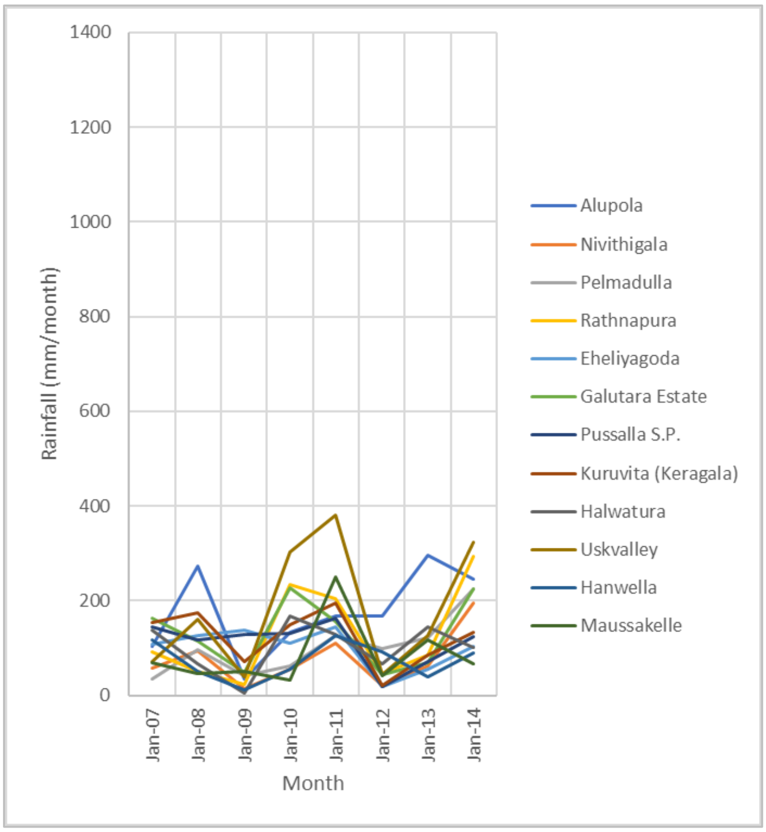


Figure C - 7: Distribution of Rainfall and Rainfall frequency of occurrence – December



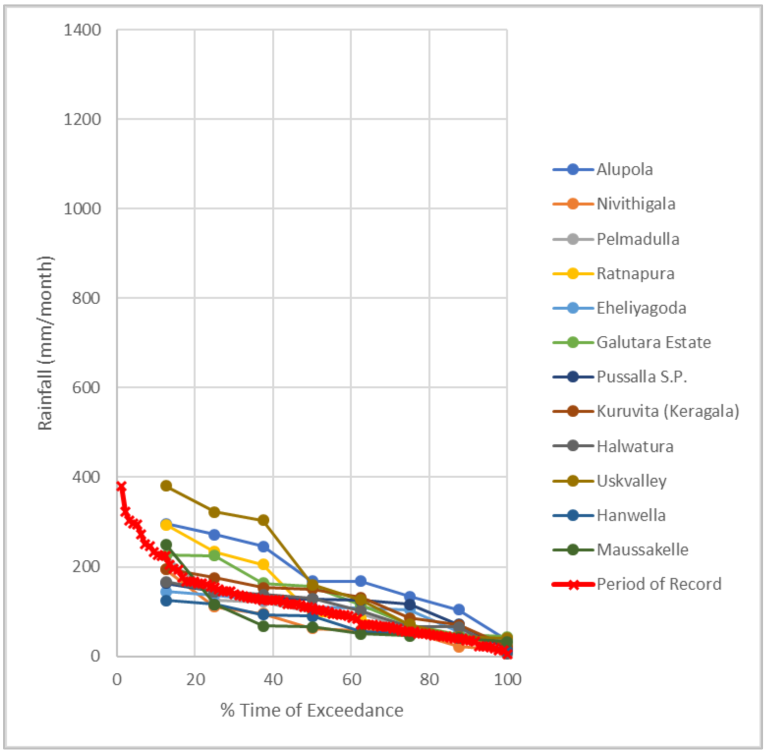
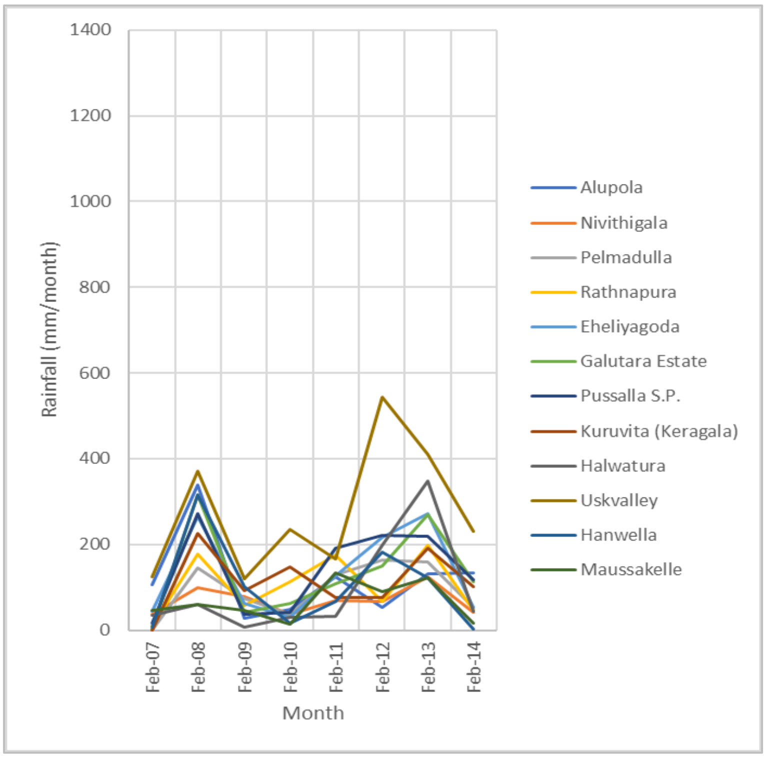


Figure C - 8: Distribution of Rainfall and Rainfall frequency of occurrence - January



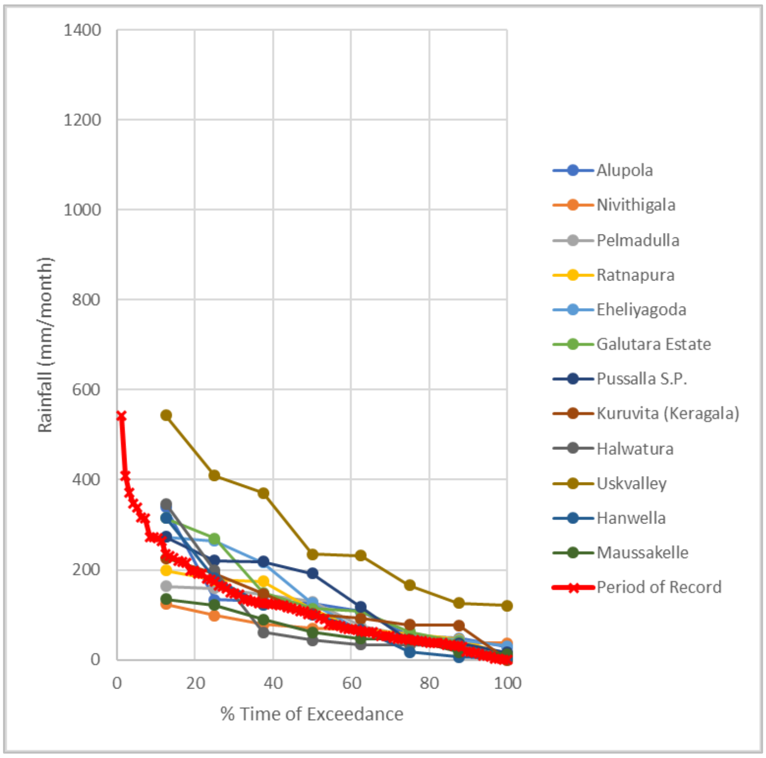
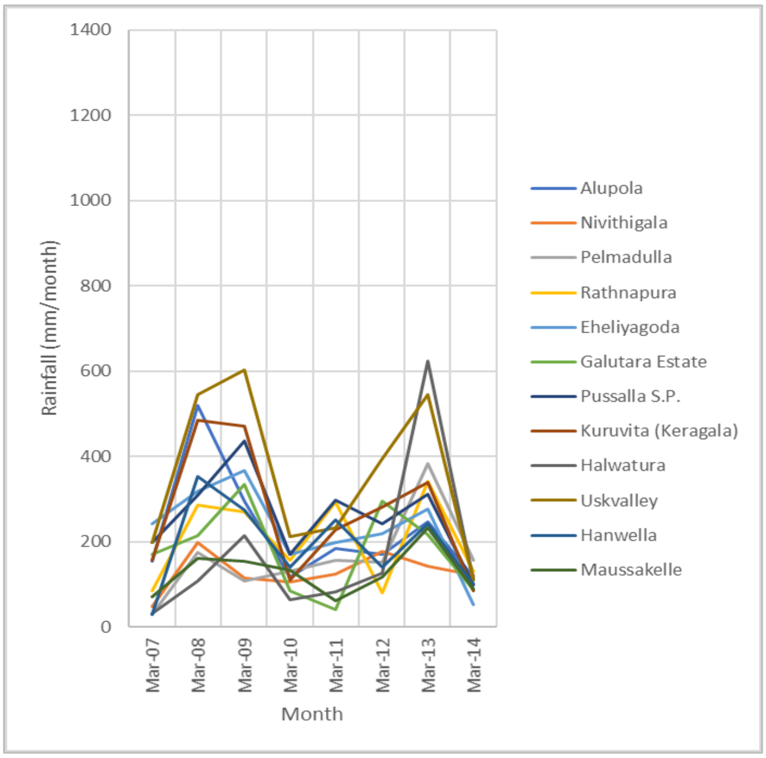


Figure C - 9: Distribution of Rainfall and Rainfall frequency of occurrence – February



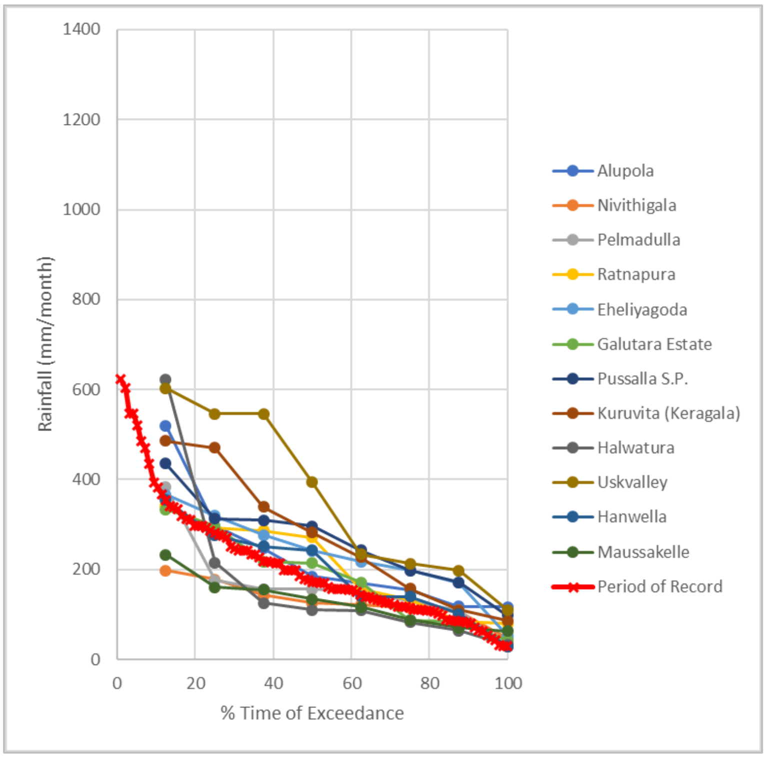
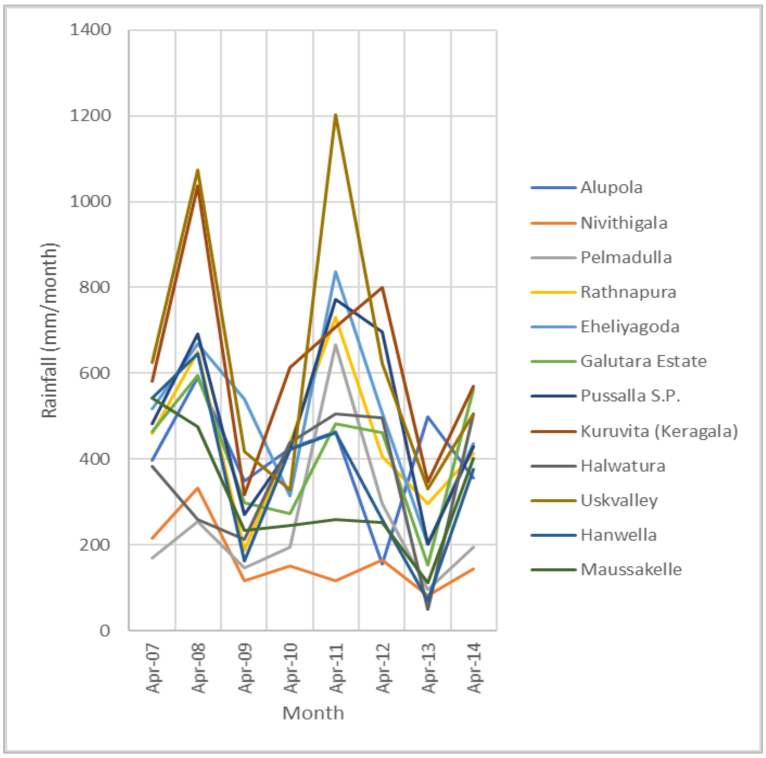


Figure C - 10: Distribution of Rainfall and Rainfall frequency of occurrence - March



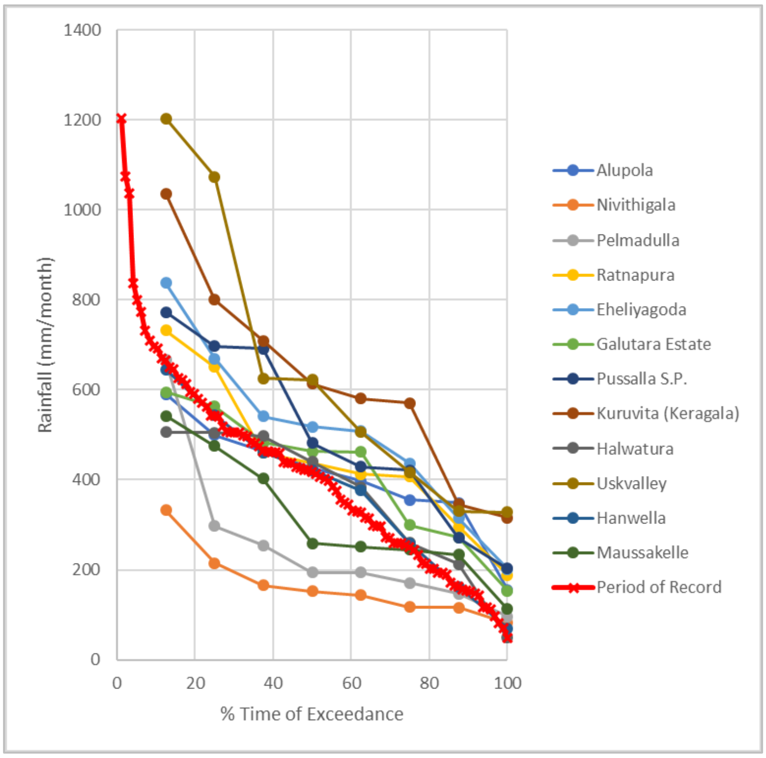
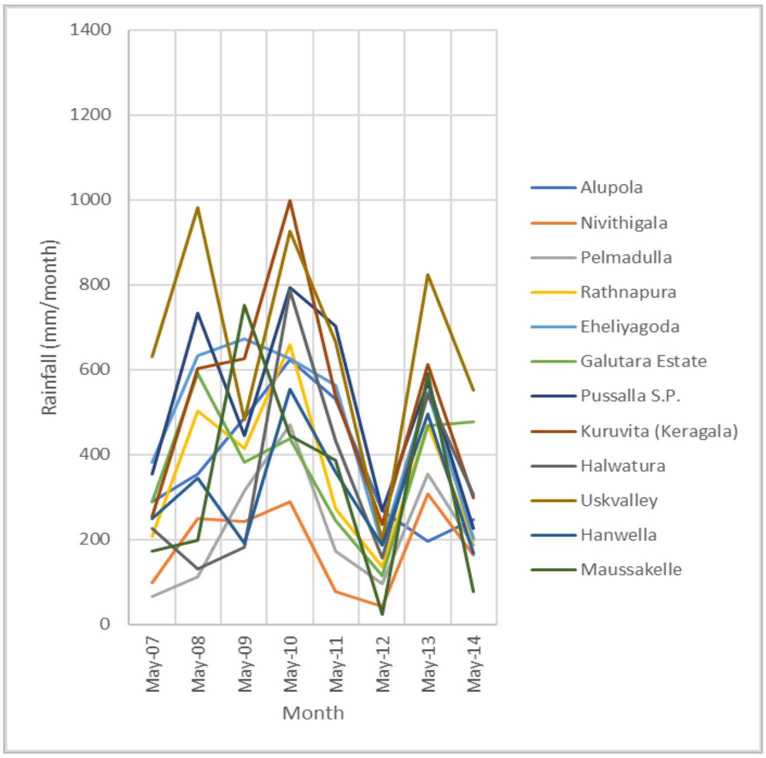


Figure C - 11: Distribution of Rainfall and Rainfall frequency of occurrence - April



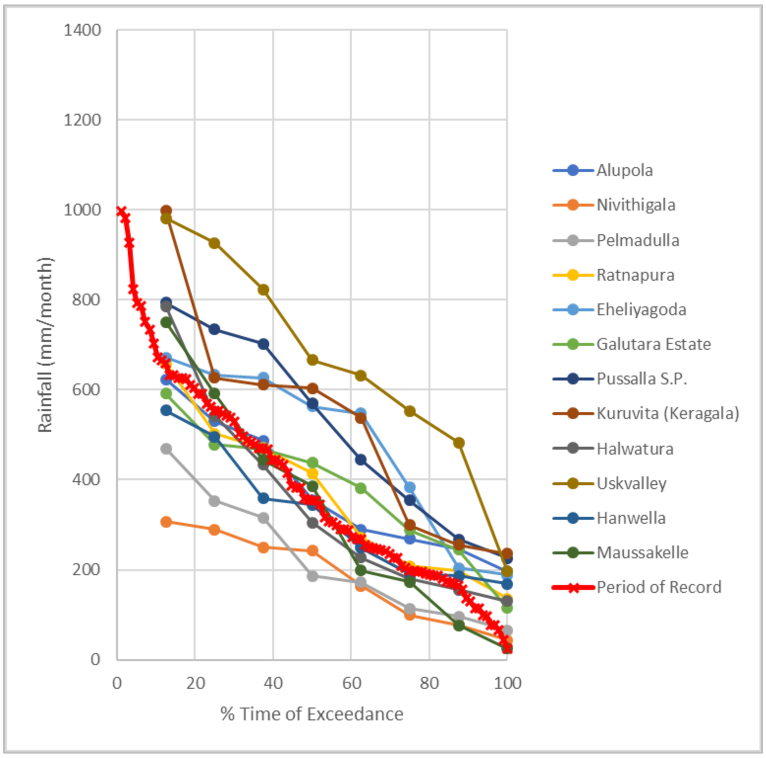
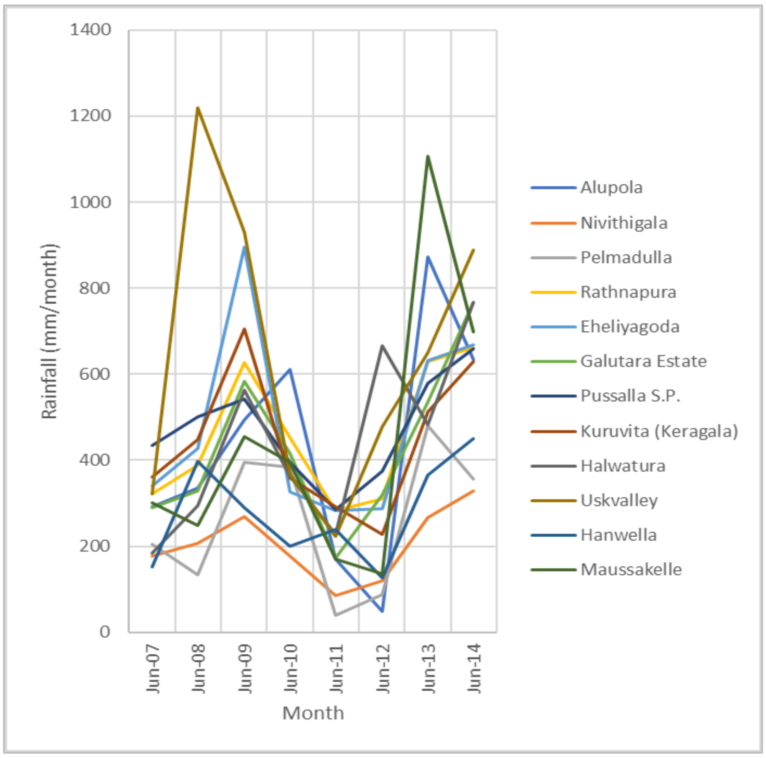


Figure C - 12: Distribution of Rainfall and Rainfall frequency of occurrence - May



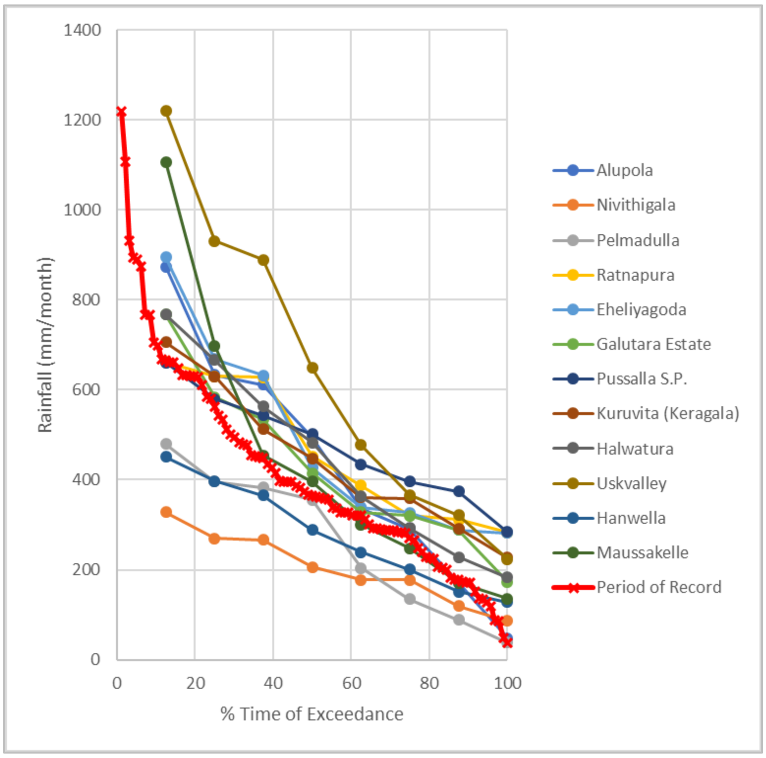
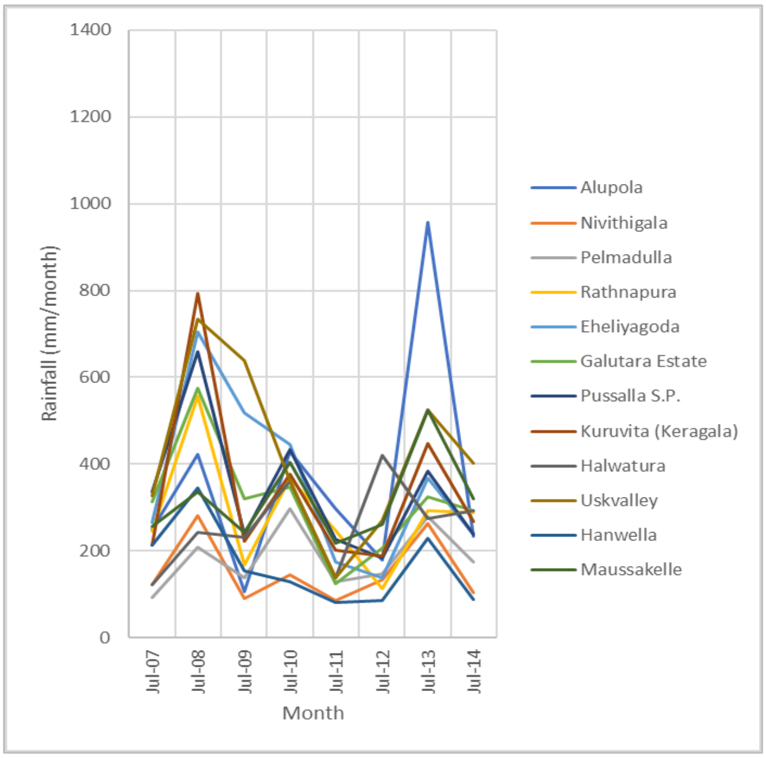


Figure C - 13: Distribution of Rainfall and Rainfall frequency of occurrence - June



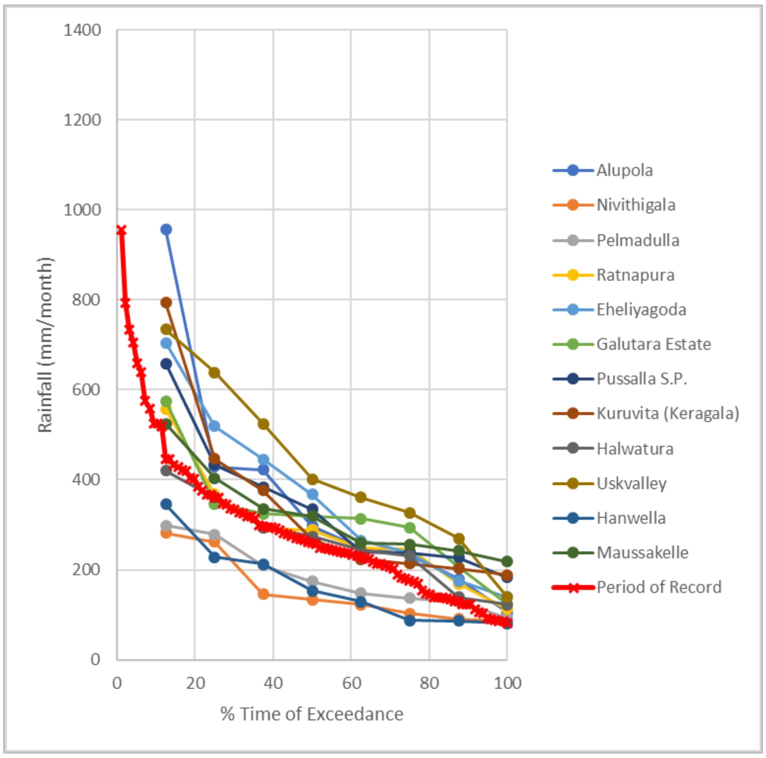
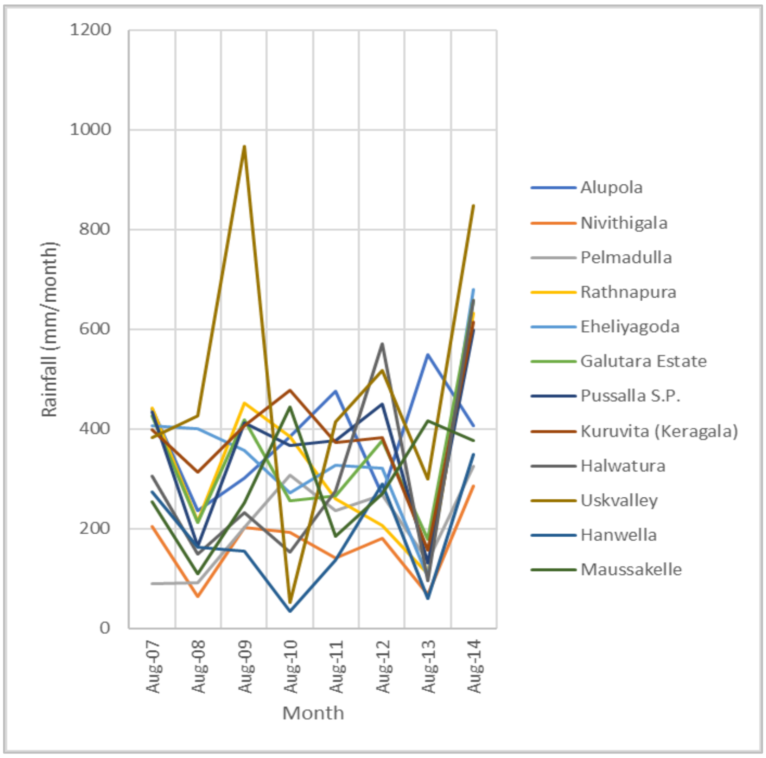


