Guyana Drainage and Irrigation Systems Rehabilitation Project

HYDROLOGY AND WATER RESOURCES INTERIM REVIEW

October 2003

1 Introduction

This report presents an assessment of hydrometeorological data of relevance to the Drainage and Irrigation Systems Rehabilitation Project. A review of the usefulness of the available hydrometeorological data is required under the terms of reference for the project. This report addresses that requirement, but also presents the results of the hydrometeorological investigations carried out in support of the project.

The terms of reference for the hydrological and water resource investigations are generally clear, and have been commented on in the Inception Report for the study. This report specifically addresses the review of the hydrometric network and the available hydrological records, and presents and analysis of baseline hydrological conditions. Chapter 2 presents the review of the hydrometric network, and of data availability. In Chapter 3 a very brief review of previous investigations is presented, from which basic information relative to design have been extracted. In Chapter 4 a review of hydroclimatic conditions in the project area is presented, addressing many of the requirements of the terms of reference. The available hydrometeorlogical data have been analysed in to the depth that data availability and quality permit, and fundamental design characteristics have been derived.

This report does not present any analysis of water resources, although does give an indication of possible problems, and of the intended approach to water resources evaluation.

2 The Hydrometric Network

2.1 General

The collection, routine processing and storage of hydrometric data in Guyana is the responsibility of the Hydrometeorological Department of the Ministry of Agriculture. The Department maintains a CLICOM database for precipitation and meteorological data. HYDATA is used for streamflow data. The Hydromet Department is poorly staffed, and currently over 60% of staff posts are vacant. As a result, they have great difficulty in maintaining their databases, and committing historical data to them. It is understood that archive records are not as well maintained as staff would like because of staff shortages, and there is a danger that valuable information may be lost. Much chart data remains unprocessed because of the staffing problems.

Despite the difficulties noted above, Hydromet staff have been extremely helpful in retrieving data for the project, and in putting additional data into digital form.

2.2 Synoptic Data

The locations of meteorological stations that collect data of relevance to potential evapotranspiration calculation for the project area are shown in Figure 2.1. The stations of relevance are Timehri Airport, Georgetown Botanical Gardens, New Amsterdam, and Skeldon. Difficulty has been experienced in retrieving synoptic data, partly because some chart information has not been processed. The parameter that has caused most difficulty at all stations is wind speed, but it is generally the case that much less meteorological data have been entered to the CLICOM database than has rainfall data. Sufficient data have been available, however, to permit reliable estimates to be made of potential evapotranspiration for the computation of crop water requirements, and potential open water evaporation for evaluation of conservancy water resources. Data at Timehri Airport have been available since 1992. At Georgetown, reasonably complete data have been available since 1962 (with the exception of wind). The parameters generally recorded are maximum and minimum temperatures, vapour pressure, relative humidity, sunshine hours and wind speed. Solar radiation data are apparently collected at Timehri and at Georgetown, but charts have not been processed.

It is considered important that the Hydromet Department be given assistance to bring their electronic databases completely up to date, and to get all archived data into the system also. The importance of good quality hydrometric data increases as pressure on water resource systems increases and as the impacts of climatic change become more apparent. Serious consideration should also be given to updating the synoptic stations with modern equipment that will log and process data automatically, making data entry to the CLICOM system much less labour intensive. With modern equipment data can be downloaded to hand held or laptop computers on a monthly basis. The existing network of synoptic stations is considered to be adequate.

2.3 The Raingauge Network

The locations of raingauges, and of those stations included in the CLICOM database are shown in Figure 2.1 An extensive network exists, and would for most purposes be considered to be quite adequate. Difficulties do arise with data availability, however. With a few exceptions, the CLICOM database is only populated with data since 1974. The availability of daily rainfall data for stations in Regions 3, 4, 5, and 6 is shown in Figures 2.2 and 2.3.

The data in Figure 2.2 only indicate missing data if half of the daily records in a month are missing. In Figure 2.3, any missing data in a month results in the whole month being shown as missing. Clearly there are significant problems with eth continuity of rainfall records. There are significant gaps in much of the data, particularly in the 1980's and early 1990's. While for the present study it will be possible to work the data available, it would clearly be preferable to have longer term records, particularly for frequency analysis, and efforts should be made to provide Hydromet with the resources to transfer all historic rainfall data into the CLICOM databse. The database generally begine in 1974, but the reality is that many of the records prior to 1974 will be more complete than those after 1980. The successful management of water resources is dependent on good quality hydrometric data, and creating and maintaining that data should be a national priority.

There is significant variability in rainfall over the project area. Isohyets of mean annual rainfall for the 1974 – 2002 period are shown in Figure 2.4. These isohyets were prepared from incomplete data, and are intended to provide an impression of annual rainfall characteristics only. Region 3 clearly experiences significantly higher annual rainfall than Region 6, and it is only at this level that Figure 2.4 may be used..

Data quality has been checked at a sample of stations through cross correlation and double mass curve analysis. Figure 2.5 presents cross correlations on annual rainfall for a group of stations around Georgetown and spanning Regions 3 and 4. The cross correlations are generally consistent, with the exception of those with the Enmore Front raingauge.

The Enmore Front gauge is poorly correlated with its neighbours. A double mass curve analysis was carried out between Georgtown and Enmore Front. Figure 2.6 shows the results of the analysis. There are two occasions when a change in the relationship between the data occurs, both of which occur after a period of missing record at Enmore Front. It is likely that the gauge has been moved, or that some change in exposure took place. The Enmore Front record will not be used in analysis.

Data quality has also been checked for three stations in Regions 6. The cross correlations are shown in Figure 2.7. New Amsterdam, Skeldon Front and Crabwood Creek have been cross correlated. There is a good relationship between New Amsterdam and Skeldon Front, but Crabwood Creek is poorly correlated with Skeldon Front which is very close by, and has no correlation at all with New Amsterdam. Double mass curve analysis of the Crabwood Creek gauge against New Amsterdam and Skeldon Front is shown in Figure 2.8. There are problems of concurrent data availability at these stations, but clearly from Figure 2.8, there have been a number of changes in the relationship between the data at these stations.

In carrying out hydroclimatic studies for design, cross correlation will be used as the primary means of identifying suspect data in groups of stations around the areas to be rehabilitated.

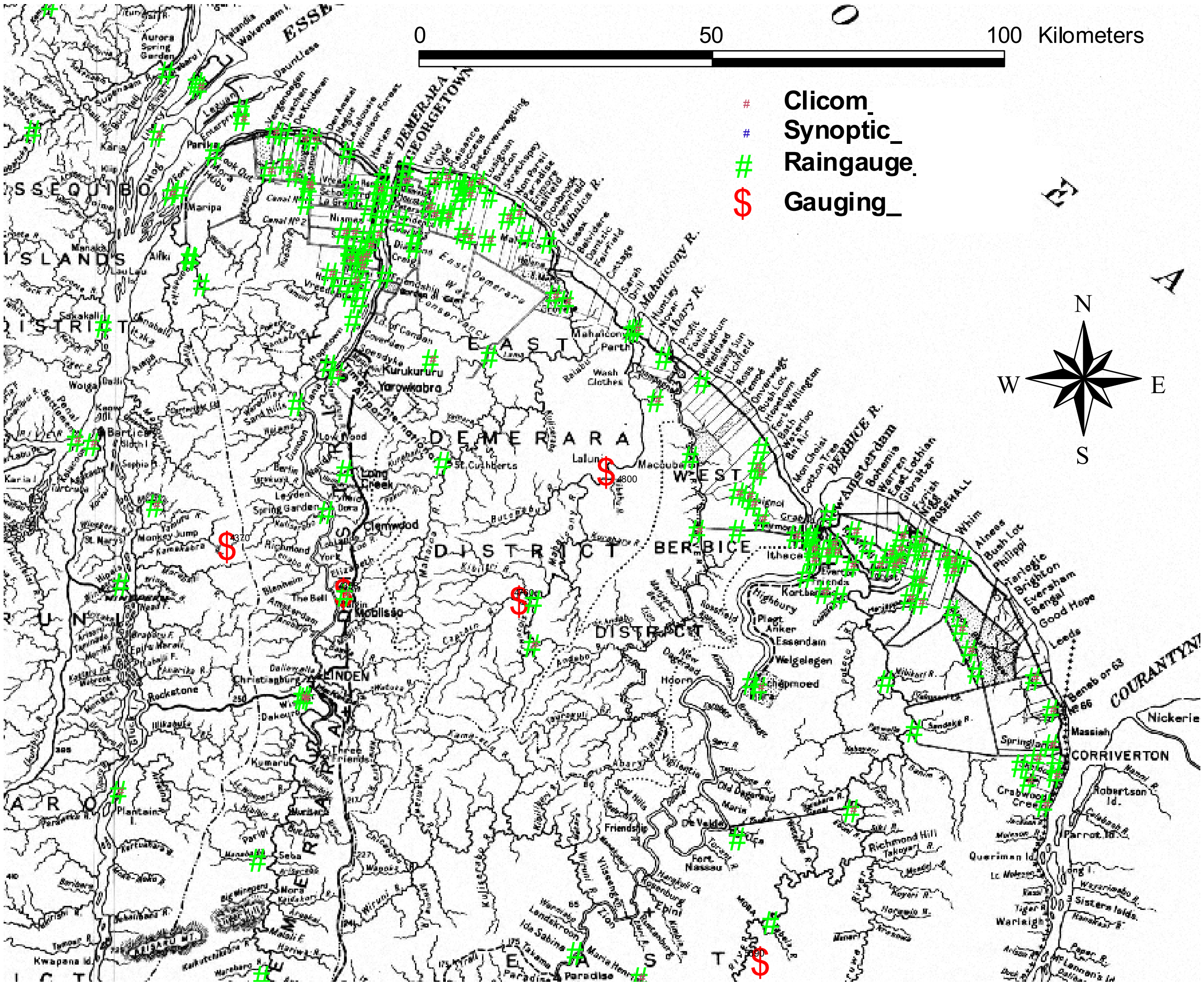

Figure 2.1 The hydrometric network

Figure 2.2 Availability of rainfall data (up to 50% of month missing not flagged)

Figure 2.3 Availability of rainfall data (all missing values flagged)

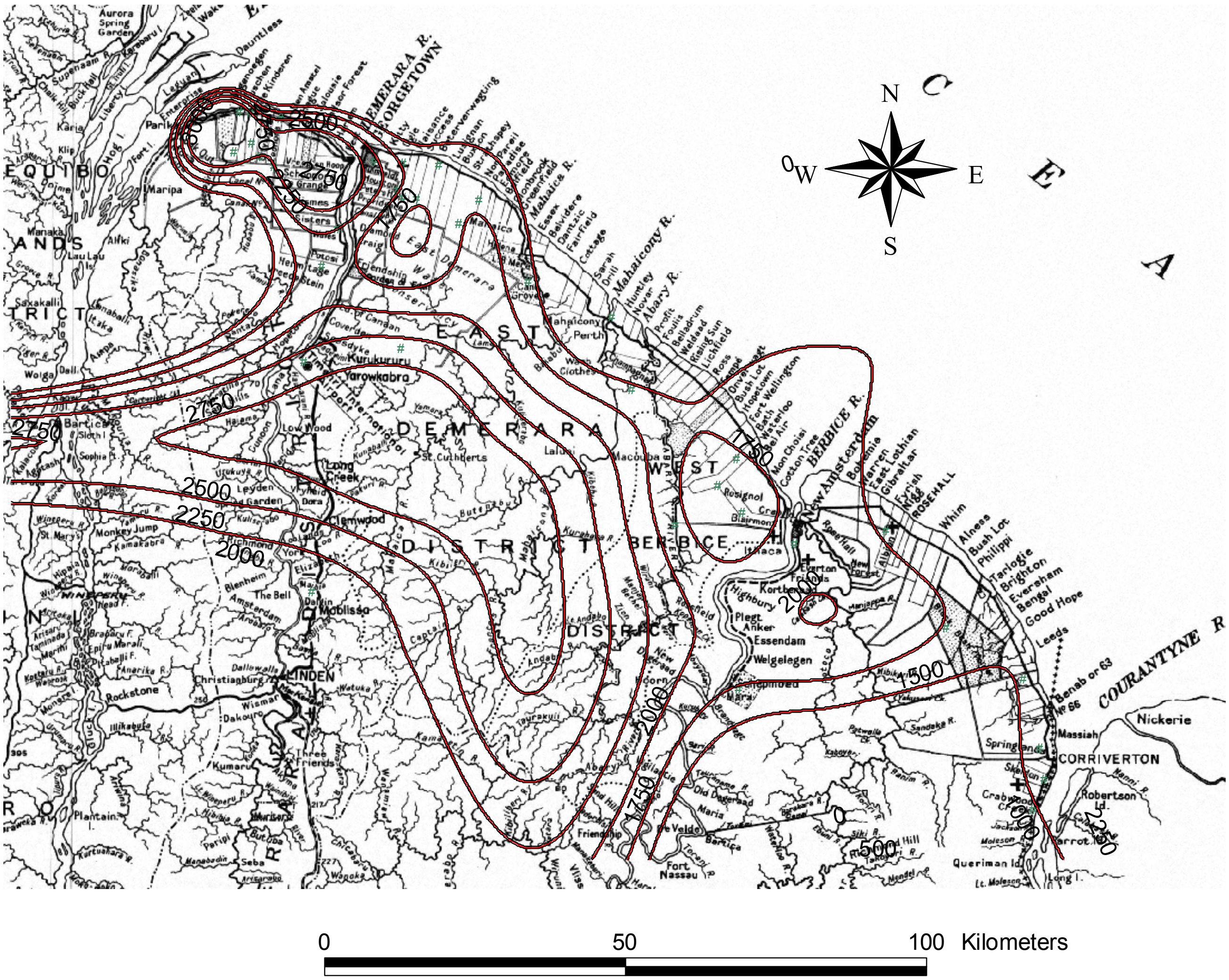

Figure 2.4 Mean annual rainfall in Regions 3 – 6
(N.B. contouring significantly constrained by missing records in electronic data – map is indicative only)

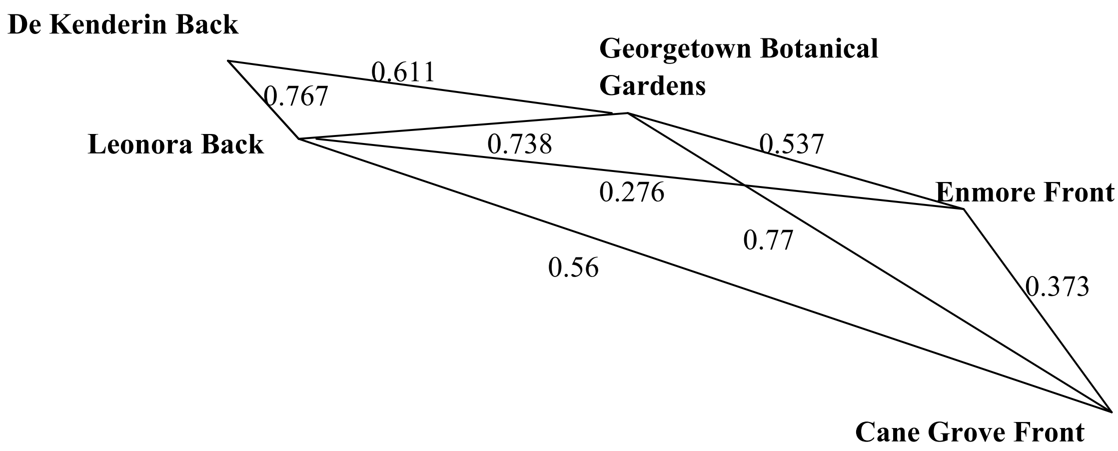

Figure 2.5 Cross correlations on annual rainfall in Regions 3 and 4

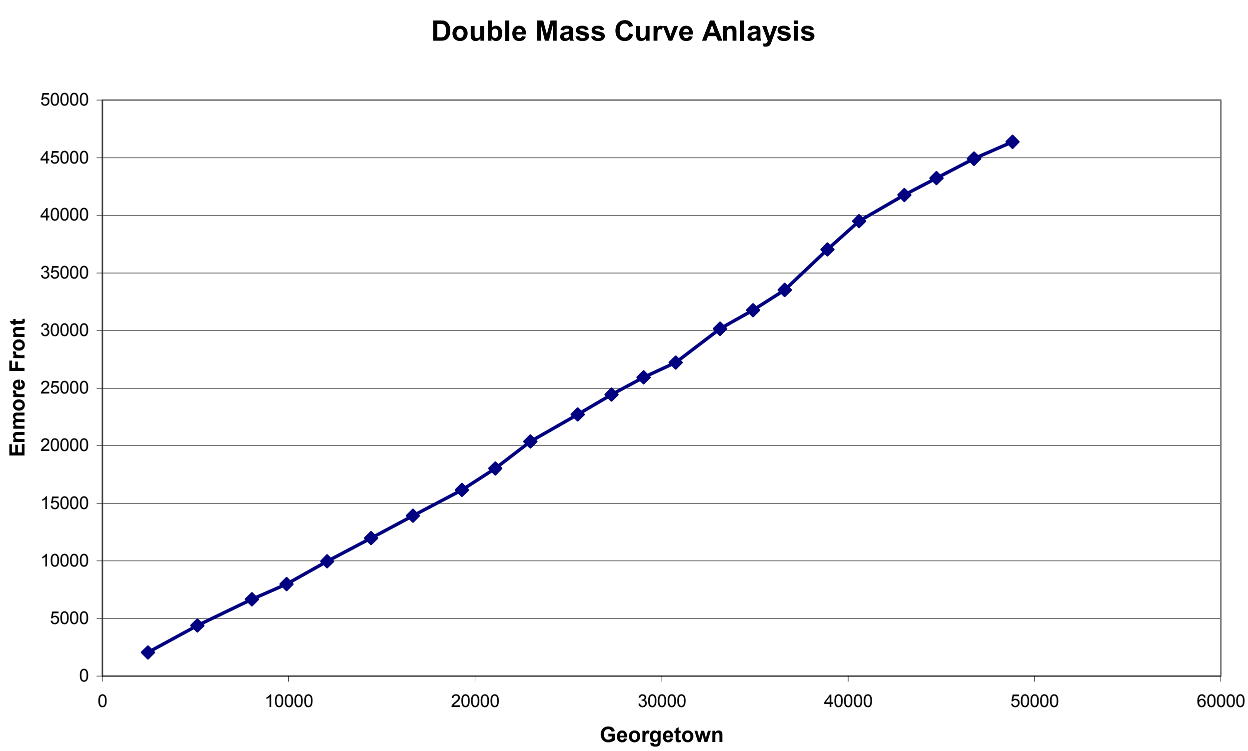

Figure 2.6 Double mass curve analysis: Georgetown and Enmore Front

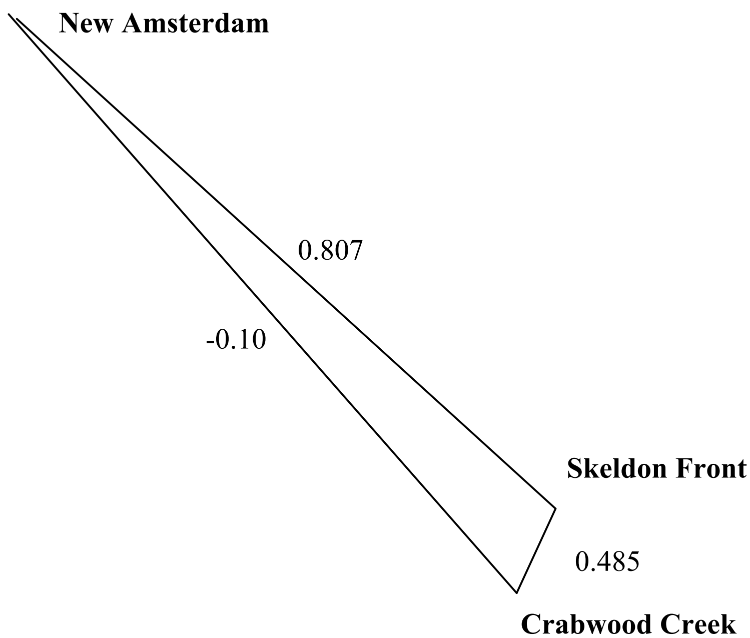

Figure 2.7 Cross correlations on annual rainfall in Region 6.

