Engineering Assessment of 2006 Floods
February 2006

APPENDIX 4 RAINFALL

Analysis of hydro-meteorological and hydraulic conditions in Guyana Regions 2 to 6 and Georgetown
during
December 2005 and January 2006

1. General

1.1 Introduction

Guyana is administratively dived into a number of Regions. The Regions along the coast are Region 1 in the west bordering Venezuela to Region 6 at the border with Surinam. The objective of this Appendix is to give an assessment of the hydrological and hydraulic conditions in the Regions 2 to 6 and Georgetown in December 2005-January 2006, which lead to the flooding particularly in the Regions 2 and 5. In the subsequent chapters the rainfall events of December 2005 and January 2006 are discussed and the extremity of the events is estimated to arrive at a return period of rainfall events which cause flooding. Furthermore an inventory is given of the relief capacity of the water conservancies to assess needs for further upgrading of this capacity.

Prior to that, some relevant features of the climatic variability in the coastal zone of Guyana are presented to value the rainfall and flooding processes. Attention is also given to sea level rise.

This Appendix is based on the following data sources and reports:

1. Basin maps by Region, scale 1:100,000, Lands and Surveys Department
2. Rainfall data: Hydro-meteorological Service, Ministry of Agriculture, Mahaica-Mahaicony-Abary Agricultural Development Authority and NDIA
3. Water level data: Hydro-meteorological Service, Ministry of Agriculture, Mahaica-Mahaicony-Abary Agricultural Development Authority and NDIA
4. Draft Report on Conservancy Flood Management Modelling. Mott MacDonald, May 2005
5. Conservancy Flood Management Modelling, Model Update Report. Mott MacDonald, August 2005
6. Guyana Drainage and Irrigation Systems Rehabilitation Project: Hydrology and Water Resources. Mott MacDonald, HTS Development, CEMCO, SRKN'gineering & Associates, and F&A Consultants, June 2004

1.2 Climatic variability

Seasonal and annual rainfall

Rainfall records are available for Georgetown since 1882. In 1940 the network was further extended, but most stations have records from 1974 onward.

In the coastal region there are two distinct rainy seasons induced by the meridional migration of the ITCZ. This results in the primary wet season in May-July and a second rainy season in November to January during the southward migration of the ITCZ. This pattern is clearly observed from the rainfall statistics of Georgetown Botanical Garden as presented in Figure 1.1, which pattern is very characteristic for the rest of the coastal zone. It is observed that the rainfall in the primary wet season May-July is largest and also very dependable in view of its low variation coefficient, in contrast to the second rainy season of November-January, whose variation coefficient is twice as large. Part of this variation can be explained by the latter's correlation with El Nino. Due to this larger variability, the rainfall in the months December and January generally have caused more flood events along the coast than the rainfall in the primary wet season May-July.

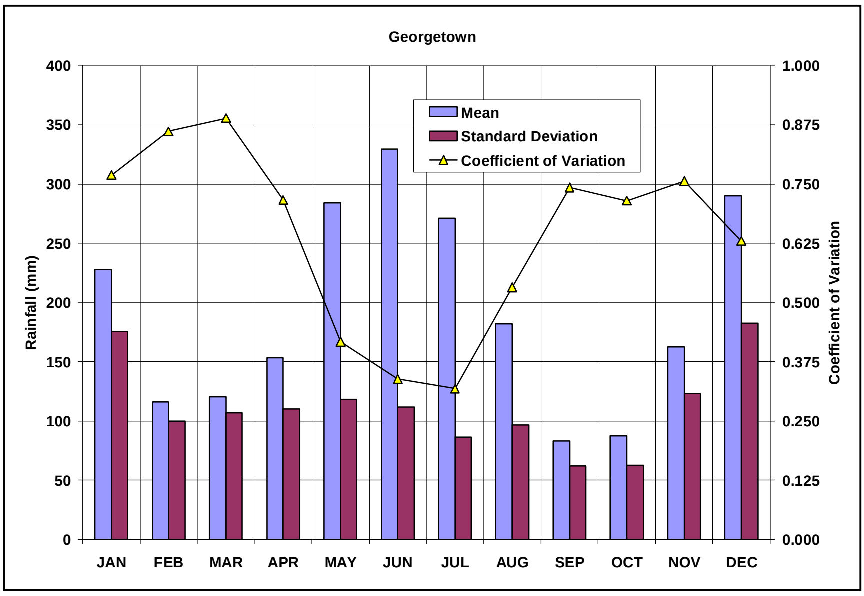

Figure 1.1

Statistics of monthly rainfall in Georgetown Botanical Gardens

The annual rainfall in the Regions 2 to 6, based on normals from selected stations, is presented in Table 1.1. It is observed that the annual rainfall in the coastal zone varies somewhat from west to east, with the largest values in the Regions 3 and 4 near the mouths of the Essequibo and Demerara Rivers, and the lowest towards the border with Surinam.

Table 1.1 Annual average rainfall in Regions 2 to 6

Region	Annual rainfall (mm)
2	2226
3	2401
4	2304
5	1955
6	1905

The long term development of the annual rainfall may be observed from Figure 1.2, which displays an estimate of the rainfall in Region 4 based on the records of Georgetown Botanical Gardens, Timehri and Ogle. From the Figure it is observed that the annual rainfall is fairly stable with a variation coefficient of 0.2, whereas no trend can be observed in the annual totals.