Figure C - 14: Distribution of Rainfall and Rainfall frequency of occurrence - July



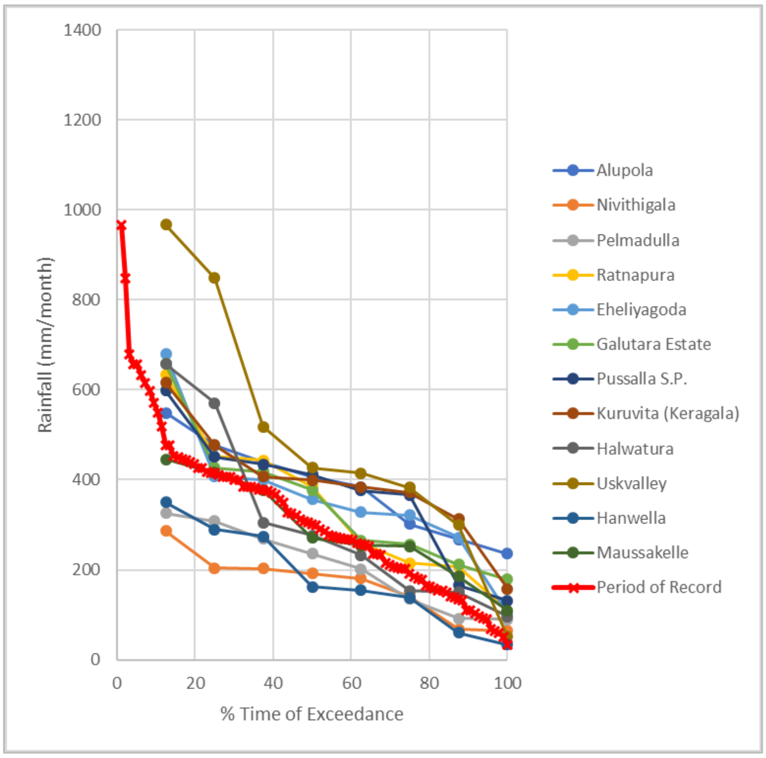


Figure C - 15: Distribution of Rainfall and Rainfall frequency of occurrence - August

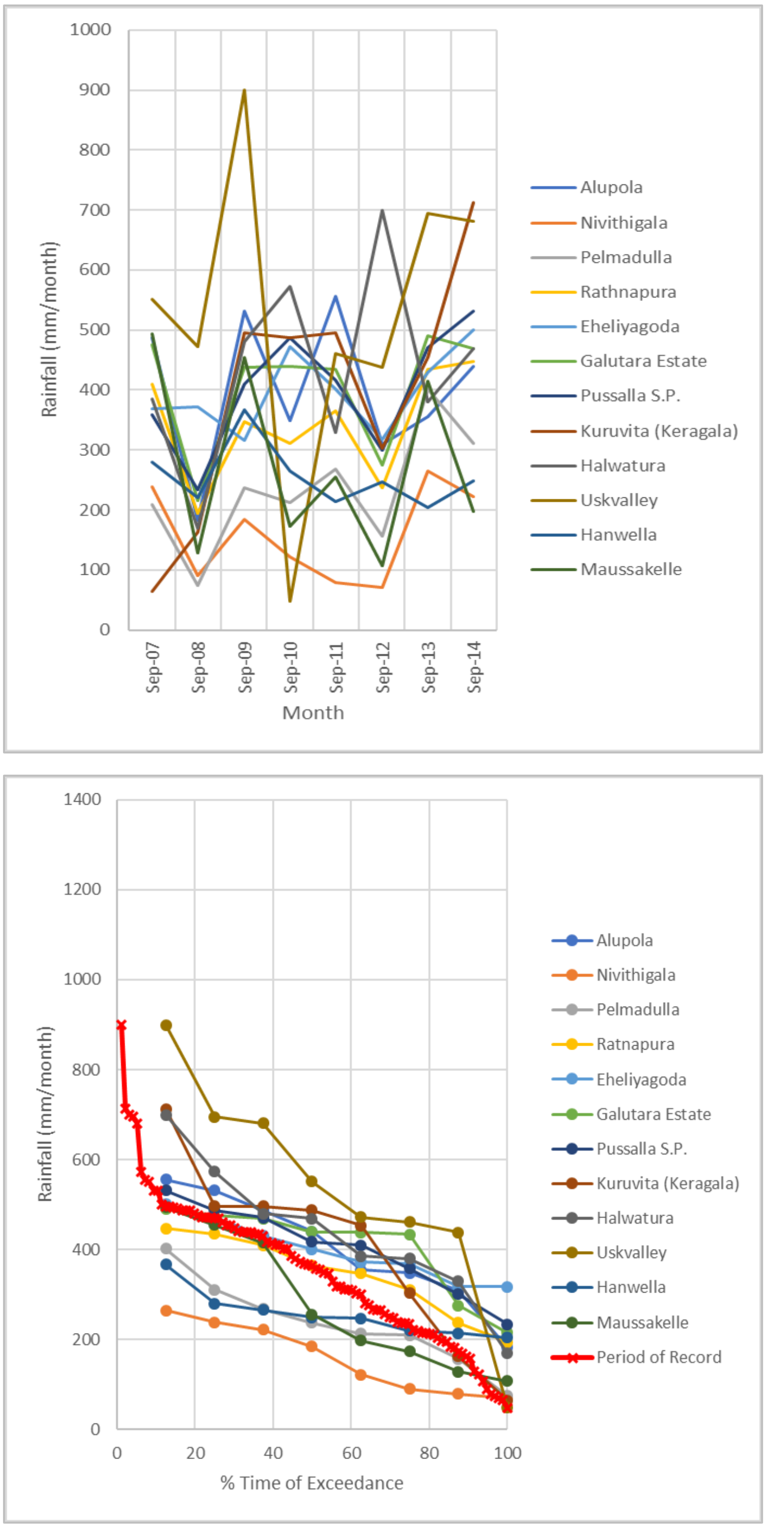


Figure C - 16: Distribution of Rainfall and Rainfall frequency of occurrence - September

Monthly Rainfall with Statistical Indicators

Table C - 2: Monthly rainfall with statistical indicators for varying station density

Station Density (km²/station)	1,395	698	465	349	279	233	200	175	155	140
Number of Combinations	12	40	34	61	50	32	17	13	14	10
Inside only Combination Number	8	28	22	45	38	20	8	1	-	-
Outside only Combination Number	4	-	-	-	-	-	-	-	-	-
Station Number	1	2	3	4	5	6	7	8	9	10
October Rainfall										
October Rainfall - Average (mm)	419.95	405.42	374.21	374.42	369.88	360.60	363.39	358.57	358.93	358.21
October Rainfall - Median (mm)	446.53	414.40	376.32	363.97	368.33	359.02	362.48	358.85	359.05	358.04
October Rainfall - Max (mm)	534.39	522.59	450.21	481.91	478.99	455.12	393.19	364.25	362.71	362.85
October Rainfall - Min (mm)	202.71	220.44	280.71	305.88	311.83	326.63	340.04	352.93	353.18	353.32
October Rainfall - Max Dev(mm)	331.68	302.15	169.50	176.04	167.16	128.49	53.15	11.32	9.53	9.53
October Rainfall - Deviation [(Max-Min)/ Min](%)	164%	137%	60%	58%	54%	39%	16%	3%	3%	3%
October Rainfall - Std Dev (mm)	107.33	74.54	51.10	49.68	35.35	26.76	12.29	3.93	3.26	3.20
November Rainfall										
November Rainfall - Average (mm)	394.37	386.20	348.56	355.73	354.06	346.51	350.06	345.14	345.30	344.38
November Rainfall - Median (mm)	401.59	367.52	354.54	346.14	350.99	348.28	350.25	345.57	345.88	343.77
November Rainfall - Max (mm)	672.15	596.83	431.76	480.42	479.92	436.83	377.91	348.78	349.04	348.54
November Rainfall - Min (mm)	191.59	220.14	266.97	287.32	289.14	299.89	320.59	340.15	339.93	340.19
November Rainfall - Max Dev(mm)	480.56	376.69	164.78	193.10	190.78	136.94	57.33	8.63	9.11	8.35
November Rainfall - Deviation [(Max-Min)/ Min](%)	251%	171%	62%	67%	66%	46%	18%	3%	3%	2%
November Rainfall - Std Dev (mm)	133.76	85.08	47.23	52.82	37.54	27.33	11.71	2.66	3.02	2.98
December Rainfall										
December Rainfall - Average (mm)	209.84	207.35	189.52	191.92	190.94	185.22	187.76	184.64	185.34	184.94
December Rainfall - Median (mm)	214.38	208.35	190.48	186.14	193.05	184.78	187.48	184.59	185.92	184.85
December Rainfall - Max (mm)	379.53	327.96	247.07	260.80	260.24	240.90	201.89	188.14	188.29	187.73
December Rainfall - Min (mm)	87.40	107.45	143.14	144.58	146.28	158.10	172.31	181.31	181.03	181.18
December Rainfall - Max Dev(mm)	292.13	220.51	103.93	116.22	113.96	82.80	29.58	6.83	7.26	6.55
December Rainfall - Deviation [(Max-Min)/ Min](%)	334%	205%	73%	80%	78%	52%	17%	4%	4%	4%
December Rainfall - Std Dev (mm)	85.04	47.49	28.82	30.95	21.99	16.35	6.68	2.24	2.21	2.11

Table C - 1: page 2

Station Density (km^2/station)	1,395	698	465	349	279	233	200	175	155	140
January Rainfall										
January Rainfall - Average (mm)	115.59	123.67	118.03	118.94	118.11	115.45	116.12	114.62	115.05	114.52
January Rainfall - Median (mm)	107.06	122.83	118.90	120.45	119.37	115.27	115.92	115.26	115.16	114.65
January Rainfall - Max (mm)	180.85	178.74	147.58	149.99	148.73	141.75	123.18	116.64	116.21	115.42
January Rainfall - Min (mm)	72.64	82.75	91.79	96.56	95.31	102.28	108.59	111.59	114.12	113.26
January Rainfall - Max Dev(mm)	108.21	95.99	55.79	53.42	53.42	39.47	14.59	5.05	2.09	2.16
January Rainfall - Deviation [(Max-Min)/ Min](%)	149%	116%	61%	55%	56%	39%	13%	5%	2%	2%
January Rainfall - Std Dev (mm)	35.22	21.14	13.28	14.74	10.53	7.75	3.39	1.53	0.59	0.68
February Rainfall										
February Rainfall - Average (mm)	120.54	112.16	105.46	106.11	106.55	105.83	105.49	106.20	105.43	104.93
February Rainfall - Median (mm)	109.59	111.16	106.20	106.17	105.91	105.74	105.61	105.88	105.59	105.46
February Rainfall - Max (mm)	274.96	173.64	136.00	128.11	124.17	118.07	111.63	109.18	106.71	106.21
February Rainfall - Min (mm)	65.98	78.81	86.08	89.30	93.85	97.16	101.43	104.28	103.61	102.03
February Rainfall - Max Dev(mm)	208.99	94.83	49.92	38.82	30.33	20.91	10.20	4.90	3.10	4.18
February Rainfall - Deviation [(Max-Min)/ Min](%)	317%	120%	58%	43%	32%	22%	10%	5%	3%	4%
February Rainfall - Std Dev (mm)	54.00	18.11	10.69	8.90	6.67	4.85	2.67	1.47	0.93	1.24
March Rainfall										
March Rainfall - Average (mm)	208.94	211.50	198.28	197.22	196.69	195.26	194.63	191.20	191.45	190.38
March Rainfall - Median (mm)	198.73	208.52	204.17	194.59	195.44	195.50	193.98	191.25	192.01	190.10
March Rainfall - Max (mm)	355.40	288.82	231.44	233.99	223.45	220.15	202.15	193.21	193.00	192.16
March Rainfall - Min (mm)	127.98	141.18	157.75	168.31	174.30	180.24	188.21	188.47	189.59	187.91
March Rainfall - Max Dev(mm)	227.43	147.64	73.68	65.68	49.15	39.91	13.94	4.75	3.40	4.24
March Rainfall - Deviation [(Max-Min)/ Min](%)	178%	105%	47%	39%	28%	22%	7%	3%	2%	2%
March Rainfall - Std Dev (mm)	64.72	35.18	21.98	17.42	11.99	7.90	3.85	1.61	1.22	1.40

Table C - 1: page 3

Station Density (km²/station)	1,395	698	465	349	279	233	200	175	155	140
April Rainfall										
April Rainfall - Average (mm)	414.95	426.02	395.05	384.66	382.46	375.87	375.68	363.60	367.09	363.26
April Rainfall - Median (mm)	407.99	433.26	389.00	370.76	380.54	369.34	374.94	365.09	367.80	364.33
April Rainfall - Max (mm)	638.08	625.14	528.34	523.80	468.78	453.60	402.17	375.08	372.89	369.18
April Rainfall - Min (mm)	165.36	197.50	237.88	303.23	319.51	339.85	359.07	353.32	360.49	348.06
April Rainfall - Max Dev(mm)	472.71	427.64	290.46	220.57	149.27	113.75	43.09	21.76	12.40	21.13
April Rainfall - Deviation [(Max-Min)/ Min](%)	286%	217%	122%	73%	47%	33%	12%	6%	3%	6%
April Rainfall - Std Dev (mm)	138.97	103.96	75.91	53.38	35.94	22.66	10.74	7.80	3.48	6.19
May Rainfall										
May Rainfall - Average (mm)	389.67	381.27	347.37	342.73	339.97	336.72	335.29	330.08	330.34	328.59
May Rainfall - Median (mm)	366.24	364.31	351.13	333.84	339.60	335.93	332.64	330.09	330.24	328.53
May Rainfall - Max (mm)	657.63	551.24	459.56	459.62	411.82	398.08	352.22	332.89	332.96	331.32
May Rainfall - Min (mm)	184.16	198.04	233.76	282.57	295.38	316.38	322.85	325.89	327.32	325.03
May Rainfall - Max Dev(mm)	473.46	353.21	225.80	177.06	116.44	81.69	29.37	7.00	5.63	6.29
May Rainfall - Deviation [(Max-Min)/ Min](%)	257%	178%	97%	63%	39%	26%	9%	2%	2%	2%
May Rainfall - Std Dev (mm)	132.78	84.58	56.75	41.37	27.51	16.69	7.85	2.12	1.64	2.11
June Rainfall										
June Rainfall - Average (mm)	414.29	406.83	389.34	379.35	374.02	364.68	364.42	359.47	361.59	361.57
June Rainfall - Median (mm)	440.29	437.85	379.65	369.38	372.04	361.37	364.22	361.44	361.61	362.09
June Rainfall - Max (mm)	634.71	501.88	463.69	458.71	455.53	446.65	390.57	365.82	362.85	363.60
June Rainfall - Min (mm)	203.89	224.58	266.17	307.62	309.34	327.14	346.37	343.06	359.43	358.04
June Rainfall - Max Dev(mm)	430.83	277.30	197.52	151.08	146.18	119.51	44.20	22.77	3.42	5.56
June Rainfall - Deviation [(Max-Min)/ Min](%)	211%	123%	74%	49%	47%	37%	13%	7%	1%	2%
June Rainfall - Std Dev (mm)	115.99	68.80	57.77	43.73	30.53	21.90	10.27	7.49	1.10	1.74

Station Density (km^2/station)	1,395	698	465	349	279	233	200	175	155	140
July Rainfall										
July Rainfall - Average (mm)	291.44	293.78	271.55	271.07	267.89	262.52	263.52	260.62	260.71	259.36
July Rainfall - Median (mm)	316.44	299.97	270.81	261.52	264.46	261.36	262.94	261.11	261.00	258.72
July Rainfall - Max (mm)	424.64	381.66	329.83	343.46	343.37	326.17	284.07	263.13	263.04	262.54
July Rainfall - Min (mm)	153.44	164.51	204.25	222.16	231.57	239.90	248.98	255.65	258.05	257.21
July Rainfall - Max Dev(mm)	271.20	217.15	125.58	121.29	111.80	86.27	35.08	7.48	5.00	5.33
July Rainfall - Deviation [(Max-Min)/ Min](%)	177%	132%	61%	55%	48%	36%	14%	3%	2%	2%
July Rainfall - Std Dev (mm)	85.18	51.42	36.46	34.33	24.50	17.82	8.14	2.27	1.76	1.96
August Rainfall										
August Rainfall - Average (mm)	318.72	328.00	306.96	303.62	300.17	294.00	294.53	289.80	290.97	289.51
August Rainfall - Median (mm)	343.41	345.05	302.27	293.71	298.30	293.41	293.15	290.77	291.10	289.49
August Rainfall - Max (mm)	488.60	418.99	371.45	373.96	373.13	362.38	312.44	293.47	292.65	291.44
August Rainfall - Min (mm)	167.43	182.10	222.72	250.61	255.13	267.22	279.75	282.22	288.73	285.79
August Rainfall - Max Dev(mm)	321.18	236.89	148.73	123.35	118.00	95.16	32.69	11.25	3.92	5.65
August Rainfall - Deviation [(Max-Min)/ Min](%)	192%	130%	67%	49%	46%	36%	12%	4%	1%	2%
August Rainfall - Std Dev (mm)	94.46	57.02	43.38	37.68	25.97	18.32	7.94	3.45	1.16	1.68
September Rainfall										
September Rainfall - Average (mm)	353.04	346.51	322.00	320.24	319.08	312.86	313.86	311.08	312.12	311.83
September Rainfall - Median (mm)	397.05	358.28	315.01	315.41	318.55	312.00	312.58	312.62	312.37	311.41
September Rainfall - Max (mm)	530.69	445.74	402.22	401.72	401.04	381.94	335.57	314.34	314.50	313.99
September Rainfall - Min (mm)	158.60	186.41	228.82	263.87	263.53	281.71	300.20	304.21	309.30	309.45
September Rainfall - Max Dev(mm)	372.08	259.32	173.40	137.85	137.51	100.23	35.37	10.13	5.20	4.54
September Rainfall - Deviation [(Max-Min)/ Min](%)	235%	139%	76%	52%	52%	36%	12%	3%	2%	1%
September Rainfall - Std Dev (mm)	103.00	62.71	46.75	39.98	27.74	19.29	7.84	3.19	1.60	1.50

Deviation of Average Monthly Rainfall in Density Variation

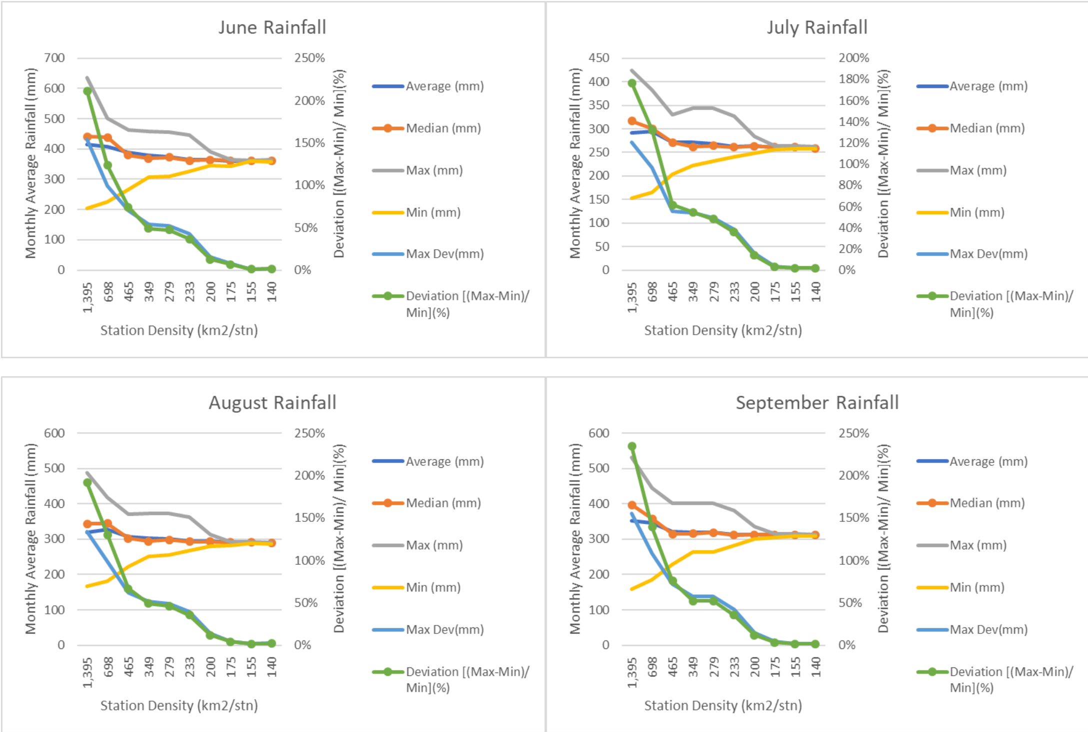


Figure C - 17: Deviation of Average Monthly Rainfall in density variation

ANNEX D - RESULTS SUMMARY (RR OPTION 1)

Overall Results (RR Option 1)

Table D - 1: All results RR1

Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
1St-C1	1.0279	0.5405	0.4463	1.2357	1.1054	390.36	2350.34	1175.51	1218.91	858.14	630.84	271.37	31%	47%	19%
1St-C2	0.8549	0.9195	0.8729	0.8754	0.8249	265.90	194.46	102.82	93.04	1297.75	441.85	854.50	437%	209%	1001%
1St-C3	0.6023	0.6860	0.6327	0.6148	0.5742	335.55	665.06	312.40	352.90	827.15	232.26	594.64	94%	49%	145%
1St-C4	0.5216	0.2930	0.4036	0.5355	0.5663	398.54	1757.12	706.28	1080.98	264.91	161.62	133.44	13%	20%	10%
1St-C5	0.7946	0.5767	0.6575	0.9693	0.6839	406.42	2363.90	977.34	1424.57	871.69	432.67	477.03	32%	38%	29%
1St-C6	0.6376	0.3131	0.4757	0.5944	0.7628	402.10	1875.98	783.02	1119.64	383.77	238.35	172.11	17%	26%	13%
1St-C7	0.7677	0.5774	0.5278	0.9021	0.7497	409.18	2294.74	893.05	1441.81	802.53	348.38	494.27	30%	33%	30%
1St-C8	0.8616	0.6265	0.7117	0.9015	0.8957	416.35	2443.19	945.12	1589.07	950.99	400.45	641.53	34%	37%	36%
1St-C9	1.0320	0.3653	0.5235	1.2649	1.0473	402.10	1972.32	978.43	994.35	480.12	433.76	46.81	21%	41%	4%
1St-C10	2.0071	1.5700	1.3078	1.9810	2.3836	416.61	3845.95	1621.81	2330.49	2353.75	1077.14	1382.95	55%	58%	57%
1St-C11	0.4948	0.3883	0.4756	0.5156	0.4831	314.38	1061.77	581.37	520.12	430.43	36.70	427.42	32%	5%	69%
1St-C12	0.5733	0.3817	0.4999	0.5364	0.6480	312.61	1216.28	414.60	810.28	275.93	130.07	137.26	19%	29%	13%
2St-C1	0.4428	0.1879	0.0745	0.0825	0.3529	402.58	1430.66	585.15	871.63	61.54	40.49	75.91	3%	5%	7%
2St-C2	0.4321	0.2819	0.2202	0.1577	0.4403	381.20	1145.21	511.17	641.19	347.00	33.50	306.35	23%	5%	37%
2St-C5	0.7590	0.4555	0.3161	0.6592	0.3161	397.67	2105.41	983.32	1159.55	613.21	438.65	212.01	24%	38%	15%
2St-C6	0.8488	0.6217	0.4773	0.8835	0.4253	412.22	2367.89	1046.52	1388.43	875.68	501.85	440.89	31%	41%	28%
2St-C8	0.5845	0.6310	0.4832	0.5199	0.8190	353.93	678.76	318.48	367.78	813.45	226.19	579.76	81%	48%	108%
2St-C9	0.4529	0.4229	0.3153	0.3235	0.5788	382.33	957.97	409.33	572.38	534.24	135.34	375.15	41%	25%	50%
2St-C10	0.5641	0.5622	0.4423	0.4432	0.7442	330.44	770.25	402.20	380.73	721.96	142.47	566.81	64%	24%	107%
2St-C11	0.5533	0.2078	0.0920	0.0519	0.4257	366.55	1324.50	656.54	682.16	167.70	111.88	265.37	10%	13%	31%
2St-C12	0.5984	0.3593	0.2632	0.5196	0.2429	396.91	1928.98	842.89	1122.07	436.77	298.22	174.53	19%	30%	13%
2St-C13	0.8548	0.5773	0.4376	0.8815	0.3351	398.25	2326.19	1092.45	1276.97	833.98	547.78	329.43	30%	43%	22%
2St-C14	0.8002	0.5969	0.3926	0.8674	0.4214	401.75	2297.13	1023.31	1317.39	804.92	478.64	369.85	29%	40%	24%
2St-C15	0.4489	0.4452	0.4052	0.3292	0.5843	359.84	879.25	387.26	503.72	612.95	157.41	443.82	50%	29%	64%