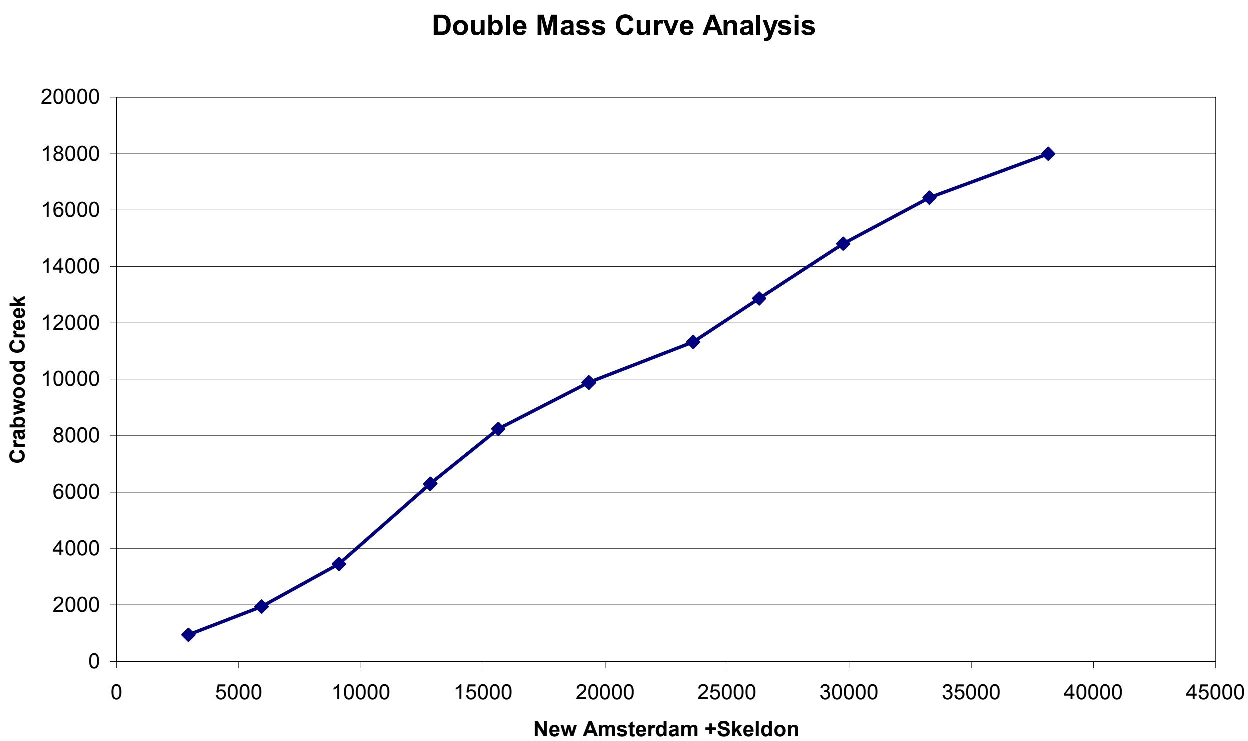

Figure 2.8 Double mass curve analysis: Crabwood Creek and New Amsterdam + Skeldon Front

2.4 The Streamgauging Network

The locations of streamgauging stations are shown in Figure 2.9, and the availability of data at these stations is summarised in Figure 2.10. The deterioration in data availablility since the early 1980's should be noted. Catchment areas are listed in Table 2.1. The streamgauging network is by any standards extremely sparse, and the continuity of records is extremely poor. The lack of streamflow data will affect the reliability with which the water resources can be assessed. In a number of previous investigations, very simple runoff coefficients have been used to assess water resources. It is hoped that a more sophisticated approach can be adopted that will make better use of the more complete rainfall records. Of note is the much lower runoff from the Canje and Abary catchements.

Table 2.1

Catchment areas to Gauging Stations

Station	Area (km^2)	Mean Annual Runoff (mm)
Loo River	48.2	1280
Kairuni River	29.5	1170
Mahaiconi at Laluni	1260.8	1000
Mahaiconi at Keraha	517.8	1130
Abary at Big Pond	453.1	620
Canje at Karaikuri	1139.1	560
Canje at Reynold's Bridge	277.0	470

(n.b. mean annual runoff estimates are unreliable, being based on available data only)

The stations on the Abary and Mahaicony rivers are not included in the HYDATA database. Hard copy data has been located for these stations for the late 1950's, and efforts will be made to locate any other records that exist. It is expected that data will be available for the Berbice River also. It should be noted that the average annual runoffs presented in Table 2.1 have been calculated simply on the basis of the available data, and are not true average annual runoff figures. Runoff rates are of the correct order of magnitude, being approximately the difference between rainfall and potential evapotranspiration. Runoff in the Canje catchment is, however, about 50% of that in the Abary and Mahaicony rivers. This may be related to geology, but clearly there needs to be further investigation of this.

Streamflow hydrographs have been plotted from the data held in electronic form, and serve to give a preliminary indication of catchment response. Figures 2.11 and 2.12 show hydrographs for the Loo River and for the Kairuni River. The rivers drain small catchments, and are relatively close to the catchment of the East Demerara conservancy. The Kairuni River has a smaller catchment area than the Loo River, but exhibits very similar discharge characteristics. There is a very high baseflow component in both rivers, and surprisingly little evidence of the double peak that occurs in rainfall.

Hydrographs for the Canje River at Karaikuri and at Reynold's Bridge are given in Figures 2.13 and 2.14. The Canje River also exhibits a strong baseflow. A preliminary inspection of the hydrographs indicates that the flow records appear to be consistent. The hydrographs are dominated by baseflow. From a water resources stand point, this does indicate that inter-annual variability in river flows may be lower than that of rainfall.