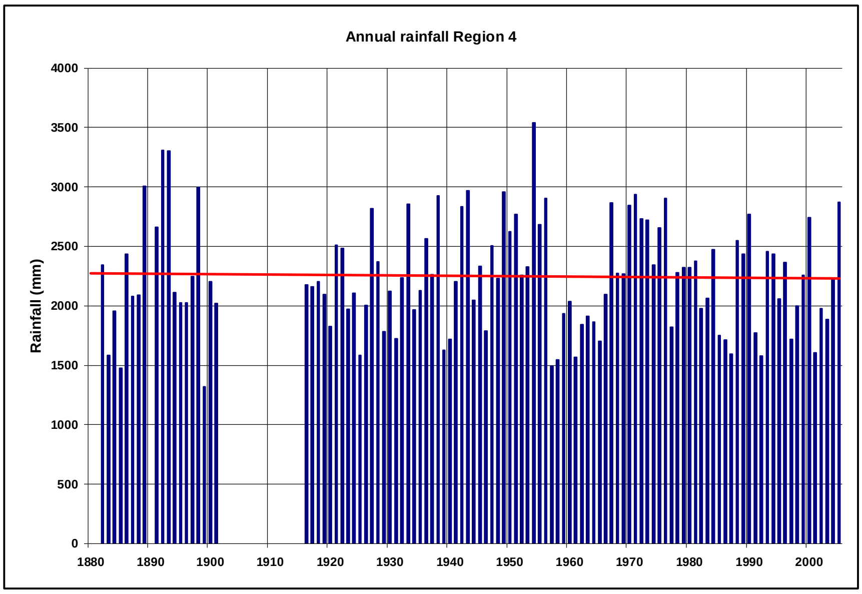

Figure 1.2

Annual rainfall in Region 4 with trend line

ENSO effect on rainfall

In the Final Report on Hydrology and water Resources of the Guyana Drainage and Irrigation Systems Rehabilitation Project (Mott MacDonald et al. 2004) the validity of the statements made in various studies, which state that Guyana experiences droughts during El Nino events and heavy rainfall and flooding during La Nina events, has been investigated. 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. In the above mentioned investigation the following classification has been used:

- an El Nino event (or warm episode) is one in which the five month running mean values of the SOI remains below -0.5 standard deviations for a period of five months or longer
- a La Nina event (or cold episode) is one in which the five month running mean values of the SOI remains above 0.5 standard deviations for a period of five months or longer, and
- periods falling into neither El Nino or La Nina classifications are considered to be neutral.

Adopting this classification, an analysis has been carried out of monthly SOI and rainfall at Georgetown Botanical Gardens using the entire period of historical record.

The analysis comprised seasonal data, of which in this case only the wet seasons are of interest. The results for the seasons May-August and November-January are displayed in the Figures 1.3 and 1.4 based on a gamma distribution fitted to the data in the classes. From Figure 1.3 it is revealed that there is basically no El Nino effect on the rainfall in the rainy season May to August. However, there is a distinct El Nino effect on the rainfall in the rainy season November to January as may be observed from Figure 1.4. The latter observation implies that for those regions were flooding is generally produced by the rains in November to January the SOI provides a proper indicator for an extra flood preparedness status.