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Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
2St-C17	0.4328	0.2018	0.1203	0.0731	0.3746	370.80	983.13	422.42	574.69	509.08	122.25	372.85	39%	22%	49%
2St-C18	0.7824	0.2018	0.1203	0.0731	0.3746	296.08	304.12	157.19	147.79	1188.09	387.48	799.75	231%	126%	389%
2St-C19	0.4074	0.2307	0.1157	0.0856	0.4371	384.82	1268.13	534.60	746.14	224.08	10.07	201.40	14%	1%	21%
2St-C20	0.3905	0.2595	0.1876	0.1171	0.4415	377.31	1199.59	535.42	671.13	292.62	9.25	276.41	19%	1%	32%
2St-C21	0.3876	0.1685	0.1175	0.0567	0.3087	385.73	1349.17	565.84	794.89	143.04	21.18	152.65	8%	3%	15%
2St-C22	0.5559	0.3576	0.3108	0.4556	0.2805	408.62	1932.84	763.46	1213.95	440.63	218.79	266.42	19%	25%	19%
2St-C23	0.5294	0.3565	0.2704	0.4541	0.2993	402.09	1890.84	749.69	1173.85	398.63	205.02	226.32	18%	23%	16%
2St-C24	0.5058	0.2824	0.1949	0.3520	0.2547	399.44	1765.27	714.40	1079.87	273.07	169.73	132.33	13%	20%	10%
2St-C25	0.5208	0.3221	0.2482	0.4162	0.2625	400.14	1849.13	746.16	1134.30	356.92	201.50	186.76	16%	23%	14%
2St-C26	0.6367	0.3715	0.1817	0.5873	0.2450	402.89	1949.82	812.86	1165.43	457.61	268.19	217.89	20%	28%	16%
2St-C27	0.7629	0.5843	0.4211	0.9061	0.3357	408.96	2299.53	900.71	1438.74	807.32	356.04	491.20	30%	33%	30%
2St-C28	0.8461	0.6268	0.5873	0.8537	0.4136	416.59	2426.38	944.29	1566.88	934.18	399.62	619.34	33%	37%	35%
2St-C29	0.6689	0.4758	0.2560	0.7539	0.3004	406.42	2093.70	838.04	1289.51	601.50	293.37	341.97	24%	29%	23%
2St-C30	0.7191	0.5068	0.3924	0.7152	0.3501	415.03	2180.66	866.05	1375.09	688.45	321.38	427.55	27%	32%	27%
2St-C31	0.8247	0.6167	0.5482	0.8550	0.4064	416.52	2390.48	923.53	1543.52	898.28	378.86	595.98	32%	36%	34%
2St-C32	0.9023	0.4633	0.4345	0.6255	0.3113	396.29	2174.12	1085.76	1111.86	681.91	541.09	164.32	26%	43%	12%
2St-C33	1.2053	0.9570	0.7287	1.2373	0.7836	408.13	2827.91	1311.12	1580.34	1335.70	766.46	632.80	41%	50%	36%
2St-C34	0.8148	0.4105	0.3707	0.5754	0.2611	380.40	2070.13	1052.43	1061.30	577.92	507.76	113.76	23%	41%	9%
2St-C35	0.7706	0.3778	0.3043	0.5367	0.2516	374.69	1999.49	936.85	1096.89	507.28	392.18	149.35	21%	36%	11%
2St-C36	0.4773	0.2633	0.1425	0.2829	0.3036	391.61	1666.16	657.39	1034.55	173.96	112.72	87.01	9%	15%	7%
2St-C37	0.4855	0.2696	0.1975	0.2756	0.2994	395.84	1699.72	695.47	1035.10	207.51	150.80	87.56	10%	19%	7%
2St-C38	0.5400	0.3182	0.2643	0.3771	0.2848	400.20	1831.26	736.94	1127.27	339.05	192.28	179.73	15%	22%	14%
2St-C39	0.5289	0.3032	0.2058	0.3274	0.3270	399.16	1772.62	742.77	1051.53	280.41	198.11	104.00	13%	23%	8%
2St-C40	0.8355	0.6053	0.5268	0.8276	0.4164	416.61	2356.55	934.92	1492.78	864.35	390.25	545.24	31%	37%	32%
2St-C41	1.0182	0.8125	0.7859	1.0375	0.5948	416.40	2723.07	1077.69	1740.48	1230.87	533.02	792.94	39%	43%	42%
2St-C42	0.8424	0.6117	0.5799	0.8316	0.4019	416.48	2413.80	937.68	1565.96	921.60	393.01	618.43	33%	37%	36%
2St-C43	0.6036	0.4042	0.3272	0.5195	0.3243	409.05	1979.26	741.85	1291.88	487.05	197.18	344.34	21%	23%	23%
3St-C1	0.4182	0.1470	0.0937	0.0979	0.2239	393.85	1459.77	652.72	845.11	32.44	108.05	102.43	2%	13%	10%
3St-C3	0.4358	0.2211	0.1844	0.0872	0.3768	376.52	1221.55	570.95	668.71	270.65	26.28	278.83	17%	4%	32%
3St-C4	0.4628	0.2165	0.0949	0.2490	0.2439	403.97	1619.35	684.79	969.09	127.14	140.12	21.55	6%	16%	2%
3St-C5	0.4744	0.4767	0.3917	0.3757	0.6230	366.75	869.68	400.92	474.37	622.52	143.75	473.16	51%	26%	72%

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Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
3St-C7	0.4168	0.3128	0.2292	0.1697	0.5014	390.02	1124.12	473.10	670.52	368.09	71.57	277.02	25%	11%	33%
3St-C8	0.6153	0.6586	0.5172	0.5799	0.8100	326.08	626.74	322.54	310.00	865.46	222.13	637.54	90%	43%	143%
3St-C9	0.4421	0.1910	0.1113	0.0880	0.3364	381.26	1399.53	628.35	795.09	92.68	83.68	152.45	5%	11%	15%
3St-C10	0.4318	0.2119	0.1630	0.0725	0.3795	369.29	1280.69	614.02	687.65	211.51	69.36	259.88	13%	9%	29%
3St-C11	0.4168	0.1689	0.1258	0.1263	0.2343	378.29	1403.09	636.99	789.83	89.12	92.32	157.71	5%	11%	16%
3St-C12	0.4118	0.3465	0.2331	0.2110	0.5422	377.05	1092.31	468.78	633.95	399.90	75.89	313.59	28%	12%	38%
3St-C13	0.4697	0.4867	0.4064	0.3759	0.6406	357.56	852.83	395.27	463.14	639.38	149.40	484.40	53%	26%	76%
3St-C14	0.3863	0.3275	0.3010	0.1895	0.4824	371.54	1055.68	456.76	608.20	436.53	87.91	339.34	31%	14%	43%
3St-C15	0.4116	0.1594	0.0665	0.0643	0.3034	399.18	1449.24	593.48	879.27	42.96	48.81	68.27	2%	6%	6%
3St-C16	0.3800	0.1545	0.0798	0.0684	0.2803	389.35	1406.49	583.14	838.23	85.72	38.47	109.30	5%	5%	11%
3St-C17	0.3945	0.1959	0.1359	0.0522	0.3733	386.42	1283.03	548.53	746.53	209.18	3.86	201.00	13%	1%	21%
3St-C18	0.3795	0.1742	0.0863	0.0495	0.3460	387.12	1363.48	578.51	798.69	128.73	33.84	148.85	7%	5%	15%
3St-C19	0.5127	0.3114	0.2228	0.4058	0.2588	400.18	1826.69	739.09	1117.92	334.49	194.43	170.39	15%	22%	13%
3St-C20	0.5259	0.3520	0.2667	0.4627	0.2811	401.73	1895.29	756.73	1171.05	403.09	212.07	223.51	18%	24%	16%
3St-C21	0.5423	0.3552	0.3056	0.4626	0.2698	406.09	1921.80	765.98	1195.53	429.60	221.31	247.99	19%	25%	18%
3St-C22	0.7172	0.5158	0.3879	0.7300	0.3599	414.59	2188.91	872.54	1374.73	696.70	327.87	427.19	27%	32%	27%
3St-C23	0.6704	0.4865	0.2632	0.7701	0.3071	406.34	2106.74	846.36	1294.36	614.53	301.69	346.82	24%	30%	23%
3St-C24	0.7097	0.5068	0.3728	0.7240	0.3507	414.27	2170.47	862.04	1364.80	678.26	317.37	417.26	26%	32%	27%
3St-C25	0.6385	0.3790	0.2460	0.5192	0.3017	397.61	1951.89	885.31	1093.95	459.68	340.64	146.41	20%	33%	11%
3St-C26	0.6227	0.3943	0.2952	0.5836	0.2494	398.76	2008.98	878.09	1169.78	516.77	333.42	222.24	21%	32%	16%
3St-C27	0.5666	0.3363	0.2335	0.4742	0.2460	393.76	1873.97	834.37	1076.21	381.76	289.70	128.68	17%	29%	10%
3St-C28	0.5789	0.3472	0.2395	0.4970	0.2473	394.81	1892.15	820.38	1106.09	399.94	275.72	158.55	17%	28%	12%
3St-C29	0.4479	0.4400	0.3330	0.2909	0.6464	363.44	956.71	403.13	565.85	535.49	141.54	381.69	42%	27%	50%
3St-C30	0.4471	0.4514	0.3533	0.3148	0.6406	364.76	928.13	409.86	532.71	564.08	134.81	414.83	45%	25%	58%
3St-C31	0.4092	0.3666	0.2762	0.2233	0.5589	374.10	1050.73	450.63	616.12	441.48	94.04	331.42	32%	16%	41%
3St-C32	0.4126	0.3943	0.3019	0.2899	0.5475	372.26	999.86	461.92	546.06	492.34	82.75	401.48	37%	14%	54%
3St-C33	0.5517	0.3565	0.2767	0.4340	0.3167	406.64	1894.77	768.79	1160.55	402.56	224.12	213.01	18%	25%	15%
3St-C34	0.5718	0.3817	0.3382	0.4913	0.2911	409.20	1980.33	783.52	1243.28	488.13	238.86	295.74	21%	26%	20%
3St-C35	0.5430	0.3438	0.2987	0.4343	0.2733	407.61	1905.19	756.77	1192.15	412.99	212.10	244.61	18%	24%	18%
3St-C36	0.5138	0.3276	0.2459	0.4132	0.2806	404.29	1847.11	719.86	1166.68	354.90	175.19	219.14	16%	21%	16%
4St-C1	0.4457	0.1868	0.0922	0.1958	0.2248	397.95	1540.08	669.36	895.94	47.88	124.69	51.60	2%	15%	5%

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Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
4St-C2	0.4315	0.1486	0.1093	0.1111	0.2067	390.66	1452.10	658.88	825.22	40.10	114.21	122.32	2%	14%	12%
4St-C3	0.4280	0.2472	0.2120	0.1065	0.4093	374.84	1171.90	550.23	634.95	320.31	5.56	312.59	21%	1%	38%
4St-C4	0.4002	0.1885	0.1273	0.0604	0.3507	392.57	1311.10	569.87	768.62	181.10	25.21	178.92	11%	3%	19%
4St-C5	0.4056	0.3147	0.2454	0.1828	0.4848	379.10	1107.89	483.74	634.06	384.32	60.93	313.48	26%	10%	38%
4St-C6	0.3837	0.2125	0.1310	0.0750	0.3945	393.51	1273.20	528.93	764.86	219.00	15.74	182.68	13%	2%	19%
4St-C7	0.4183	0.3063	0.2450	0.1737	0.4730	386.86	1112.43	478.29	649.37	379.78	66.38	298.16	26%	10%	35%
4St-C8	0.4172	0.1612	0.0971	0.1071	0.2488	388.67	1450.52	635.56	832.35	41.68	90.90	115.19	2%	11%	11%
4St-C9	0.4469	0.2113	0.1107	0.2182	0.2545	400.76	1608.67	676.49	962.45	116.47	131.82	14.91	6%	16%	1%
4St-C10	0.6469	0.4413	0.3329	0.6284	0.3036	405.09	2066.45	897.40	1214.74	574.25	352.73	267.20	23%	33%	19%
4St-C11	0.4082	0.2253	0.1416	0.0598	0.4371	379.77	1252.37	551.18	716.66	239.84	6.51	230.88	15%	1%	25%
4St-C12	0.4042	0.2829	0.2517	0.1235	0.4620	367.16	1132.89	534.02	611.88	359.31	10.65	335.65	24%	1%	42%
4St-C13	0.3792	0.1911	0.2028	0.0434	0.3369	376.49	1255.15	557.37	713.20	237.06	12.71	234.34	14%	2%	26%
4St-C14	0.3562	0.2178	0.1847	0.0729	0.3830	382.01	1229.67	518.71	723.54	262.54	25.96	224.00	16%	4%	24%
4St-C15	0.3660	0.2658	0.1983	0.1175	0.4517	379.69	1186.72	513.04	685.15	305.49	31.62	262.39	20%	5%	30%
4St-C16	0.3780	0.1710	0.1050	0.0464	0.3319	387.36	1343.78	573.51	783.33	148.43	28.84	164.21	9%	4%	17%
4St-C17	0.3745	0.1540	0.0754	0.0699	0.2795	389.03	1411.08	590.59	835.23	81.12	45.92	112.31	5%	6%	11%
4St-C18	0.3925	0.1590	0.0699	0.0699	0.2950	395.48	1437.88	597.47	860.30	54.33	52.80	87.24	3%	7%	8%
4St-C19	0.5344	0.3450	0.2767	0.4503	0.2710	405.24	1893.03	757.78	1172.56	400.82	213.11	225.02	18%	24%	16%
4St-C20	0.5193	0.3381	0.2422	0.4459	0.2755	401.48	1869.71	749.89	1151.23	377.51	205.22	203.69	17%	23%	15%
4St-C21	0.7130	0.2018	0.1203	0.0731	0.3746	414.24	2183.67	870.38	1369.83	691.46	325.72	422.29	27%	32%	27%
4St-C22	0.4205	0.1901	0.0899	0.1819	0.2485	389.38	1528.87	664.25	883.87	36.67	119.58	63.66	2%	14%	6%
4St-C23	0.4212	0.2049	0.1116	0.2157	0.2404	391.51	1568.03	666.48	921.94	75.83	121.81	25.60	4%	14%	2%
4St-C24	0.6205	0.4043	0.2874	0.6087	0.2531	398.71	2013.00	887.42	1162.14	520.79	342.76	214.60	21%	33%	16%
4St-C25	0.6337	0.4485	0.3058	0.6665	0.2962	400.17	2073.58	899.97	1212.15	581.37	355.30	264.61	23%	33%	19%
4St-C26	0.6517	0.4555	0.3438	0.6619	0.2996	404.77	2098.86	908.67	1236.35	606.65	364.00	288.81	24%	34%	20%
4St-C27	0.7540	0.5335	0.3402	0.7695	0.3880	400.22	2192.29	994.79	1237.42	700.08	450.12	289.88	27%	38%	20%
4St-C28	0.7728	0.5475	0.3883	0.7695	0.3993	405.50	2219.96	1003.10	1265.55	727.75	458.43	318.01	27%	39%	22%
4St-C29	0.7638	0.5394	0.3732	0.7545	0.4018	404.67	2202.49	992.77	1256.60	710.28	448.10	309.06	27%	39%	21%
4St-C30	0.4441	0.4248	0.3503	0.3196	0.5702	374.88	934.49	409.68	541.26	557.71	134.99	406.28	43%	24%	56%
4St-C31	0.4405	0.1698	0.0998	0.1038	0.2725	377.59	1383.86	655.23	751.12	108.34	110.56	196.41	6%	13%	21%
4St-C32	0.4328	0.2007	0.0955	0.1900	0.2642	383.73	1498.71	676.61	847.46	6.50	131.94	100.08	0%	16%	10%

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Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
4St-C33	0.4398	0.1579	0.0881	0.0969	0.2555	383.05	1422.91	649.51	796.74	69.29	104.84	150.79	4%	13%	15%
4St-C34	0.4268	0.1921	0.1152	0.2219	0.2000	385.98	1538.52	680.60	884.44	46.31	135.93	63.09	2%	16%	6%
4St-C35	0.4377	0.1982	0.1321	0.2105	0.2186	396.50	1580.68	692.92	925.43	88.48	148.26	22.11	4%	17%	2%
4St-C36	0.4068	0.3520	0.2874	0.2058	0.5345	374.16	1052.77	459.95	607.06	439.44	84.72	340.48	31%	14%	42%
4St-C37	0.3696	0.2927	0.2555	0.1467	0.4612	375.85	1118.44	478.25	656.14	373.77	66.42	291.40	25%	11%	34%
4St-C38	0.3822	0.2880	0.2198	0.1506	0.4631	384.11	1146.49	486.27	681.62	345.72	58.40	265.92	23%	9%	30%
4St-C39	0.4278	0.4106	0.3513	0.2975	0.5563	368.45	952.31	434.85	524.26	539.90	109.82	423.28	41%	18%	59%
4St-C40	0.3774	0.3235	0.2977	0.1863	0.4773	371.36	1059.90	463.76	605.30	432.31	80.91	342.24	30%	13%	43%
4St-C41	0.4017	0.3136	0.2445	0.1730	0.4923	385.43	1110.80	476.06	650.98	381.41	68.61	296.56	26%	11%	35%
4St-C42	0.3863	0.3177	0.2960	0.1880	0.4616	374.82	1066.83	467.37	608.52	425.37	77.29	339.01	30%	12%	42%
4St-C43	0.3817	0.1646	0.1457	0.0402	0.3017	386.00	1315.80	566.29	760.31	176.40	21.62	187.23	10%	3%	19%
4St-C44	0.4104	0.1749	0.1037	0.0698	0.3183	394.71	1355.58	575.40	796.95	136.62	30.74	150.59	8%	4%	15%
4St-C45	0.5288	0.3413	0.2651	0.4384	0.2799	404.47	1875.86	748.11	1163.44	383.66	203.44	215.90	17%	23%	16%
4St-C47	0.6472	0.4440	0.3381	0.6377	0.2981	406.42	2085.34	893.25	1241.87	593.13	348.58	294.34	24%	33%	20%
4St-C48	0.6457	0.4414	0.3397	0.6328	0.2958	406.30	2082.65	899.55	1233.49	590.44	354.88	285.95	24%	33%	20%
4St-C49	0.6849	0.4928	0.3757	0.6939	0.3451	408.12	2160.48	928.63	1285.00	668.28	383.96	337.46	26%	35%	23%
4St-C50	0.6634	0.4529	0.3283	0.6204	0.3432	405.36	2073.13	912.15	1202.21	580.92	367.48	254.68	23%	34%	18%
4St-C51	0.3921	0.3013	0.2410	0.1829	0.4529	385.25	1121.86	489.42	649.64	370.34	55.24	297.90	25%	9%	35%
4St-C52	0.3768	0.2506	0.1702	0.1294	0.4152	390.20	1201.98	501.76	726.91	290.23	42.91	220.63	19%	7%	24%
4St-C53	0.3904	0.3022	0.2145	0.1829	0.4686	386.57	1131.72	476.69	679.51	360.49	67.98	268.03	24%	11%	31%
4St-C54	0.3986	0.3027	0.2142	0.1677	0.4854	383.95	1137.04	468.92	690.97	355.17	75.75	256.56	24%	13%	29%
4St-C55	0.4359	0.1937	0.1135	0.0646	0.3664	378.22	1363.76	606.72	779.42	128.45	62.05	168.12	7%	8%	17%
4St-C56	0.4204	0.1856	0.1196	0.0579	0.3497	376.24	1345.32	618.58	751.26	146.89	73.91	196.28	8%	9%	21%
4St-C57	0.4396	0.1906	0.1077	0.1482	0.2756	384.01	1474.60	661.34	839.69	17.61	116.67	107.85	1%	14%	10%
4St-C58	0.4473	0.1582	0.0764	0.0909	0.2681	382.42	1423.33	672.77	767.03	68.87	128.11	180.51	4%	15%	18%
4St-C59	0.4217	0.3439	0.2095	0.2414	0.5164	377.38	1094.98	503.78	596.14	397.23	40.88	351.39	28%	6%	44%
4St-C60	0.3969	0.3037	0.2102	0.1660	0.4918	379.10	1143.11	490.95	663.98	349.10	53.72	283.56	23%	8%	33%
4St-C61	0.4134	0.3924	0.2858	0.2675	0.5740	370.43	1016.63	448.67	578.38	475.58	96.00	369.16	35%	16%	49%
4St-C62	0.4181	0.3784	0.2539	0.2495	0.5730	371.49	1048.58	446.40	611.30	443.62	98.27	336.24	32%	17%	42%
5St-C1 (Typical configuration)	**0.4214**	**0.2018**	**0.1203**	**0.0731**	**0.3746**	**381.00**	**1277.43**	**595.67**	**690.97**	**214.77**	**51.00**	**256.57**	**13%**	**7%**	**29%**

Table D - 1: page 6

Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
5St-C2	0.3983	0.1797	0.1453	0.0598	0.3199	389.41	1302.43	576.53	748.13	189.77	31.86	199.41	11%	4%	21%
5St-C4	0.4001	0.1605	0.0847	0.0860	0.2749	395.42	1431.43	611.51	847.18	60.78	66.84	100.36	3%	9%	10%
5St-C5	0.4001	0.1962	0.1522	0.0610	0.3568	381.68	1273.90	570.37	718.55	218.31	25.70	228.99	13%	3%	25%
5St-C6	0.4395	0.1773	0.1210	0.1789	0.2038	393.14	1536.96	684.66	884.90	44.76	139.99	62.64	2%	17%	6%
5St-C7	0.4312	0.1957	0.1050	0.1979	0.2387	397.74	1564.02	668.05	921.62	71.82	123.38	25.92	4%	15%	2%
5St-C8	0.4314	0.1854	0.1027	0.1787	0.2337	396.70	1540.18	664.38	900.61	47.98	119.71	46.93	2%	14%	4%
5St-C10	0.3758	0.2692	0.2153	0.1278	0.4413	380.10	1167.77	508.56	670.07	324.44	36.11	277.47	21%	5%	32%
5St-C11	0.3498	0.2157	0.1822	0.0683	0.3837	381.73	1234.11	525.89	720.66	258.09	18.78	226.88	16%	3%	25%
5St-C12	0.3675	0.2192	0.1488	0.0897	0.3872	389.23	1261.33	532.62	745.91	230.88	12.05	201.63	14%	2%	21%
5St-C13	0.4050	0.1711	0.1094	0.0635	0.3125	393.43	1350.60	574.17	792.18	141.60	29.50	155.36	8%	4%	16%
5St-C14	0.4387	0.4173	0.3445	0.3079	0.5660	374.87	946.92	417.02	546.49	545.28	127.65	401.05	42%	23%	54%
5St-C15	0.7683	0.5461	0.3803	0.7702	0.3990	404.63	2215.09	1000.97	1261.14	722.89	456.30	313.60	27%	39%	21%
5St-C16	0.3869	0.1895	0.1167	0.0715	0.3471	382.31	1350.87	598.47	769.19	141.33	53.81	178.35	8%	7%	18%
5St-C17	0.3798	0.1669	0.1289	0.0874	0.2674	384.57	1390.07	601.66	806.28	102.14	56.99	141.26	6%	7%	14%
5St-C18	0.4147	0.1775	0.0912	0.1691	0.2292	389.58	1511.57	660.85	869.28	19.37	116.18	78.26	1%	14%	7%
5St-C19	0.4157	0.2017	0.1060	0.2212	0.2295	391.21	1572.45	673.93	918.74	80.25	129.26	28.80	4%	15%	3%
5St-C20	0.4298	0.2075	0.1060	0.2241	0.2411	397.25	1597.39	680.25	943.25	105.18	135.58	4.29	5%	16%	0%
5St-C21	0.4298	0.1995	0.1241	0.2195	0.2167	392.53	1568.44	695.42	906.06	76.24	150.75	41.47	4%	17%	4%
5St-C22	0.4222	0.1970	0.1081	0.2295	0.2082	385.69	1542.64	687.70	881.30	50.44	143.03	66.23	3%	17%	6%
5St-C23	0.4346	0.1800	0.0888	0.1635	0.2425	384.03	1483.15	674.67	833.07	9.06	130.00	114.47	0%	15%	11%
5St-C24	0.4169	0.1615	0.0983	0.1400	0.2152	380.76	1429.36	657.18	795.70	62.85	112.52	151.84	3%	14%	15%
5St-C25	0.4244	0.1531	0.1005	0.1270	0.2060	388.82	1459.47	665.22	824.57	32.73	120.55	122.97	2%	14%	12%
5St-C26	0.4349	0.1878	0.0867	0.2086	0.2169	396.41	1548.20	676.51	895.44	56.00	131.84	52.10	3%	15%	5%
5St-C27	0.4226	0.1836	0.0911	0.2064	0.2064	389.20	1520.09	671.26	866.21	27.88	126.59	81.33	1%	15%	8%
5St-C28	0.6307	0.4378	0.2986	0.6460	0.2938	399.96	2051.96	896.18	1193.30	559.76	351.51	245.76	23%	33%	17%
5St-C29	0.6462	0.4468	0.3305	0.6441	0.3024	403.90	2074.21	903.57	1214.38	582.00	358.90	266.84	23%	34%	19%
5St-C30	0.3931	0.3019	0.2389	0.1709	0.4679	382.88	1119.58	479.68	659.40	372.62	64.98	288.13	25%	10%	34%
5St-C31	0.3800	0.3072	0.2682	0.1705	0.4669	375.93	1094.96	472.79	637.30	397.25	71.88	310.24	27%	12%	37%
5St-C32	0.3772	0.3087	0.2888	0.1761	0.4547	374.80	1079.18	475.10	613.24	413.03	69.57	334.30	28%	11%	41%
5St-C33	0.4031	0.2973	0.2463	0.1618	0.4618	384.84	1119.92	485.15	648.94	372.29	59.51	298.60	25%	9%	35%
5St-C34	0.3760	0.1511	0.0907	0.0560	0.2789	388.91	1387.38	585.32	816.03	104.83	40.65	131.51	6%	5%	13%