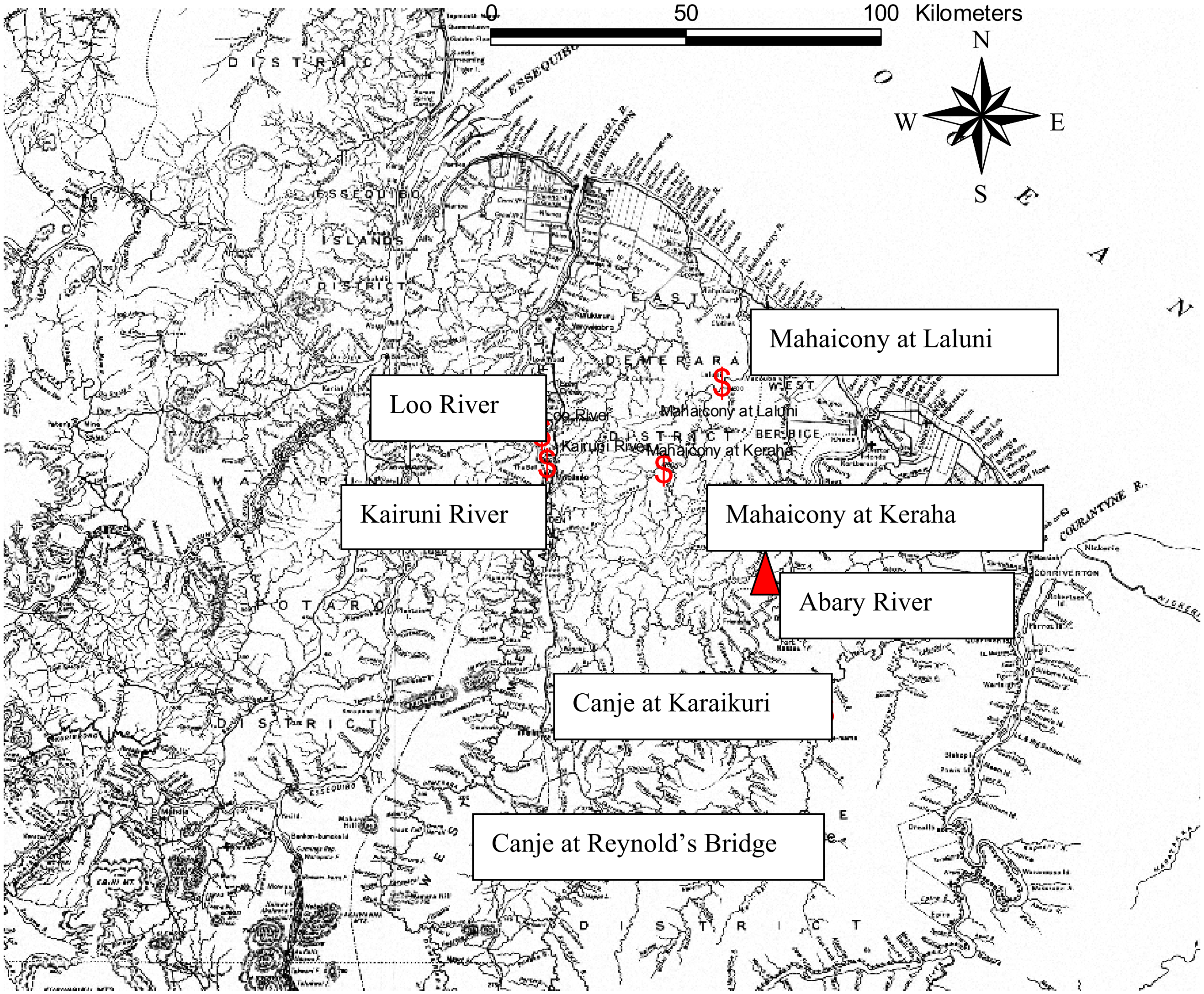

Figure 2.9 Location of streamgauging stations

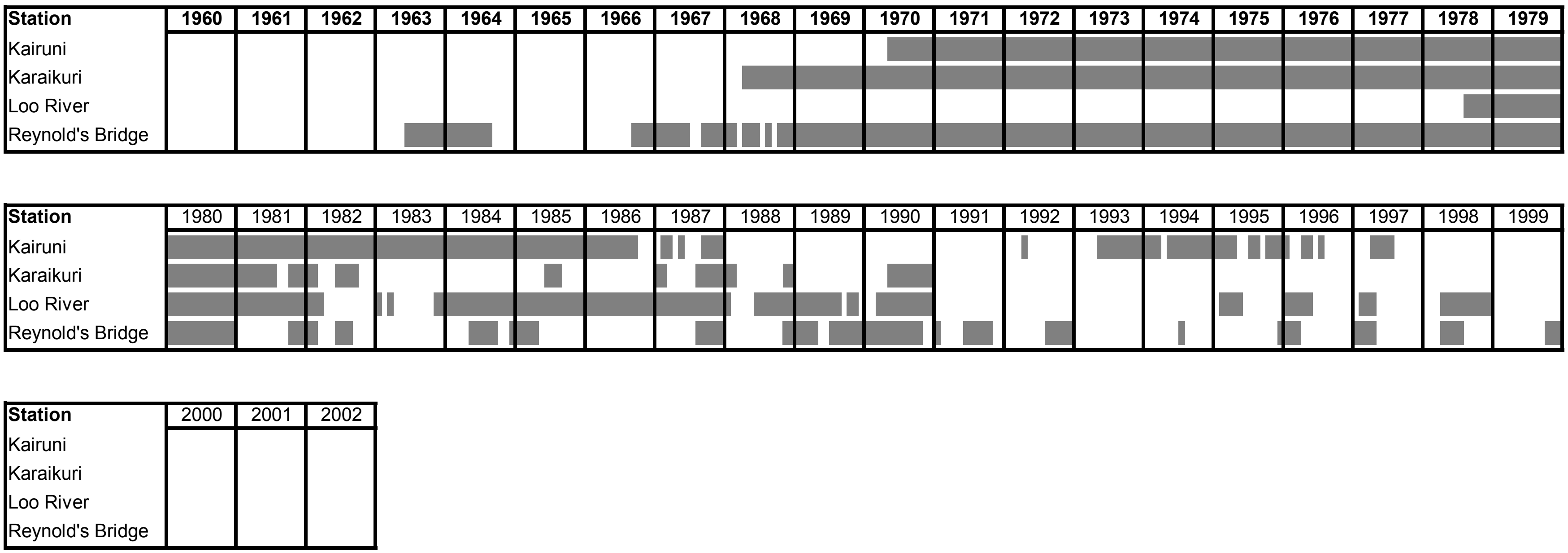

Figure 2.10 Availability of streamflow data

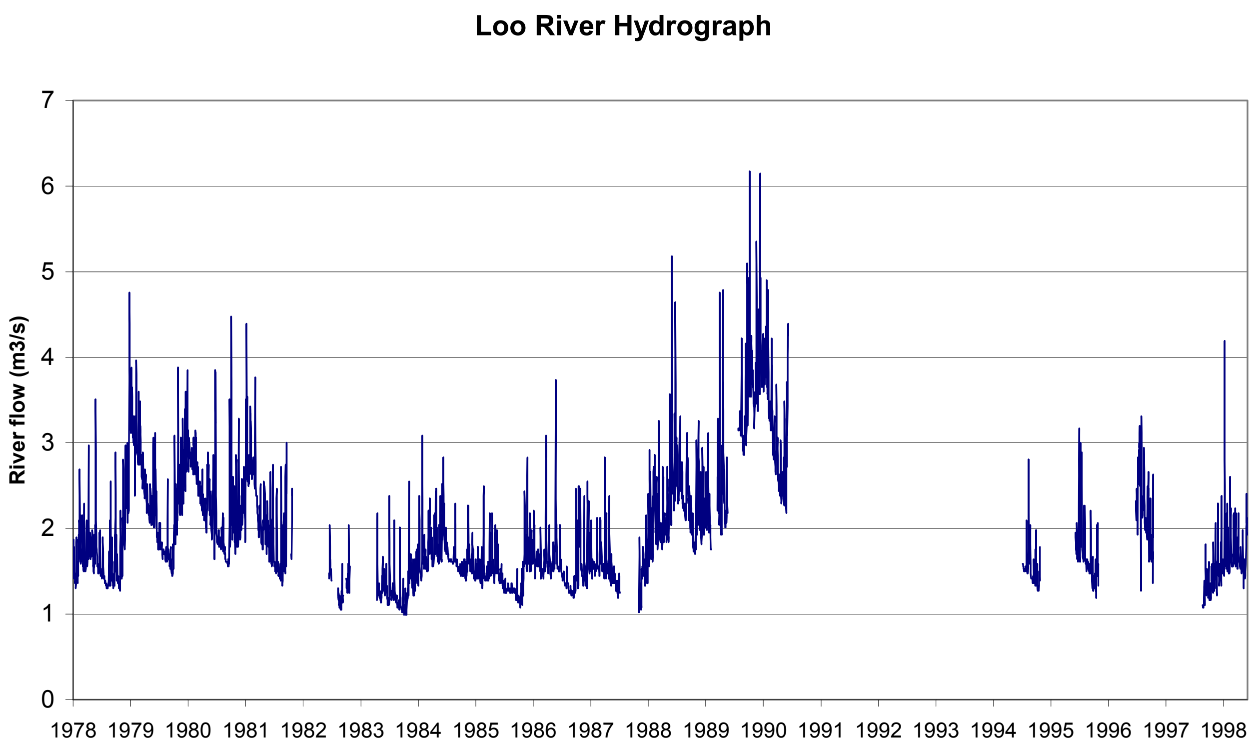

Figure 2.11 Mean daily discharges on the Loo River

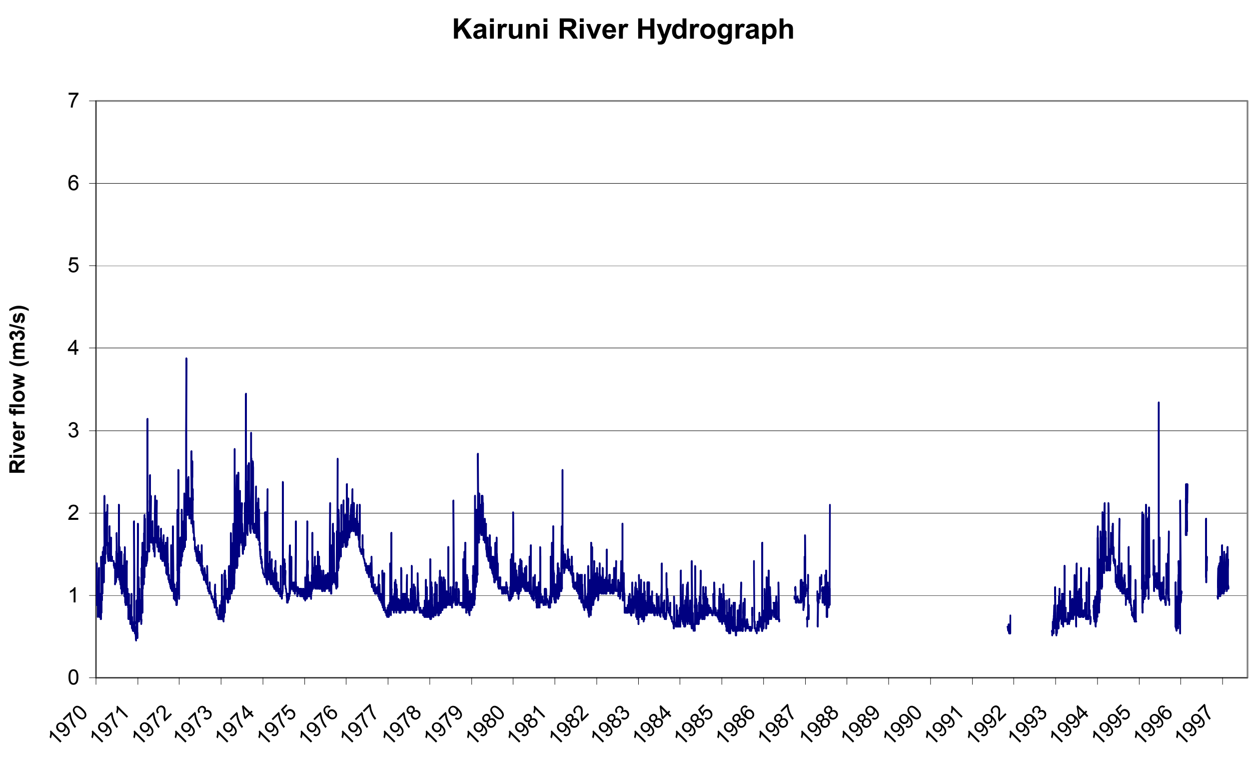

Figure 2.12 Mean daily discharges in the Kairuni River

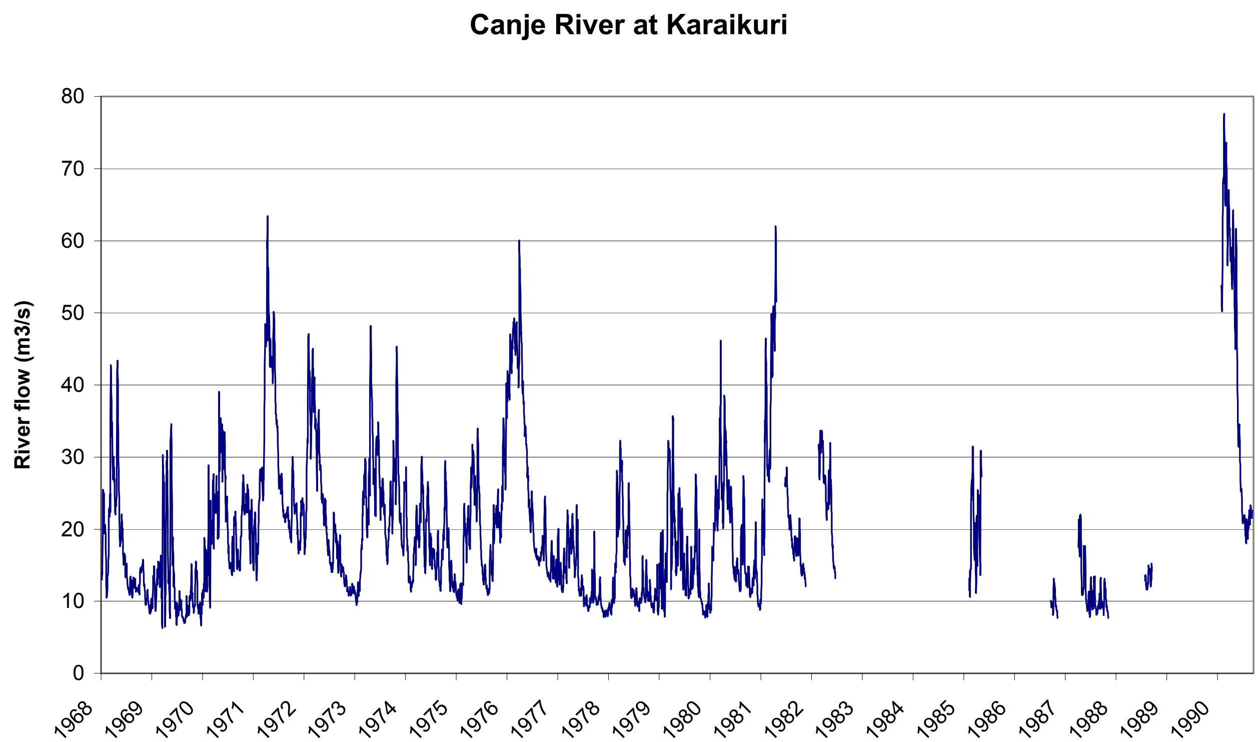

Figure 2.13 Mean daily discharges in the Canje River at Karaikuri

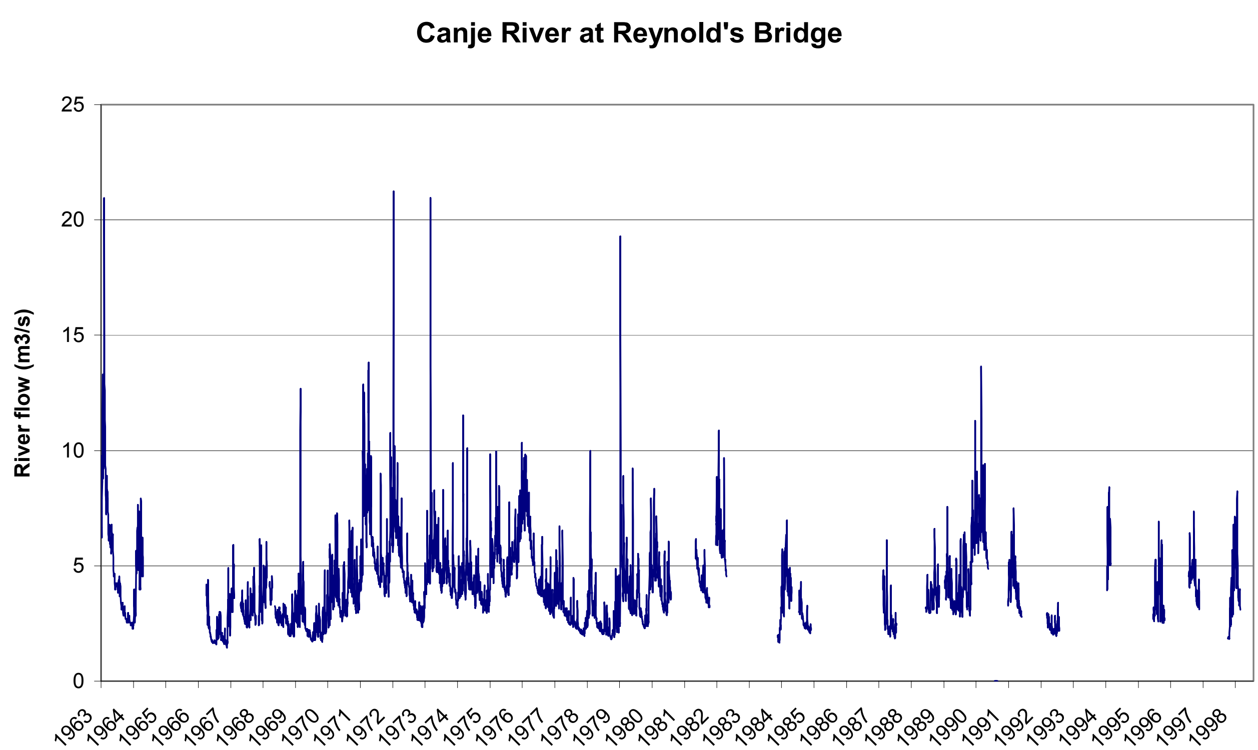

Figure 2.14 Mean daily discharges in the Canje River at Reynold's Bridge

3 Hydroclimatic Conditions

3.1 Cimatic Norms

The locations of climatic stations relevant to the project have been shown in Figure 2.1. The data at these stations is of variable length and there are gaps in records. Climatic norms at Timehri Airport are shown in Figure 3.1, and at Georgetown Botanical Gardens in Figure 3.2. Data for Timehri Airport were available from 1991. Data at Georgetown Botanical Gardens are available for a much longer period, with some parameters being measured since the 1880's. Data plotted are for a common period 1962 – 2002. Difficulties were experienced in gathering climatic data as only limited records are held centrally by the Hydromet Department of the Ministry of Agriculture, and apparently much chart data remains to be processed.

The climatic norms at Timehri Airport and at Georgetown Botanical Gardens show little variability. Mean daily temperatures are generally between 26^{o}C and 27^{o}C, with higher temperatures being experienced in September and October when mean daily maximums exceed 30^{o}C. The range in mean daily temperatures is lower at Georgetown Botanical Gardens than at Timheri Airport, reflecting the stronger maritime influence at Georgetown.

The recorded relative humidity values at Georgetown are lower than at Timehri, by about 5% on average. The maximum and minimum values of relative humidity shown in Figures 3.1 and 3.2 are the maximum and minimum of the mean monthly values over the record period, and are therefore indicative of inter-annual variability. The lower values of relative humidity in February and March, and in September and October, correspond with the two dry seasons.

Wind speeds, like the other climatic parameters vary little throughout the year. Maximum wind speeds tend to occur in the period February to May. At the time of preparing this report only a short period of historic wind speed records for Georgetown Botanical gardens had been collated by the Hydromet Department. The mean wind speeds shown in Figure 3.2 have been taken from the FAO database. The maximum and minimum wind speeds shown in Figure 3.1 are of the mean monthly values in the historic record, and do not reflect mean daily maximums or minimums.

The pattern of daily sunshine hours shows maximums in the two dry seasons of February – March and August – September. Georgetown has more sunshine that Timehri Airport, and this in part explains the differences in relative humidity between these locations. The maximum and minimum values give an indication of inter-annual variability.

Rainfall data have not (at the time of writing) been available for Timehri Airport. They have, however, been available for Georgetown Botanical Gardens. Figure 3.3 shows mean monthly rainfalls at Georgeown, along with rainfalls at non-exceedance probabilities of 10% and 80%. Mean annual rainfall in Georgetown is 2300 mm. The rainfall pattern of Figure 3.3 is entirely consistent with the relative humidity and sunshine data presented in Figures 3.1 and 3.3. It is of interest to note that the greatest variability in monthly rainfall occurs in the months of December and January. Rainfall is discussed in more detail in sections 4.2 and 3.7.

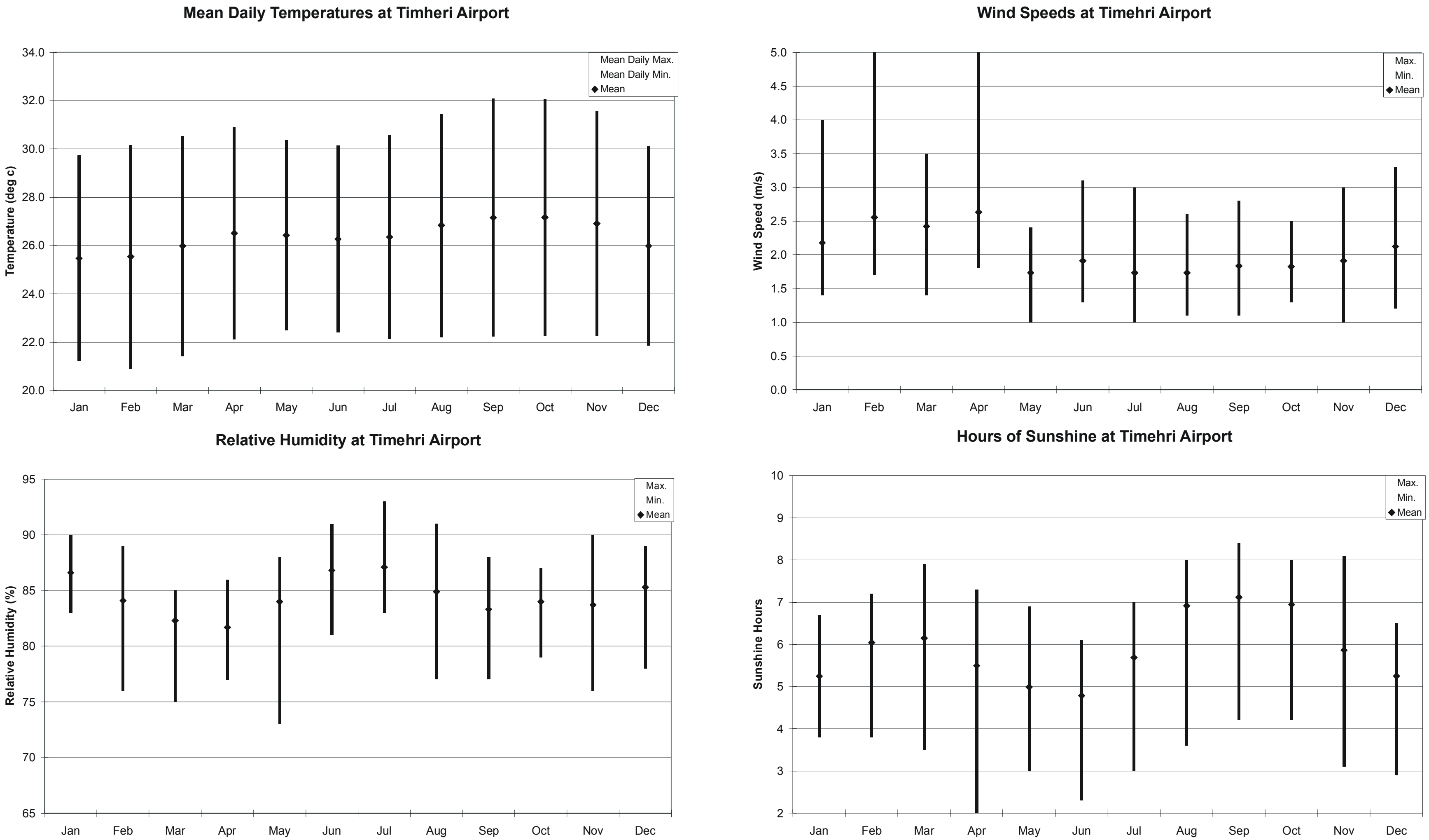

Figure 3.1 Climatic norms at Timehri Airport, 1991 – 2002
(N.B. With the exception of temperatures, maxim and minimums relate to recorded monthly means in the 1991 – 2002 period.)

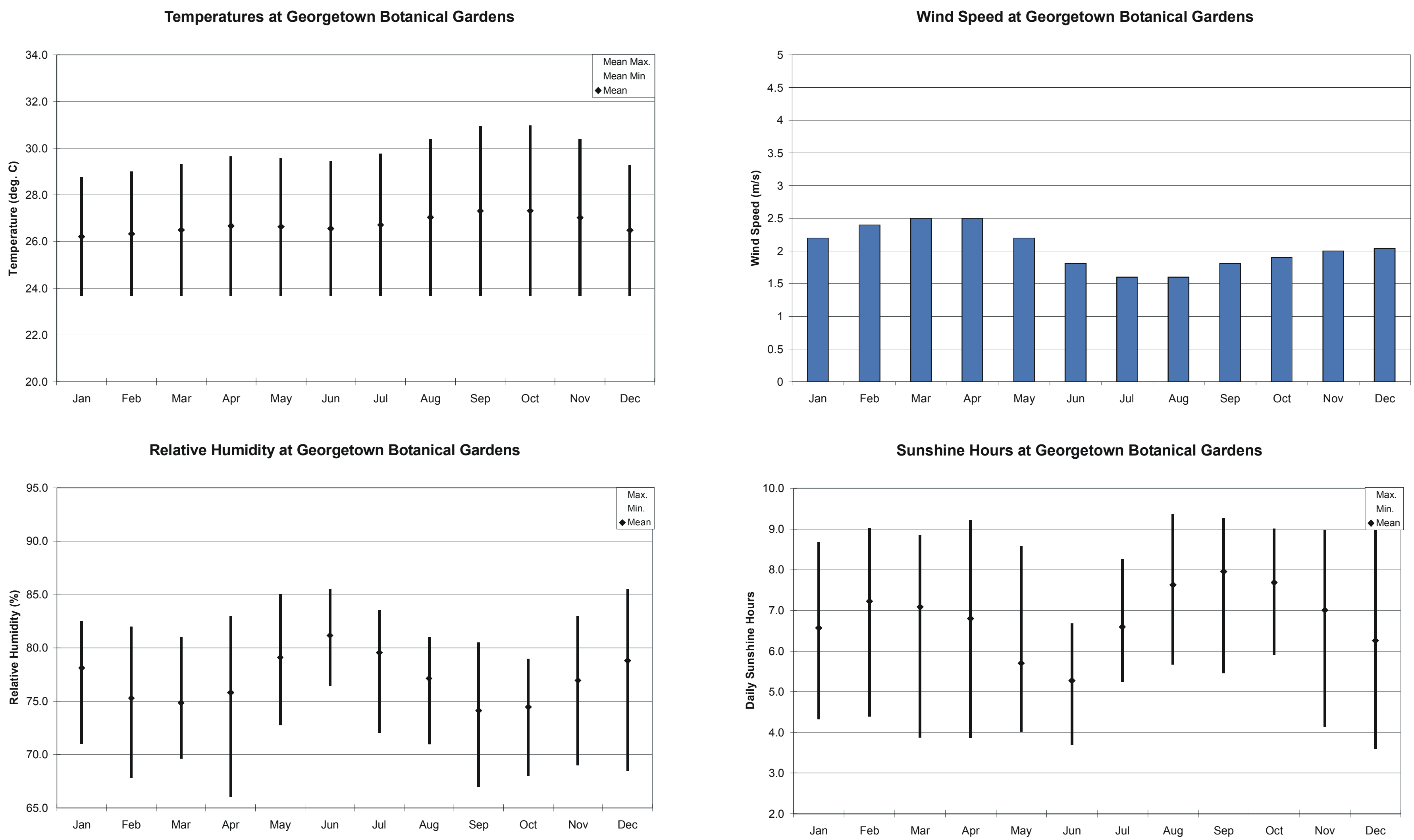

Figure 3.2 Climatic norms at Georgetown Botanical Gardens (1962-2002)
(N.B. With the exception of temperatures, maximums and minimums relate to recorded monthly means in the 1962 – 2002 period.)