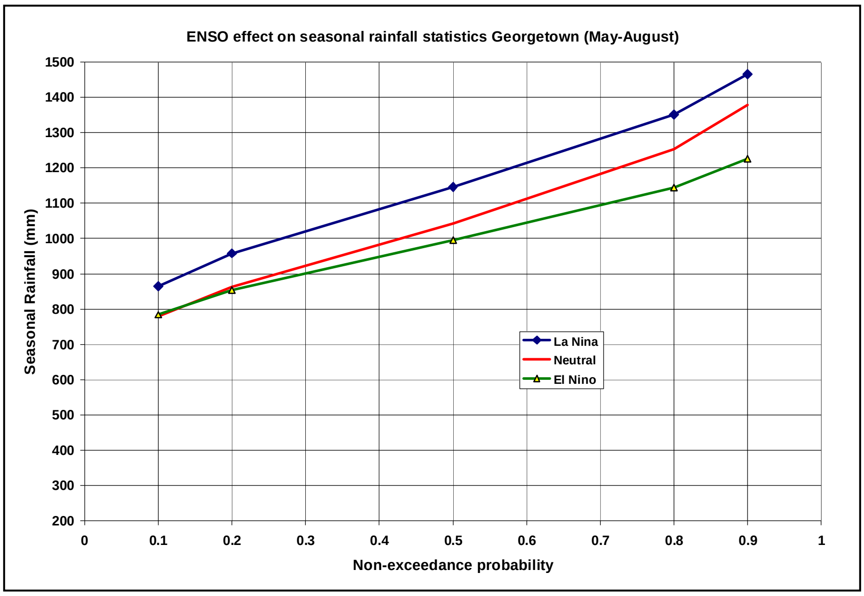

Figure 1.3

ENSO effect on seasonal rainfall in Georgetown for the Season May-August

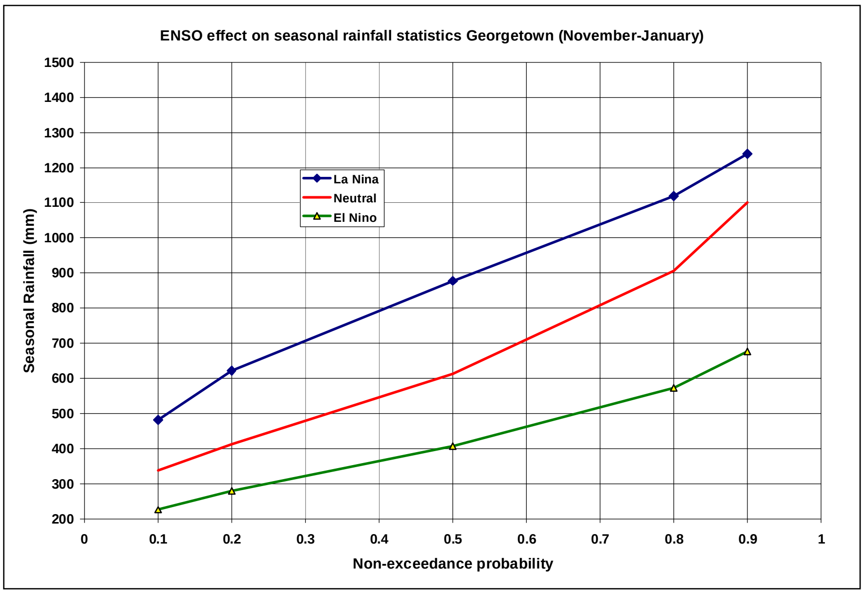

Figure 1.4

ENSO effect on seasonal rainfall in Georgetown for the Season November-January

1.3 Sea level rise

Sea level rise will reduce the gravity drainage capacity. Due to rising sea levels the duration that sluices can be operated to release water will reduce. Best estimates of the sea level rise at the coast of Guyana amount 4 mm/year (Mott MacDonald, 2004).

2. Region 2

2.1 Description of basins

Figure 2.1 shows the catchment areas of Region 2. For its greater part the Region is drained by the Pomeroon River, covering a drainage area of over 3,000 km^2. From source to mouth its length is about 150 km. The river debouches into the Atlantic Ocean, north-west of Charity. About 1/3 of the basin drains downstream of Charity by tributaries entering the Pomeroon on its left bank; these comprise the Akawani River and further downstream the Wakapau River. The river is tidal to well beyond Charity. The mouth of the river is partly silted up.

The south-eastern part of Region 2 is drained by the Supenaam River with a catchment area of roughly 650 km^2, which debouches into the Essequibo River. North of this basin the Ituribisi River drains a small area in the west of Region 2. Its waters are stored in the Ituribisi Conservation for water supply to the cultivated coastal zone along the western fringe of the Region. Further supply is created by the Capoey, Mainstay and Tapakuma Lakes, north of Ituribisi.