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Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
5St-C35	0.3904	0.1512	0.0690	0.0603	0.2856	394.39	1410.96	591.24	837.84	81.25	46.57	109.70	5%	6%	11%
5St-C36	0.3908	0.1506	0.0788	0.0537	0.2858	393.17	1393.62	581.95	828.61	98.59	37.28	118.93	6%	5%	12%
5St-C37	0.5309	0.3446	0.2690	0.4501	0.2742	404.38	1888.42	755.99	1168.27	396.22	211.32	220.73	17%	24%	16%
5St-C38	0.6374	0.4398	0.3186	0.6310	0.3041	403.04	2057.23	893.70	1205.52	565.03	349.03	257.98	23%	33%	18%
5St-C39	0.4364	0.1859	0.0931	0.1987	0.2193	395.22	1530.78	667.04	886.10	38.57	122.37	61.44	2%	14%	6%
5St-C40	0.4257	0.1517	0.1071	0.1204	0.2062	387.35	1442.02	655.69	815.08	50.19	111.02	132.46	3%	13%	13%
5St-C41	0.4048	0.2753	0.1816	0.1147	0.4870	375.68	1184.75	515.43	682.59	307.46	29.24	264.95	20%	4%	30%
5St-C42	0.3896	0.2790	0.2010	0.1282	0.4729	373.53	1165.21	524.81	655.54	326.99	19.86	292.00	21%	3%	35%
5St-C43	0.3988	0.1953	0.1324	0.0375	0.3887	381.76	1293.64	567.73	742.66	198.57	23.06	204.88	12%	3%	22%
5St-C44	0.4177	0.2265	0.1378	0.1028	0.3977	380.11	1244.29	580.21	672.57	247.92	35.54	274.96	15%	5%	31%
5St-C45	0.4055	0.2463	0.1616	0.1207	0.4174	389.44	1217.31	529.38	700.62	274.90	15.29	246.92	17%	2%	27%
5St-C46	0.3833	0.1953	0.1233	0.0587	0.3714	393.99	1296.60	539.92	778.07	195.61	4.75	169.47	12%	1%	17%
5St-C47	0.3817	0.2428	0.1611	0.1099	0.4201	390.67	1225.13	514.33	730.16	267.08	30.34	217.38	17%	4%	24%
5St-C48	0.3841	0.2403	0.1529	0.1021	0.4259	389.98	1232.77	510.73	740.81	259.44	33.93	206.73	16%	5%	22%
5St-C49	0.4326	0.1932	0.0936	0.1723	0.2644	398.94	1555.54	650.44	932.73	63.33	105.77	14.81	3%	13%	1%
5St-C50	0.4288	0.1898	0.0946	0.1699	0.2578	398.74	1552.44	655.76	924.99	60.24	111.09	22.55	3%	13%	2%
5St-C51	0.4457	0.2198	0.1200	0.2351	0.2541	401.36	1629.25	684.00	976.00	137.04	139.33	28.46	7%	16%	2%
5St-C52	0.4505	0.1954	0.0896	0.1573	0.2874	397.60	1544.31	670.54	894.25	52.10	125.87	53.29	3%	15%	5%
6St-C1	0.3855	0.1852	0.1288	0.0792	0.3222	382.66	1334.30	595.61	754.83	157.90	50.95	192.71	9%	7%	20%
6St-C2	0.3738	0.1715	0.1180	0.0994	0.2723	384.29	1394.37	608.92	803.17	97.83	64.25	144.36	5%	8%	14%
6St-C3	0.3865	0.1691	0.0861	0.1009	0.2805	391.34	1419.70	615.07	827.92	72.51	70.41	119.62	4%	9%	12%
6St-C4	0.3967	0.1554	0.0988	0.0689	0.2724	392.01	1387.17	603.35	806.67	105.04	58.68	140.87	6%	8%	14%
6St-C5	0.3822	0.1579	0.1266	0.0659	0.2680	384.31	1360.42	597.13	780.12	131.79	52.46	167.42	8%	7%	17%
6St-C6	0.3858	0.1642	0.1098	0.0927	0.2647	389.10	1407.07	605.42	822.92	85.13	60.75	124.62	5%	8%	12%
6St-C7	0.3761	0.1908	0.1806	0.0801	0.3096	379.21	1280.52	577.12	718.67	211.69	32.46	228.87	13%	4%	25%
6St-C8	0.3867	0.1850	0.1486	0.0758	0.3152	387.50	1310.07	583.39	747.52	182.14	38.72	200.01	11%	5%	21%
6St-C9	0.3899	0.1792	0.1605	0.0552	0.3157	385.99	1292.65	574.21	737.98	199.55	29.54	209.56	12%	4%	22%
6St-C10	0.4291	0.1809	0.0932	0.2072	0.1977	385.62	1521.69	684.35	862.81	29.48	139.69	84.73	2%	16%	8%
6St-C11	0.4346	0.1836	0.1113	0.2002	0.2026	391.40	1544.39	690.94	884.35	52.18	146.27	63.19	3%	17%	6%
6St-C12	0.4365	0.1767	0.1092	0.1880	0.1989	390.06	1527.28	681.47	875.15	35.07	136.80	72.39	2%	16%	7%
6St-C13	0.4244	0.1968	0.1071	0.1974	0.2411	395.03	1554.99	665.61	912.17	62.79	120.94	35.37	3%	14%	3%

Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
6St-C14	0.4151	0.1937	0.1048	0.2062	0.2253	391.07	1550.19	669.68	899.91	57.98	125.01	47.63	3%	15%	4%
6St-C15	0.4257	0.1972	0.0995	0.2113	0.2317	396.19	1572.08	675.01	921.23	79.87	130.34	26.30	4%	15%	2%
6St-C16	0.4318	0.1875	0.0869	0.2103	0.2145	395.18	1543.40	675.13	890.77	51.19	130.46	56.77	3%	15%	5%
6St-C17	0.6420	0.4456	0.3232	0.6453	0.3019	402.98	2069.47	901.59	1210.01	577.27	356.92	262.48	23%	33%	18%
6St-C18	0.3878	0.3018	0.2461	0.1690	0.4659	381.25	1114.48	478.17	654.70	377.73	66.50	292.84	26%	11%	34%
6St-C19	0.3973	0.2970	0.2524	0.1632	0.4566	383.23	1114.75	483.91	644.09	377.46	60.76	303.45	25%	9%	36%
6St-C20	0.3868	0.1517	0.0737	0.0626	0.2821	393.12	1406.23	589.94	833.36	85.98	45.27	114.18	5%	6%	11%
6St-C21	0.4134	0.1517	0.0976	0.0291	0.3045	391.57	1362.32	603.43	776.80	129.89	58.76	170.74	7%	8%	17%
6St-C22	0.3973	0.1574	0.0870	0.0932	0.2586	395.91	1443.12	615.31	855.44	49.08	70.64	92.09	3%	9%	9%
6St-C23	0.3881	0.1645	0.0971	0.0532	0.3124	392.78	1370.39	588.70	807.08	121.81	44.03	140.46	7%	6%	14%
6St-C24	0.3912	0.1667	0.0930	0.0547	0.3184	393.06	1373.57	583.64	814.68	118.63	38.97	132.86	7%	5%	13%
6St-C25	0.3986	0.2449	0.1846	0.1161	0.4072	388.90	1206.41	519.96	700.40	285.80	24.71	247.13	18%	4%	27%
6St-C26	0.3930	0.2429	0.1843	0.1094	0.4093	389.23	1208.29	513.06	711.44	283.91	31.61	236.09	18%	5%	26%
6St-C27	0.3918	0.2525	0.1930	0.1205	0.4178	388.14	1193.50	508.99	700.59	298.71	35.68	246.95	19%	5%	28%
6St-C28	0.3959	0.2594	0.1977	0.1206	0.4327	386.19	1186.98	501.62	700.38	305.23	43.05	247.16	20%	7%	27%
6St-C29	0.3615	0.2408	0.1855	0.0985	0.4145	382.80	1208.00	505.18	716.76	284.21	39.49	230.78	18%	6%	25%
6St-C30	0.3593	0.2375	0.1849	0.1013	0.4035	384.93	1210.83	511.39	714.44	281.37	33.28	233.10	18%	5%	26%
6St-C31	0.3612	0.1953	0.1547	0.0543	0.3603	387.49	1269.30	533.02	752.53	222.91	11.65	195.01	13%	2%	21%
6St-C32	0.3891	0.2464	0.1805	0.1235	0.4056	385.51	1204.51	525.49	689.72	287.70	19.18	257.82	18%	3%	29%
7St-C1	0.3776	0.1630	0.1198	0.0824	0.2674	384.27	1372.72	604.99	784.68	119.48	60.33	162.86	7%	8%	16%
7St-C2	0.3879	0.1610	0.0970	0.0851	0.2709	390.21	1394.95	610.20	806.19	97.26	65.53	141.35	5%	8%	14%
7St-C3	0.3810	0.1700	0.1008	0.1040	0.2725	388.83	1411.58	612.67	820.00	80.63	68.00	127.54	4%	9%	12%
7St-C4	0.3887	0.1567	0.1100	0.0717	0.2673	388.83	1377.82	600.99	796.96	114.39	56.32	150.58	6%	7%	15%
7St-C5	0.3836	0.1843	0.1547	0.0731	0.3133	385.98	1305.08	582.02	742.72	187.13	37.35	204.82	11%	5%	22%
7St-C6	0.4331	0.1839	0.1079	0.2032	0.2021	390.02	1539.47	689.20	879.76	47.27	144.53	67.78	2%	17%	6%
7St-C7	0.4225	0.1979	0.1019	0.2111	0.2323	394.98	1567.42	673.58	916.76	75.22	128.91	30.78	4%	15%	3%
7St-C8	0.3707	0.2220	0.1795	0.0814	0.3874	386.60	1230.10	525.47	719.21	262.11	19.20	228.33	16%	3%	25%
7St-C10	0.4005	0.1516	0.1159	0.0274	0.2968	387.82	1349.96	599.44	765.93	142.25	54.77	181.61	8%	7%	19%
7St-C11	0.4000	0.1554	0.1111	0.0438	0.2921	391.03	1352.87	594.89	777.32	139.33	50.22	170.22	8%	7%	17%
7St-C12	0.3930	0.1612	0.1132	0.0543	0.2949	391.34	1355.27	588.26	788.85	136.93	43.59	158.69	8%	6%	16%
7St-C13	0.3893	0.1654	0.1222	0.0513	0.3041	390.31	1340.32	584.19	777.81	151.88	39.52	169.73	9%	5%	17%

Table D - 1: page 9

Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
7St-C14	0.3901	0.1718	0.1263	0.0500	0.3195	389.47	1329.16	575.34	774.32	163.04	30.67	173.22	9%	4%	18%
7St-C15	0.3794	0.1789	0.1075	0.0719	0.3244	388.74	1361.91	587.26	795.60	130.30	42.60	151.93	7%	6%	15%
7St-C16	0.3833	0.1631	0.0854	0.1054	0.2612	391.94	1430.72	618.33	836.10	61.49	73.66	111.44	3%	9%	11%
7St-C17	0.3996	0.1571	0.1015	0.0451	0.2999	389.85	1366.79	605.36	779.21	125.41	60.69	168.33	7%	8%	17%
7St-C18	0.3832	0.1668	0.1150	0.0680	0.2942	389.46	1361.22	594.40	787.24	130.99	49.73	160.30	7%	7%	16%
8St-C1	0.3885	0.1626	0.1153	0.0585	0.2931	389.40	1358.54	597.37	780.32	133.66	52.70	167.21	8%	7%	17%
8St-C2	0.3833	0.1663	0.1141	0.0687	0.2927	389.52	1363.04	595.13	788.39	129.17	50.46	159.15	7%	7%	16%
8St-C3	0.3809	0.1773	0.1276	0.0652	0.3171	387.57	1336.96	582.23	773.91	155.24	37.56	173.63	9%	5%	18%
8St-C4	0.3803	0.1721	0.1389	0.0500	0.3139	386.11	1319.84	573.12	764.66	172.37	28.45	182.88	10%	4%	19%
8St-C5	0.3812	0.1639	0.1320	0.0498	0.2969	387.43	1334.83	582.88	771.13	157.38	38.22	176.41	9%	5%	18%
8St-C6	0.3836	0.1613	0.1257	0.0537	0.2896	388.11	1345.89	585.96	779.12	146.32	41.29	168.42	8%	5%	17%
8St-C7	0.3905	0.1570	0.1262	0.0434	0.2891	387.97	1343.46	592.08	768.52	148.75	47.41	179.02	9%	6%	18%
8St-C8	0.3789	0.1663	0.1201	0.0666	0.2919	388.02	1356.42	593.05	782.64	135.79	48.38	164.89	8%	6%	17%
8St-C9	0.3755	0.1659	0.1393	0.0585	0.2893	383.36	1336.22	592.32	758.81	155.98	47.65	188.73	9%	6%	20%
8St-C10	0.3715	0.1691	0.1360	0.0684	0.2889	383.49	1340.78	590.01	766.87	151.42	45.34	180.67	9%	6%	19%
8St-C11	0.3693	0.1825	0.1509	0.0670	0.3169	381.71	1313.31	575.47	753.02	178.90	30.80	194.52	10%	4%	20%
8St-C12	0.3865	0.1950	0.1740	0.0698	0.3340	385.14	1269.17	568.80	717.77	223.03	24.13	229.77	13%	3%	25%
8St-C13	0.3817	0.1967	0.1723	0.0739	0.3349	385.27	1273.71	566.75	725.64	218.49	22.08	221.90	13%	3%	24%
9St-C1	0.3842	0.1635	0.1215	0.0600	0.2908	387.96	1353.72	596.02	775.74	138.48	51.35	171.80	8%	7%	18%
9St-C2	0.3790	0.1659	0.1191	0.0673	0.2904	388.08	1358.24	593.77	783.79	133.96	49.10	163.74	8%	6%	17%
9St-C3	0.3766	0.1779	0.1333	0.0663	0.3147	386.07	1332.20	580.91	769.35	160.01	36.24	178.19	9%	5%	18%
9St-C4	0.3886	0.1621	0.1145	0.0591	0.2916	389.46	1360.36	598.09	781.47	131.85	53.43	166.07	8%	7%	17%
9St-C5	0.3861	0.1723	0.1286	0.0536	0.3158	387.51	1334.33	585.25	767.01	157.88	40.58	180.52	9%	5%	19%
9St-C6	0.3809	0.1767	0.1267	0.0656	0.3157	387.63	1338.78	582.95	775.06	153.43	38.28	172.48	9%	5%	18%
9St-C9	0.3842	0.1635	0.1215	0.0600	0.2908	387.96	1353.72	596.02	775.74	138.48	51.35	171.80	8%	7%	18%
9St-C10	0.3790	0.1659	0.1191	0.0673	0.2904	388.08	1358.24	593.77	783.79	133.96	49.10	163.74	8%	6%	17%
9St-C11	0.3782	0.1748	0.1444	0.0484	0.3199	385.46	1310.61	570.76	757.83	181.60	26.09	189.71	11%	4%	20%
9St-C12	0.3812	0.1632	0.1312	0.0501	0.2954	387.49	1336.64	583.61	772.27	155.56	38.94	175.26	9%	5%	18%
9St-C13	0.3803	0.1715	0.1380	0.0506	0.3124	386.17	1321.65	573.84	765.80	170.55	29.17	181.73	10%	4%	19%
9St-C14	0.3869	0.1671	0.1391	0.0405	0.3110	386.02	1319.30	580.05	755.23	172.91	35.38	192.30	10%	5%	20%

Table D - 1: page 10

Station Configuration	MRAE - RR1	MRAE Flow Duration (RR1)	MRAE-Highflow (< 20%) (RR1)	MRAE-Intermediate flow (20% - 60%) (RR1)	MRAE-Lowflow (> 60%) (RR1)	Initial Soil Moisture	Annual Average Streamflow (RR1)	Maha Average Streamflow (RR1)	Yala Average Streamflow (RR1)	Absolute Water Balance Error Annual average (RR1)	Absolute Water Balance Error Maha average (RR1)	Absolute Water Balance Error Yala average (RR1)	**% Water Balance Error Annual (RR1)**	**% Water Balance Error Maha (RR1)**	**% Water Balance Error Yala (RR1)**
9St-C15	0.3905	0.1565	0.1253	0.0439	0.2876	388.04	1345.27	592.80	769.66	146.93	48.13	177.88	8%	6%	18%
9St-C16	0.3894	0.1581	0.1283	0.0428	0.2913	387.75	1339.87	590.95	766.12	152.34	46.28	181.42	9%	6%	19%
10St-C1	0.3816	0.1729	0.1350	0.0544	0.3134	386.01	1329.54	583.94	762.46	162.67	39.27	185.08	9%	5%	19%
10St-C2	0.3843	0.1630	0.1206	0.0606	0.2893	388.02	1355.54	596.74	776.88	136.66	52.08	170.65	8%	7%	17%
10St-C3	0.3765	0.1773	0.1325	0.0667	0.3132	386.14	1334.01	581.63	770.50	158.19	36.96	177.04	9%	5%	18%
10St-C5	0.3894	0.1576	0.1274	0.0435	0.2898	387.81	1341.68	591.67	767.26	150.52	47.00	180.27	9%	6%	19%
10St-C6	0.3869	0.1664	0.1383	0.0405	0.3096	386.09	1321.11	580.76	756.38	171.10	36.10	191.16	10%	5%	20%
10St-C7	0.3781	0.1742	0.1435	0.0487	0.3184	385.52	1312.42	571.48	758.97	179.78	26.81	188.56	11%	4%	20%
10St-C8	0.3860	0.1687	0.1414	0.0411	0.3133	385.79	1315.71	578.91	752.84	176.49	34.25	194.69	10%	5%	20%
10St-C9	0.3947	0.1668	0.1274	0.0397	0.3170	388.77	1324.05	581.53	760.70	168.15	36.86	186.84	10%	5%	19%
10St-C10	0.3773	0.1718	0.1582	0.0379	0.3161	381.46	1298.64	574.26	737.76	193.57	29.59	209.78	11%	4%	22%

Hydrographs (RR Option 1)

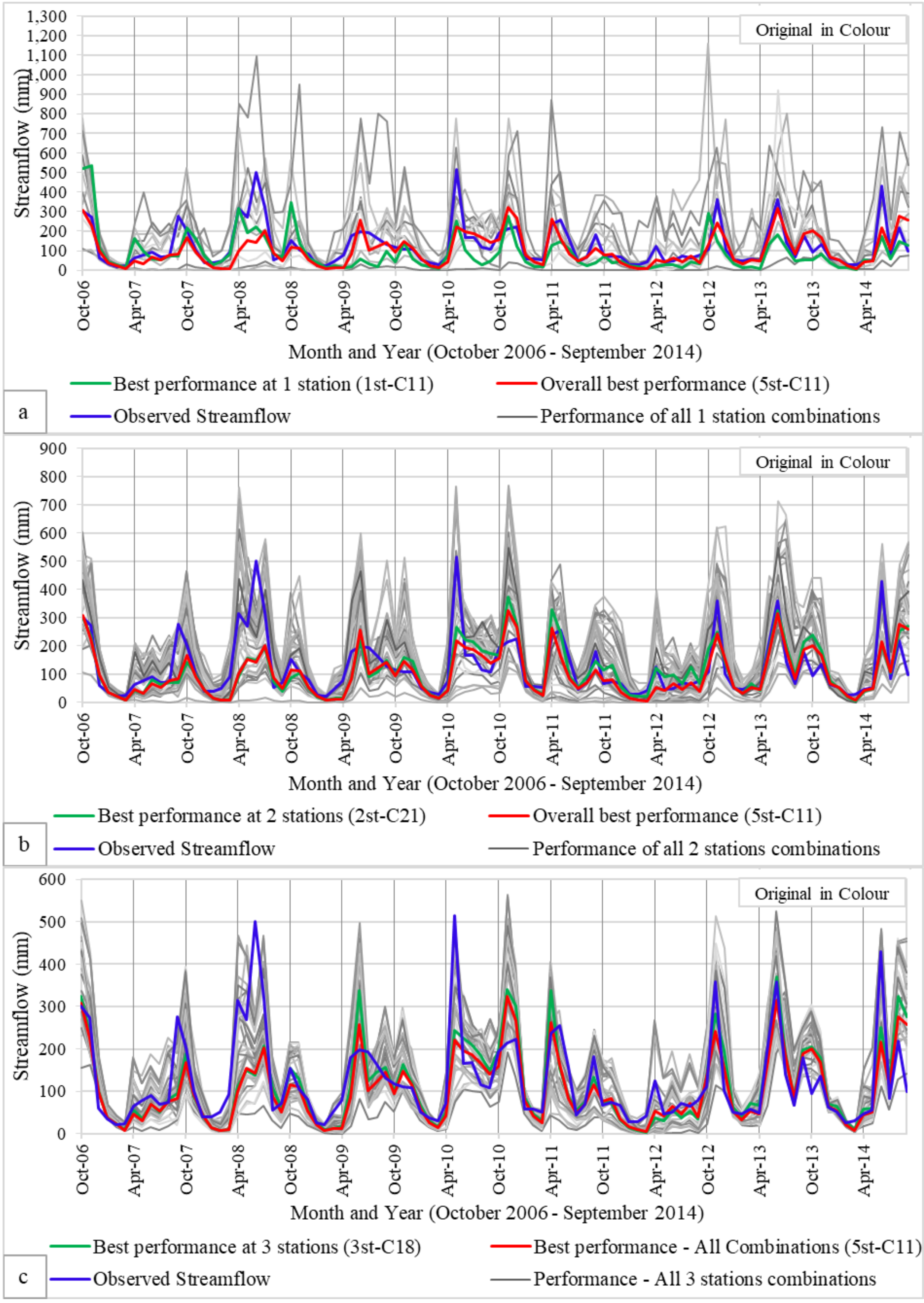


Figure D - 1: (i). All Hydrographs highlighting best performing streamflow estimations RR1 (a - 1 station combinations; b - 2 stations combinations; c - 3 stations combinations)

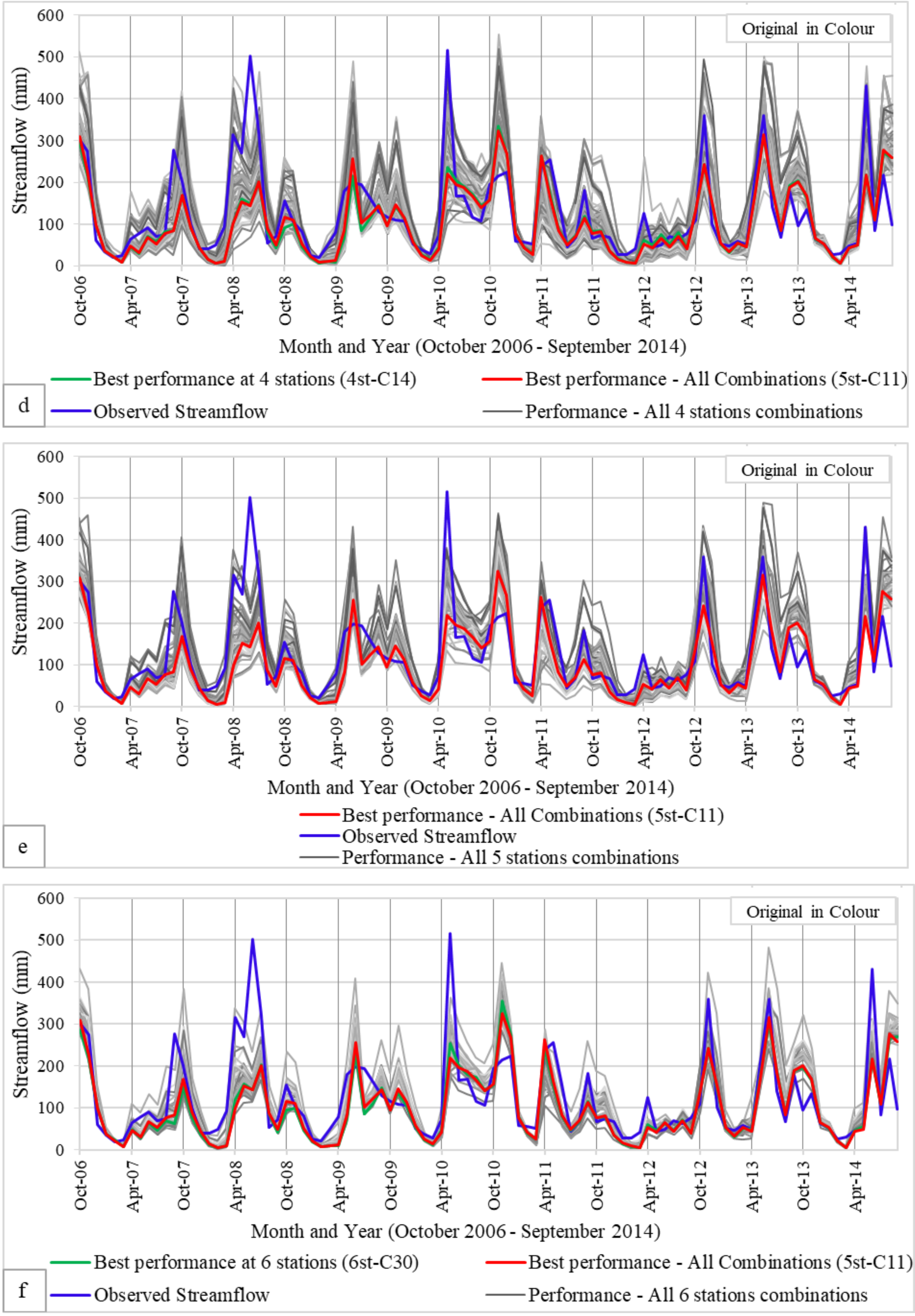
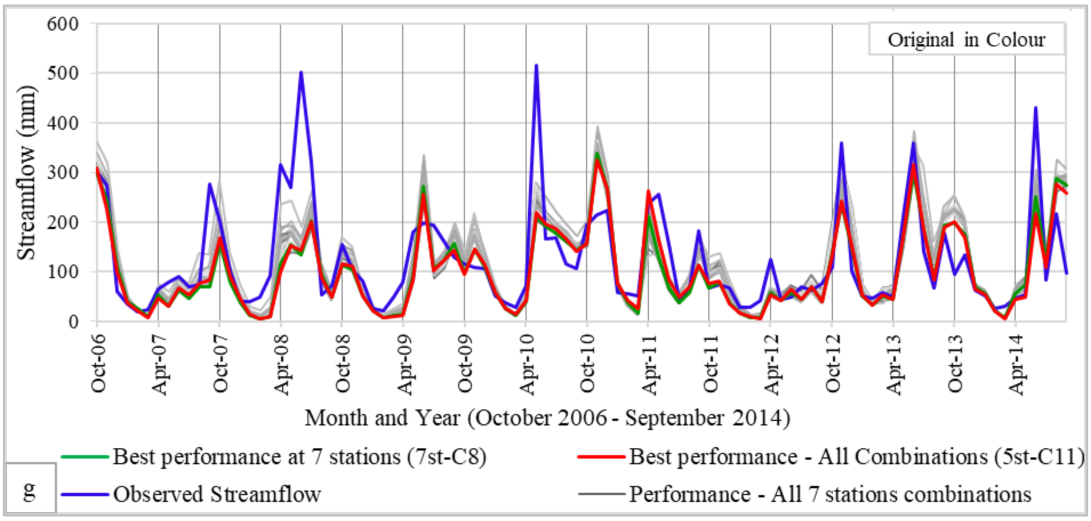
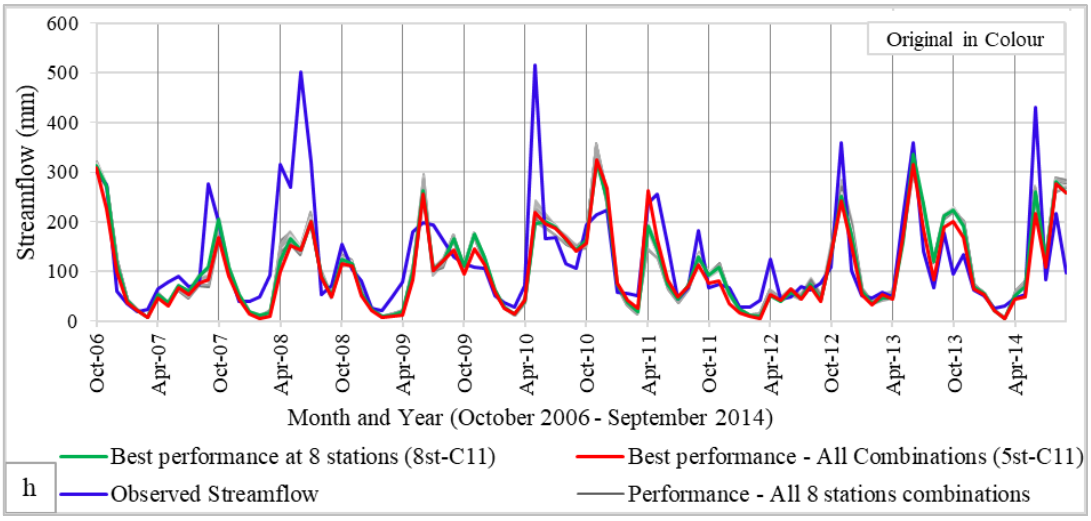


Figure D - 2: (ii). All Hydrographs highlighting best performing streamflow estimations RR1(d - 4 stations combinations; e - 5 stations combinations; f - 6 stations combinations)