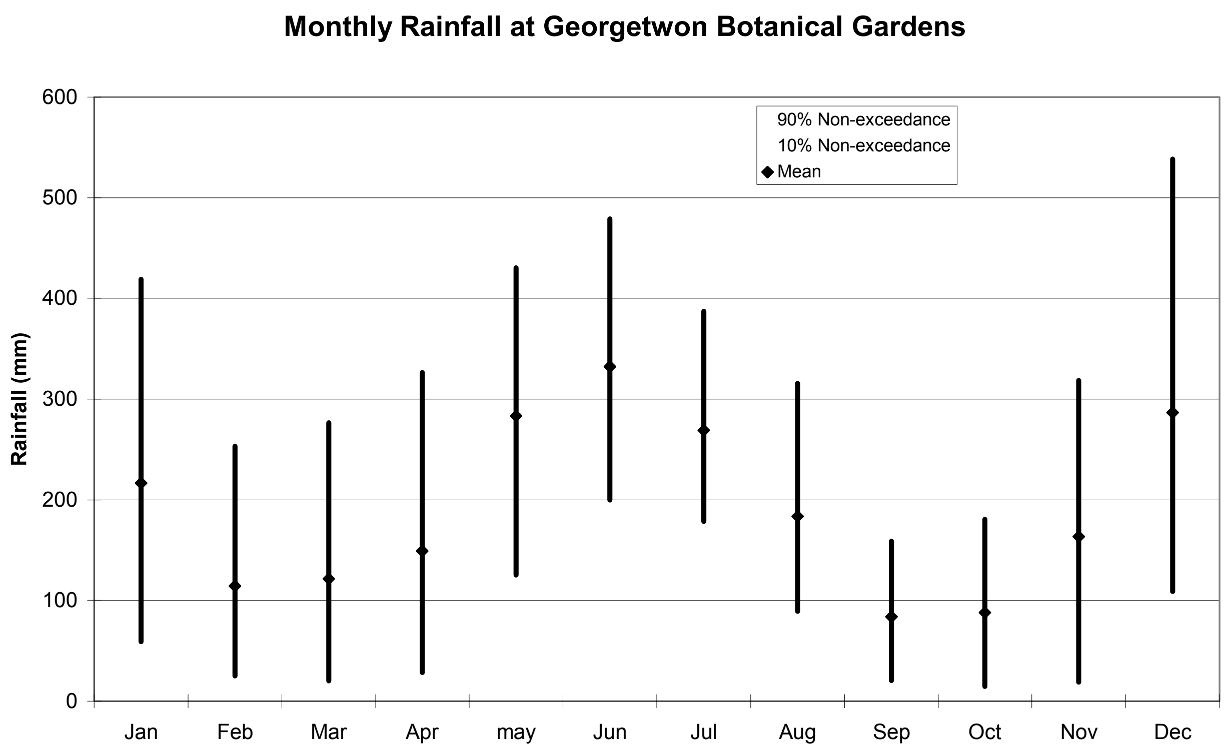

Figure 3.3 Monthly rainfall at Georgetown

3.2 Influence of El Nino

It has been reported (e.g. Guyana National Communication: Monitoring and Understanding Climate Change and Impacts, 2002) that Guyana experiences acute droughts during El Nino events and heavy rainfall and flooding during La Nina events. The El Nino is a warm coastal current off the west coast of South America and is associated with changes in the Walker circulation system over the Pacific. During an El Nino event there is a weakening of the Walker circulation system, and during a La Nina event there is a strengthening of the Walker circulation system. The variability of the Walker circulation system is measured by the Southern Oscillation Index (SOI), which is calculated by the difference in atmospheric pressure (at sea level) between Tahiti and Darwin. The El Nino and the Southern Oscillation are thus two characteristics of the Walker circulation system, and the combined term ENSO is often applied. The SOI provides an objective means of measuring the strength of ENSO activity.

A historical record of the SOI is available from several internet sites (e.g. http://www.cru.uea.ac.uk/) where numerous other links are also found). Monthly and annual values of the SOI have been correlated with monthly and annual rainfall for Georgetown in order to establish whether any links exist, and whether there might be any potential to use ENSO forecasts as a means of rainfall forecasting in Guyana. Were such forecasts possible they would be of value to farmers, and of value in managing water resources.

Figure 3.4 shows a time series plot of the SOI over the period for which rainfall records exist for Georgetown. Negative values of the SOI are associated with El Nino years. Figure 3.5 shows the time series of annual rainfalls for Georgetown, expressed as a percentage of the long term mean. The 5 year running mean is included in thee plots.

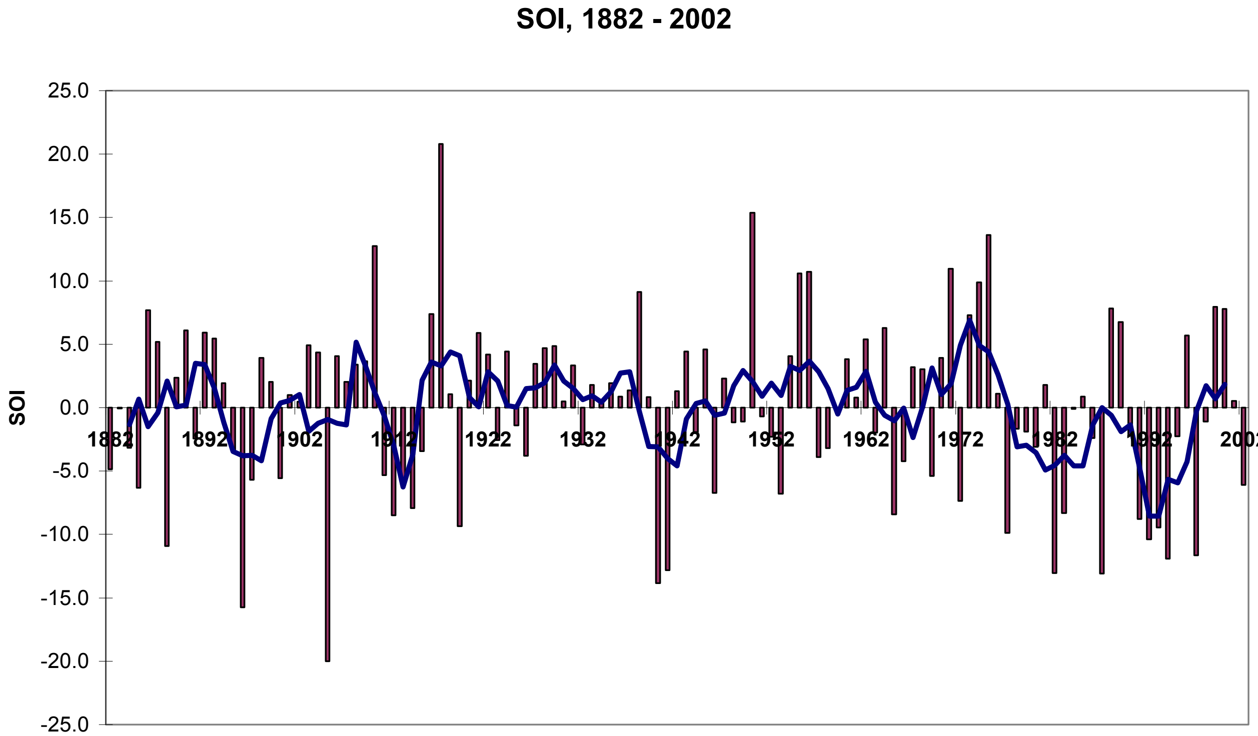

Figure 3.4 The SOI, 1882 – 2002

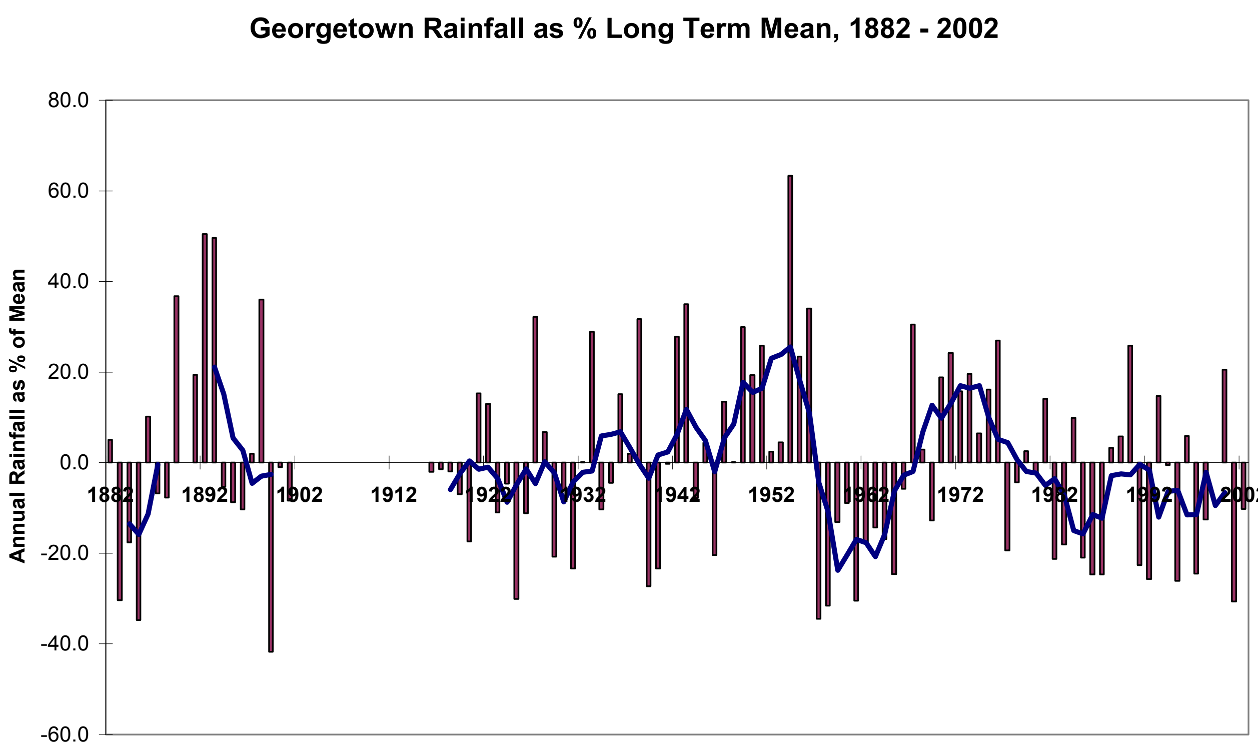

Figure 3.5 Annual rainfall at Georgetown

It is apparent from Figures 3.4 and 3.5, that there has been an increased frequency of El Nino years since the 1970's, and that during this time, below average rainfall has been experienced in Georgetown. Annual rainfall between 1974 and 2002 was 5% below the long term average. The five year moving means on these plots follow similar patterns. Figure 3.6 shows the November – January rainfalls in the same way. The low November – January rainfall in 1997 was associated with an El Nino year, and this has been the catalyst for much of the El Nino – drought associations in Guyana. There is not, however, strong statistical evidence in support of this association.

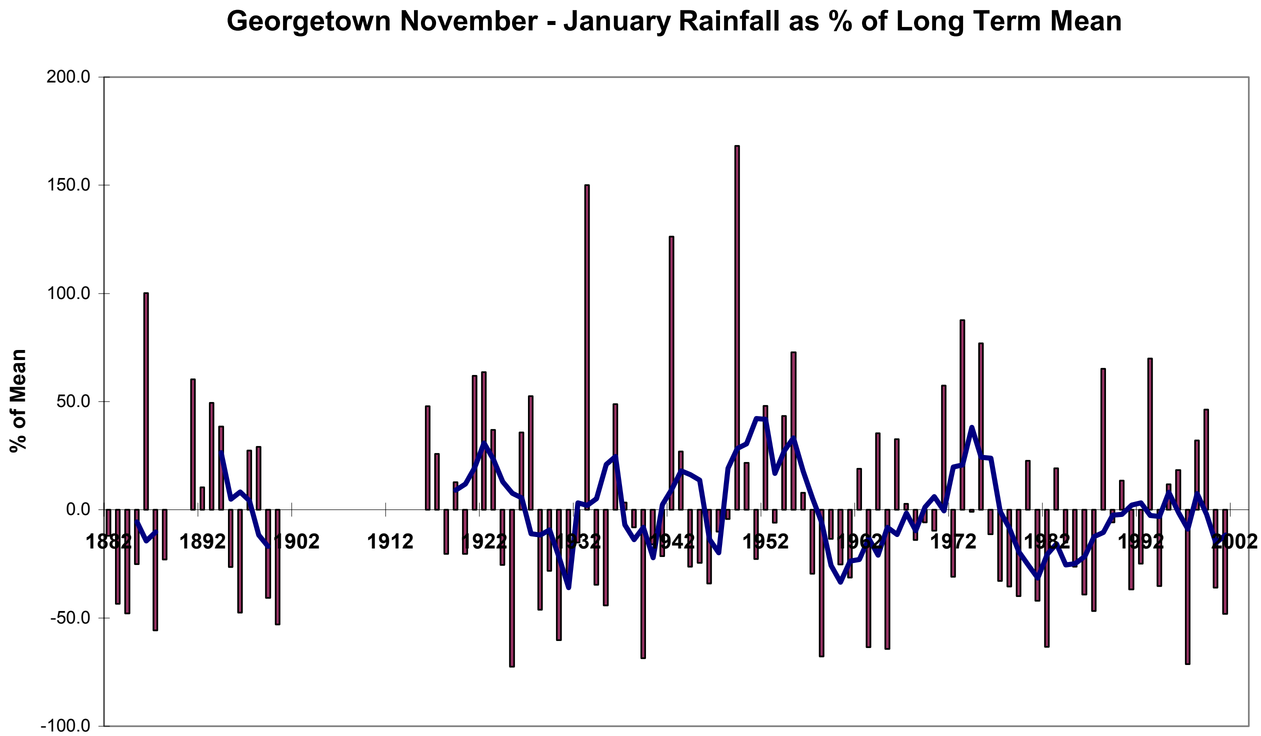

Figure 3.6 November – January rainfall at Georgetown

The 1997 November – January rainfall was one of the lowest on record, but there have in fact been at least 6 other years with similar droughts during the past 100 years, not all of which have been associated with El Nino years. In order to explore the links between Georgetown rainfall and ENSO activity further, rainfall at different durations has been correlated with the SOI. Figure 3.7 shows the relationship between annual rainfall in Georgetown and the SOI. While there is some evidence of a correlation, it is extremely weak. Analysis has been carried out on monthly rainfall data and SOI, on monthly rainfall data lagged by one and two months, and on seasonal rainfall. It was only with the November – January seasonal rainfall data that a reasonable indication of correlation was found. The November – January correlation is shown in Figure 3.8. The correlation is extremely weak, and could not form the basis of any objective forecast of seasonal rainfall based on forecast ENSO characteristics. No relationship whatsoever exists between March – August rainfall and the SOI.

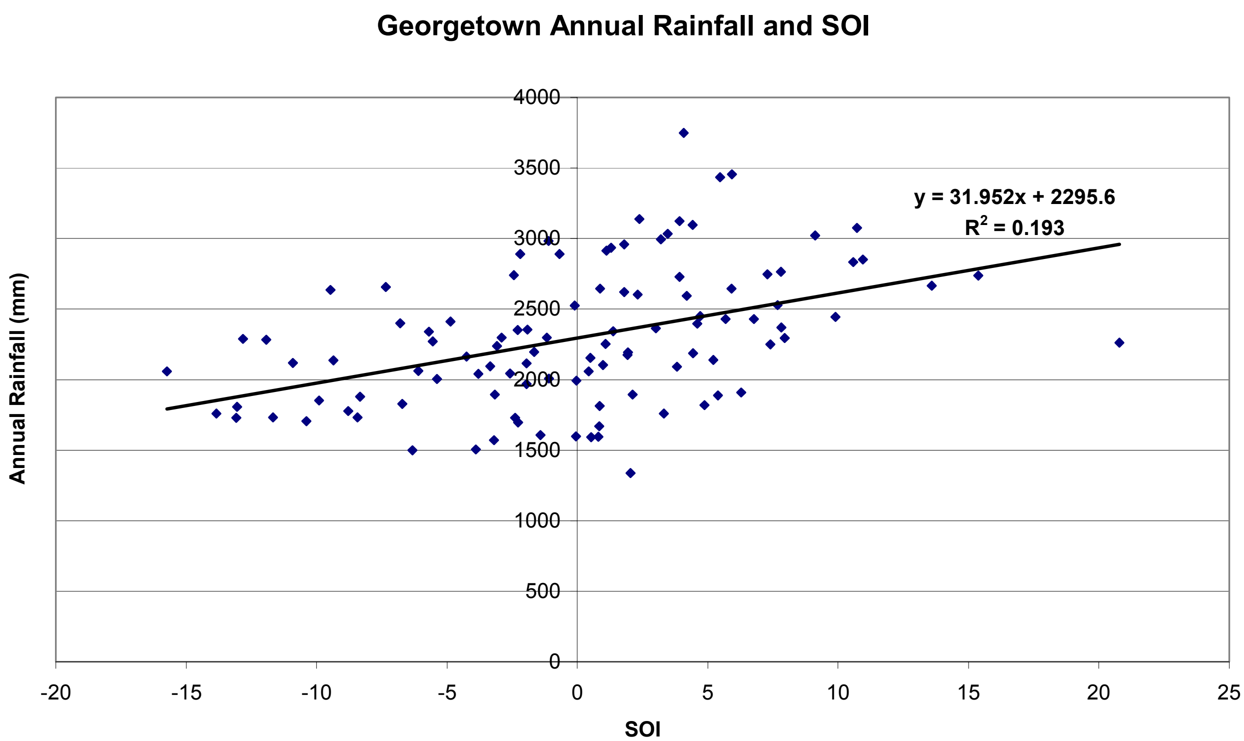

Figure 3.7 Relationship between Georgetown Rainfall and the SOI

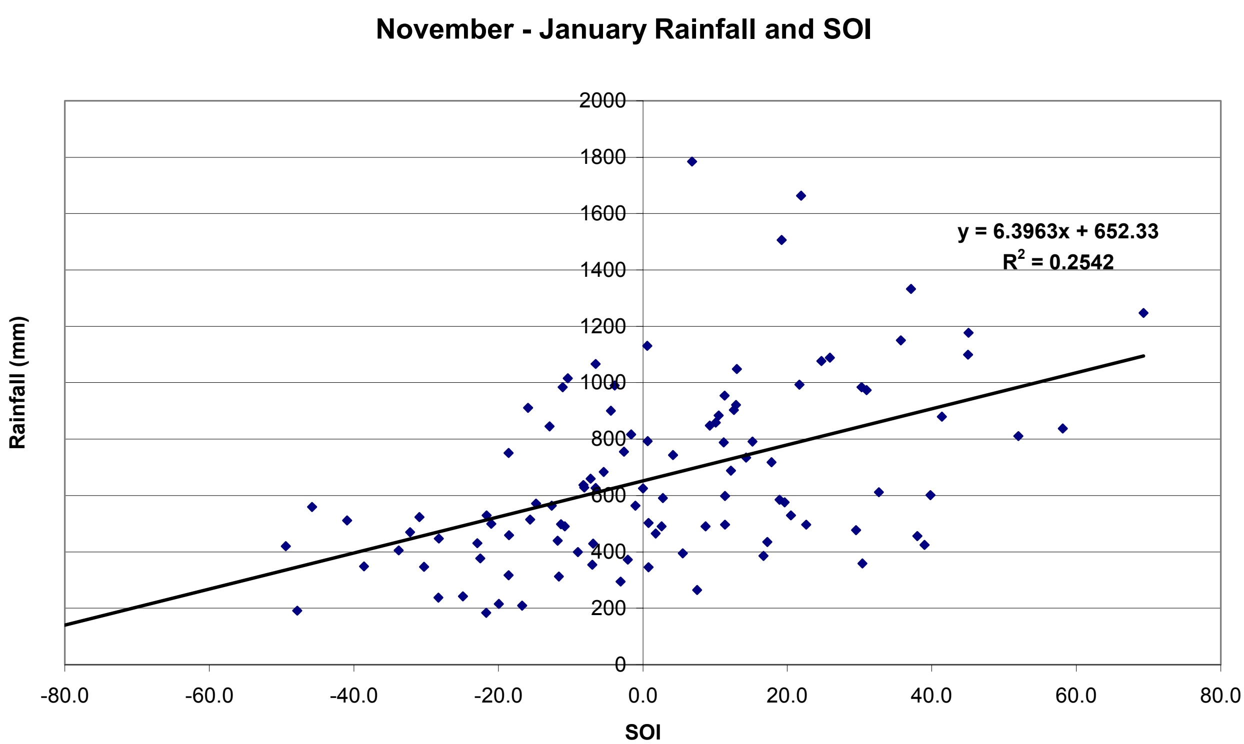

Figure 3.8 Relationship between November – January rainfall and SOI

3.3 Possible Impacts of Climatic Change

A brief review has been undertaken of General Circulation Model (GCM) predictions of future climate conditions in Guyana. The HADCM3 model has been looked at in particular. The indications from this model are that precipitation in Guyana is likely to reduce under scenarios of future climate change. At this time, model data sets have not been downloaded to permit extraction of data specific to Guyana. It is, however, the intention to do this and to evaluate seasonal precipitation and potential evapotranspiration shifts for the 2020's and 2050's. Some of this work will be done in the UK making use of fast internet connections as the model data sets are very large.