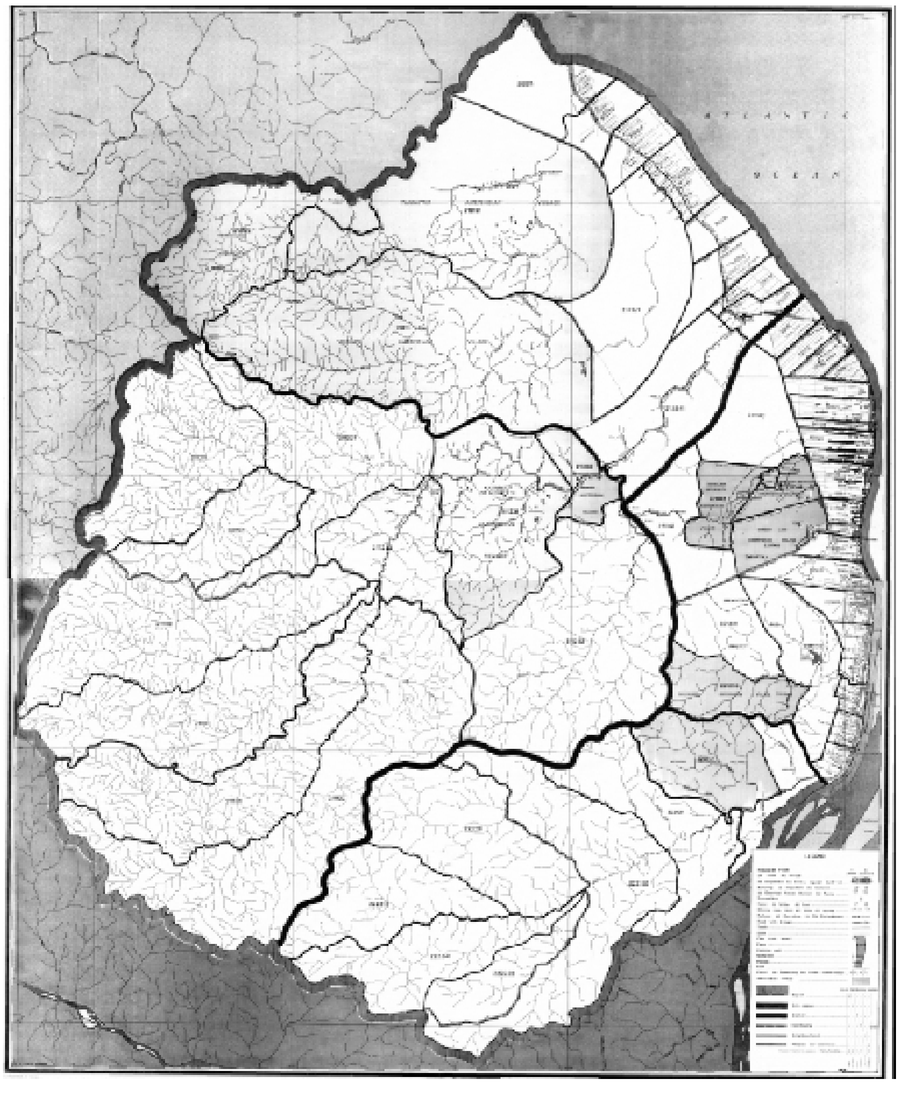

Figure 2.1 Drainage area map of Region 2

2.2 Rainfall normals

The monthly rainfall normals for Region 2 as an average of the normals of the stations Charity, Anna Regina and Onderneeming are presented in Table 2.1 and Figure 2.2. It is observed that there are two distinct wet periods, viz. May to July and November to January, with May and June being the wettest months on average. The annual average rainfall in Region 2 amounts 2226 mm.

Table 2.1 Monthly rainfall normals in Region 2

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Charity	182.6	105.9	107.4	158.7	312.3	339.4	283.9	207.6	120.7	134.4	209.7	331.7
Anna Regina	167.3	72.4	88.2	123.8	282.5	301.0	246.7	180.2	94.7	108.7	188.8	253.2
Onderneeming	147.0	103.3	82.6	176.1	298.5	279.3	200.3	175.1	133.8	106.2	162.8	210.8
Average	165.6	93.9	92.7	152.9	297.8	306.6	243.6	187.6	116.4	116.4	187.1	265.2

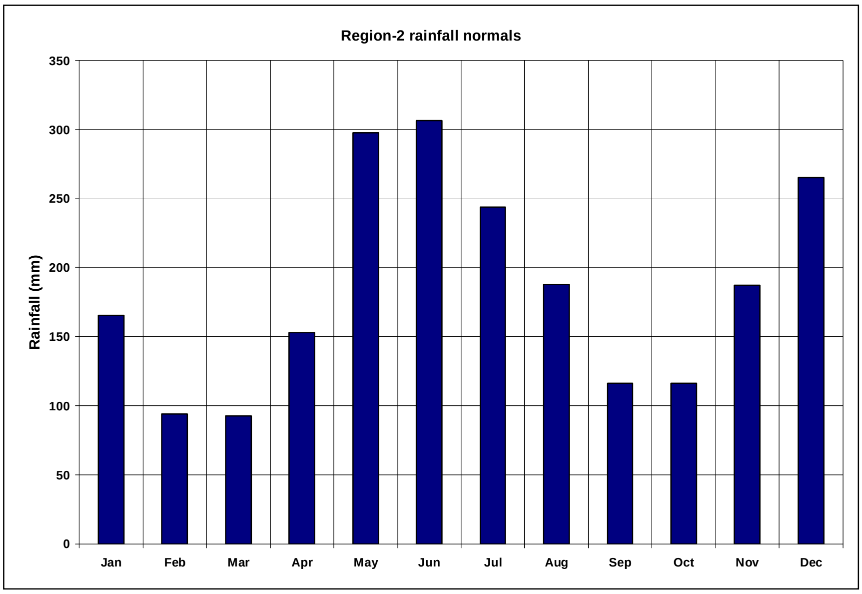

Figure 2.2 Monthly rainfall normals for Region 2 as the average of Stations Charity, Anna Regina and Onderneeming

The normals are used to assess the severity of the rainfall in December 2005 and January 2006, which caused the flooding along the lower Pomeroon river and elsewhere in Region 2. It is noted, though, that above normals may not give an entirely unbiased picture of the average rainfall distribution in Region 2 as the data is based on 3 stations near the coast in absence of data for the upper areas.

2.3 Rainfall from November 2005 to January 2006

The rainfall in Region 2 in the months November 2005 to January 2006 is shown in Table 2.2 and Figure 2.3. In the Table and Figure a comparison is made with the rainfall normals and the rainfall in the season one year ago, when in the Regions 3 to 5 wide spread flooding occurred.

Table 2.2 Monthly rainfall November to January 2005-2006 compared with 2004-2005 and normals

Season	November		December		January	
	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal
2004-2005	11.3	6	172.3	65	817.1	493
2005-2006	209.4	112	540.1	204	908.1	548
Normal	187.1		265.2		165.6	

From Table 2.2 and Figure 2.3 it is observed that in the November 2005 - January 2006 rainy season, although the November rains were about normal, the December and particularly January totals were far above normal. The December total was twice the normal value, whereas the January total was even 5.5 times the January normal.