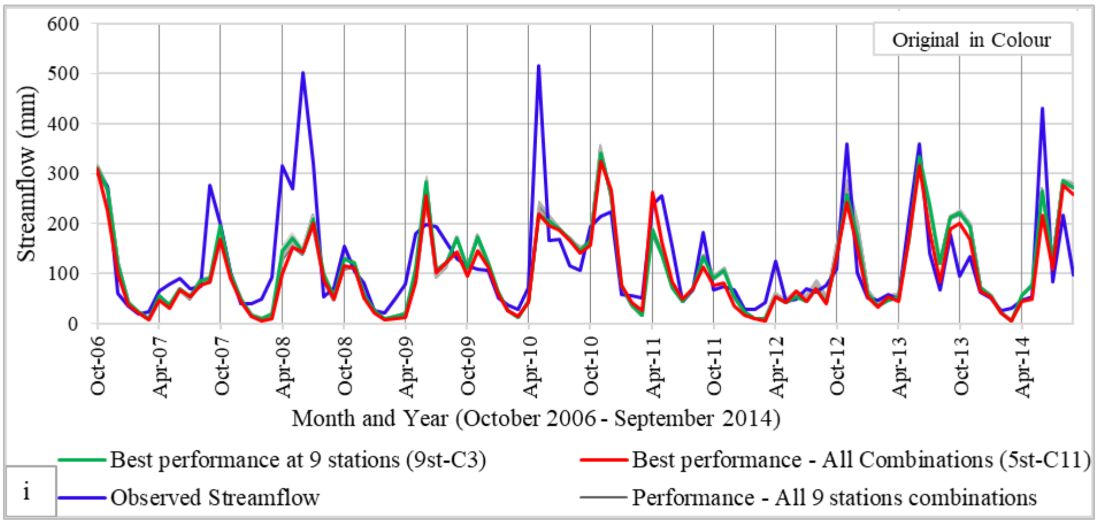


Figure D - 3: (iii). All Hydrographs highlighting best performing streamflow estimations (g - 7 stations combinations; h - 8 stations combinations; i - 9 stations combinations)

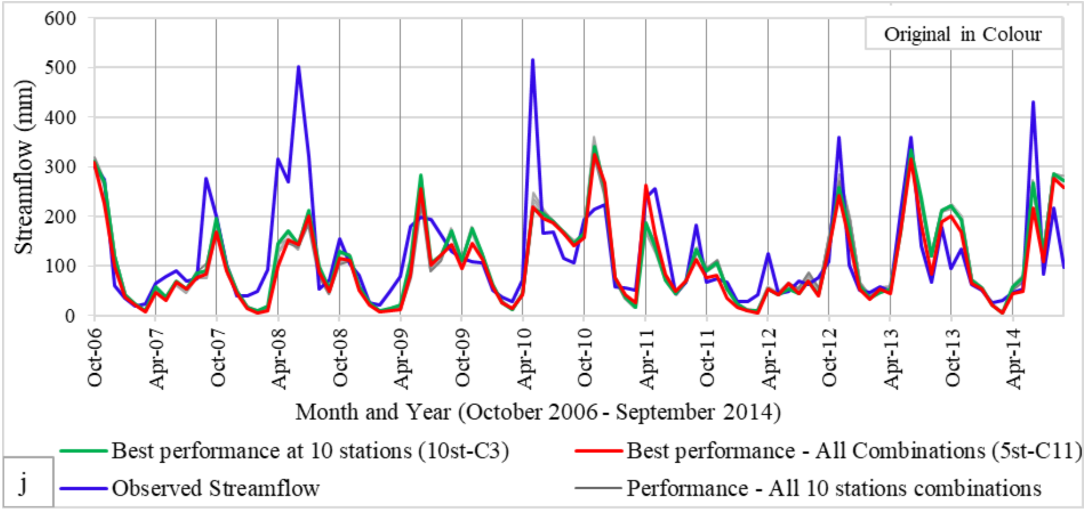


Figure D - 4: (iv). All Hydrographs highlighting best performing streamflow estimations (j - 10 stations combinations)

Flow Duration Curves (RR Option 1)

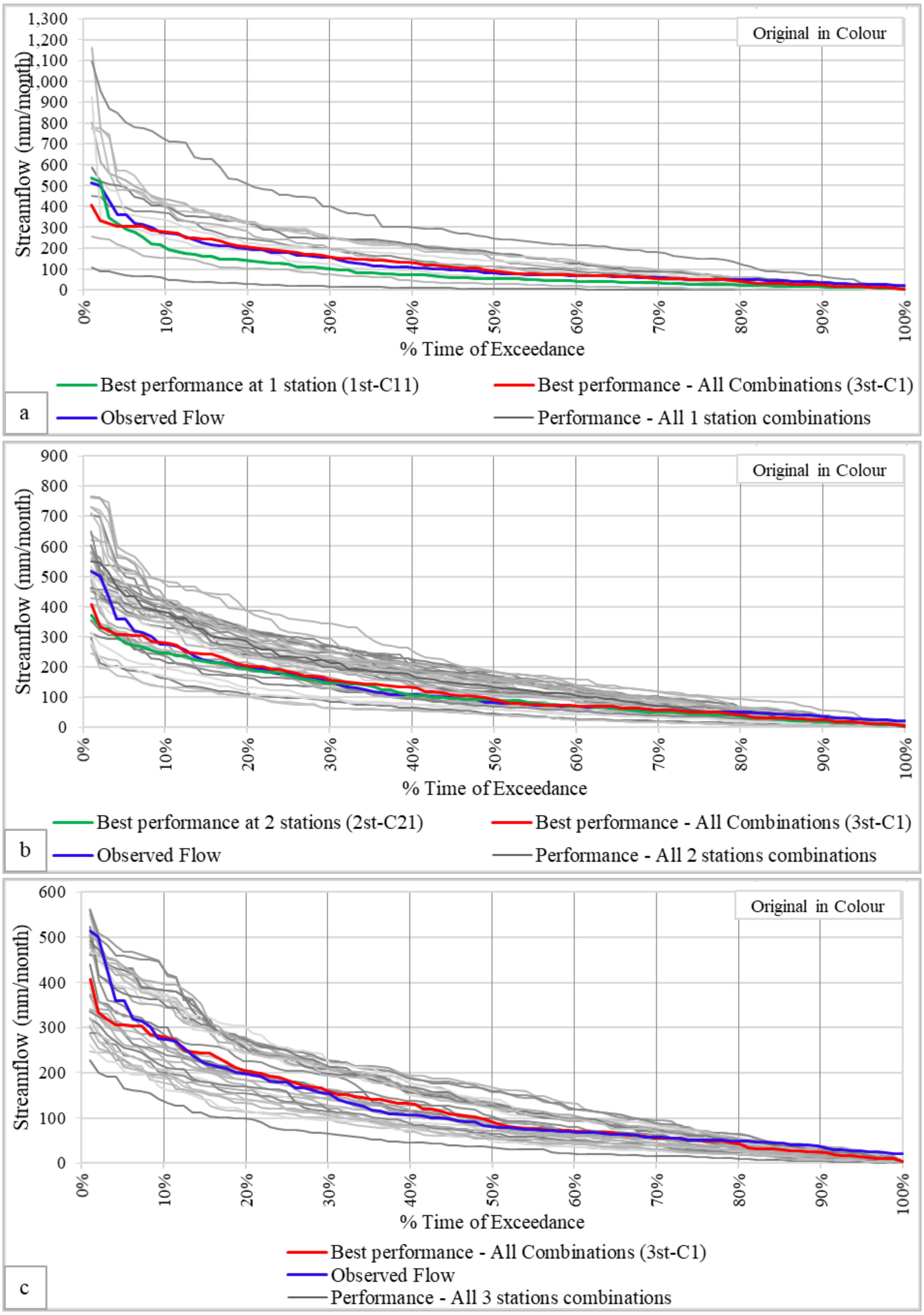


Figure D - 5: (i). Flow Duration curves highlighting best performing streamflow estimations (a - 1 station combinations; b - 2 stations combinations; c - 3 stations combinations)

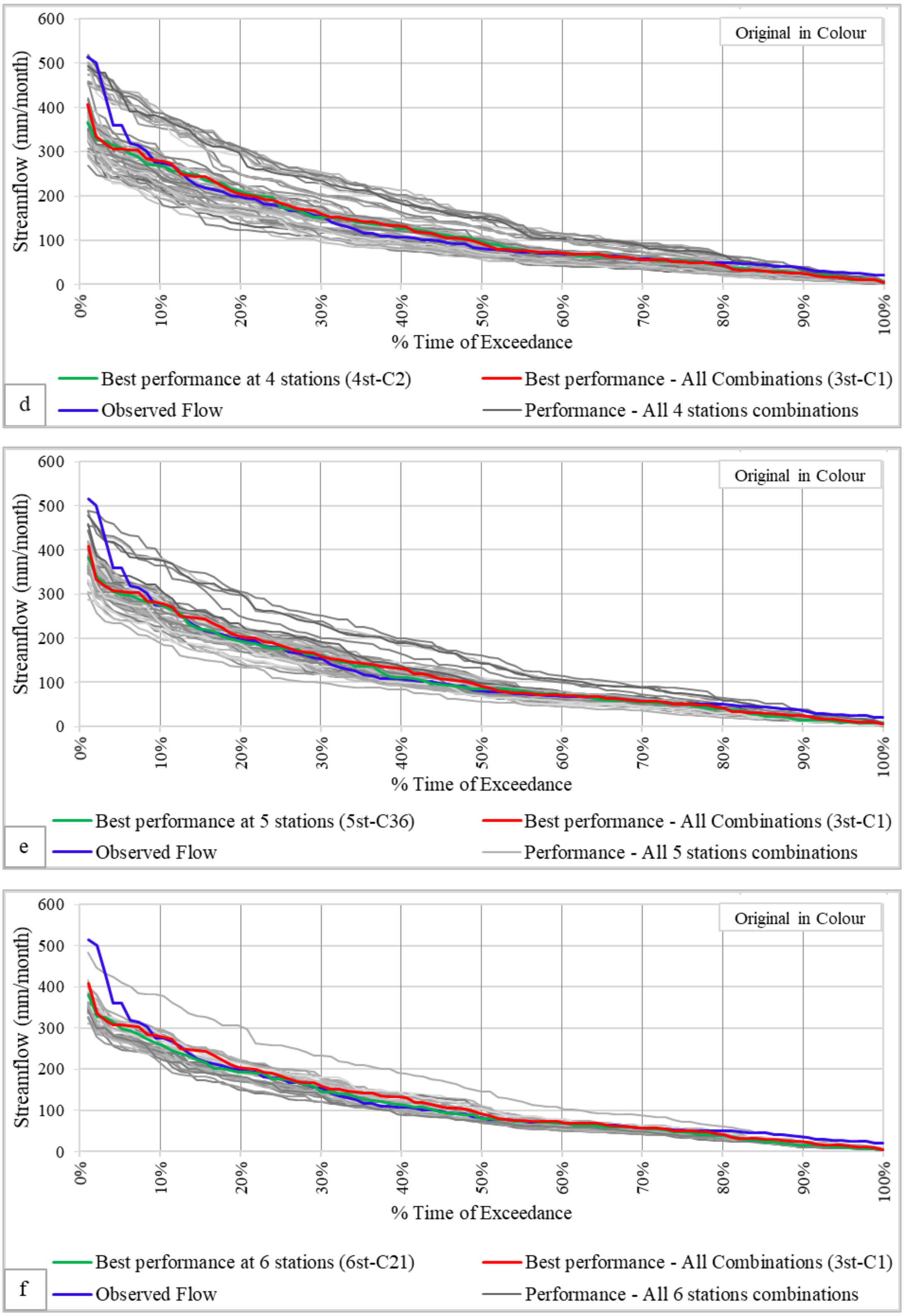


Figure D - 6: (ii). Flow Duration curves highlighting best performing streamflow estimations (d - 4 stations combinations; e - 5 stations combinations; f - 6 stations combinations)

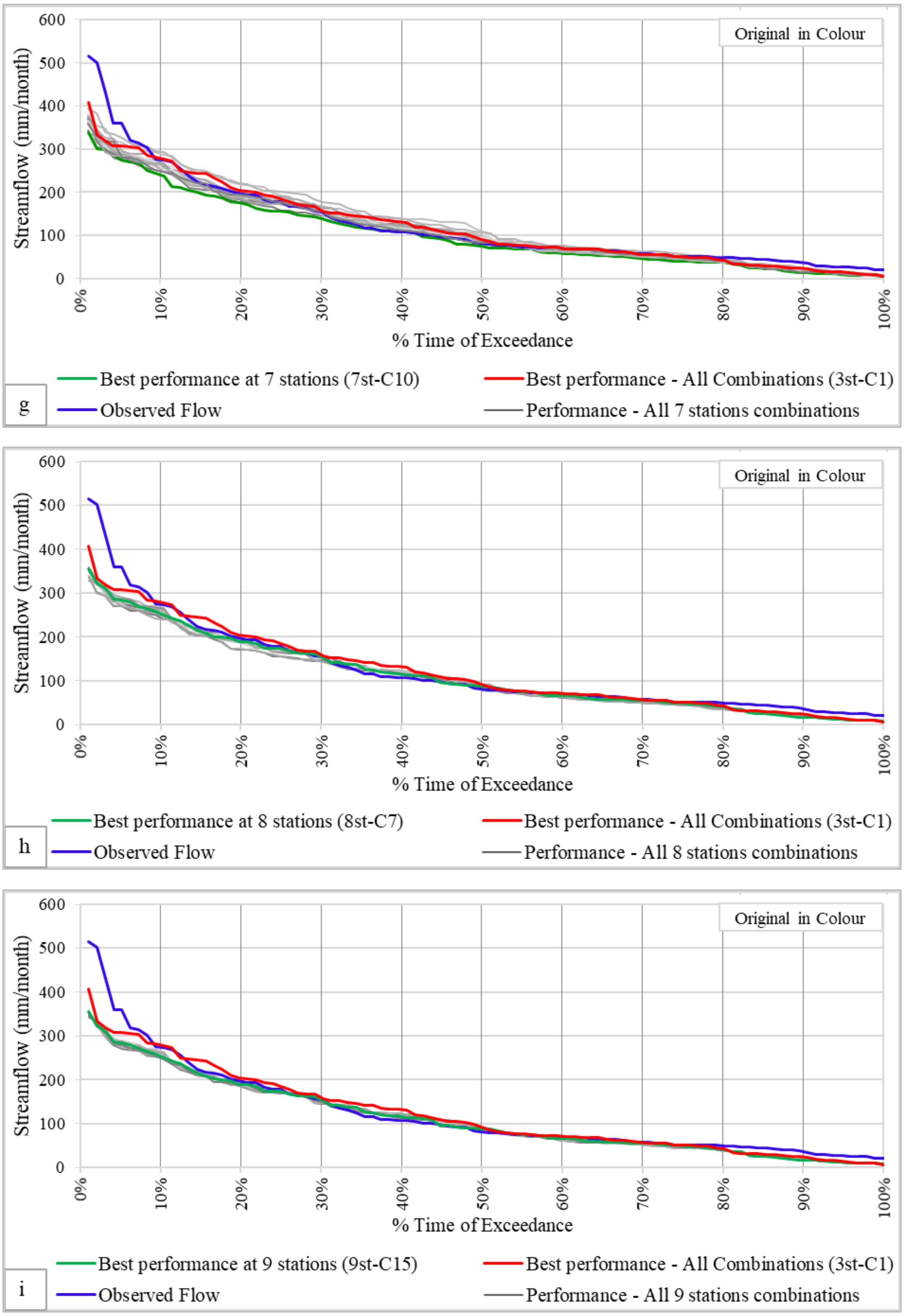


Figure D - 7: (iii). Flow Duration curves highlighting best performing streamflow estimations (g - 7 stations combinations; h - 8 stations combinations; i - 9 stations combinations)

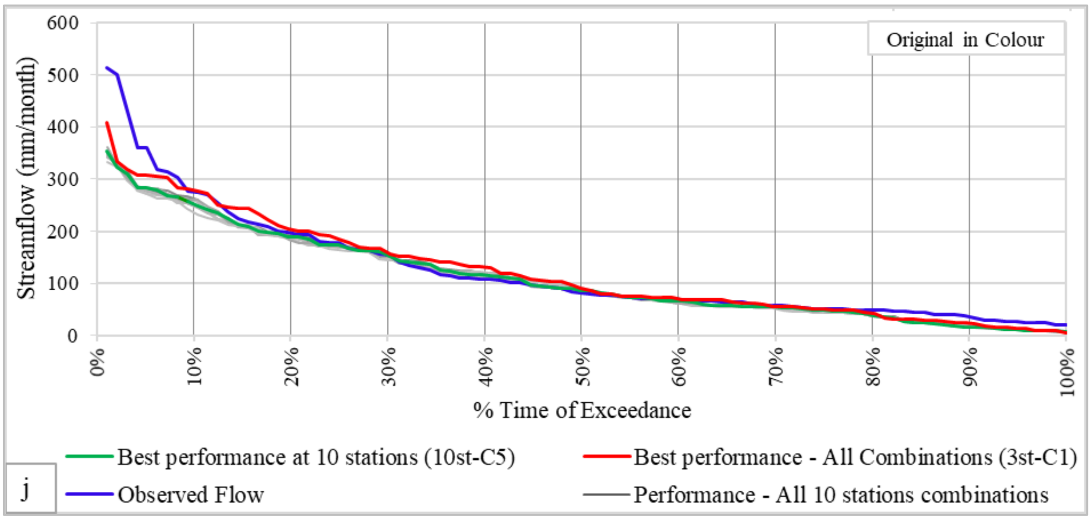


Figure D - 8: (iv). Flow Duration curves highlighting best performing streamflow estimations (j - 10 stations combinations)

ANNEX E - RESULTS SUMMARY (RR OPTION 2)

Overall Results (RR Option 2)

Table E - 1: All results RR2

	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
1St-C1	3.54	5000.00	0.7345	0.4484	0.6158	0.7017	0.8275	657.71	1006.37	589.90	427.68	485.84	45.24	519.86	18%	3%	37%
1St-C2	0.79	672.94	0.3252	0.1549	0.3694	0.3058	0.3230	183.51	1147.05	510.30	665.22	345.16	34.37	282.31	116%	16%	331%
1St-C3	1.37	1038.47	0.4680	0.2316	0.5100	0.5157	0.3980	274.96	1211.89	539.50	679.62	280.32	5.16	267.92	32%	1%	65%
1St-C4	2.53	1945.48	0.4429	0.2306	0.3602	0.4593	0.4674	485.29	1360.46	565.09	811.82	131.75	20.42	135.72	6%	2%	11%
1St-C5	3.10	3296.02	0.5200	0.1886	0.5020	0.4738	0.5764	696.03	1424.51	660.79	773.22	67.69	116.12	174.31	2%	10%	11%
1St-C6	2.71	2556.98	0.5095	0.1961	0.4541	0.4470	0.6014	603.80	1297.65	595.58	712.57	194.56	50.91	234.96	9%	6%	18%
1St-C7	3.35	5000.00	0.4670	0.2484	0.4474	0.3484	0.5987	814.86	1119.46	526.71	599.69	372.74	17.96	347.85	14%	2%	21%
1St-C8	3.13	3768.41	0.4997	0.1992	0.4411	0.3748	0.6572	840.89	1474.50	632.48	869.43	17.71	87.82	78.11	1%	8%	4%
1St-C9	3.16	4604.83	0.8115	0.5089	0.6239	0.9312	0.7824	850.78	1116.64	654.48	462.22	375.56	109.81	485.32	17%	10%	40%
1St-C10	5.00	2321.65	0.7030	0.4902	0.4417	0.9045	0.6270	578.63	1363.68	585.80	796.81	128.53	41.13	150.73	3%	2%	6%
1St-C11	1.87	1865.00	0.4392	0.1939	0.4338	0.4498	0.4311	376.75	1232.81	660.22	613.12	259.39	115.55	334.42	19%	16%	54%
1St-C12	1.99	3254.57	0.4989	0.2005	0.4768	0.4858	0.5235	557.70	1281.11	502.52	787.72	211.09	42.15	159.81	14%	9%	16%
2St-C1	2.29	2611.86	0.4278	0.2139	0.1996	0.0823	0.3563	599.39	1226.46	538.00	702.04	265.74	6.67	245.50	15%	1%	23%
2St-C2	1.75	1068.56	0.4102	0.1508	0.0878	0.0953	0.2392	291.12	1429.99	604.30	840.63	62.22	59.63	106.91	4%	9%	13%
2St-C5	3.13	5000.00	0.5823	0.2613	0.2532	0.1490	0.3806	835.98	1127.09	619.31	518.74	365.12	74.64	428.80	14%	6%	31%
2St-C6	3.25	5000.00	0.5555	0.1982	0.1944	0.0820	0.3194	859.29	1273.36	645.84	645.67	218.84	101.17	301.87	8%	8%	19%
2St-C8	1.40	1231.27	0.3578	0.1167	0.2291	0.0755	0.1027	319.25	1262.90	554.01	731.22	229.30	9.34	216.32	23%	2%	40%
2St-C9	1.65	1719.08	0.3323	0.1019	0.1686	0.0802	0.0909	436.02	1329.10	569.71	793.21	163.11	25.04	154.33	13%	5%	21%
2St-C10	1.40	865.24	0.3985	0.1144	0.1301	0.0728	0.1493	233.11	1366.18	646.01	750.82	126.03	101.34	196.72	11%	17%	37%
2St-C11	1.95	1330.59	0.5443	0.1791	0.0711	0.0837	0.3311	338.98	1431.98	698.23	750.87	60.22	153.56	196.67	4%	18%	23%
2St-C12	3.00	5000.00	0.5017	0.3060	0.3054	0.1344	0.4824	828.97	1078.25	542.17	545.78	413.95	2.50	401.76	18%	0%	30%
2St-C13	3.34	5000.00	0.5937	0.2837	0.2532	0.1006	0.4870	756.15	1148.45	631.17	528.45	343.75	86.51	419.09	12%	7%	28%
2St-C14	3.20	5000.00	0.5516	0.1727	0.2390	0.0592	0.2560	789.16	1244.64	652.41	604.72	247.57	107.74	342.82	9%	9%	23%
2St-C15	1.65	1450.18	0.3131	0.1440	0.2374	0.1072	0.1350	364.52	1255.42	536.67	739.95	236.79	8.00	207.59	19%	1%	30%
2St-C16	1.29	937.32	0.2931	0.0963	0.1643	0.0737	0.0853	252.76	1345.30	580.63	792.79	146.90	35.97	154.75	15%	8%	30%
2St-C17	1.65	1313.19	0.3534	0.2018	0.1203	0.0731	0.3746	342.29	1345.93	563.84	806.86	146.28	19.18	140.68	11%	3%	19%
2St-C18	1.00	662.67	0.3151	0.2018	0.1203	0.0731	0.3746	182.69	1163.86	510.53	674.31	328.35	34.14	273.22	64%	11%	133%

Table E - 1: page 2

	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
2St-C19	1.98	1426.93	0.4003	0.1726	0.0795	0.0357	0.3597	371.91	1347.49	563.72	798.63	144.72	19.05	148.91	9%	3%	16%
2St-C20	2.00	2022.94	0.3695	0.1585	0.1994	0.0558	0.2436	472.51	1259.56	576.52	690.71	232.64	31.85	256.83	15%	4%	30%
2St-C21	2.03	1865.72	0.3772	0.1352	0.1342	0.0893	0.1828	456.49	1380.70	594.02	798.20	111.50	49.36	149.34	6%	7%	15%
2St-C22	2.66	2458.20	0.4458	0.2054	0.0687	0.0796	0.4029	597.41	1404.88	589.63	835.69	87.33	44.96	111.85	4%	5%	8%
2St-C23	2.55	2146.41	0.4277	0.2071	0.0803	0.1217	0.3581	528.07	1454.31	607.62	863.94	37.89	62.95	83.60	2%	7%	6%
2St-C24	2.55	1811.89	0.4433	0.2373	0.0690	0.0717	0.4915	460.26	1341.03	561.81	794.53	151.18	17.14	153.01	7%	2%	12%
2St-C25	2.58	1857.79	0.4400	0.2440	0.0597	0.0920	0.4921	469.48	1398.88	582.91	832.23	93.33	38.24	115.31	4%	4%	9%
2St-C26	2.86	2842.24	0.4868	0.2397	0.1859	0.1028	0.4071	647.09	1228.12	576.30	660.64	264.09	31.63	286.90	11%	3%	21%
2St-C27	3.37	5000.00	0.4582	0.2551	0.3536	0.0980	0.3671	813.17	1104.77	524.63	586.72	387.43	20.04	360.82	14%	2%	22%
2St-C28	3.12	3695.42	0.4932	0.2029	0.0687	0.1431	0.3315	823.57	1468.80	633.47	860.47	23.41	88.81	87.07	1%	8%	5%
2St-C29	3.05	4341.66	0.4477	0.2038	0.2991	0.1104	0.2520	830.60	1193.33	571.48	630.39	298.87	26.82	317.15	12%	3%	21%
2St-C30	3.07	4025.23	0.4756	0.1928	0.1964	0.0592	0.3282	851.59	1266.01	578.35	703.03	226.19	33.68	244.51	9%	3%	15%
2St-C31	3.24	4137.94	0.4814	0.2142	0.1616	0.0741	0.3843	851.51	1314.73	579.67	752.69	177.48	35.00	194.85	6%	3%	11%
2St-C32	3.21	5000.00	0.6935	0.3339	0.1796	0.2267	0.5211	789.58	1130.35	668.31	465.77	361.85	123.64	481.77	14%	10%	36%
2St-C33	3.85	5000.00	0.6909	0.3208	0.1875	0.1281	0.5852	802.75	1149.96	628.52	533.79	342.25	83.85	413.75	10%	5%	24%
2St-C34	3.23	5000.00	0.6464	0.3949	0.3123	0.2667	0.5678	658.74	1001.94	582.42	433.20	490.27	37.75	514.34	20%	3%	41%
2St-C35	3.05	5000.00	0.6391	0.3366	0.2517	0.2125	0.5064	698.87	1096.65	584.29	522.60	395.55	39.62	424.94	16%	4%	33%
2St-C36	2.37	1628.80	0.4402	0.2328	0.0655	0.0663	0.4874	414.69	1404.04	559.63	861.81	88.16	14.96	85.73	4%	2%	7%
2St-C37	2.43	1758.19	0.4275	0.2200	0.0820	0.0649	0.4482	445.55	1391.37	581.21	830.16	100.84	36.54	117.38	5%	4%	9%
2St-C38	2.55	1924.11	0.4404	0.2264	0.0754	0.0823	0.4498	483.83	1411.89	585.78	844.16	80.31	41.11	103.37	4%	5%	8%
2St-C39	2.51	1909.98	0.4393	0.1985	0.0621	0.0549	0.4140	480.00	1383.91	608.33	786.21	108.29	63.66	161.32	5%	7%	13%
2St-C40	3.26	5000.00	0.4945	0.1927	0.1997	0.0534	0.3323	961.29	1274.20	595.57	690.54	218.00	50.90	257.00	8%	5%	15%
2St-C41	3.63	5000.00	0.5072	0.2309	0.1521	0.0685	0.4369	966.24	1278.24	578.19	715.91	213.96	33.52	231.63	7%	3%	12%
2St-C42	3.12	3827.04	0.4955	0.1951	0.0726	0.1258	0.3275	844.07	1457.60	629.22	855.34	34.61	84.55	92.19	1%	8%	5%
2St-C43	2.77	4086.48	0.4574	0.1804	0.1470	0.0916	0.2883	810.18	1347.54	576.21	788.66	144.67	31.55	158.87	6%	4%	11%
3St-C1	2.14	1454.45	0.4135	0.1676	0.0911	0.0669	0.3092	383.77	1394.92	624.48	806.98	97.29	79.81	140.56	5%	10%	14%
3St-C3	1.97	1307.60	0.4271	0.1895	0.1351	0.0874	0.3214	339.93	1307.94	598.86	730.34	184.27	54.19	217.20	11%	7%	25%
3St-C4	2.40	2641.49	0.4478	0.1732	0.1544	0.0694	0.2891	604.50	1320.05	596.17	741.58	172.16	51.50	205.96	9%	6%	18%
3St-C5	1.52	965.91	0.3605	0.1286	0.1521	0.0764	0.1703	263.35	1358.13	576.69	800.36	134.07	32.02	147.18	11%	6%	22%
3St-C7	1.83	1429.09	0.3749	0.1419	0.1269	0.0403	0.2538	380.31	1342.90	560.23	810.33	149.31	15.56	137.20	10%	2%	16%