3.4 Sea Level Rise

A change in sea levels will influence the drainage characteristics in the project area. Relative sea level is rising in Guyana, and the result will be a reduction in the period of time for which gravity drainage can operate, and a progressively increasing dependency on pumped drainage. In Guyana's "Initial National Communication: Monitoring and Understanding Climate Change (2002)", it was estimated that the current rate of relative mean sea level rise for Guyana was of the order of 10 mm/year on the basis of historic records. It was also reported that the results from the CGCM 1 model indicated a mean sea level rise along eth Guyana coast of about 4 mm/year during the next century. Interestingly, the mean sea level published in tide tables for Georgetown, indicate that the mean sea level is now 0.158 m higher than it was in 1951. This equates to a rate of relative sea level rise of 3 mm/year. The Transport and Harbours Department have established the change in mean sea level on the basis of their records of sea level. Investigation of this is continuing.

Historic sea level records for Georgetown were obtained from the Hydromet Department. These records date between 1951 and 1979. Data post 1979 are being colleted, but were not available for inclusion in analysis for this report. A plot of deviations from the long term mean of annual maximum tide levels recorded at Georgetown is shown in Figure 3.9 (a plot of the annual mean monthly maximums was very similar). A progressive rise in recorded maximum sea levels may be noted between 1971 and 1976. This followed a four month period of missing data in 1970. It is therefore likely that following an instrument failure, or similar, the gauge datum changed from 1971 onwards. Figure 3.9 does not present any basis for determining rates of sea level rise at Georgetown. It is strongly recommended that a tide gauge be re-established as a matter of some urgency at Georgetown. This is essential to the planning of future coastal defence and drainage works.

For the purposes of drainage design at feasibility level, it is recommended that the mean sea level published in the 2003 tide table be adopted, and that a rate of future sea level rise of 4 mm/year be assumed. It is understood that unpublished sea level data exist with the Transport and Harbours Department. These data are being collected and the analysis of historic sea levels will be updated.

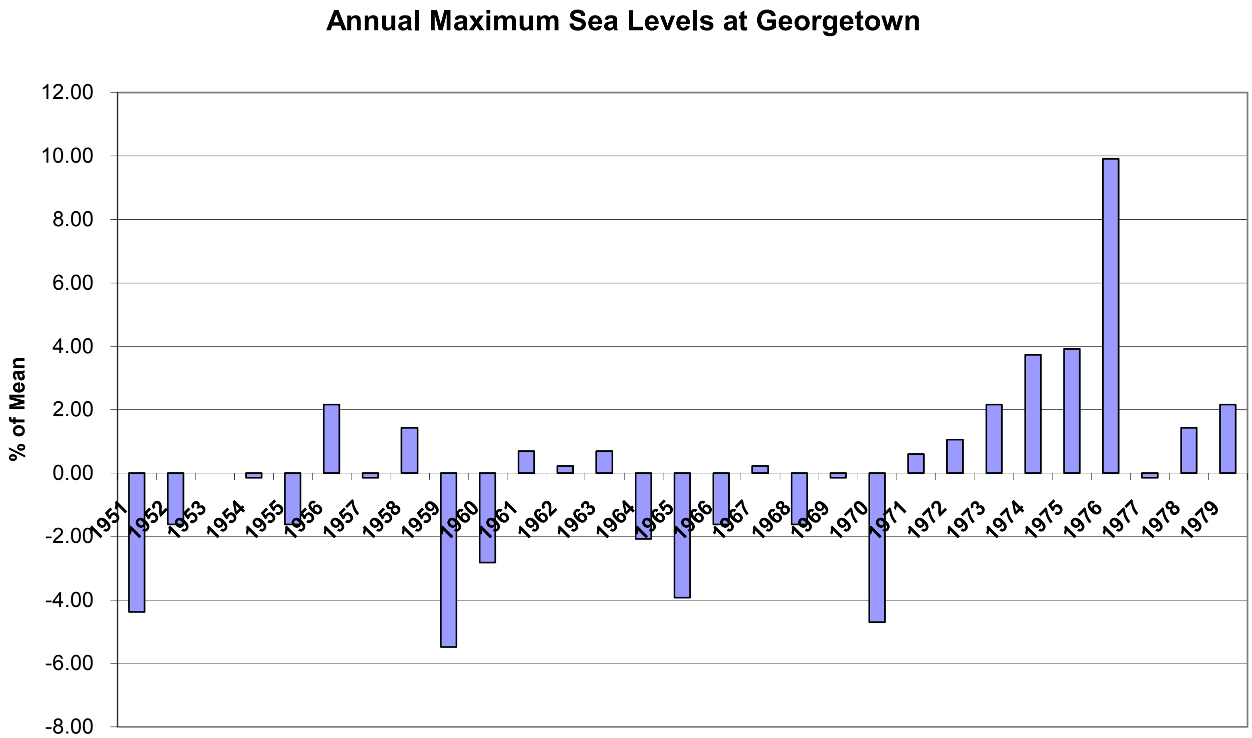

Figure 3.9 Annual maximum sea levels at Georgetown

3.5 Potential Evpotranspiration

Potential evapotranspiration (ETo) has been calculated on the basis of climatic records available at Timehri Airport and at Georgetown Botanical Gardens. Monthly temperature, relative humidity, vapour pressure, wind speed and hours of sunshine data formed the basis of the calculations using the FAO Modified Penman approach (Allen et. al., 1988). Use was also made of the FAO climatic database which includes data for Georgetown and New Amsterdam, and the CROPWATW software package in order to verify and check calculations made with the FAO Penman approach.

Potential evapotranspiration is often calculated using mean monthly climatic data, and inter annual variations in potential evapotranspiration are ignored. However, for the present study it has been recognised that there is significant variability in November – January rainfall, and climatic parameters also. In combination these have an influence on water requirements and on the water resource of the conservancies. Time series of monthly potential evapotranspiration have therefore been calculated to permit the estimation of evapotranspiration at different non-exceedance probabilities.

Figures 3.10 and 3.11 show potential evapotranspiration calculated for Timehri Airport and Georgetown Botanical gardens respectively. At Timehri, only ten years of data were available, and it was not appropriate to compute values at particular non-exceedance probabilities. Mean monthly values have therefore been plotted along with the maximum and minimum values. For Georgetown Botanical Gardens it has been possible to calculate potential evapotranspiration for the period 1961 – 2001, although some difficulties have been experienced with wind speed data at Georgetown.

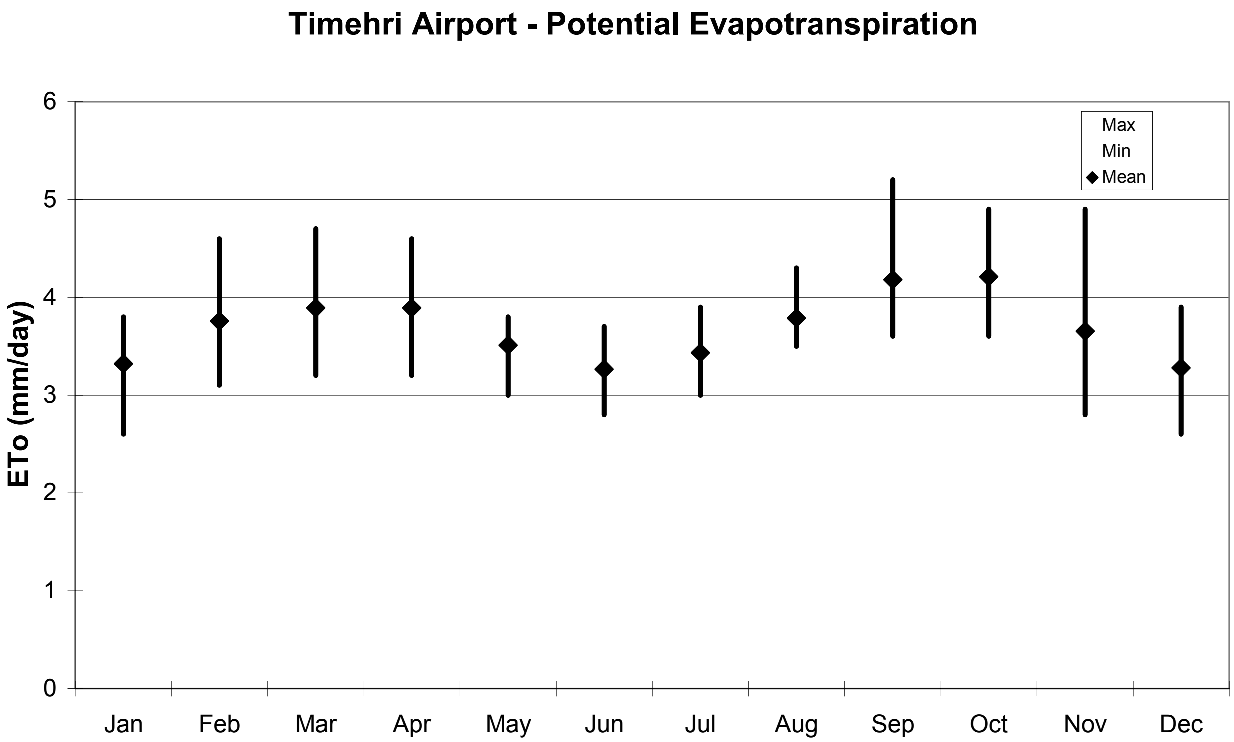

Figure 3.10 Potential evapotranspiration at Timehri Airport

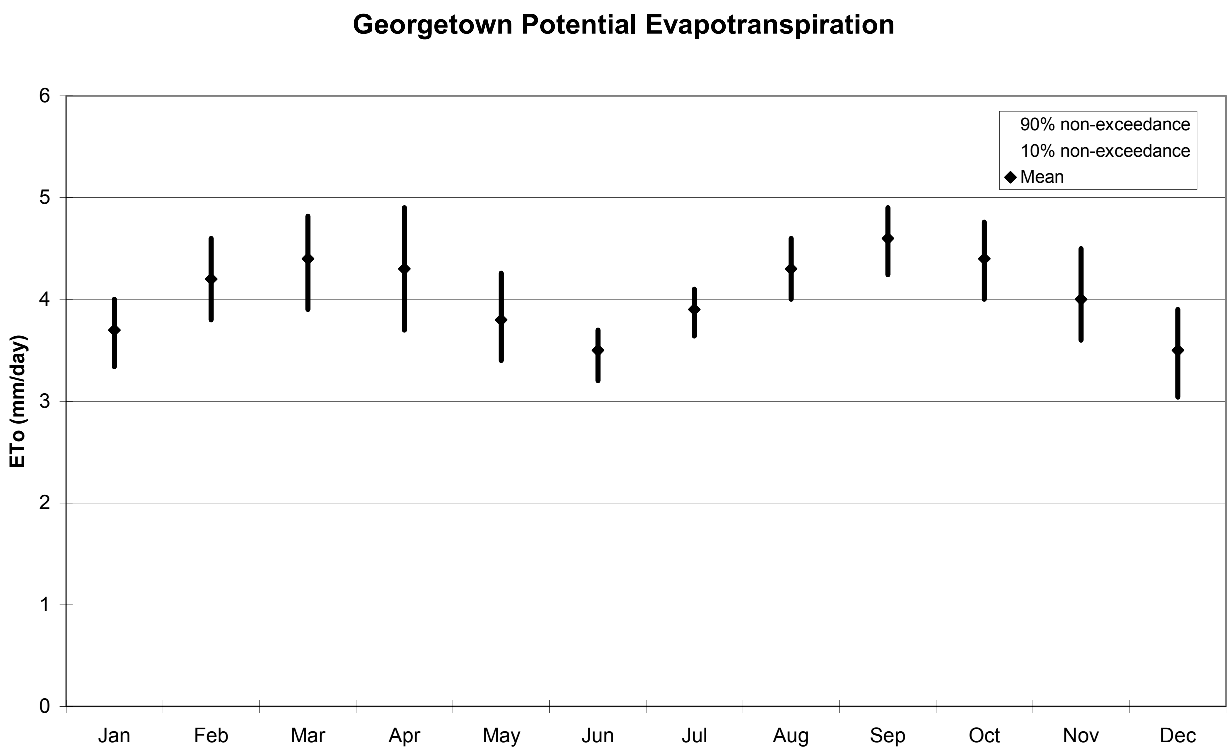

Figure 3.11 Potential evapotranspiration at Georgetown Botanical Gardens

The potential evapotranspration computed for Georgetown is slightly higher than at Timehri Airport. Hours of sunshine are greater at Georgetown, and relative humidity lower than at Timehri, so this result is expected. In order to verify the calculate values, ETo was also calculated for Georgetown using the CROPWAT computer program (Smith et. al.) and climatic norms for Georgetown held in the FAO climatic data base. Figure 3.12 compares the ETo estimates made with the FAO modified Penman approach and with the CROPWAT modified Penman approach. The results are very similar, and differences probably due mostly to minor differences in the data used.

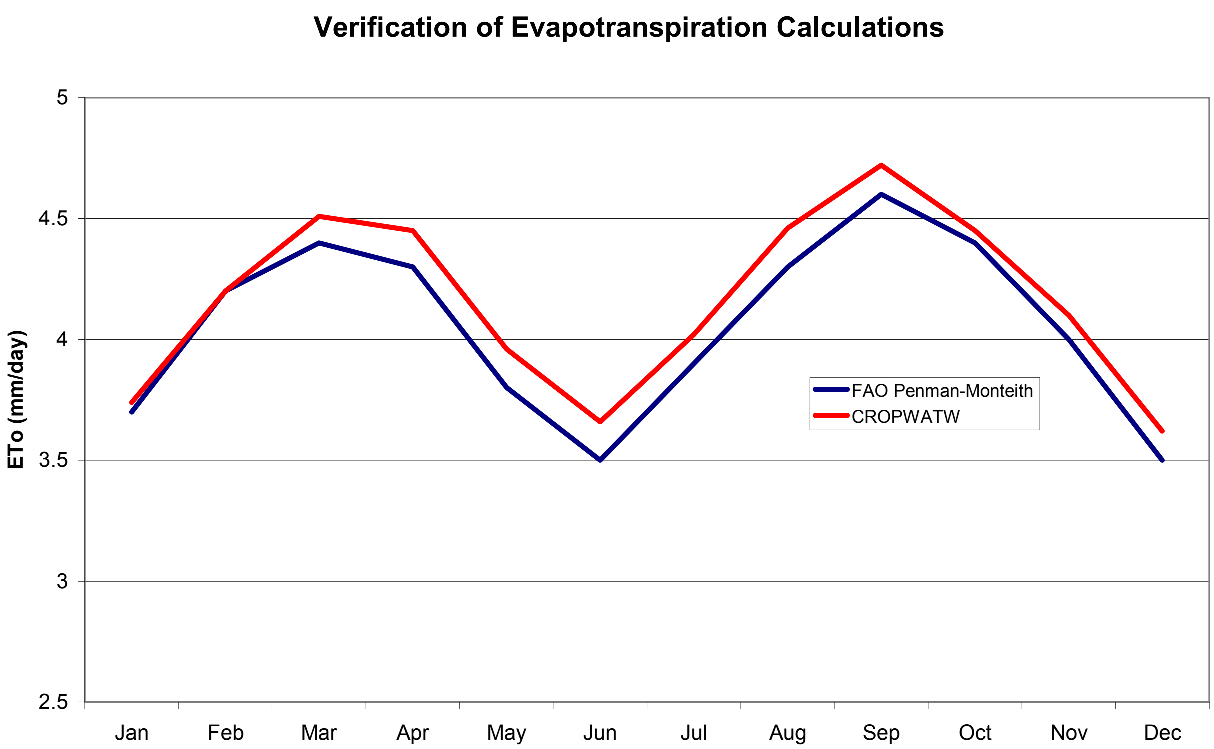

Figure 3.12 Verification of evapotranspiration calculations

As indicated above there have been difficulties in collating wind speed data for Georgetown. Data were only available for the 1996-2001 period, and calculated mean monthly wind speeds for this period were slightly different from those in the FAO database. Table 3.1 presents a comparison of the data. The differences are small, and in calculating ETo for Georgetown, the FAO values have been adopted. Time series monthly values were available for all other parameters used in the ETo calculations.