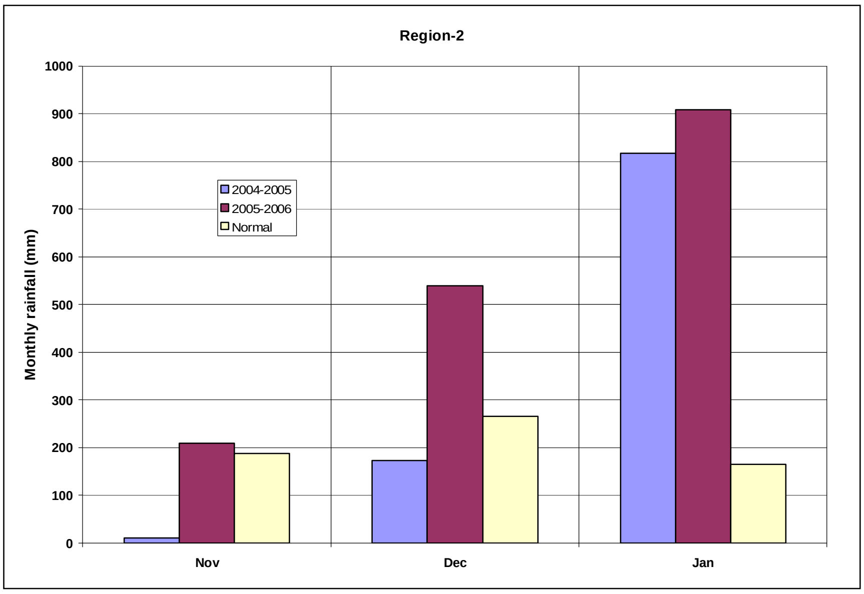

Figure 2.3

Monthly rainfall in Region 2 from November to January 2005-2006 compared with previous year and normals

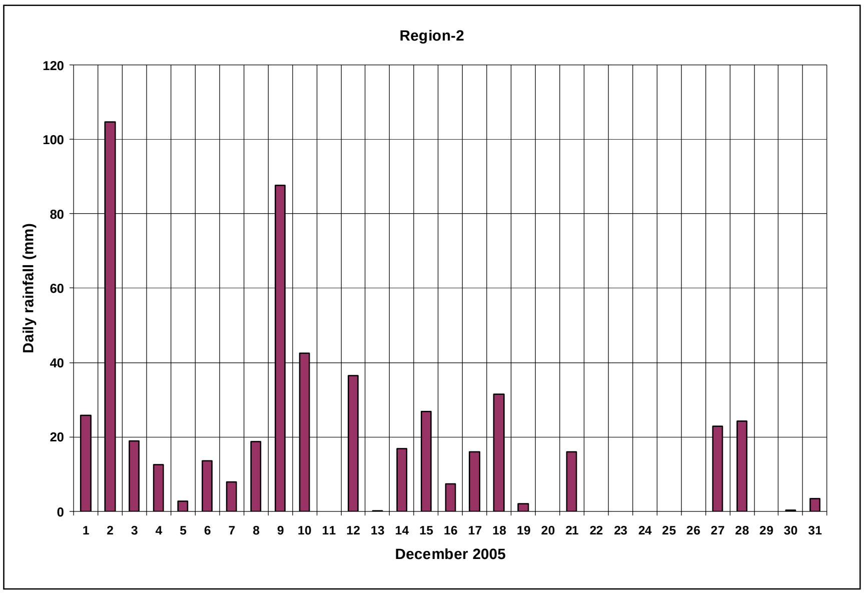

Figure 2.4

Average daily rainfall in Region 2 in December 2005

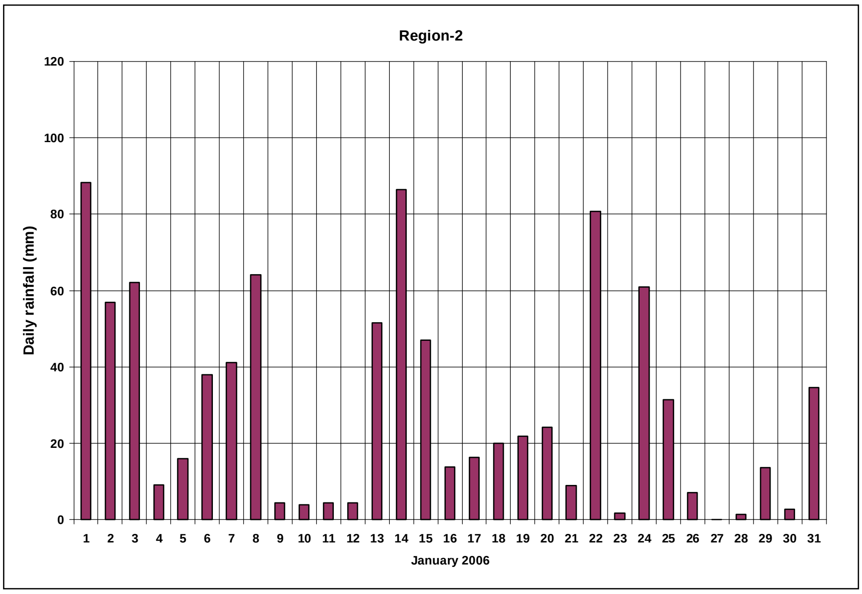

Figure 2.5

Average daily rainfall in Region 2 in January 2006

The 2004-2005 rainy season is observed to have been below normal in November and December, whereas the January 2005 rainfall was almost as severe as the January 2006 total.