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	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
3St-C8	1.23	695.85	0.3435	0.0966	0.1320	0.0871	0.0887	192.57	1372.72	622.23	777.92	119.49	77.56	169.61	12%	15%	38%
3St-C9	1.97	1287.65	0.4383	0.1968	0.1019	0.1432	0.2992	339.32	1488.80	656.70	860.07	3.41	112.04	87.47	0%	14%	9%
3St-C10	1.87	1159.54	0.4111	0.1765	0.0938	0.1383	0.2571	306.16	1458.41	675.46	810.77	33.79	130.79	136.76	2%	17%	15%
3St-C11	2.23	2520.92	0.4109	0.1458	0.2533	0.0729	0.1670	534.71	1256.39	605.51	667.81	235.82	60.84	279.73	13%	7%	28%
3St-C12	1.77	1350.25	0.3728	0.1360	0.1042	0.0393	0.2511	352.91	1356.83	570.70	803.75	135.38	26.03	143.79	9%	4%	18%
3St-C13	1.54	1160.44	0.3017	0.1062	0.1794	0.0501	0.1273	305.78	1325.72	579.01	764.25	166.49	34.34	183.29	14%	6%	29%
3St-C14	1.79	1496.53	0.3283	0.1386	0.1962	0.0722	0.1781	379.09	1302.37	556.02	761.37	189.84	11.35	186.17	13%	2%	23%
3St-C15	2.21	2012.84	0.4035	0.1750	0.1189	0.0553	0.3260	500.45	1319.13	560.33	775.56	173.07	15.67	171.98	9%	2%	16%
3St-C16	2.19	2069.94	0.3714	0.1535	0.1631	0.0351	0.2703	494.69	1298.18	562.32	746.97	194.02	17.65	200.57	11%	2%	19%
3St-C17	1.96	1460.74	0.3905	0.1368	0.0900	0.0419	0.2576	380.85	1382.00	586.52	810.05	110.20	41.86	137.49	7%	6%	14%
3St-C18	2.09	1459.73	0.3785	0.1870	0.0889	0.0513	0.3754	379.18	1347.67	570.67	790.43	144.54	26.00	157.11	8%	4%	16%
3St-C19	2.58	1796.23	0.4351	0.2466	0.0566	0.0910	0.5012	457.34	1370.34	573.12	812.74	121.87	28.45	134.80	6%	3%	10%
3St-C20	2.64	3129.59	0.4306	0.1941	0.1459	0.1212	0.2929	684.34	1380.86	609.36	785.50	111.35	64.69	162.04	5%	7%	12%
3St-C21	2.62	1849.55	0.4406	0.2399	0.0679	0.0883	0.4814	476.94	1431.62	587.40	864.92	60.59	42.73	82.62	3%	5%	6%
3St-C22	3.08	4140.64	0.4704	0.1967	0.2093	0.0652	0.3254	860.13	1259.44	580.28	693.55	232.76	35.62	253.99	9%	4%	16%
3St-C23	3.06	3930.26	0.4449	0.2113	0.2846	0.0963	0.2927	782.07	1197.31	569.54	636.19	294.90	24.88	311.35	12%	2%	21%
3St-C24	3.05	3967.34	0.4673	0.1913	0.2057	0.0680	0.3108	836.64	1266.83	580.32	701.16	225.38	35.66	246.38	9%	4%	16%
3St-C25	3.02	4845.67	0.5228	0.3015	0.2775	0.1797	0.4386	821.76	1084.59	574.37	516.22	407.61	29.70	431.32	17%	3%	33%
3St-C26	3.09	5000.00	0.5037	0.3140	0.3122	0.1299	0.5039	831.15	1072.58	540.65	541.57	419.62	4.01	405.97	17%	0%	30%
3St-C27	2.96	5000.00	0.4908	0.3066	0.3268	0.1423	0.4650	810.75	1062.05	541.38	531.24	430.16	3.29	416.30	19%	0%	33%
3St-C28	2.95	5000.00	0.4981	0.2995	0.3013	0.1319	0.4706	825.34	1083.40	540.73	552.21	408.81	3.94	395.33	18%	0%	30%
3St-C29	1.63	1272.17	0.3486	0.1422	0.1412	0.0530	0.2343	328.86	1338.14	548.12	813.49	154.07	3.45	134.05	12%	1%	18%
3St-C30	1.60	1153.67	0.3361	0.1342	0.1244	0.0525	0.2229	304.89	1335.29	564.77	798.62	156.92	20.10	148.92	13%	4%	21%
3St-C31	1.70	1357.09	0.3502	0.1162	0.1131	0.0447	0.1911	353.10	1373.91	577.64	821.95	118.30	32.98	125.59	8%	6%	16%
3St-C32	1.81	1344.88	0.3749	0.1983	0.1897	0.0955	0.3080	347.32	1228.55	547.12	695.08	263.66	2.45	252.46	20%	0%	34%
3St-C33	2.63	2522.91	0.4378	0.1848	0.0801	0.0656	0.3594	604.74	1388.70	607.71	795.83	103.50	63.04	151.70	5%	7%	11%
3St-C34	2.69	2271.01	0.4449	0.2132	0.0556	0.0814	0.4273	564.79	1421.78	591.57	851.70	70.42	46.91	95.84	3%	5%	7%
3St-C35	2.64	2490.34	0.4412	0.2018	0.0755	0.0748	0.3952	600.18	1395.00	589.79	825.60	97.21	45.12	121.94	4%	5%	9%
3St-C36	2.50	2307.10	0.4421	0.2098	0.0647	0.1316	0.3626	562.62	1455.63	598.85	878.07	36.58	54.18	69.46	2%	6%	5%

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	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
4St-C1	2.37	2741.23	0.4356	0.1597	0.2070	0.0602	0.2381	611.21	1264.37	593.23	684.44	227.83	48.56	263.10	12%	6%	24%
4St-C2	2.19	2187.29	0.4267	0.1224	0.1634	0.0538	0.1725	514.74	1337.77	631.79	730.39	154.43	87.13	217.14	8%	11%	21%
4St-C3	1.80	1075.36	0.4094	0.1568	0.0988	0.1124	0.2313	290.00	1412.51	629.79	804.02	79.70	85.12	143.51	5%	12%	17%
4St-C4	1.96	1380.89	0.3933	0.1550	0.0970	0.0756	0.2656	369.59	1408.45	605.74	834.48	83.76	61.08	113.06	5%	8%	12%
4St-C5	1.75	1117.20	0.3668	0.1336	0.0906	0.0570	0.2337	301.75	1397.97	582.05	834.77	94.23	37.38	112.76	6%	6%	14%
4St-C6	2.02	1645.67	0.3788	0.1597	0.1245	0.0430	0.2972	425.54	1321.14	554.09	788.23	171.06	9.42	159.30	10%	1%	17%
4St-C7	1.77	1288.96	0.3713	0.1290	0.1157	0.0677	0.1986	346.98	1383.11	580.04	828.08	109.10	35.37	119.46	7%	5%	14%
4St-C8	2.14	1533.42	0.4133	0.1699	0.0980	0.0651	0.3133	395.26	1389.12	612.37	792.44	103.08	67.70	155.09	6%	8%	15%
4St-C9	2.29	1772.50	0.4223	0.1879	0.0901	0.0816	0.3458	455.42	1410.71	606.88	825.78	81.49	62.21	121.76	4%	7%	10%
4St-C10	3.03	5000.00	0.4958	0.2110	0.2672	0.0687	0.3289	869.91	1182.17	595.84	599.02	310.03	51.17	348.52	12%	5%	24%
4St-C11	1.88	1234.97	0.3991	0.1663	0.0959	0.0697	0.3007	327.97	1420.90	609.36	832.93	71.31	64.69	114.61	4%	9%	13%
4St-C12	1.78	1206.56	0.3549	0.1457	0.1216	0.1048	0.1996	316.81	1397.86	633.58	785.09	94.35	88.91	162.44	6%	12%	20%
4St-C13	1.96	1484.20	0.3683	0.1527	0.1603	0.0905	0.2127	377.07	1357.57	598.41	777.13	134.64	53.74	170.40	8%	7%	19%
4St-C14	2.03	1917.31	0.3468	0.1510	0.2000	0.0513	0.2289	461.51	1267.97	549.95	730.53	224.24	5.28	217.01	14%	1%	24%
4St-C15	1.90	1221.98	0.3481	0.1799	0.1040	0.0595	0.3413	324.72	1334.40	560.61	790.10	157.81	15.94	157.44	10%	2%	18%
4St-C16	2.06	1453.76	0.3775	0.1698	0.0968	0.0466	0.3327	378.59	1352.55	575.13	790.82	139.65	30.47	156.72	8%	4%	16%
4St-C17	2.19	2010.76	0.3685	0.1627	0.1602	0.0393	0.2905	484.16	1298.03	565.18	743.82	194.18	20.51	203.72	11%	3%	20%
4St-C18	2.11	1708.05	0.3892	0.1532	0.0788	0.0610	0.2850	439.08	1400.54	591.07	827.20	91.67	46.40	120.34	5%	6%	11%
4St-C19	2.56	1780.46	0.4384	0.2327	0.0683	0.1031	0.4480	462.40	1449.39	596.43	873.80	42.82	51.76	73.74	2%	6%	5%
4St-C20	2.59	2012.34	0.4266	0.2018	0.1203	0.0731	0.3746	501.79	1403.49	591.06	828.27	88.72	46.39	119.27	4%	5%	9%
4St-C21	3.10	4260.68	0.4663	0.2044	0.2297	0.0717	0.3280	869.20	1235.17	573.20	675.37	257.04	28.53	272.16	10%	3%	17%
4St-C22	2.19	1710.74	0.4153	0.1909	0.0987	0.1032	0.3270	430.18	1416.25	626.90	804.91	75.95	82.23	142.62	4%	10%	13%
4St-C23	2.28	2223.30	0.3968	0.1490	0.1384	0.0787	0.2264	520.72	1370.63	614.12	769.97	121.58	69.45	177.57	6%	8%	16%
4St-C24	3.05	5000.00	0.4968	0.2720	0.3052	0.1008	0.4310	838.47	1108.53	570.79	547.48	383.67	26.12	400.05	16%	2%	29%
4St-C25	3.05	5000.00	0.4938	0.2389	0.2890	0.0892	0.3674	827.68	1167.49	591.30	586.77	324.72	46.63	360.77	13%	4%	25%
4St-C26	3.09	5000.00	0.4964	0.2501	0.2825	0.0780	0.4104	847.81	1156.30	579.49	588.63	335.91	34.82	358.91	13%	3%	25%
4St-C27	3.13	5000.00	0.5403	0.1867	0.2516	0.0817	0.2621	827.52	1207.71	646.18	573.28	284.49	101.51	374.26	11%	9%	26%
4St-C28	3.13	5000.00	0.5404	0.1882	0.2358	0.0831	0.2722	856.20	1232.72	648.69	598.19	259.48	104.02	349.35	10%	9%	24%
4St-C29	3.11	5000.00	0.5385	0.1705	0.2320	0.0791	0.2334	854.80	1239.86	652.53	601.39	252.35	107.86	346.15	10%	9%	24%
4St-C30	1.64	1415.05	0.3380	0.1265	0.1734	0.1013	0.1288	368.25	1315.88	562.30	781.48	176.33	17.63	166.05	14%	3%	23%
4St-C31	1.99	1340.78	0.4373	0.1625	0.0760	0.1348	0.2342	347.74	1452.09	677.29	799.97	40.11	132.62	147.57	2%	16%	15%

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	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
4St-C32	2.07	1473.25	0.4324	0.2020	0.0948	0.1894	0.2686	379.10	1499.96	676.21	849.29	7.75	131.55	98.24	0%	16%	9%
4St-C33	2.00	1266.79	0.4365	0.1744	0.0803	0.1469	0.2496	335.49	1488.98	666.17	849.58	3.22	121.51	97.96	0%	15%	10%
4St-C34	2.16	1575.25	0.4189	0.1864	0.1179	0.1548	0.2532	399.80	1454.02	649.73	828.10	38.19	105.06	119.44	2%	12%	11%
4St-C35	2.17	1461.28	0.4287	0.1899	0.1152	0.1251	0.2937	387.30	1484.62	652.14	867.56	7.59	107.47	79.98	0%	13%	7%
4St-C36	1.64	1096.77	0.3376	0.1319	0.0853	0.1088	0.1790	295.58	1433.49	595.52	865.34	58.72	50.85	82.20	4%	8%	10%
4St-C37	1.85	1559.99	0.3217	0.1481	0.1751	0.0859	0.1984	393.69	1317.79	560.46	778.17	174.41	15.79	169.36	12%	3%	20%
4St-C38	1.84	1482.33	0.3339	0.1388	0.1221	0.0772	0.2104	385.83	1352.41	568.98	811.16	139.80	24.31	136.38	9%	4%	16%
4St-C39	1.54	1017.67	0.3299	0.1210	0.1145	0.1096	0.1360	276.46	1422.92	606.28	836.60	69.28	61.61	110.94	5%	10%	16%
4St-C40	1.81	1471.82	0.3221	0.1459	0.1996	0.0710	0.1958	373.64	1291.55	556.17	749.99	200.66	11.50	197.55	14%	2%	25%
4St-C41	1.78	1327.02	0.3540	0.1325	0.1176	0.0573	0.2170	355.02	1371.76	576.39	821.17	120.45	31.72	126.37	8%	5%	15%
4St-C42	1.74	1241.01	0.3414	0.1408	0.1523	0.0883	0.1889	328.95	1364.12	575.12	806.04	128.09	30.45	141.50	9%	5%	18%
4St-C43	2.07	1830.99	0.3741	0.1421	0.1752	0.0551	0.2149	450.83	1312.60	578.74	744.01	179.61	34.08	203.53	11%	5%	21%
4St-C44	2.19	2631.06	0.4030	0.1524	0.2267	0.0572	0.2130	594.44	1245.08	566.45	689.55	247.13	21.78	257.99	14%	3%	26%
4St-C45	2.66	2467.46	0.4336	0.2186	0.1158	0.0824	0.4098	588.82	1340.70	576.04	780.32	151.50	31.38	167.22	7%	4%	12%
4St-C47	3.11	5000.00	0.4991	0.2703	0.2815	0.0995	0.4401	851.98	1125.79	558.02	579.83	366.42	13.35	367.71	15%	1%	25%
4St-C48	3.09	5000.00	0.4974	0.2533	0.2797	0.0845	0.4133	852.20	1142.54	569.20	586.18	349.67	24.53	361.36	14%	2%	25%
4St-C49	3.17	5000.00	0.5040	0.2650	0.2773	0.0846	0.4439	858.46	1138.57	566.23	584.82	353.64	21.57	362.72	14%	2%	24%
4St-C50	3.13	5000.00	0.5100	0.2938	0.2884	0.1538	0.4401	848.73	1091.73	562.40	537.84	400.48	17.73	409.70	16%	2%	29%
4St-C51	1.86	1601.90	0.3584	0.1374	0.1709	0.0502	0.2100	411.00	1306.87	567.79	761.09	185.33	23.12	186.45	13%	4%	22%
4St-C52	1.89	1595.63	0.3490	0.1259	0.1104	0.0628	0.1985	414.27	1363.41	571.05	823.38	128.79	26.38	124.16	8%	4%	13%
4St-C53	1.86	1556.77	0.3446	0.1405	0.1345	0.0601	0.2261	403.22	1318.69	554.68	793.97	173.52	10.01	153.57	12%	2%	18%
4St-C54	1.84	1673.40	0.3464	0.1370	0.1392	0.0750	0.1996	424.20	1339.18	556.80	810.23	153.02	12.13	137.31	10%	2%	15%
4St-C55	1.94	1303.66	0.4322	0.1928	0.0960	0.1397	0.2957	340.94	1478.02	645.93	859.01	14.18	101.26	88.53	1%	13%	9%
4St-C56	1.96	1290.57	0.4174	0.1793	0.0984	0.1031	0.2979	336.53	1439.51	650.19	818.03	52.70	105.52	129.50	3%	13%	14%
4St-C57	2.00	1265.31	0.4369	0.2076	0.1138	0.1838	0.2788	335.94	1541.33	679.10	892.51	49.12	134.44	55.02	3%	16%	5%
4St-C58	2.22	1659.16	0.4352	0.2007	0.1189	0.0679	0.3780	410.77	1290.36	624.43	678.79	201.84	79.76	268.75	11%	10%	27%
4St-C59	1.88	1363.63	0.4035	0.2000	0.1244	0.1038	0.3366	354.17	1264.03	566.06	706.39	228.18	21.40	241.15	16%	3%	30%
4St-C60	1.83	1183.77	0.3702	0.1500	0.0855	0.0304	0.3050	316.56	1359.33	565.46	812.90	132.88	20.79	134.64	9%	3%	16%
4St-C61	1.72	1179.77	0.3484	0.1499	0.1210	0.0411	0.2760	312.46	1323.10	562.14	780.79	169.11	17.47	166.75	12%	3%	22%
4St-C62	1.72	1286.44	0.3650	0.1330	0.1053	0.0356	0.2469	336.13	1358.83	563.33	813.05	133.37	18.66	134.49	10%	3%	17%

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	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
5St-C1 (Typical configuration)	2.07	1496.10	0.4214	0.2018	0.1203	0.0731	0.3746	381.00	1277.43	595.67	690.97	214.77	51.00	256.57	13%	7%	29%
5St-C2	2.03	1520.51	0.3969	0.1574	0.1319	0.0626	0.2675	395.21	1338.37	592.24	769.23	153.84	47.57	178.31	9%	6%	19%
5St-C4	2.06	1421.88	0.3996	0.1672	0.0843	0.0849	0.2932	379.29	1435.50	610.12	853.45	56.71	65.46	94.09	3%	8%	9%
5St-C5	1.88	1151.60	0.3907	0.1586	0.0914	0.1033	0.2490	309.86	1441.20	621.73	840.72	51.00	77.06	106.82	3%	10%	12%
5St-C6	2.15	1404.95	0.4286	0.1823	0.1086	0.1137	0.2895	372.10	1458.48	648.85	840.81	33.73	104.18	106.73	2%	12%	10%
5St-C7	2.24	1981.94	0.4171	0.1491	0.1002	0.0883	0.2360	492.65	1408.50	623.55	803.58	83.71	78.88	143.96	4%	9%	13%
5St-C8	2.25	1833.75	0.4196	0.1624	0.1053	0.0596	0.2965	462.23	1375.19	610.30	783.14	117.02	65.63	164.40	6%	8%	15%
5St-C10	1.83	1150.68	0.3520	0.1472	0.0894	0.0527	0.2731	309.38	1381.65	578.25	821.15	110.56	33.58	126.39	7%	5%	15%
5St-C11	2.04	1760.92	0.3415	0.1718	0.1944	0.0490	0.2866	432.95	1258.11	545.57	724.92	234.10	0.90	222.62	15%	0%	24%
5St-C12	2.02	1628.41	0.3608	0.1760	0.1426	0.0729	0.2984	417.14	1305.19	555.36	767.67	187.01	10.70	179.87	11%	2%	19%
5St-C13	2.03	1681.97	0.3977	0.1405	0.1096	0.0778	0.2204	432.75	1387.61	597.04	806.56	104.60	52.37	140.98	6%	7%	14%
5St-C14	1.62	1419.52	0.3325	0.1197	0.1613	0.1073	0.1118	369.50	1345.76	577.65	796.60	146.45	32.98	150.94	11%	6%	20%
5St-C15	3.12	5000.00	0.5387	0.1800	0.2343	0.0819	0.2535	852.52	1239.86	653.44	600.33	252.35	108.77	347.21	10%	9%	24%
5St-C16	1.97	1344.94	0.3847	0.1763	0.0967	0.1163	0.2776	352.63	1437.54	627.50	829.84	54.67	82.84	117.69	3%	11%	12%
5St-C17	2.10	1838.66	0.3759	0.1421	0.1482	0.0746	0.2083	448.89	1362.86	604.12	774.73	129.34	59.45	172.81	7%	8%	17%
5St-C18	2.17	1697.38	0.4079	0.1719	0.0956	0.1065	0.2771	428.58	1418.54	631.46	802.56	73.66	86.79	144.97	4%	10%	13%
5St-C19	2.25	2098.99	0.3971	0.1575	0.1196	0.1116	0.2236	501.22	1405.99	629.54	790.68	86.21	84.87	156.86	4%	10%	14%
5St-C20	2.25	2015.47	0.4128	0.1660	0.0981	0.1175	0.2496	497.16	1435.65	633.58	820.82	56.55	88.91	126.72	3%	10%	11%
5St-C21	2.11	1446.09	0.4258	0.1980	0.1183	0.1837	0.2525	381.12	1528.74	677.13	883.98	36.53	132.47	63.56	2%	15%	6%
5St-C22	2.12	1531.32	0.4170	0.1917	0.1070	0.1916	0.2343	391.72	1494.33	669.53	849.65	2.12	124.87	97.89	0%	15%	9%
5St-C23	2.11	1322.87	0.4316	0.1994	0.0845	0.1285	0.3296	346.94	1445.80	652.06	818.55	46.41	107.39	128.99	2%	13%	12%
5St-C24	2.16	2168.96	0.4127	0.1379	0.1783	0.1088	0.1475	496.34	1343.73	643.54	719.04	148.48	98.87	228.50	8%	12%	23%
5St-C25	2.13	1428.11	0.4210	0.1783	0.0988	0.0970	0.3015	373.45	1400.34	638.40	791.19	91.86	93.73	156.35	5%	11%	15%
5St-C26	2.35	2636.27	0.4258	0.1584	0.1953	0.0789	0.2214	592.82	1290.30	605.45	698.01	201.91	60.78	249.53	10%	7%	23%
5St-C27	2.38	2446.31	0.4072	0.1757	0.2262	0.0562	0.2730	546.75	1234.04	586.09	657.38	258.17	41.42	290.16	13%	5%	27%
5St-C28	3.04	5000.00	0.4930	0.2332	0.2901	0.0875	0.3544	839.38	1152.79	590.46	572.71	339.42	45.80	374.83	14%	4%	27%
5St-C29	3.03	5000.00	0.4951	0.2160	0.2718	0.0712	0.3368	861.92	1186.34	600.13	598.38	305.86	55.46	349.15	12%	5%	24%
5St-C30	1.81	1418.36	0.3414	0.1407	0.1285	0.0831	0.2059	371.53	1347.92	568.71	805.99	144.29	24.04	141.55	10%	4%	16%
5St-C31	1.82	1457.35	0.3316	0.1484	0.1692	0.0940	0.1939	373.71	1321.31	561.65	780.85	170.89	16.98	166.69	12%	3%	20%
5St-C32	1.76	1304.32	0.3349	0.1376	0.1596	0.0898	0.1756	342.32	1355.63	578.06	793.88	136.57	33.40	153.66	9%	5%	19%

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	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
5St-C33	1.78	1241.97	0.3594	0.1344	0.1154	0.0666	0.2136	334.79	1380.43	580.41	823.57	111.77	35.74	123.97	7%	5%	15%
5St-C34	2.22	2165.76	0.3679	0.1794	0.2019	0.0600	0.2908	510.35	1247.95	554.29	703.34	244.26	9.62	244.20	14%	1%	24%
5St-C35	2.14	1797.66	0.3869	0.1585	0.1179	0.0516	0.2885	454.83	1342.78	576.08	781.73	149.43	31.41	165.80	8%	4%	16%
5St-C36	2.17	1969.09	0.3833	0.1574	0.1523	0.0418	0.2786	484.55	1300.55	563.42	750.18	191.66	18.75	197.36	11%	3%	19%
5St-C37	2.59	1872.32	0.4347	0.2277	0.0603	0.0914	0.4513	479.38	1420.50	589.47	849.85	71.71	44.81	97.69	3%	5%	7%
5St-C38	3.01	5000.00	0.4935	0.2073	0.2708	0.0755	0.3109	859.55	1186.36	600.69	597.67	305.84	56.02	349.87	12%	5%	25%
5St-C39	2.35	2395.11	0.4246	0.1656	0.1956	0.0579	0.2611	552.93	1273.01	591.87	693.94	219.20	47.20	253.60	11%	6%	23%
5St-C40	2.19	2241.69	0.4177	0.1236	0.1799	0.0637	0.1570	517.66	1329.93	631.94	719.88	162.28	87.27	227.66	9%	11%	22%
5St-C41	1.84	1204.07	0.3851	0.1612	0.0887	0.0513	0.3103	319.03	1389.89	586.59	823.42	102.32	41.92	124.12	7%	6%	14%
5St-C42	1.83	1173.92	0.3685	0.1499	0.0998	0.0397	0.2880	311.56	1382.68	602.11	803.45	109.52	57.44	144.09	7%	8%	17%
5St-C43	1.95	1323.73	0.3941	0.1604	0.0997	0.0619	0.2917	347.96	1405.66	606.73	819.62	86.55	62.06	127.92	5%	8%	14%
5St-C44	2.02	1440.77	0.4172	0.1939	0.1187	0.0690	0.3598	369.88	1285.51	594.69	700.29	206.70	50.02	247.25	13%	7%	28%
5St-C45	2.04	1739.30	0.3985	0.1960	0.1701	0.0829	0.3249	438.67	1246.97	550.10	709.65	245.23	5.43	237.89	15%	1%	26%
5St-C46	2.03	1663.23	0.3806	0.1578	0.1253	0.0474	0.2873	429.30	1328.37	559.23	790.46	163.83	14.57	157.08	10%	2%	16%
5St-C47	1.98	1574.45	0.3714	0.1662	0.1349	0.0481	0.3031	408.58	1304.98	549.67	776.71	187.23	5.00	170.83	12%	1%	19%
5St-C48	1.99	1660.16	0.3733	0.1665	0.1369	0.0548	0.2958	424.92	1305.44	546.32	779.21	186.77	1.65	168.32	12%	0%	18%
5St-C49	2.23	1730.21	0.4149	0.1816	0.0935	0.0744	0.3357	445.44	1407.18	599.71	828.79	85.03	55.04	118.75	4%	7%	10%
5St-C50	2.23	1656.33	0.4125	0.1856	0.0880	0.0723	0.3506	430.08	1402.73	601.27	823.81	89.47	56.60	123.73	5%	7%	11%
5St-C51	2.27	1639.03	0.4211	0.1900	0.0863	0.1018	0.3324	429.48	1448.21	616.21	855.70	44.00	71.54	91.84	2%	8%	8%
5St-C52	2.36	2409.43	0.4366	0.1828	0.1524	0.0560	0.3282	560.77	1278.73	592.12	697.41	213.48	47.45	250.13	11%	6%	23%
6St-C1	2.00	1372.69	0.3812	0.1670	0.0995	0.0957	0.2739	358.34	1398.07	616.25	800.13	94.14	71.58	147.41	5%	9%	15%
6St-C2	2.09	1823.79	0.3719	0.1481	0.1405	0.0946	0.2068	446.37	1376.49	614.24	778.36	115.72	69.57	169.18	6%	9%	17%
6St-C3	2.07	1355.88	0.3856	0.1825	0.0793	0.0997	0.3191	361.12	1422.74	610.47	836.72	69.46	65.80	110.82	4%	8%	11%
6St-C4	2.13	1844.84	0.3942	0.1507	0.1446	0.0542	0.2528	459.97	1330.51	593.01	756.87	161.69	48.35	190.67	9%	6%	19%
6St-C5	2.15	1941.02	0.3776	0.1581	0.1937	0.0516	0.2496	465.52	1283.65	582.68	714.71	208.56	38.01	232.83	12%	5%	24%
6St-C6	2.17	2058.30	0.3811	0.1512	0.1723	0.0563	0.2380	491.28	1316.23	588.40	744.40	175.97	43.73	203.14	10%	6%	20%
6St-C7	2.12	2111.42	0.3714	0.1628	0.2444	0.0721	0.2152	485.76	1231.93	577.30	667.36	260.28	32.64	280.18	16%	4%	30%
6St-C8	2.06	1791.80	0.3860	0.1551	0.1685	0.0862	0.2191	445.27	1320.08	597.91	741.74	172.13	53.24	205.80	10%	7%	22%
6St-C9	2.10	1907.57	0.3866	0.1589	0.2042	0.0607	0.2369	462.81	1267.34	578.09	706.36	224.87	33.42	241.18	13%	4%	26%
6St-C10	2.19	1556.96	0.4191	0.1848	0.0953	0.1187	0.2972	395.28	1409.14	641.23	790.11	83.07	96.57	157.43	4%	11%	15%