Table 3.1
Mean monthly wind speeds at Georgetown (m/s)

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1996-2001	2.23	2.66	2.80	2.68	2.07	1.60	1.29	1.40	1.74	1.86	1.83	1.99
FAO Values	2.20	2.40	2.50	2.50	2.20	1.81	1.60	1.60	1.81	1.90	2.00	2.44

The FAO database also contains data for New Amsterdam. Sufficient climatic data could not be gathered as part of the study to permit calculation of ETo at New Amsterdam directly. Estimates of ETo at New

Amsterdam have therefore been based on the FAO database. Table 3.2 summarises the computed monthly ETo values. Average annual potential evapotranspiration is estimated to be 1475 mm at Georgetown, 1345 mm at Timehri airport and 1620 mm at New Amsterdam. It is recommended that Georgetown ETo be used in calculation of crop water requirements in Regions 3 and 4, and that New Amsterdam be used for Region 6.

Table 3.2

Calculated reference crop potential evapotranspiration, ETo (mm/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Georgetown												
Mean	3.7	4.2	4.4	4.3	3.8	3.5	3.9	4.3	4.6	4.4	4.0	3.5
80% non-exceed.	4.0	4.5	4.7	4.8	4.1	3.6	4.0	4.5	4.8	4.7	4.3	3.8
90% non-exceed	4.0	4.6	4.8	4.9	4.3	3.7	4.1	4.6	4.9	4.8	4.5	3.9
Timehri Airport	3.3	3.8	3.9	3.9	3.5	3.3	3.4	3.9	4.2	4.2	3.7	3.3
New Amsterdam	4.0	4.7	4.9	4.7	4.2	4.0	4.3	4.7	4.9	4.6	4.3	3.9

Potential evapotranspiration is inversely correlated with rainfall. Good relationships have been found in each month of the year. Figure 3.13 shows the relationship between January rainfall at Georgetown at ETo at Timheri. In dry years potential evapotranspiration is higher than in wet years as a result of reduced cloud cover. It is recommended therefore that in the determination of irrigation requirements, potential evapotranspiration at 90% non-exceedance probability be used along with rainfall at 10% non-exceedance probability.

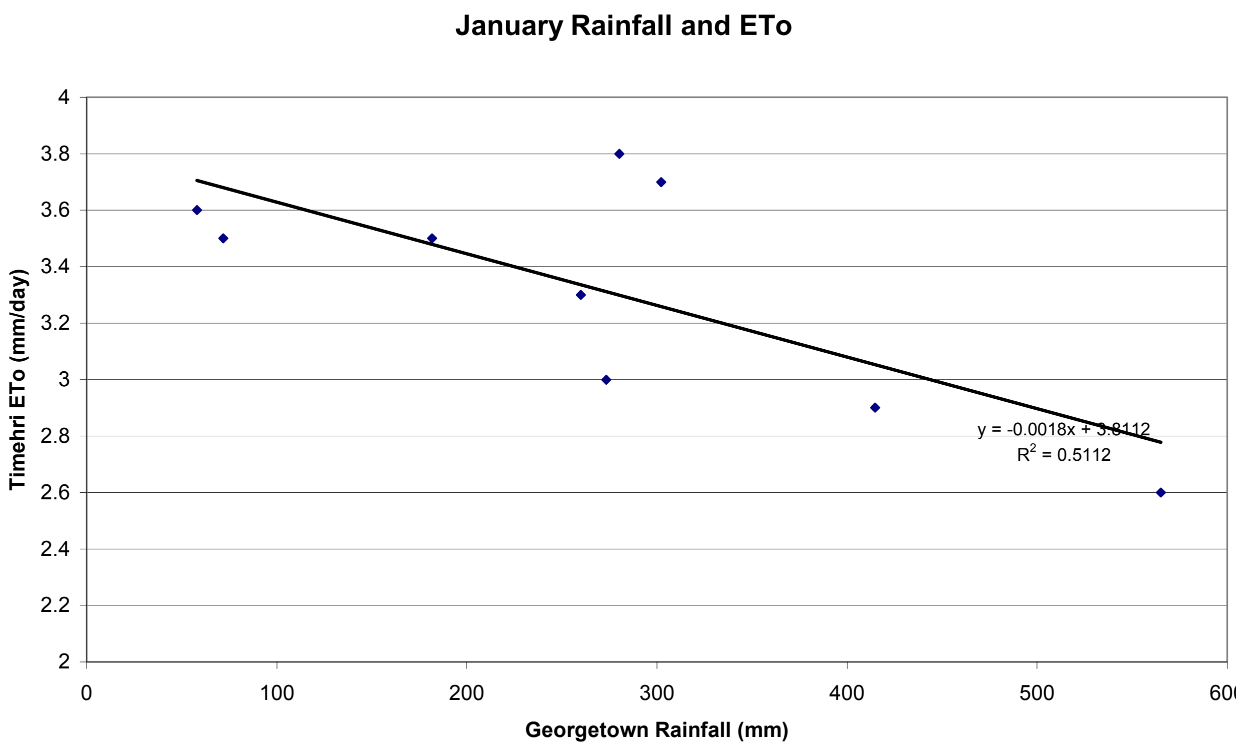

Figure 3.13 Typical relationship between ETo and rainfall

3.6 Rainfall Characteristics

3.6.1 Annual Rainfall Distribution

Mean annual rainfall has been determined using a standard record period of 1974 – 2002, this being the most complete period of record in the Hydromet Departments CLICOM database. No attempt has been made to infill periods of missing data as isohyetal plots of annual data are intended only to provide an impression of annual rainfall totals. Figure 2.4 shows mean annual rainfall for the 1974 – 2002 period. Stations with significant periods of missing data were excluded from the analysis, and at many stations the sum of monthly means had to be used as there were too many incomplete years of annual totals Rainfall in Region 3 is generally in excess of 2500 mm, while in Region 6, annual rainfall is of the order of 1750 mm. Figure 2.4 should be treated with some caution, however, and is intended for indicative purposes only.

It had been intended to map annual rainfall at different non-exceedance probabilities. However, in view of the incompleteness of the rainfall database, it was considered that this could be misleading. Representative stations have been identified that will be used to determine rainfalls for irrigation and drainage design. Selection of stations has been based on period and completeness of record and proximity to drainage and irrigation areas being considered under the project. Table 3.4 summarises the stations to be used. The file reference is given in brackets.

Table 3.4

Raingauges to be used in drainage and irrigation design

Region	Drainage and Irrigation Area	Raingauges
3	Vergenogen-Bonasika	Tuschen Front (03tusenf) Boerasirie (03boeras) De Kinderen Back (03dekenb) Uitvlugt Back (03uivlbk)
3	Den Amstel-Fellowship La Jalousie-Vreed-en-Hoop Canals Polder	Leonora Back (03lnorab) Leonora Front (03lnoraf) Wales Front (03walesf)
4	Golden Grove-Victoria Cane Grove	Enmore Front (04enmorf) Cane Grove Front (04cgrovf)
6	Black Bush Polder Lots 52 to 74 Crabwood Creek	No 54 Village Berbice (06no54vl) No 73 Village (06no73vl) Skeldon Front (06skeldf) Crabwood Creek (06crbcrk)

The rainfall record at Georgetown is the longest available. A plot of the time series of annual rainfall at Georgetown has been presented in Figure 3.5. A series of statistical test have been made on the Georgetown annual record in order to check for the existence of persistence or trend in the record. The results of these statistical tests are presented in Table 3.5.

Table 3.5
Tests for trend and persistence in Georgetown annual rainfall

Test	Expected	Observed
GENERAL RANDOMNESS TESTS:		
1) NUMBER OF MEDIAN-CROSSES	52 +/- 14	43
2) NUMBER OF TURNING-POINTS	69 +/- 8	66
PERSISTANCE TESTS		
3) FIRST-ORDER SERIAL CORRELATION	-0.01 +/- 0.19	0.21
4) SPEARMAN RANK TEST	-0.01 +/- 0.19	0.15
TREND TESTS		
5) RANK ORDER TEST	-0.01 +/- 0.19	-0.14
6) MANN-WHITNEY U TEST	1405 +/- 310	1314
7) WALD-WOLFOWITZ RUNS TEST	54 +/- 10	40

The above tests indicate that the annual data for Georgetown are random. There is weak persistence, which is the tendency for wet and dry year to occur in groups, but no evidence of trend in the record.

A normal distribution has been fitted to the annual rainfall totals at Georgetown. Figure 3.14 presents the fitted distribution. The data fit the distribution very well, except at the lower probabilities of non-exceedance. It is of interest to note that in a dry year with a 10% non-exceedance probability, annual rainfall is about 73% of the long term average.

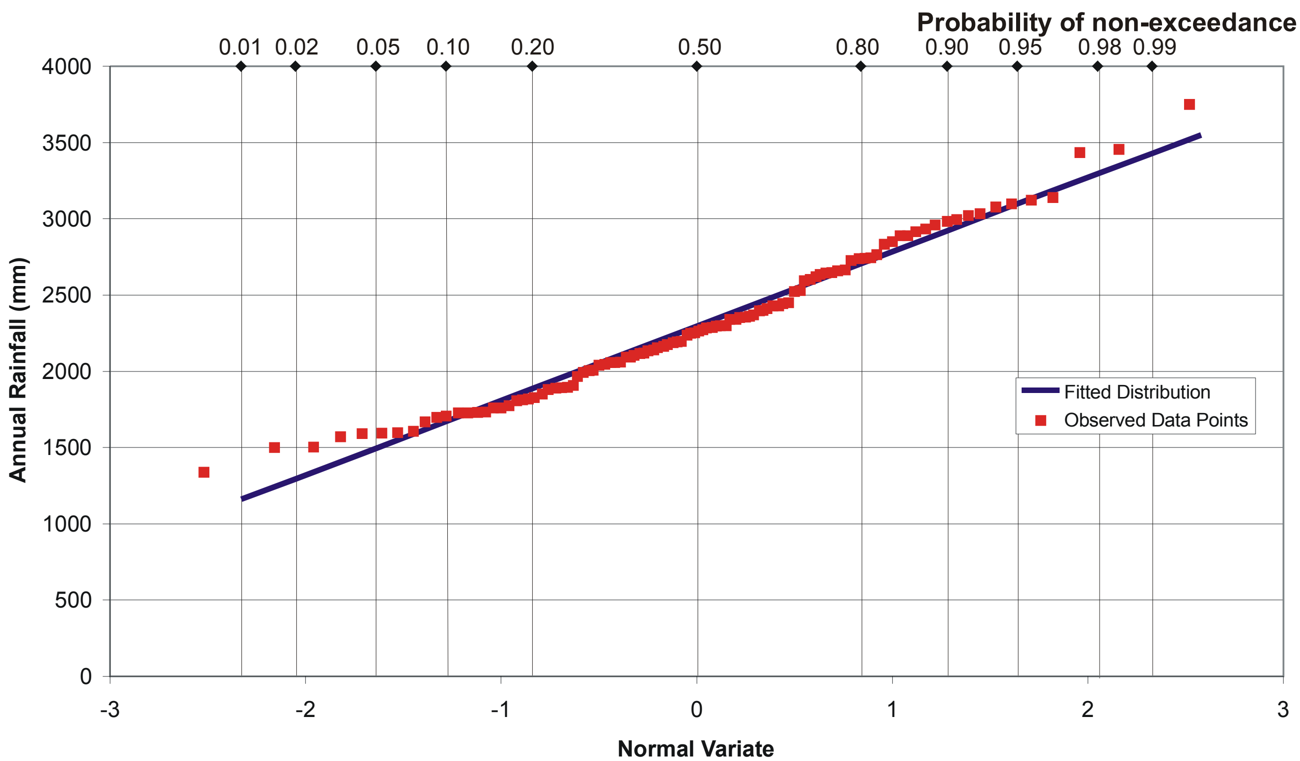

Figure 3.14 Annual rainfall probabilities at Georgetown

3.6.2 Ten Day Rainfalls

An analysis of ten day rainfall totals has been carried out for the purpose of determining effective rainfall for crop water requirement calculations. Tabulations of 10 day rainfalls at the stations listed in Table 3.4 are given in Appendix A. For irrigation design, the capacity of system components should be based on an envelope of effective rainfalls at 80% or 90% non-exceedance probabilities. For water resource evaluation, irrigation demands should be based on a sequence of effective rainfalls for which the annual total is equalled or exceeded in 80% or 90% of years. Ideally such a sequence would be determined through probability analysis of the rainfall sequences conditioned on a particular critical month. However, the data for the project area are not sufficiently complete to permit this approach to be taken. The approach adopted has been to select particular years that have annual totals close that at the selected non-exceedance probability, and to work with these sequences. Table 3.6 summarises 10 day rainfalls to be used in the determination of irrigation demands when sizing components of the irrigation system. Table 3.7 summarises 10 day rainfalls to be used in determining irrigation demands for water resources evaluation. It should be noted that in Table 3.7, because the data presented are for a particular year, it is possible that individual 10 day periods may appear to be drier at 80% non-exceedance than at 90% non-exceedance. The design rainfalls in Regions 6 are clearly lower than in Regions 3 and 4.

3.6.3 Analysis of Rainfall Extremes

An analysis of rainfall extremes has been carried out for the purpose of drainage design. Annual maximum 1-day, 2-day, 3-day and 5-day rainfalls have been analysed for each station listed in Table 3.4. An Extreme Value Type I (EV1 or Gumbel) distribution has been fitted at each station and values at particular return periods averaged to give design values for each drainage and irrigation area. Figure 3.18 - 3.21 show a plots of the distributions fitted to the data for Georgetown. The EV1 distribution fits the data very well. 95% confidence limits are included in Figures 3.15 – 4.18. Statistical tests have been carried out on the annual maximum series for Georgetown to check for trend. Figure 3.19 presents annual maximum 1-day rainfalls for Georgetown. The results of statistical tests are presented in Table 3.8. The impression from Figure 3.19 is that there may be a trend of declining annual maximum 1-day rainfalls. However, this is not statistically significant, as can be seen from Table 3.9. There is certainly no indication of increasing storm rainfall magnitudes as has been reported anecdotally.

The rainfalls for drainage design in each of the drainage and irrigation areas are summarised in Table 3.10.

Table 3.7

Design rainfalls for irrigation system component design

Design Rainfalls at 80% non-exceedance probability - not a homogeneous sequence

Region	Drainage & Irrigation Area	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
3	Vergenogen-Bonasika	21	13	12	5	3	5	8	5	4	3	7	14	29	51	65	69	88	79	57	54	47	40	30	24	12	5	9	4	11	13	11	12	21	45	28	33
	Den Amstel-Fellowship	15	12	12	9	5	5	8	5	4	2	6	14	24	57	68	62	75	64	59	47	43	32	31	20	8	2	7	9	10	10	5	9	23	30	20	19
	LaJalousie-Vreed-en-Hoop																																				
	Canals Polder																																				
4	Golden Grove-Victoria	16	8	10	4	5	4	7	8	3	4	9	16	17	34	50	43	39	54	42	38	33	22	18	16	1	0	4	0	0	3	1	6	6	20	14	18
	Cane Grove																																				
6	Black Bush Polder	10	5	6	2	2	4	3	0	2	2	6	13	14	33	39	42	43	35	35	30	20	15	12	10	2	0	3	1	5	1	6	6	6	17	10	13
	Lots 52-74																																				
	Crabwood Creek																																				

Design Rainfalls at 90% non-exceedance probability - not a homogeneous sequence

Region	Drainage & Irrigation Area	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
3	Vergenogen-Bonasika	10	7	4	2	1	2	3	2	2	1	3	5	18	34	45	47	54	57	40	34	38	22	20	13	5	2	4	1	1	10	2	6	8	29	17	15
	Den Amstel-Fellowship	6	6	5	2	1	3	2	2	2	1	4	6	14	31	53	45	53	55	43	27	35	18	23	8	5	1	2	3	2	6	1	6	9	21	11	12
	LaJalousie-Vreed-en-Hoop																																				
	Canals Polder																																				
4	Golden Grove-Victoria	6	3	4	0	2	1	4	2	1	1	3	6	6	22	26	29	33	41	30	28	28	8	10	11	0	0	0	0	0	0	0	2	1	14	10	13
	Cane Grove																																				
6	Black Bush Polder	2	1	4	1	1	0	1	0	0	0	3	6	8	23	24	25	23	25	18	16	12	7	4	2	0	0	0	0	1	0	3	3	1	7	5	7
	Lots 52-74																																				
	Crabwood Creek																																				

Table 3.8

Design rainfalls for irrigation demands in water resource assessments

Design rainfalls at 80% non-exceedance probability, year of data with annual total closes to 80% non-exceedance

Region	Drainage & Irrigation Area	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
3	Vergenogen-Bonasika	96	22	33	20	33	15	17	22	30	36	50	74	57	138	161	92	114	157	88	58	127	87	81	61	62	26	18	7	22	17	21	25	43	88	60	124
	Den Amstel-Fellowship	70	54	98	31	17	13	23	132	25	83	10	57	52	82	107	88	83	55	121	46	51	18	84	39	16	26	36	66	40	55	43	45	66	65	40	72
	LaJalousie-Vreed-en-Hoop																																				
	Canals Polder																																				
4	Golden Grove-Victoria	12	14	40	8	21	14	20	10	41	55	70	36	42	70	101	80	108	98	86	66	62	55	17	16	36	25	21	16	56	0	42	30	30	44	20	51
	Cane Grove																																				
6	Black Bush Polder	7	16	22	33	25	6	13	39	13	19	20	27	51	49	66	57	112	67	46	49	24	35	32	68	43	7	9	9	10	20	19	12	78	54	31	28
	Lots 52-74																																				
	Crabwood Creek																																				

Design rainfalls at 90% non-exceedance probability, year of data with annual total closes to 90% non-exceedance

Region	Drainage & Irrigation Area	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
3	Vergenogen-Bonasika	32	26	32	22	6	2	32	33	4	4	7	12	87	67	83	44	178	42	78	97	93	68	82	60	71	10	37	14	88	60	64	26	132	124	50	15
	Den Amstel-Fellowship	37	22	8	17	3	4	10	1	8	74	15	43	92	134	73	52	164	85	176	104	86	67	65	58	47	40	80	24	40	26	12	6	60	40	31	15
	LaJalousie-Vreed-en-Hoop																																				
	Canals Polder																																				
4	Golden Grove-Victoria	67	9	6	20	10	31	26	14	33	52	13	18	50	43	59	79	56	63	77	47	51	45	114	12	23	22	27	21	10	7	6	6	31	33	33	48
	Cane Grove																																				
6	Black Bush Polder	37	35	31	43	21	8	22	5	16	35	25	47	59	58	49	62	123	38	67	35	43	32	16	14	14	21	47	13	19	15	4	9	12	57	11	26
	Lots 52-74																																				
	Crabwood Creek																																				