The daily rainfall during December 2005 and January 2006 is presented in Figures 2.4 and 2.5. Figure 2.4 shows that a few very wet days were experienced in the first half of December, followed by a fairly dry period in the second half of the month. January 2006, however, has been wet throughout as is observed from Figure 2.5.

2.4 The January 2006 flood event

The areas downstream of Charity along the Pomeroon and along its downstream tributaries are cultivated. The areas are protected by small dams/levees against the river tides. In January 2006 when the river was in flood, the water levels exceeded the levees and flooded the low laying lands along the river and tributaries causing severe damages to the crop. Farmers claimed that the flooding started in December, which is - based on the previous analysis - likely caused by poor drainage of rainwater fallen in the first half of December 2005. It is unlikely that the December flooding was caused by water entering from the river as the rainfall in the basin at that time was of a too short period to create large floods. If the latter would have been the case then the flooding of the adjacent land would have been a frequent phenomenon, which is according to local population not so. The last time they said flooding took place was in the early seventies.

The mouth of the Pomeroon river is partly silted up. This sedimentation negatively affects the discharge capacity of the river. However, the scale of it and its effect on the flood levels is difficult to assess as neither hydrographic surveys nor hydrologic monitoring results are available. The Mission was told that in the past once the river mouth was dredged and that 6 months thereafter the channel was silted up again, indicating that dredging, if embarked upon, would need a short recurrent interval.

Furthermore, the flood levels in the Pomeroon are increased by drainage of the Coizer/Pomeroon area, which used to drain directly to the Atlantic Ocean, and by drainage of a swamp in the Wakapau area, which outlet now joins the Pomeroon further upstream. The sizes of these areas are however small compared to the basin area and their effects on the flood levels are likely to be very small.

It was further reported that in January the dam of the Ituribisi Conservancy was overtopped and that the area adjacent to its outlet downstream of the Conservancy dam was flooded, caused by lack of drainage capacity.

No reports of flooding were received from areas in the rest of the coastal zone.

2.5 Extremity of the 2006 flood events

To assess the return period of the 2006 flood events, in absence of any flow records, the monthly rainfall records of the rainfall stations Charity, Anna Regina and Onderneeming for the months December and January have been analysed. Rainfall records are available for the stations since 1940. The rainfalls of December and January are presented in Figure 2.6 and 2.7 as areal averages. The Figure shows that the rainfall in January 2006 has been the largest on record, though the December 1973, January 2005 and December 1942 were of almost equal magnitude.

Though the rainfall in January 2005 was almost equal to January 2006 it did not cause the Pomeroon river to flood its surroundings. The difference is likely to be found in the rainfall prior to January. The heavy rains in the first half of December 2005 have apparently saturated the basin such that a large percentage of the January 2006 rainfall came to runoff, whereas January 2005 was preceded by a month with below average rainfall and hence the basin had a much larger absorption capacity. Therefore, the sum of the December and following January rainfall has been investigated as well. The result is shown in Figure 2.7. It is observed that the December and January sum of 2005-2006 is the highest on record, but it is almost equalled by the sums of 1942-1943, 1949-1950 and 1973-1974.

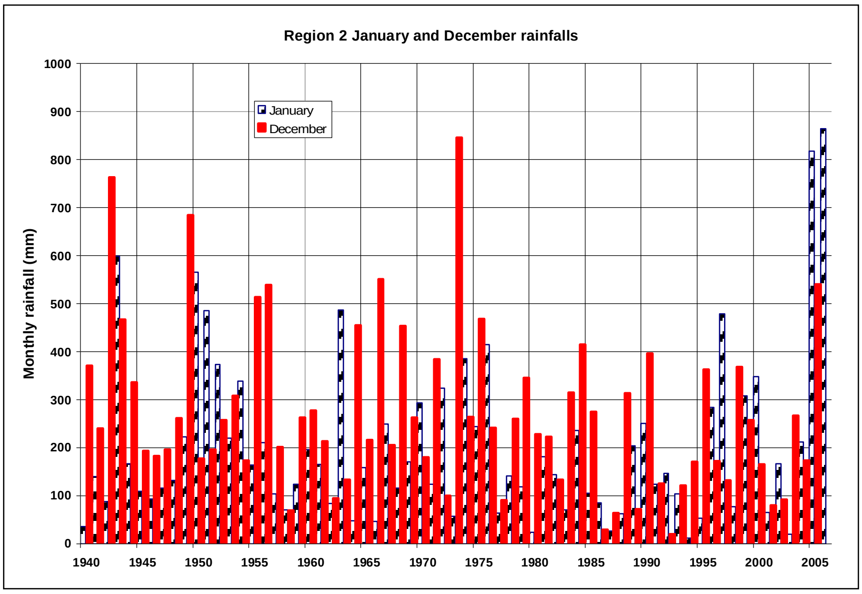

Figure 2.6

January and December rainfall in Region 2 based on data of the Stations Charity, Anna Regina and Onderneeming, Period 1940-2006