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	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
6St-C11	2.14	1338.02	0.4273	0.1974	0.1038	0.1448	0.2981	356.07	1481.44	658.65	853.38	10.76	113.98	94.16	1%	13%	9%
6St-C12	2.18	1480.93	0.4237	0.1811	0.0973	0.1051	0.3011	384.76	1421.09	637.72	809.87	71.12	93.06	137.67	4%	11%	13%
6St-C13	2.31	2205.62	0.4065	0.1543	0.1465	0.0593	0.2556	525.19	1338.02	603.72	748.83	154.19	59.05	198.71	8%	7%	18%
6St-C14	2.31	2118.84	0.3974	0.1681	0.1511	0.0738	0.2734	503.33	1332.71	605.30	739.90	159.50	60.63	207.63	8%	7%	19%
6St-C15	2.21	1614.27	0.4108	0.1791	0.0874	0.1077	0.2983	418.94	1440.04	626.67	833.06	52.17	82.00	114.48	3%	10%	10%
6St-C16	2.37	2666.76	0.4196	0.1645	0.2117	0.0692	0.2387	593.04	1263.57	595.99	679.58	228.63	51.32	267.96	12%	6%	24%
6St-C17	3.02	5000.00	0.4944	0.2153	0.2720	0.0793	0.3266	857.64	1189.03	602.67	598.26	303.17	58.00	349.28	12%	5%	25%
6St-C18	1.83	1474.12	0.3387	0.1438	0.1491	0.0829	0.2036	381.60	1328.06	563.21	789.44	164.15	18.55	158.10	11%	3%	18%
6St-C19	1.80	1283.48	0.3539	0.1366	0.1313	0.0643	0.2134	343.03	1361.38	575.00	807.84	130.82	30.33	139.70	9%	5%	17%
6St-C20	2.20	1974.37	0.3820	0.1785	0.1594	0.0577	0.3121	484.55	1284.78	559.66	737.58	207.43	14.99	209.96	12%	2%	20%
6St-C21	2.21	2167.69	0.4110	0.1953	0.1929	0.0770	0.3179	512.55	1230.95	570.86	672.41	261.25	26.19	275.13	15%	3%	28%
6St-C22	2.07	1371.61	0.3963	0.1703	0.0849	0.0831	0.3025	368.33	1439.62	608.69	859.64	52.58	64.02	87.90	3%	8%	8%
6St-C23	2.04	1413.05	0.3879	0.1611	0.0867	0.0602	0.3019	375.43	1398.73	596.97	828.77	93.48	52.30	118.77	5%	7%	12%
6St-C24	2.04	1450.82	0.3911	0.1618	0.0861	0.0612	0.3029	383.80	1396.96	591.32	831.49	95.25	46.65	116.04	5%	6%	11%
6St-C25	1.89	1371.60	0.3845	0.1384	0.1069	0.0323	0.2631	365.05	1366.05	578.90	806.39	126.15	34.23	141.15	8%	5%	16%
6St-C26	1.92	1449.28	0.3741	0.1423	0.1259	0.0325	0.2632	381.81	1338.09	563.49	794.92	154.11	18.82	152.61	10%	3%	17%
6St-C27	1.86	1315.51	0.3703	0.1350	0.0998	0.0430	0.2470	352.31	1377.74	575.65	824.84	114.46	30.98	122.69	7%	5%	14%
6St-C28	1.85	1307.90	0.3697	0.1408	0.1007	0.0549	0.2490	349.34	1383.78	572.27	833.46	108.43	27.60	114.08	7%	4%	13%
6St-C29	2.00	1762.19	0.3513	0.1600	0.1791	0.0463	0.2672	435.60	1272.51	541.25	746.00	219.70	3.42	201.54	14%	1%	22%
6St-C30	2.02	1764.87	0.3525	0.1738	0.1901	0.0577	0.2849	437.86	1251.23	537.64	728.69	240.98	7.02	218.85	15%	1%	24%
6St-C31	2.08	1858.78	0.3569	0.1677	0.1898	0.0490	0.2785	456.94	1259.46	542.60	731.54	232.75	2.06	216.00	14%	0%	23%
6St-C32	2.02	1748.88	0.3815	0.1829	0.1834	0.0755	0.2928	435.95	1246.95	551.79	706.36	245.25	7.13	241.18	16%	1%	27%
7St-C1	2.17	1981.54	0.3750	0.1679	0.1940	0.0702	0.2552	472.02	1283.59	586.32	710.76	208.62	41.65	236.77	12%	5%	24%
7St-C2	2.11	1811.90	0.3871	0.1538	0.1391	0.0770	0.2400	451.76	1352.70	604.66	766.77	139.51	59.99	180.77	8%	8%	18%
7St-C3	2.10	1486.07	0.3798	0.1791	0.1040	0.0874	0.3108	386.17	1383.49	600.89	802.97	108.71	56.22	144.57	6%	7%	14%
7St-C4	2.18	1930.62	0.3849	0.1714	0.1857	0.0484	0.2904	469.27	1272.26	573.85	714.07	219.95	29.18	233.46	12%	4%	23%
7St-C5	2.08	1857.51	0.3815	0.1596	0.1874	0.0828	0.2244	454.56	1296.68	591.11	723.39	195.52	46.44	224.14	12%	6%	24%
7St-C6	2.16	1472.92	0.4240	0.1842	0.0939	0.1339	0.2808	383.49	1454.64	653.69	828.26	37.57	109.02	119.27	2%	13%	11%
7St-C7	2.29	2139.92	0.4069	0.1584	0.1313	0.0815	0.2509	514.59	1367.37	616.06	766.48	124.84	71.39	181.06	6%	8%	16%
7St-C8	1.94	1441.39	0.3591	0.1464	0.1248	0.0523	0.2538	377.58	1351.06	571.73	797.48	141.14	27.06	150.06	9%	4%	16%

	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average (RR2)	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
7St-C10	2.17	1975.28	0.3983	0.1760	0.1835	0.0598	0.2916	475.55	1260.65	579.77	692.83	231.56	35.10	254.71	13%	5%	26%
7St-C11	2.11	1842.71	0.3974	0.1486	0.1480	0.0517	0.2482	458.75	1318.02	593.29	741.56	174.19	48.63	205.97	10%	6%	21%
7St-C12	2.12	1925.84	0.3902	0.1491	0.1620	0.0540	0.2403	474.28	1312.40	586.11	744.78	179.81	41.44	202.75	10%	5%	20%
7St-C13	2.10	1878.29	0.3867	0.1491	0.1621	0.0525	0.2418	464.43	1312.16	586.31	744.79	180.04	41.64	202.75	10%	6%	21%
7St-C14	2.07	1740.42	0.3870	0.1516	0.1465	0.0537	0.2547	438.33	1328.45	584.38	763.28	163.75	39.71	184.26	10%	5%	19%
7St-C15	2.02	1337.39	0.3760	0.1780	0.0841	0.0842	0.3212	355.55	1402.69	597.14	828.83	89.51	52.47	118.71	5%	7%	12%
7St-C16	2.11	1417.41	0.3825	0.1845	0.0876	0.0853	0.3347	374.42	1391.99	599.38	815.71	100.22	54.71	131.83	5%	7%	13%
7St-C17	2.07	1377.60	0.3987	0.1690	0.0913	0.0476	0.3325	364.61	1368.20	601.04	785.59	124.01	56.37	161.94	7%	7%	16%
7St-C18	2.07	1729.90	0.3820	0.1499	0.1363	0.0733	0.2352	436.23	1357.40	601.74	774.79	134.81	57.07	172.75	8%	7%	17%
8St-C1	2.07	1744.73	0.3870	0.1455	0.1339	0.0702	0.2286	439.05	1356.14	605.78	768.29	136.07	61.12	179.25	8%	8%	18%
8St-C2	2.07	1732.27	0.3821	0.1499	0.1363	0.0736	0.2349	436.73	1357.78	601.97	774.95	134.42	57.30	172.59	8%	7%	17%
8St-C3	2.03	1657.31	0.3787	0.1473	0.1270	0.0807	0.2259	420.87	1372.64	603.11	788.87	119.57	58.44	158.66	7%	8%	16%
8St-C4	2.08	1794.92	0.3771	0.1521	0.1661	0.0554	0.2444	444.08	1312.62	581.70	747.47	179.59	37.03	200.07	10%	5%	21%
8St-C5	2.14	1929.76	0.3779	0.1636	0.1924	0.0478	0.2680	468.31	1271.28	572.55	714.58	220.92	27.88	232.96	13%	4%	24%
8St-C6	2.15	1955.33	0.3800	0.1644	0.1928	0.0474	0.2703	473.51	1269.89	571.59	713.78	222.32	26.92	233.75	13%	4%	24%
8St-C7	2.13	1923.86	0.3874	0.1518	0.1752	0.0491	0.2456	468.57	1291.64	586.50	719.53	200.57	41.83	228.01	12%	5%	23%
8St-C8	2.13	1882.37	0.3780	0.1644	0.1740	0.0672	0.2594	461.21	1302.94	585.26	733.99	189.27	40.59	213.55	11%	5%	22%
8St-C9	2.17	2038.21	0.3723	0.1746	0.2172	0.0607	0.2704	479.90	1244.22	573.80	682.06	247.98	29.13	265.48	14%	4%	28%
8St-C10	2.16	1989.95	0.3692	0.1746	0.2104	0.0651	0.2691	472.37	1257.56	573.82	696.61	234.64	29.16	250.93	14%	4%	26%
8St-C11	2.08	1813.44	0.3668	0.1616	0.1809	0.0714	0.2445	441.74	1303.84	583.79	734.10	188.37	39.12	213.44	11%	5%	22%
8St-C12	1.90	1214.01	0.3819	0.1573	0.0909	0.1096	0.2395	327.06	1424.38	619.65	828.34	67.83	74.99	119.19	4%	10%	13%
8St-C13	1.92	1281.86	0.3766	0.1535	0.0995	0.1023	0.2330	342.26	1408.67	612.72	819.86	83.54	68.05	127.68	5%	9%	14%
9St-C1	2.13	1917.39	0.3827	0.1622	0.1750	0.0630	0.2575	467.21	1294.77	587.03	722.75	197.44	42.36	224.79	11%	6%	23%
9St-C2	2.13	1884.78	0.3781	0.1643	0.1738	0.0674	0.2591	461.69	1303.34	585.49	734.17	188.86	40.82	213.37	11%	5%	22%
9St-C3	2.03	1457.47	0.3748	0.1654	0.1159	0.0765	0.2815	378.80	1366.48	593.13	792.53	125.73	48.47	155.00	7%	6%	16%
9St-C4	2.11	1846.57	0.3871	0.1587	0.1550	0.0695	0.2521	457.14	1319.71	594.19	742.14	172.50	49.53	205.40	10%	6%	21%
9St-C5	2.03	1671.72	0.3837	0.1422	0.1268	0.0746	0.2192	423.66	1371.36	607.18	782.31	120.85	62.51	165.23	7%	8%	17%
9St-C6	2.03	1659.66	0.3788	0.1635	0.1215	0.0600	0.2908	421.37	1373.02	603.34	789.03	119.18	58.67	158.51	7%	8%	16%
9St-C9	2.13	1917.39	0.3827	0.1622	0.1750	0.0630	0.2575	467.21	1294.77	587.03	722.75	197.44	42.36	224.79	11%	6%	23%
9St-C10	2.13	1884.81	0.3781	0.1644	0.1739	0.0674	0.2591	461.70	1303.33	585.48	734.16	188.88	40.82	213.38	11%	5%	22%

Table E - 1: page 10

	c	SC	Optimized MRAE	MRAE Flow Duration (RR2)	MRAE Highflow (< 20%) (RR2)	MRAE Intermediate flow (20% - 60%) (RR2)	MRAE Lowflow (> 60%) (RR2)	Initial Soil Moisture (RR2)	Annual Average Streamflow (RR2)	Maha Average Streamflow (RR2)	Yala Average Streamflow (RR2)	Absolute Water Balance Error Annual average	Absolute Water Balance Error Maha average (RR2)	Absolute Water Balance Error Yala average (RR2)	% Water Balance Error Annual (RR2)	% Water Balance Error Maha (RR2)	% Water Balance Error Yala (RR2)
9St-C11	2.07	1777.67	0.3749	0.1511	0.1663	0.0548	0.2423	440.28	1313.02	582.51	747.40	179.18	37.85	200.14	11%	5%	21%
9St-C12	2.14	1932.61	0.3779	0.1635	0.1923	0.0480	0.2678	468.86	1271.53	572.73	714.65	220.67	28.06	232.89	13%	4%	24%
9St-C13	2.08	1795.36	0.3772	0.1522	0.1659	0.0555	0.2446	444.20	1313.00	581.86	747.71	179.21	37.19	199.83	10%	5%	21%
9St-C14	2.11	1919.91	0.3843	0.1550	0.1822	0.0470	0.2523	465.54	1281.21	579.98	714.97	211.00	35.31	232.57	12%	5%	24%
9St-C15	2.13	1924.26	0.3875	0.1514	0.1746	0.0492	0.2448	468.72	1292.74	586.95	720.21	199.46	42.28	227.33	11%	6%	23%
9St-C16	2.12	1918.84	0.3864	0.1524	0.1762	0.0492	0.2464	467.39	1290.22	586.01	718.72	201.98	41.34	228.82	12%	5%	24%
10St-C1	2.11	1901.79	0.3798	0.1655	0.1799	0.0642	0.2622	462.25	1288.08	581.67	720.87	204.13	37.00	226.66	12%	5%	23%
10St-C2	2.13	1917.83	0.3827	0.1618	0.1745	0.0632	0.2568	467.36	1295.88	587.49	723.43	196.33	42.82	224.11	11%	6%	23%
10St-C3	2.03	1455.99	0.3749	0.1657	0.1153	0.0767	0.2823	378.52	1366.90	593.23	792.89	125.31	48.56	154.65	7%	6%	16%
10St-C5	2.12	1919.24	0.3865	0.1520	0.1757	0.0493	0.2457	467.53	1291.33	586.46	719.40	200.88	41.80	228.14	12%	5%	23%
10St-C6	2.11	1920.33	0.3844	0.1546	0.1817	0.0469	0.2516	465.69	1282.31	580.44	715.65	209.90	35.77	231.89	12%	5%	24%
10St-C7	2.07	1780.15	0.3750	0.1510	0.1662	0.0549	0.2421	440.78	1313.38	582.73	747.54	178.82	38.06	199.99	10%	5%	21%
10St-C8	2.11	1914.80	0.3834	0.1557	0.1833	0.0473	0.2532	464.34	1279.79	579.49	714.17	212.41	34.82	233.37	12%	5%	24%
10St-C9	2.06	1762.53	0.3923	0.1429	0.1429	0.0494	0.2387	441.83	1330.73	594.23	753.68	161.48	49.56	193.85	9%	7%	20%
10St-C10	2.11	1827.14	0.3744	0.1688	0.1982	0.0453	0.2809	442.72	1258.03	570.38	699.39	234.18	25.71	248.15	14%	3%	26%

Hydrographs (RR Option 2)

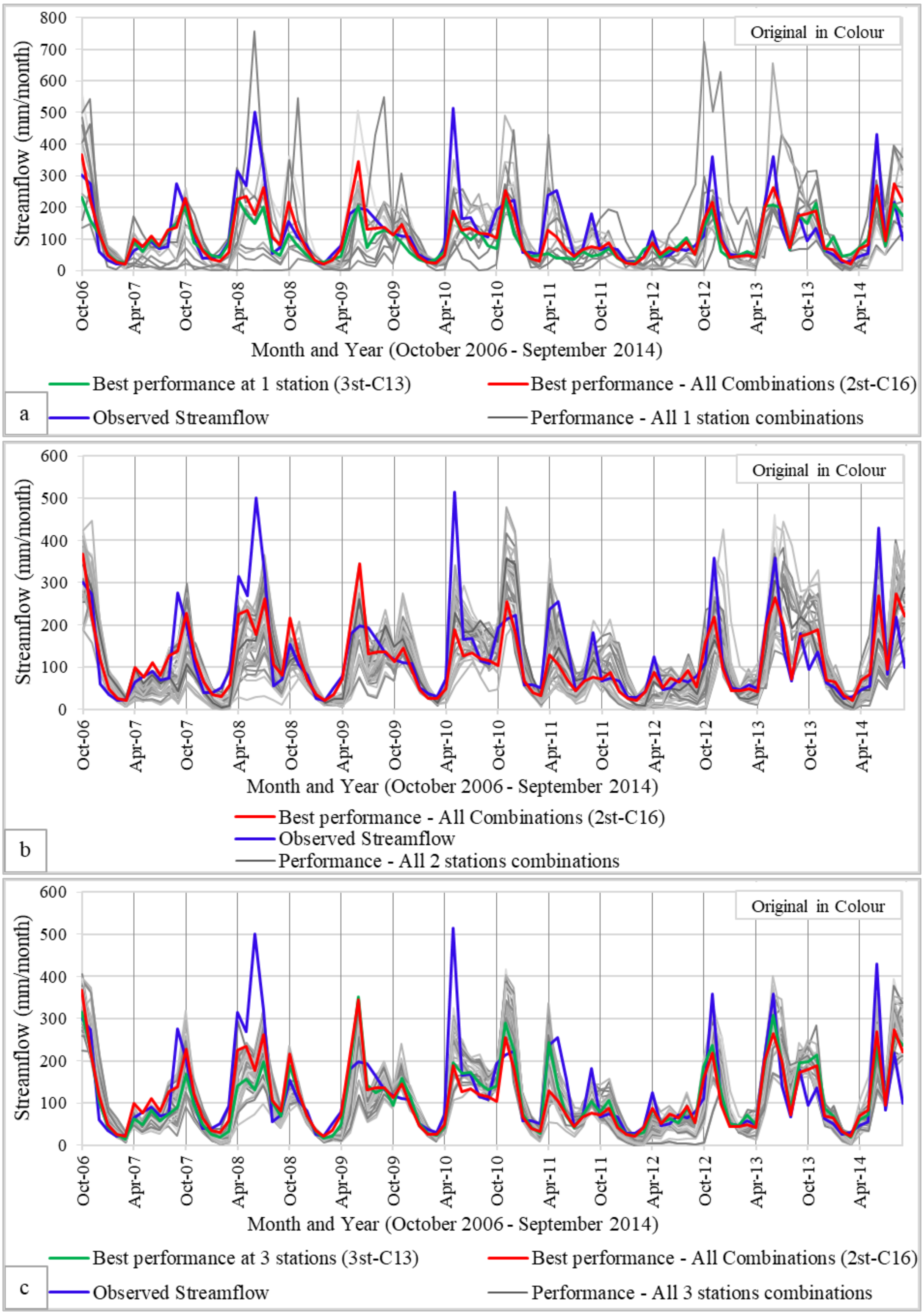

Figure E - 1: (i). All Hydrographs highlighting best performing streamflow estimations RR2 (a - 1 station combinations; b - 2 stations combinations; c - 3 stations combinations)

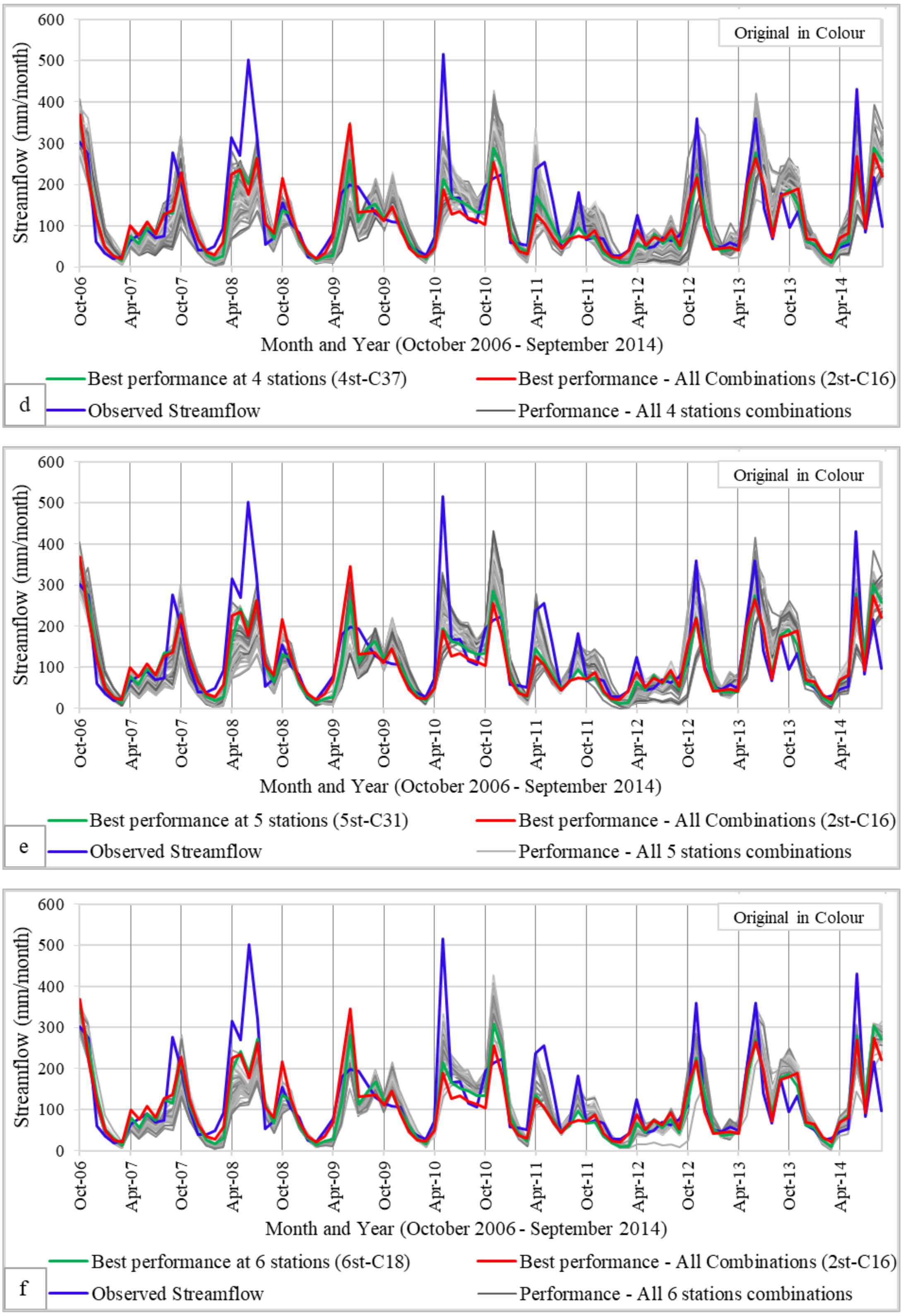

Figure E - 2: (ii). All Hydrographs highlighting best performing streamflow estimations RR2(d - 4 stations combinations; e - 5 stations combinations; f - 6 stations combinations)

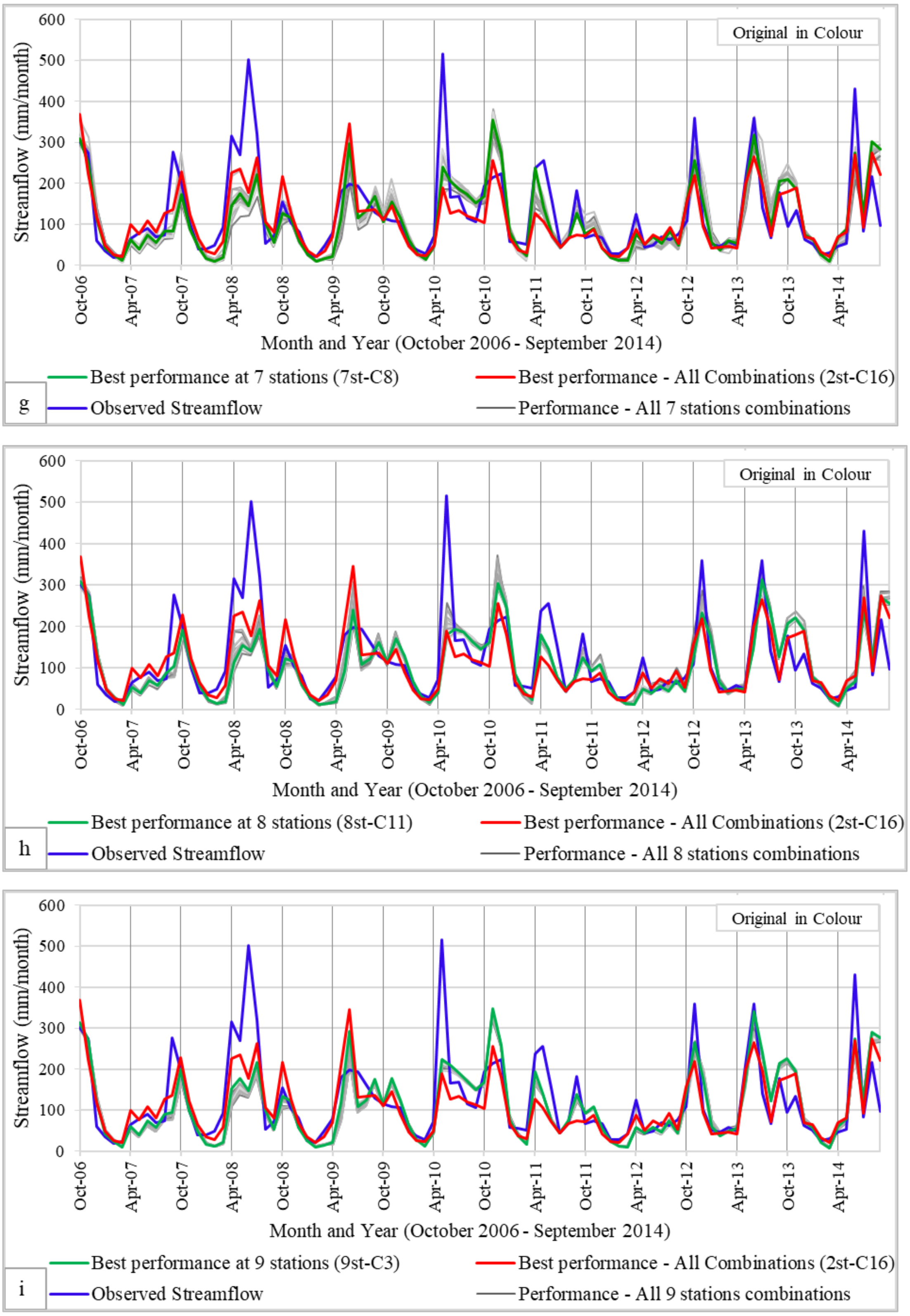

Figure E - 3: (iii). All Hydrographs highlighting best performing streamflow estimations RR2 (g - 7 stations combinations; h - 8 stations combinations; i - 9 stations combinations)