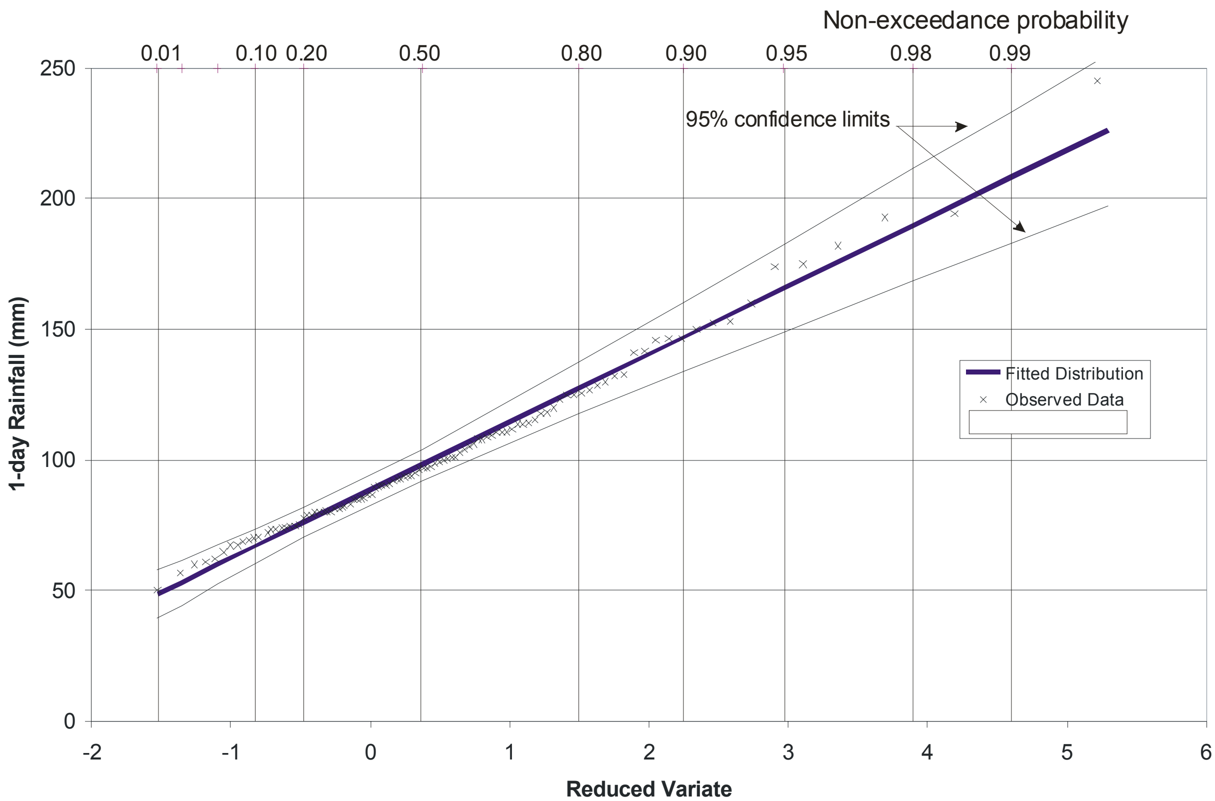

Figure 3.15 Annual maximum 1-day rainfalls at Georgetown

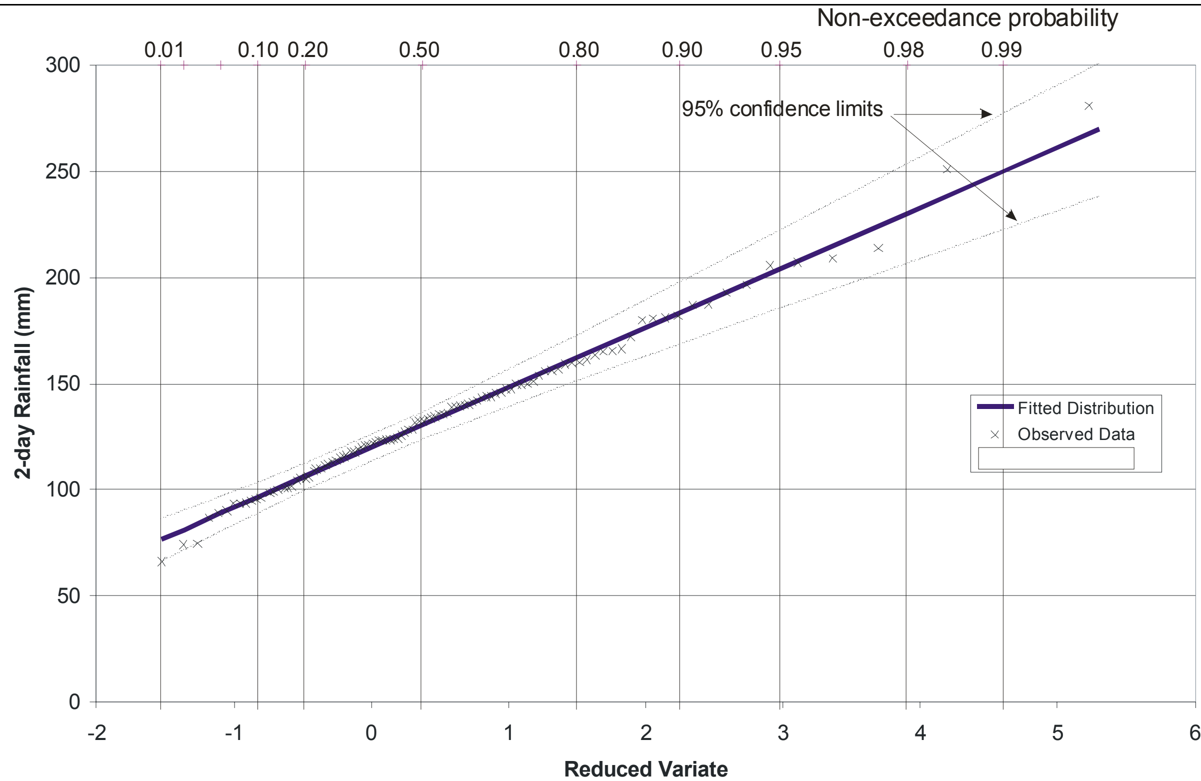

Figure 3.16 Annual maximum 2-day rainfalls at Georgetown

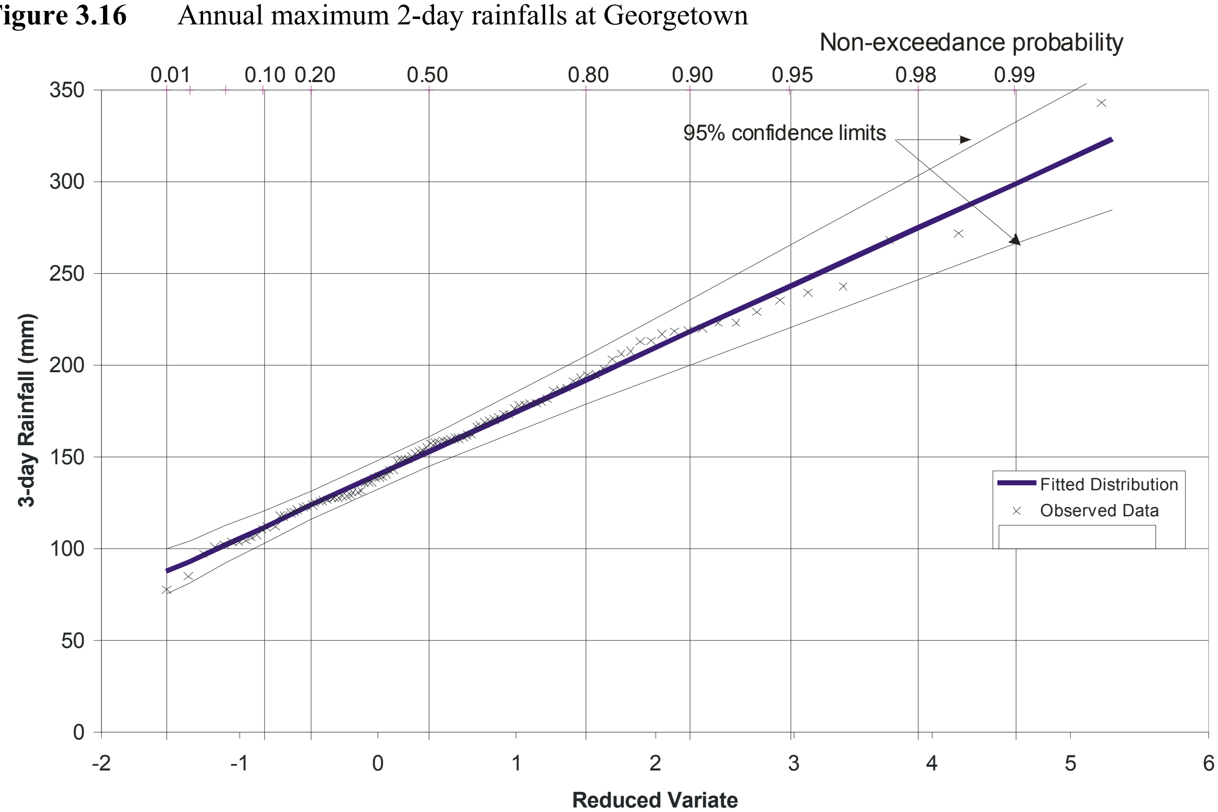

Figure 3.17 Annual maximum 3-day rainfalls at Georgetown

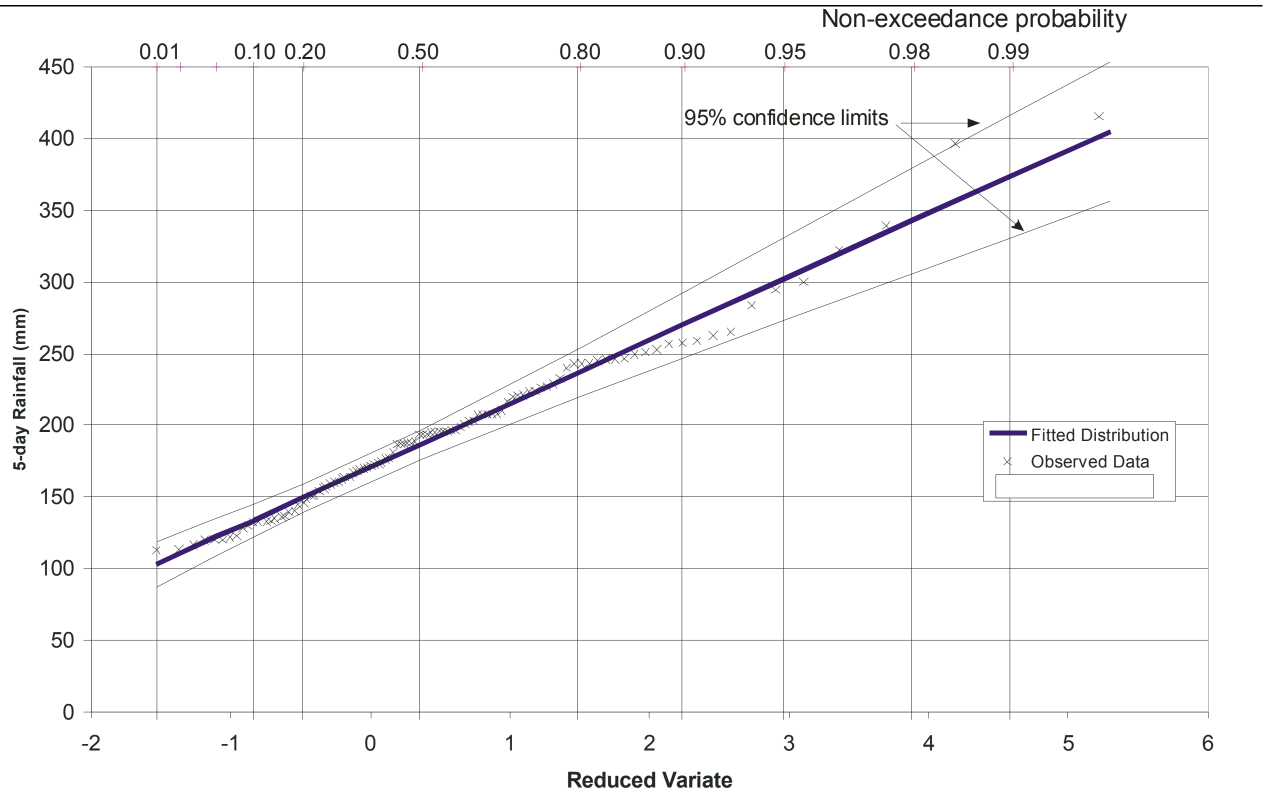

Figure 3.18 Annual maximum 5-day rainfalls at Georgetown

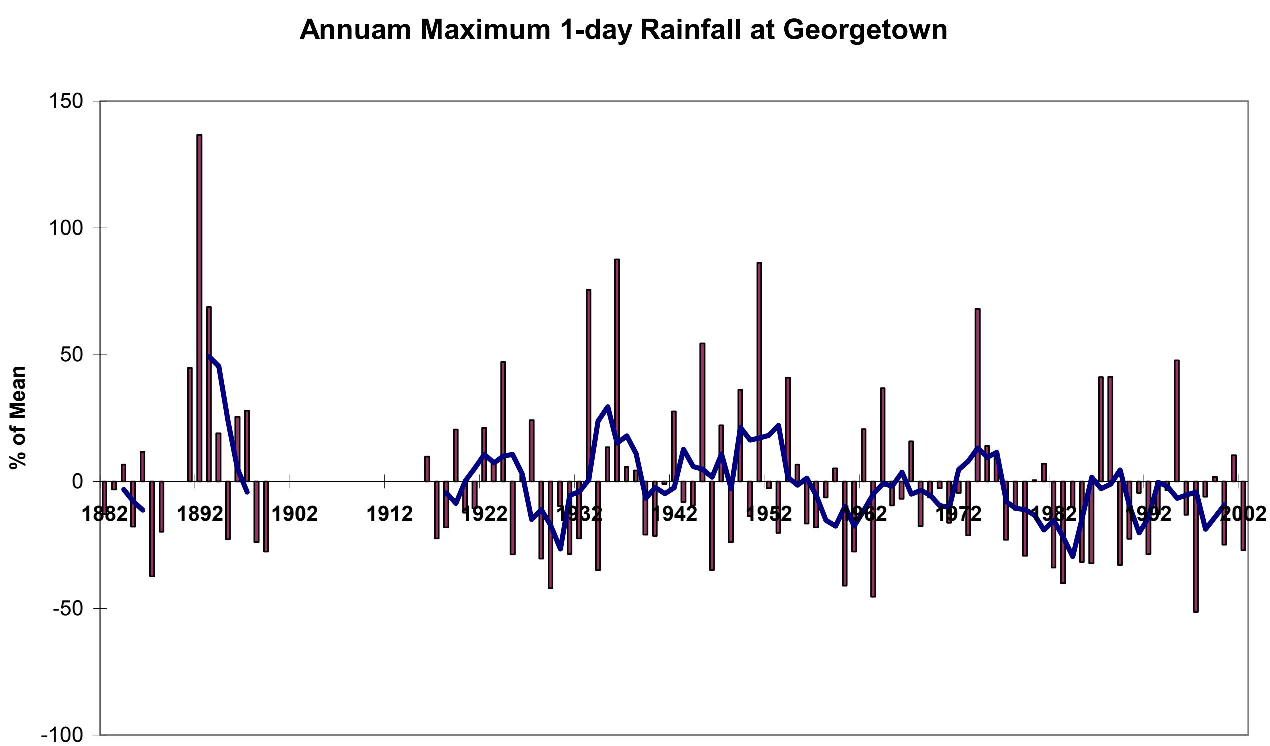

Figure 3.19 Trend in annual maximum 1-day rainfall at Georgetown

Table 3.9

Tests for trend and persistence in Georgetown annual maximum 1-day rainfall

Test	Expected	Observed
GENERAL RANDOMNESS TESTS:		
1) NUMBER OF MEDIAN-CROSSES	51 +/- 14	57
2) NUMBER OF TURNING-POINTS	68 +/- 8	64
PERSISTANCE TESTS		
3) FIRST-ORDER SERIAL CORRELATION	-0.01 +/- 0.19	0.07
4) SPEARMAN RANK TEST	-0.01 +/- 0.20	0.15
TREND TESTS		
5) RANK ORDER TEST	-0.01 +/- 0.19	-0.08
6) MANN-WHITNEY U TEST	1352 +/- 301	1156
7) WALD-WOLFOWITZ RUNS TEST	53 +/- 10	60

Table 3.10

Rainfalls for drainage design (mm)

Region	Drainage and Irrigation Area	Non-Exceed. Prob.	1-day	2-day	3-day	5-day
3	Vergenogen-Bonasika	0.5	105	140	169	210
		0.8	132	175	209	264
		0.9	150	198	236	299
3	Den Amstel-Fellowship	0.5	89	122	143	177
	La Jalousie-Vreed-en-Hoop	0.8	114	155	180	222
	Canals Polder	0.9	131	177	204	251
4	Golden Grove-Victoria	0.5	92	112	130	164
	Cane Grove	0.8	129	157	178	221
		0.9	153	186	210	258
6	Black Bush Polder	0.5	79	105	120	150
	Lots 52 to 74	0.8	109	143	162	200
	Crabwood Creek	0.9	129	168	190	233

3.6.4 Drainage Design

For drainage design purposes, it is reasonable to assume that the soils are close to saturation at the onset of extreme rainfall. Infiltration rates in the irrigation areas are very low, and almost all of the storm rainfall will require to be drained. The period in which drainage must be effected depends on the crop being grown. Some rice varieties may be submerged for periods of up to 5 days in clear water without suffering significant damage. For sugar and ground provisions the period for which inundation can be tolerated is less. At this stage the agronomic conditions in the project area have not been fully established, and general drainage rates have been determined for each drainage and irrigation area, for different inundation periods. In calculating drainage requirements for rice, it has been assumed that 100 mm of field storage exists at the start of a storm. The required drainage rates for rice and non-rice crops are given in Tables 3.11 and 3.12 respectively.

Table 3.11
Required drainage rates for rice (mm/day)

Region	Drainage and Irrigation Area	Non-Exceed. Prob.	Inundation Period			
			1-day	2-days	3-days	5-days
3	Vergenogen-Bonasika	0.5	5	20	23	22
		0.8	32	38	36	33
		0.9	50	49	45	40
3	Den Amstel-Fellowship	0.5	0	11	14	15
	La Jalousie-Vreed-en-Hoop	0.8	14	28	27	24
	Canals Polder	0.9	31	39	35	30
4	Golden Grove-Victoria	0.5	0	6	10	13
	Cane Grove	0.8	29	29	26	24
		0.9	53	43	37	32
6	Black Bush Polder	0.5	0	3	7	10
	Lots 52 to 74	0.8	9	22	21	20
	Crabwood Creek	0.9	29	34	30	27

The above figures compare favourably with the figure quoted in many previous reports of 1.5 inches / day for rice (38 mm/day).