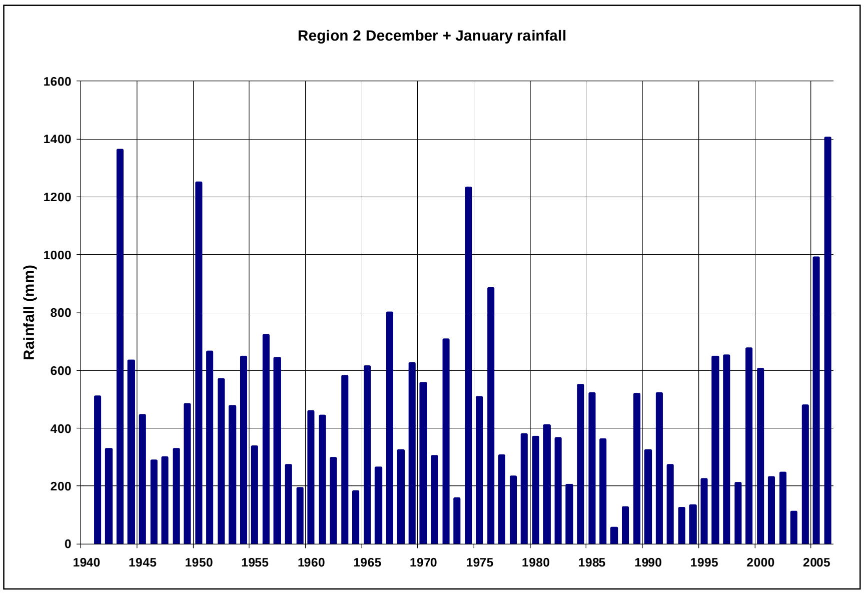

Figure 2.7

December + January rainfall in Region 2, Period 1941-2006

Since the rainfall normals for May and June exceed those for December and January and July is of equal magnitude one could expect that that rainy season even poses a higher threat of high river flow. Therefore, a similar analysis as was carried above, has been applied to the annual maximum monthly and two monthly (consecutive months) rainfall in a year. The results are displayed as time series in Figures 2.8 and 2.10 respectively, with trend lines. The ranked monthly and two monthly values since 1940 are displayed Figures 2.9 and 2.11 respectively.

From Figures 2.8 and 2.9 it is observed that the rainfall in January 2006 was the highest on record, whereas the rainfall in January 2005 the third highest. So, the January rains in the last two years have really been exceptional. However, it may also be observed from Figure 2.8 that the annual maximum monthly rainfall does not show any significant trend, and clearly not an upward one.