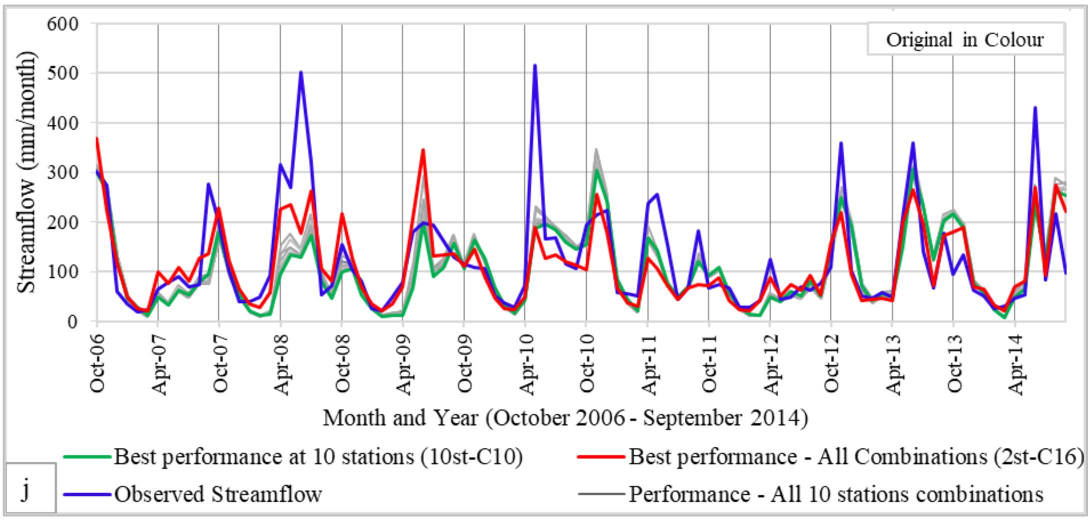

Figure E - 4: (iv). All Hydrographs highlighting best performing streamflow estimations RR2 (j - 10 stations combinations)

Flow Duration Curves (RR Option 2)

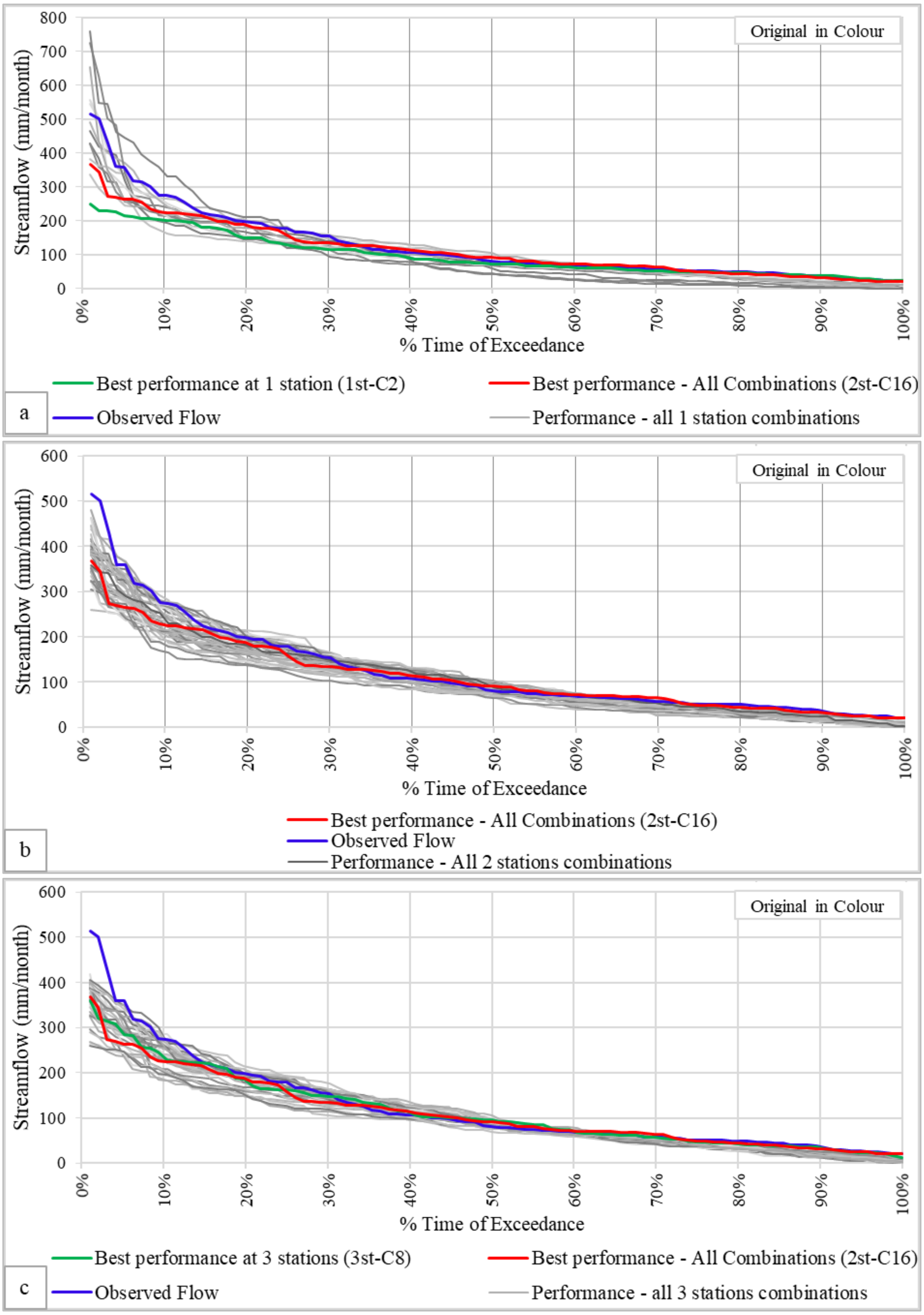

Figure E - 5: (i). Flow Duration curves highlighting best performing streamflow estimations RR2 (a - 1 station combinations; b - 2 stations combinations; c - 3 stations combinations)

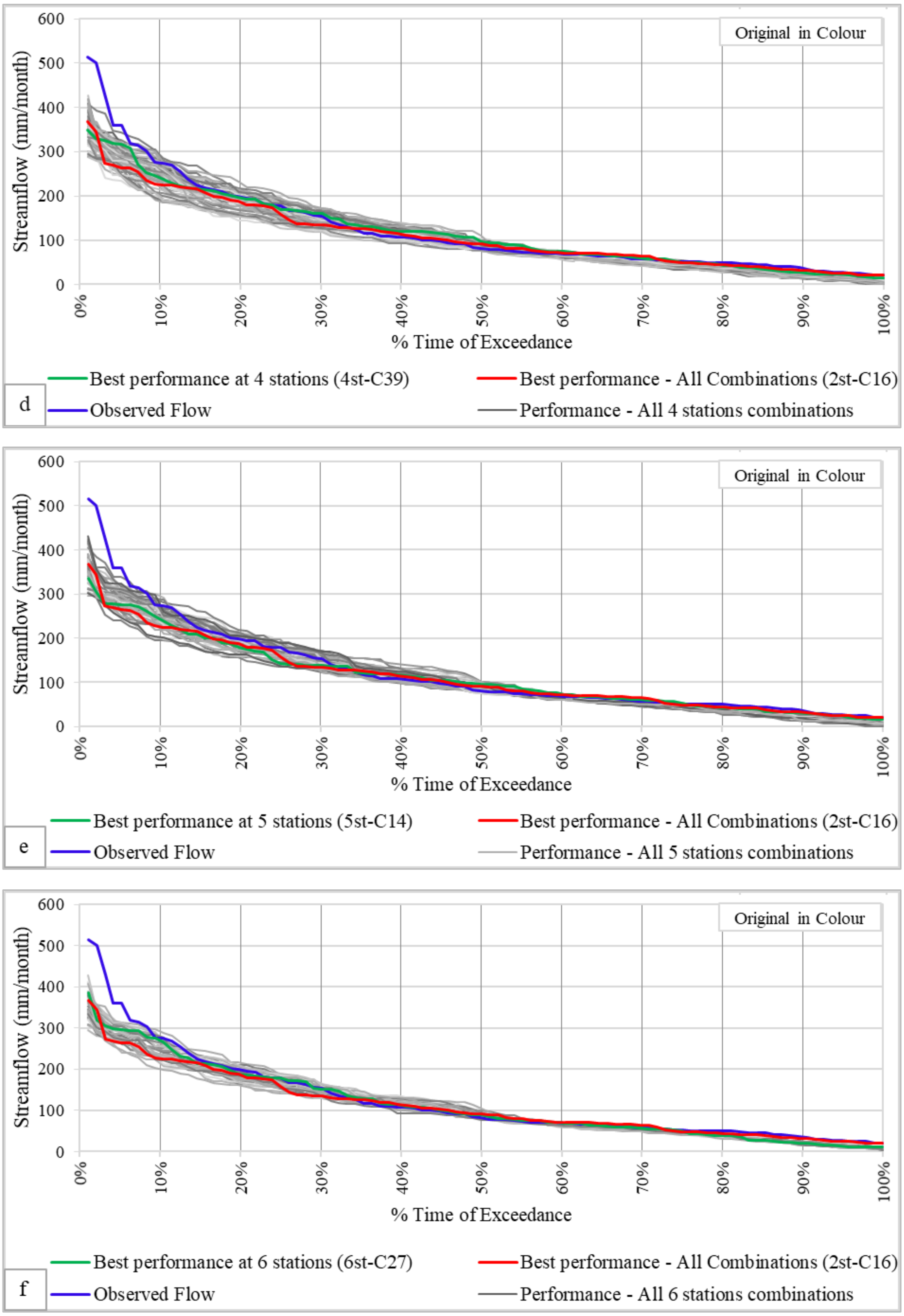

Figure E - 6: (ii). Flow Duration curves highlighting best performing streamflow estimations RR2 (d - 4 stations combinations; e - 5 stations combinations; f - 6 stations combinations)

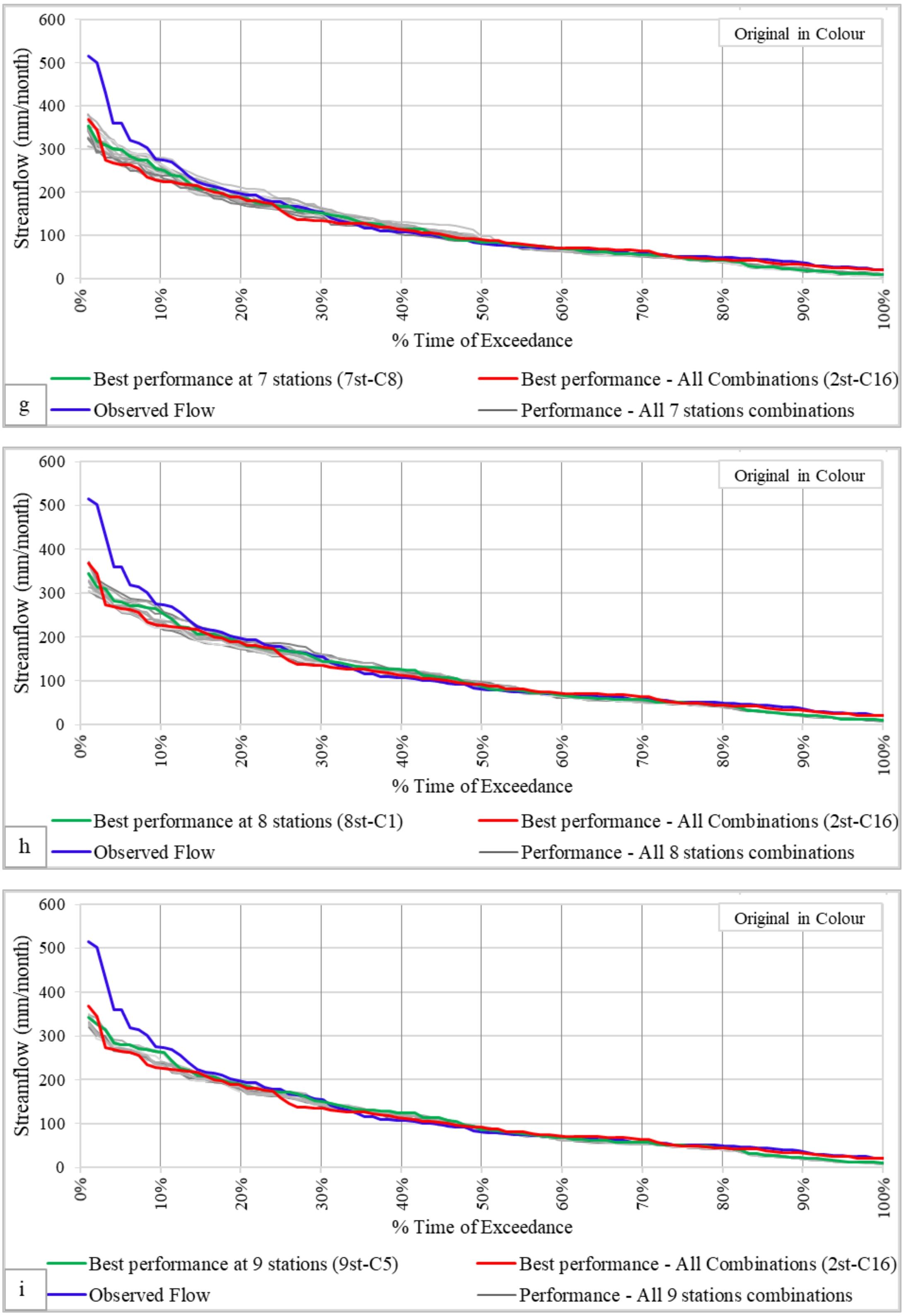

Figure E - 7: (iii). Flow Duration curves highlighting best performing streamflow estimations RR2 (g - 7 stations combinations; h - 8 stations combinations; i - 9 stations combinations)

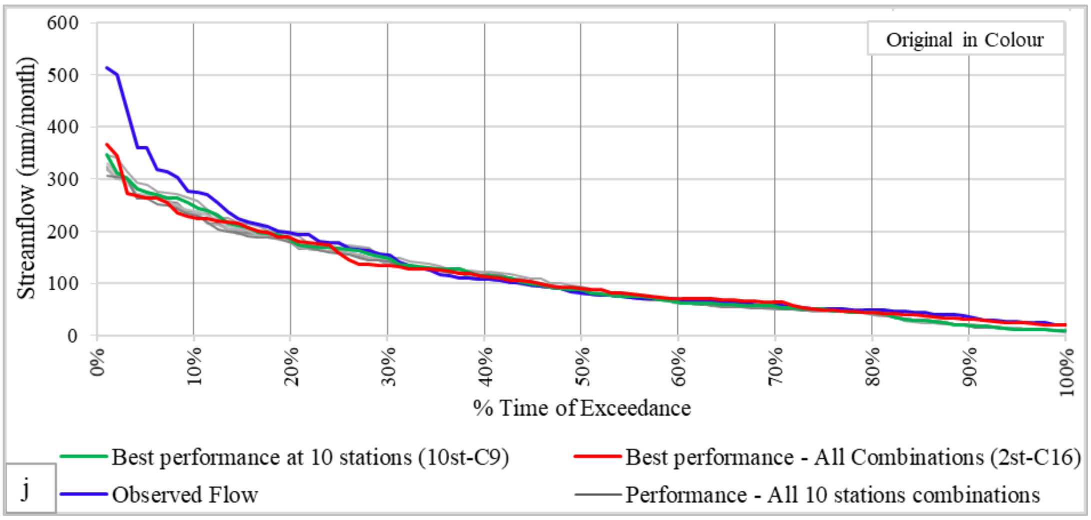

Figure E - 8: (iv). Flow Duration curves highlighting best performing streamflow estimations RR2 (j - 10 stations combinations)

ANNEX F - RESULTS SUMMARY OF STATION INFLUENCE

Table F - 1: Station influence comparison

	RR1										RR2									
	MRAE Overall	MRAE-Flow Duration	MRAE - High Flow	MRAE - Intermediate Flow	MRAE - Low flow	Annual % Absolute Water balance error	Sum of Thiessen Weights	Influencing flow considerations (Count)	Weighted Influence	% Importance	MRAE Overall	MRAE-Flow Duration	MRAE - High Flow	MRAE - Intermediate Flow	MRAE - Low flow	Annual % Absolute Water balance error	Sum of Thiessen Weights	Influencing flow considerations (Count)	Weighted Influence	% Importance
Station	**5c11**	**3c1**	**3c15**	**7c10**	**6c10**	**4c32**					**2c16**	**2c16**	**3c34**	**4c60**	**2c16**	**5c22**				
Alupola	-	0.26	-	0.10	0.25	0.25	0.86	4	3.44	19.6	-	-	-	-	-	0.25	0.25	1	0.25	1.4
Nivithigala	0.14	0.38	-	0.15	0.27	0.27	1.20	5	6.00	34.1	0.72	0.72	-	0.15	0.72	0.27	2.57	5	12.85	73.1
Pelmadulla	0.34	-	0.39	0.27	-	-	1.00	3	3.00	17.1	-	-	-	0.35	-	-	0.35	1	0.35	2.0
Rathnapura	0.24	-	0.32	0.18	0.15	0.30	1.19	5	5.97	34.0	-	-	0.69	0.47	-	0.21	1.37	3	4.11	23.4
Eheliyagoda S.P.	0.10	-	-	-	0.07	0.18	0.35	3	1.04	5.9	0.28	0.28	-	-	0.28	0.10	0.94	4	3.76	21.4
Galutara Estate	-	-	-	-	0.12	-	0.12	1	0.12	0.7	-	-	-	-	-	-	-	0	0.00	0.0
Pussalla S.P.	0.19	-	-	0.11	0.14	-	0.43	3	1.30	7.4	-	-	-	-	-	0.18	0.18	1	0.18	1.0
Kuruvita (Keragala)	-	0.37	0.28	0.11	-	-	0.76	3	2.27	12.9	-	-	0.28	-	-	-	0.28	1	0.28	1.6
Halwatura	-	-	-	0.09	-	-	0.09	1	0.09	0.5	-	-	-	-	-	-	-	0	0.00	0.0
Uskvalley	-	-	-	-	-	-	-	0	0.00	0.0	-	-	0.03	0.04	-	-	0.07	2	0.13	0.8
Hanwella	-	-	-	-	-	-	-	0	0.00	0.0	-	-	-	-	-	-	-	0	0.00	0.0
Maussakelle	-	-	-	-	-	-	-	0	0.00	0.0	-	-	-	-	-	-	-	0	0.00	0.0

Table F - 2: Station influence overall comparison

Station	RR1						RR2						Sum of Thiessen Weights	Influencing flow considerations (Count)	Weighted Influence	% Importance
	MRAE Overall	MRAE-Flow Duration	MRAE - High Flow	MRAE - Intermediate Flow	MRAE - Low flow	Annual % Absolute Water balance error	MRAE Overall	MRAE-Flow Duration	MRAE - High Flow	MRAE - Intermediate Flow	MRAE - Low flow	Annual % Absolute Water balance error				
	5c11	**3c1**	**3c15**	**7c10**	**6c10**	**4c32**	**2c16**	**2c16**	**3c34**	**4c60**	**2c16**	**5c22**				
Alupola	-	0.26	-	0.10	0.25	0.25	-	-	-	-	-	0.25	1.11	5	5.53	8.2
Nivithigala	0.14	0.38	-	0.15	0.27	0.27	0.72	0.72	-	0.15	0.72	0.27	3.77	10	37.69	55.5
Pelmadulla	0.34	-	0.39	0.27	-	-	-	-	-	0.35	-	-	1.35	4	5.39	7.9
Rathnapura	0.24	-	0.32	0.18	0.15	0.30	-	-	0.69	0.47	-	0.21	2.56	8	20.51	30.2
Eheliyagoda S.P.	0.10	-	-	-	0.07	0.18	0.28	0.28	-	-	0.28	0.10	1.29	7	9.02	13.3
Galutara Estate	-	-	-	-	0.12	-	-	-	-	-	-	-	0.12	1	0.12	0.2
Pussalla S.P.	0.19	-	-	0.11	0.14	-	-	-	-	-	-	0.18	0.61	4	2.46	3.6
Kuruvita (Keragala)	-	0.37	0.28	0.11	-	-	-	-	0.28	-	-	-	1.03	4	4.14	6.1
Halwatura	-	-	-	0.09	-	-	-	-	-	-	-	-	0.09	1	0.09	0.1
Uskvalley	-	-	-	-	-	-	-	-	0.03	0.04	-	-	0.07	2	0.13	0.2
Hanwella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maussakelle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ANNEX G - RESULTS SUMMARY OF INFLUENCE OF SPATIAL INTERPOLATION METHODS

Rainfall Variation

Table G - 1: Annual Areal Rainfall Variation

Spatial Interpolation Method	Annual Average Rainfall (mm/year)																
	5 stations							8 stations							5 & 8 Stations		
	All Inside	Maximum Outside	Upstream	Downstream	Average Rainfall	Deviation	% Deviation from Average	All Inside	Maximum Outside	Upstream	Downstream	Average Rainfall	Deviation	% Deviation from Average	Average Rainfall	Deviation	% Deviation
Thiessen	3048	4157	2996	3727	3482	1162	33	3243	3418	3267	2974	3226	445	14	3354	1184	35
IDW1	3092	4055	3188	3711	3512	962	27	3452	3581	3474	3610	3529	158	4	3520	962	27
IDW2	3058	4113	3050	3749	3493	1062	30	3353	3508	3357	3429	3412	156	5	3452	1062	31
Spline1	2947	4565	2808	3542	3465	1757	51	3171	3137	3222	2024	2888	1198	41	3177	2541	80
Spline2	3024	4507	3043	3638	3553	1483	42	3205	3321	3297	2582	3101	739	24	3327	1925	58
Kriging1	3090	4012	3292	3680	3519	922	26	3350	3534	3475	3490	3462	184	5	3490	922	26
Kriging2	3018	4667	3675	4146	3877	1649	43	3179	3712	3474	3233	3400	534	16	3638	1649	45

Table G - 2: Maha Season Average Rainfall Variation

	Maha Season Average Rainfall (mm/season)															
	5 stations							8 stations							5 & 8 Stations		
Spatial Interpolation Method	All Inside	Maximum Outside	Upstream	Downstream	Average Rainfall	Deviation	% Deviation from Average	All Inside	Maximum Outside	Upstream	Downstream	Average Rainfall	Deviation	% Deviation from Average	Average Rainfall	Deviation	% Deviation
Thiessen	1218	1785	1243	1430	1419	567	40	1309	1397	1320	1171	1299	226	17	1359	614	45
IDW1	1226	1733	1326	1467	1438	508	35	1392	1446	1398	1438	1419	54	4	1428	508	36
IDW2	1216	1769	1276	1464	1431	552	39	1361	1417	1355	1353	1372	64	5	1401	552	39
Spline1	1196	2084	1084	1344	1427	1000	70	1292	1366	1312	806	1194	560	47	1311	1278	98
Spline2	1216	2012	1221	1384	1458	796	55	1319	1402	1344	1011	1269	391	31	1364	1001	73
Kriging1	1231	1700	1366	1475	1443	469	32	1371	1428	1405	1385	1397	57	4	1420	469	33
Kriging2	1206	1971	1494	1527	1549	765	49	1309	1502	1419	1205	1359	297	22	1454	766	53

Table G - 3: Yala Season Average Rainfall Variation

	Yala Season Average Rainfall (mm/season)																	
	5 stations							8 stations							5 & 8 Stations		
Spatial Interpolation Method	All Inside	Maximum Outside	Upstream	Downstream	Average Rainfall	Deviation	% Deviation from Average	All Inside	Maximum Outside	Upstream	Downstream	Average Rainfall	Deviation	% Deviation from Average	Average Rainfall	Deviation	% Deviation
Thiessen	1831	2373	1752	2297	2063	621	30	1934	2021	1948	1802	1926	219	11	1995	621	31
IDW1	1866	2321	1862	2244	2073	459	22	2061	2135	2076	2173	2111	112	5	2092	459	22
IDW2	1842	2344	1775	2286	2062	569	28	1992	2091	2002	2076	2040	99	5	2051	569	28
Spline1	1751	2481	1724	2198	2038	757	37	1880	1771	1910	1218	1695	692	41	1866	1263	68
Spline2	1808	2495	1822	2254	2095	687	33	1886	1918	1953	1571	1832	383	21	1963	925	47
Kriging1	1859	2312	1926	2206	2076	454	22	1979	2106	2070	2105	2065	127	6	2070	454	22
Kriging2	1813	2696	2181	2619	2327	884	38	1869	2211	2055	2028	2041	342	17	2184	884	40

Streamflow Variation

Table G - 4: Streamflow (mm) variation

	279 km²/station (5 stations) density							175 km²/station (8 stations) density							All densities							
Spatial Interpolation Method	**Thiessen**	**IDW1**	**IDW2**	**Spline1**	**Spline2**	**Kriging1**	**Kriging2**	**Thiessen**	**IDW1**	**IDW2**	**Spline1**	**Spline2**	**Kriging1**	**Kriging2**	**Thiessen**	**IDW1**	**IDW2**	**Spline1**	**Spline2**	**Kriging1**	**Kriging2**	**Observed Streamflow**
Annual	1327	1364	1342	1289	1299	1371	1394	1331	1340	1351	1254	1296	1346	1366	1329	1352	1346	1271	1297	1359	1380	1492
Maha	589	629	615	590	588	632	616	577	600	594	556	576	596	584	583	614	605	573	582	614	600	545
Yala	738	735	727	699	711	739	778	754	739	757	698	720	749	782	746	737	742	698	716	744	780	948
October	166	174	169	151	156	175	169	168	171	172	147	159	171	166	167	173	170	149	158	173	167	155
November	196	207	201	181	187	208	210	191	195	194	183	186	195	191	193	201	198	182	187	202	201	172
December	125	137	133	136	133	137	139	119	128	124	112	119	126	124	122	133	129	124	126	132	132	93
January	55	59	60	63	60	59	54	52	57	55	54	56	55	55	54	58	57	58	58	57	55	42
February	27	30	31	33	30	30	25	26	29	27	30	30	27	27	27	29	29	31	30	29	26	36
March	21	21	23	26	22	22	18	21	20	20	31	26	21	20	21	21	22	28	24	21	19	47
April	72	66	69	75	71	66	62	76	68	73	87	79	73	73	74	67	71	81	75	70	68	123
May	111	108	108	106	106	110	109	118	111	116	120	115	117	117	114	110	112	113	111	114	113	201
June	170	168	165	158	162	169	182	169	164	169	138	152	166	175	169	166	167	148	157	168	179	244
July	122	127	122	117	120	127	136	127	129	130	115	122	129	137	125	128	126	116	121	128	136	136
August	126	127	125	119	122	127	138	128	129	130	113	121	127	137	127	128	128	116	122	127	138	103
September	137	139	137	125	130	140	150	136	138	139	125	130	137	143	137	139	138	125	130	138	147	140
Monthly	111	114	112	107	108	114	116	111	112	113	104	108	112	114	111	113	112	106	108	113	115	122