Table 3.12
Required drainage rates for non-rice crops

Region	Drainage and Irrigation Area	Non-Exceed. Prob.	Inundation Period			
			1-day	2-days	3-days	5-days
3	Vergenogen-Bonasika	0.5	105	70	56	42
		0.8	132	88	70	53
		0.9	150	99	79	60
3	Den Amstel-Fellowship	0.5	89	61	48	35
	La Jalousie-Vreed-en-Hoop	0.8	114	78	60	44
	Canals Polder	0.9	131	89	68	50
4	Golden Grove-Victoria	0.5	92	56	43	33
	Cane Grove	0.8	129	79	59	44
		0.9	153	93	70	52
6	Black Bush Polder	0.5	79	53	40	30
	Lots 52 to 74	0.8	109	72	54	40
	Crabwood Creek	0.9	129	84	63	47

A number of previous reports have indicated drainage requirements of 2 inches per day for sugar, and 3 inches per day for ground provisions. The above data are consistent with this although more refined geographically. For design purposes it would be pragmatic to adopt no more than two drainage rates, for a particular inundation period, across the entire project area.

3.6.5 Crop Water Requirements

Crop water requirements have been determined at 80% and 90% non-exceedance probabilities. Calculations have been made using the potential evapotranspiration estimates for Georgetown, and the ten day design rainfalls for Vergenogen-Bonasika in Region 3, and Black Bush in Region 6. These were chosen to give the maximum range in irrigation requirements.

The rainfall data in Table 3.7 and potential evapotranspiration data in Table 3.2 have been used to determine peak irrigation demands for crops of rice and sugar. For sugar, planting dates of 10 October and 10 March have been assumed, with two irrigation blocks separated by 10 days on each planting date. Effective rainfall was calculated using the USDA approach, field efficiency taken to be 70%. For rice, two crops have also been assumed, with planting starting on 10 April, and 1 October in four blocks separated by 10 days. For rice land preparation of 150 mm has been allowed in the ten days prior to planting, infiltration losses of 0.5 mm/day have been assumed, and effective rainfall computed on the assumption of 100 mm available field storage. Field efficiency has been assumed to be 85%. The maximum irrigation duties calculated are summarised in Table 3.13.

Table 3.13

Calculated maximum irrigation duties (l/s/ha)

Crop	Location	80% non-exceedance	90% non-exceedance
Sugar	Vergenogen-Bonasaki	0.76	0.83
	Black Bush Polder	0.84	0.88
Rice	Vergenogen-Bonasaki	0.90	1.03
	Black Bush Polder	0.96	1.03

Ten day irrigation requirements for use in water resource evaluation have been calculated on the basis of the ten day rainfalls given in Table 3.8, and the same assumptions on efficiency, effective rainfall and land preparation as outlined above. The computed irrigation requirements are given in Table 3.14. It should be noted that no account has been taken of sub-irrigation from capillary flux. The water table in the irrigation areas is high, and capillary flux from the water table will certainly be capable of meeting part of the crop water requirement for established sugar crops, particularly in periods of drought. Further investigation of soils properties is required to determine the potential of capillary flux to partially meet water needs.

Table 3.14

Calculated field irrigation requirements

Crop	Non-Exceed. Prob.	Region	MAR			APR			MAY			JUN			JUL			AUG		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Sugar	80%	3	0.0	0.4	0.1	0.6	0.6	0.8	0.5	0.0	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		4	0.8	0.7	0.4	0.9	0.7	0.8	0.5	0.7	0.3	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
		6	0.7	0.4	0.3	0.2	0.3	0.6	0.4	0.1	0.6	0.4	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0
	90%	3	0.5	0.6	0.7	0.7	0.9	1.0	0.6	0.6	0.8	0.2	0.6	0.3	0.0	0.0	0.0	0.1	0.0	0.0
		4	0.0	0.8	0.9	0.7	0.9	0.5	0.5	0.7	0.4	0.0	0.6	0.5	0.1	0.1	0.0	0.0	0.0	0.0
		6	0.2	0.2	0.3	0.2	0.4	0.6	0.3	0.7	0.6	0.2	0.4	0.0	0.0	0.0	0.1	0.0	0.0	0.3
Rice	80%	3	0.0	0.1	0.0	0.5	0.5	0.8	0.8	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		4	0.5	0.3	0.1	0.6	0.6	0.8	0.8	0.5	0.2	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
		6	0.5	0.3	0.2	0.5	0.6	0.8	0.8	0.2	0.5	0.4	0.4	0.3	0.1	0.1	0.0	0.1	0.0	0.0
	90%	3	0.2	0.2	0.2	0.5	0.2	0.9	0.8	0.5	0.6	0.1	0.5	0.3	0.0	0.0	0.0	0.2	0.0	0.1
		4	0.0	0.4	0.3	0.5	0.2	0.6	0.7	0.5	0.3	0.0	0.5	0.4	0.1	0.2	0.1	0.0	0.1	0.1
		6	0.2	0.1	0.1	0.4	0.6	0.8	0.7	0.6	0.5	0.2	0.3	0.1	0.0	0.0	0.2	0.1	0.0	0.3

Crop	Non-Exceed. Prob.	Region	SEP			OCT			NOV			DEC			Jan			Feb		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Sugar	80%	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.2	0.0
		4	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.6	0.0	0.3	0.4	0.3	0.6	0.0
		6	0.2	0.1	0.4	0.2	0.3	0.0	0.1	0.5	0.5	0.5	0.5	0.4	0.4	0.6	0.0	0.1	0.3	0.2
	90%	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.2	0.6	0.0	0.0	0.3	0.7
		4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.4	0.6	0.7	0.7	0.4	0.4	0.4	0.0
		6	0.0	0.3	0.2	0.3	0.5	0.5	0.4	0.3	0.1	0.4	0.3	0.5	0.7	0.6	0.6	0.1	0.6	0.3
Rice	80%	3	0.0	0.0	0.0	0.3	0.2	0.4	0.5	0.3	0.3	0.1	0.2	0.2	0.3	0.3	0.1	0.0	0.1	0.0
		4	0.0	0.0	0.0	0.3	0.6	0.7	0.6	0.4	0.4	0.4	0.0	0.7	0.2	0.3	0.4	0.2	0.5	0.0
		6	0.1	0.0	0.1	0.4	0.5	0.3	0.5	0.6	0.6	0.5	0.5	0.4	0.5	0.6	0.0	0.1	0.3	0.2
	90%	3	0.0	0.0	0.0	0.3	0.0	0.4	0.3	0.4	0.0	0.4	0.0	0.2	0.2	0.5	0.0	0.0	0.2	0.4
		4	0.0	0.0	0.0	0.4	0.0	0.8	0.8	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.4	0.4	0.3	0.0
		6	0.0	0.1	0.0	0.5	0.6	0.7	0.9	0.4	0.1	0.5	0.4	0.5	0.7	0.6	0.6	0.1	0.6	0.3

4 Water Resource Investigations

4.1 Introduction

The water resources investigations are required to determine the reliability with which irrigation demands can be met, and to identify measures that can be taken to augment the resource and utilize it more efficiently, thereby improving reliability. The water resources investigations cannot be limited to the nine irrigation and drainage areas that constitute the project, but must be inclusive of the entire resource system of which specific drainage and irrigation areas are part. Thus for the areas in Region 3, the entire catchment of the Boerasirie Conservancy and all demands on that resource must be considered. Similarly for those areas in Region 3, the entire catchment of the East Demerara Conservancy and all demands on its resource must be considered. In Region 6, all irrigated areas are supplied from the Canje River and the link canal to the Berbice River, and again all demands on the system must be considered.

An important aspect of the water resource investigations will be in considering the efficiency of water use within the drainage and irrigation areas. The soils have very low infiltration rates, the water table is high, and high field efficiencies should be achievable. The canals are used for transporting sugar cane to the sugar factories, and navigation losses are undoubtedly an issue. However, both field and canal losses ultimately end up in the drainage system, and as gradients are very low, drainage water can be re-circulated to the canal system in dry periods. It should be possible to achieve high overall system efficiencies.

A schematic of the drainage and irrigation system is shown in Figure 4.1. The only significant unavoidable loss from the system should be in evaporation from drains and canals, although clearly there recirculation carries a cost that must be enumerated.

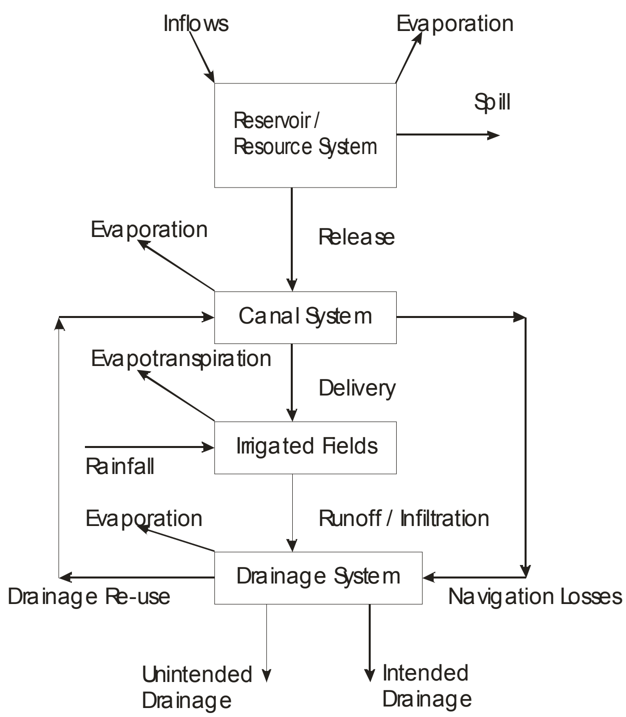

Figure 4.1 Schematic of the drainage and irrigation system

4.2 The Boerasirie Conservancy

Almost all of the physical data relating to the Berasirie Conservance originate from the studies by Mr Hutchinson in the early 1950s. The conservancy has a total catchment area of 404 km^2. The elevation – area – storage characteristics in use are those prepared by Mr Hutchinson in 1951. This is a cause for some concern, as inevitably there will have been loss of storage since that time, mostly through eutrophication as sediment inflow does not seem to be high. The elevation curve for the conservancy is shown in Figure 4.2.

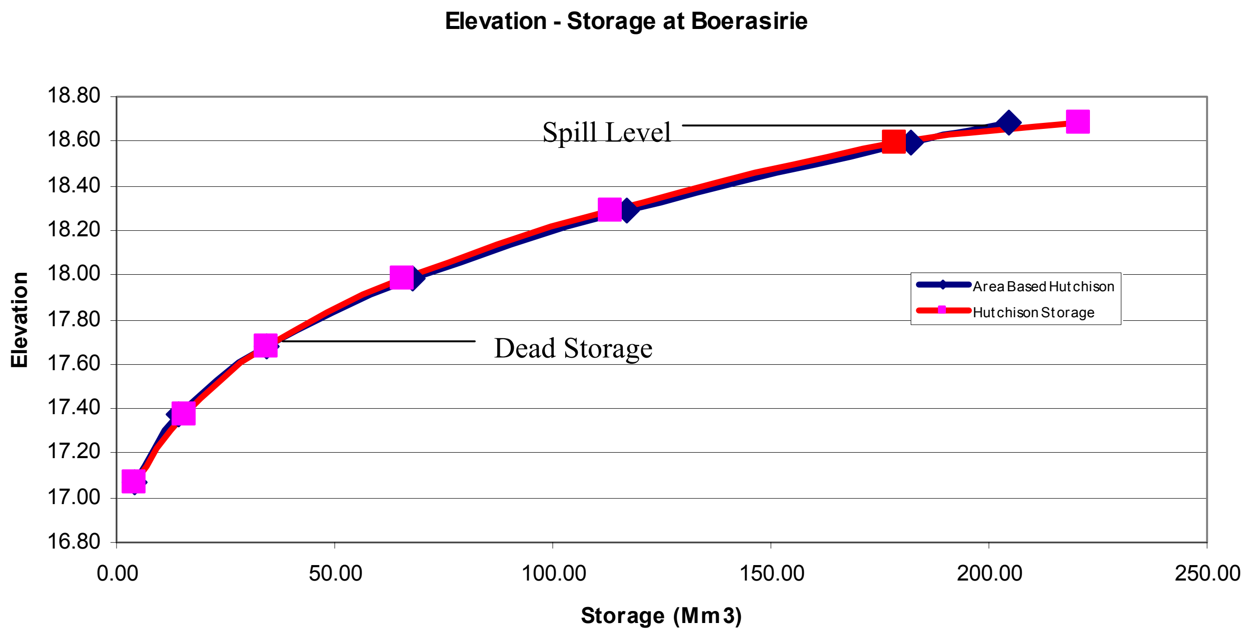

Figure 4.2 Eleavation – storage curve for Boerasirie Conservancy (Hutchinson, 1951)

The live storage in the conservancy is 187 Mm^3. The reason for plotting two curves in Figure 4.2 was to check the consistency of the elevation-area-storage curve. The line in blue represents storage calculated from change in area, and the other is Hutchinson's storage curve. The two curves are almost identical and the data are therefore consistent.

The total area irrigated from Boerasirie Conservancy is 27,032 ha. In broad terms, the cropping is 39% sugar, 32% rice, and 29% mixed crops. In very broad terms, the storage available is 6,900 m^3/ha of irrigated land, when evaporation from the conservancy is ignored. Preliminary assessment of irrigation requirements has indicated that the demand for sugar in the February – May period is about 5,000 m^3/ha, and for rice is about 3,000 m^3/ha, and an 80% non-exceedance probability. Clearly reservoir water balance studies will be required to assess the realistic conservancy yield, and this figure will be significantly less than 6,900 m^3/ha.

It is intended to use a rainfall-runoff model, calibrate on the streamflow records for the Loo River, to synthesise a time series of inflows to the conservancy. This will require additional rainfall data collection to be carried out. A reservoir simulation model will be used to determine reliable yields. Information will also be collected on existing irrigation practice to ascertain the extent to which sub-irrigation from the water table meets crop demand.

4.3 East Demerara Conservancy

Like the Boerasirie Conservany, most of the data on physical characteristics for the East Demerara Conservancy originate from the studies of Mr Hutchinson in 1951. The elevation-storage characteristics for the conservancy are shown in Figure 4.3.

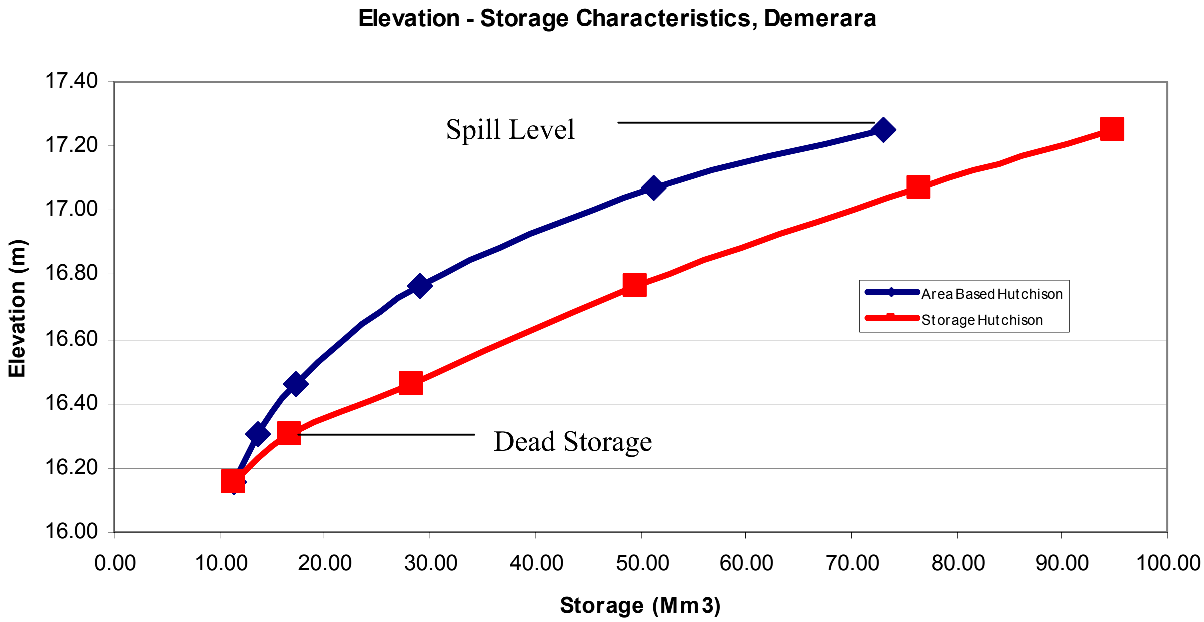

Figure 4.3 Elevation – storage characteristics for East Demerara Conservancy (Hutchinson, 1951)

There is a discrepancy in the elevation-area-storage curves available for East Demerara, as can be seen from Figure 5.3. When the storage curve is computed from the area curve, the storage differs significantly from that attributable to Hutchinson. Either the elevation-storag curve, or the elevation-area curve is in error. Whichever is the case, there will be a significant impact on water balance calculations. One curve gives a live storage of 78 Mm^3, and the other a figure of 59 Mm^3. The total catchment area of the conservancy is 518 km^2.

The East Demerara Conservancy irrigates an area of about 17,900 ha, of which about 73% is under sugar production. The available storage is thus about 4,300 m^3/ha. Preliminary analysis indicates an irrigation requirement of about 4,000 m^3/ha for sugar in the February – May period at 80% non-exceedance probability. Water resources may therefore be a problem in East Demerara. It is understood that water is pumped in to the conservancy from the Mahaico River.

The intended approach to analysis is as for the Boerasirie Conservancy. Analysis will be extended to look at the Mahaico River also.

The East Demerara Conservancy is used to supply potable water to Georgetown. Deliveries in 2003 have been of the order of 2.5 Mm^3 per month. These supplies and any planned changes will be taken into account in the water resources assessment for East Demerara.

4.4 The Canje River

Irrigation supplies in Region 6 are obtained from the Canje River, augmented by diversions through the Tarani Canal from the Berbice River. Analysis will consider low flow frequencies in each of these rivers, and the impacts of increased abstractions. There has been a number of previous investigations of the Canje Basin, and these provide a foundation for the analysis to be undertaken. As far as is possible, use will be made of existing streamflow records. The raingauge network may not be adequate to permit rainfall-runoff modelling.