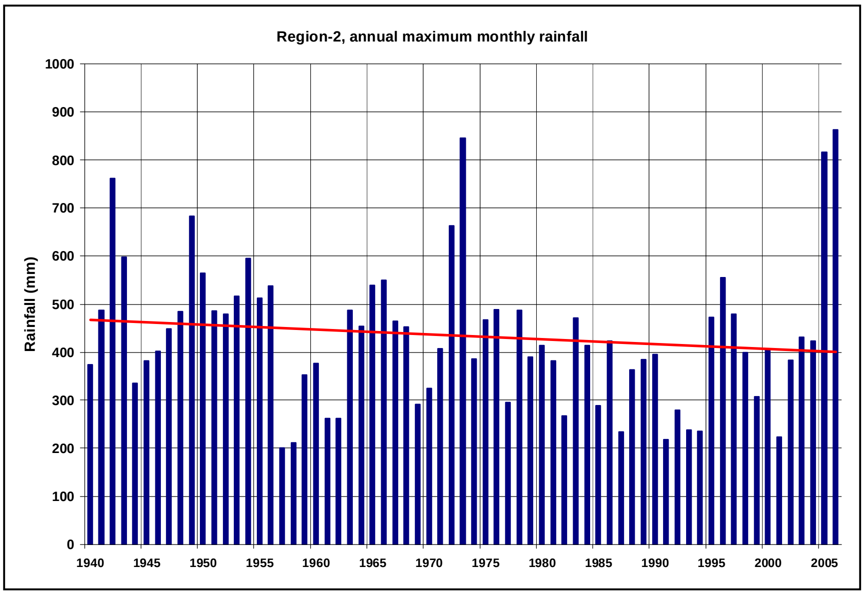

Figure 2.8

Annual maximum monthly rainfall in Region 2, Period 1940-2006 with trend line

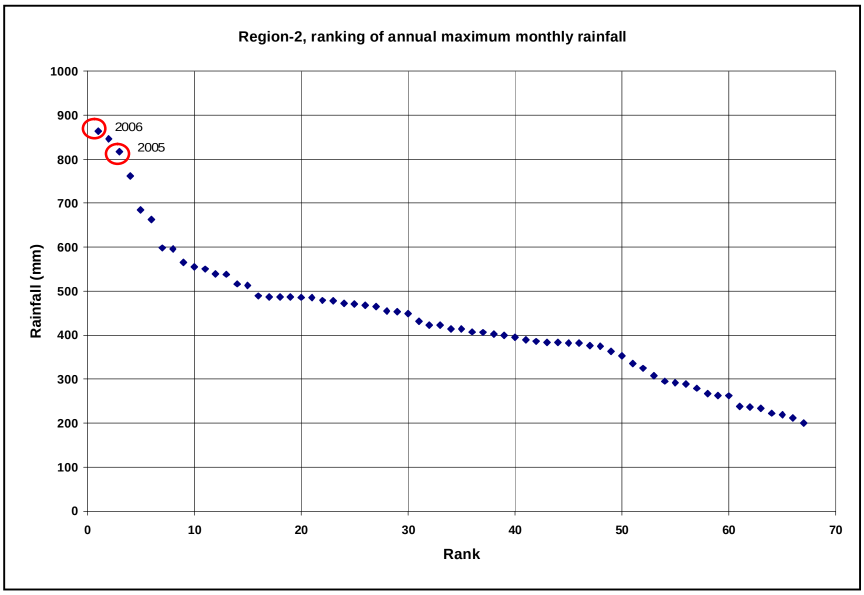

Figure 2.9

Ranked annual maximum monthly rainfall in Region 2, Period 1940-2006

Whereas the monthly rainfall is a good indicator for flooding in the cultivated coastal zone, for the Pomeroon to flood its surrounding high rainfall in two consecutive months is required. From Figure 2.10 and 2.11 it is observed that the sum of the rainfall in December 2005 and January 2006 is the highest on record, but the values for the years 1942, 1949, 1973 and 1972 were close to this extreme. From a comparison of Figure 2.10 with Figure 2.7 it is observed that the annual maximum two monthly rainfall adds only one extreme to the previous December + January rainfall series, see also Figure 2.12. It implies that apparently the variation of the rainfall in the primary rainy season in the middle of the year is less than in the period December-January. The latter period thus gives generally the highest risk to flooding.

The two monthly rainfall as an indicator for Pomeroon flooding was confirmed during the Mission's visit to the Region 2 by farmers along the Pomeroon River, who stated that before the 2005-2006 flood no flooding took place since the early seventies. In view of the magnitude of the rainfall in the early seventies and in 2005-2006 it follows that likely 5 floodings have taken place since 1940, which leads to an average recurrence interval of about 10-15 years to Pomeroon flooding.

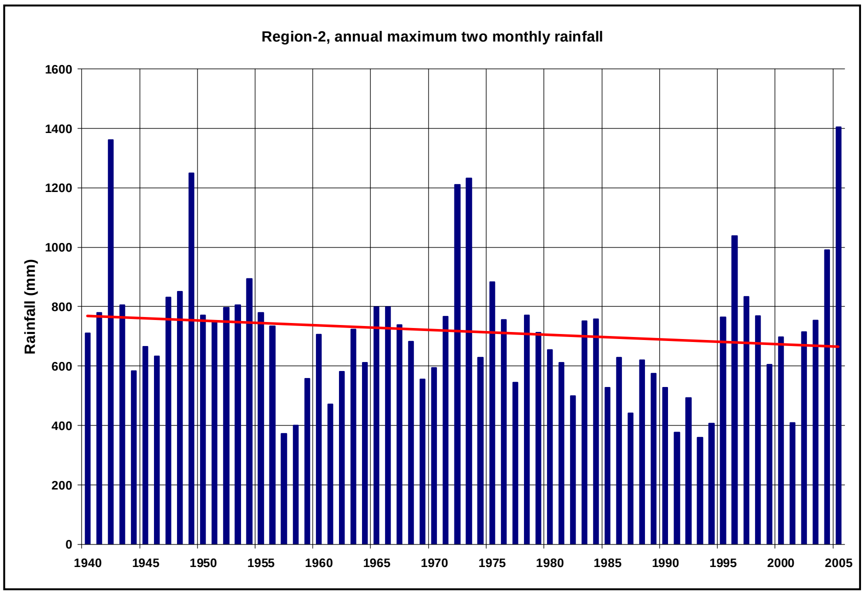

Figure 2.10

Annual maximum two monthly rainfall in Region 2, Period 1940-2005 with trend line

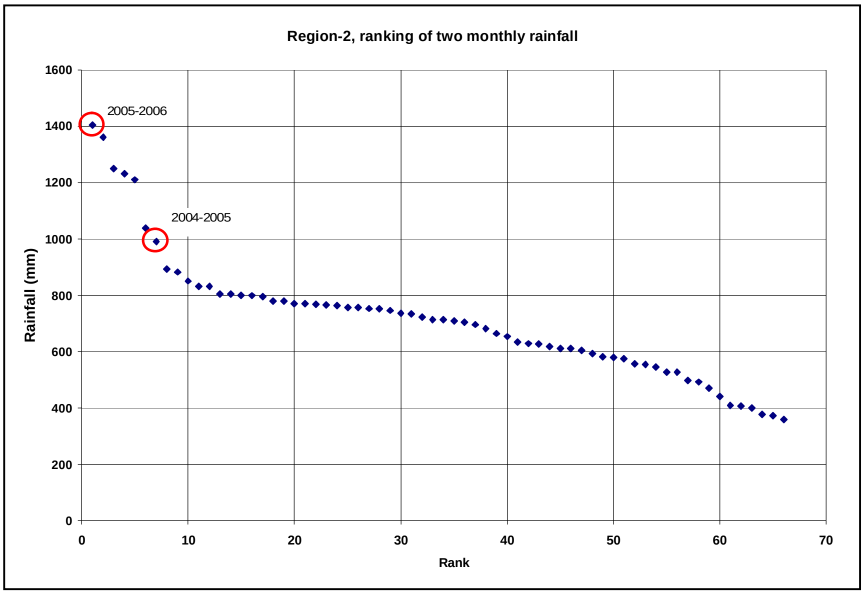

Figure 2.11

Ranked annual maximum two monthly rainfall in Region 2, Period 1940-2005

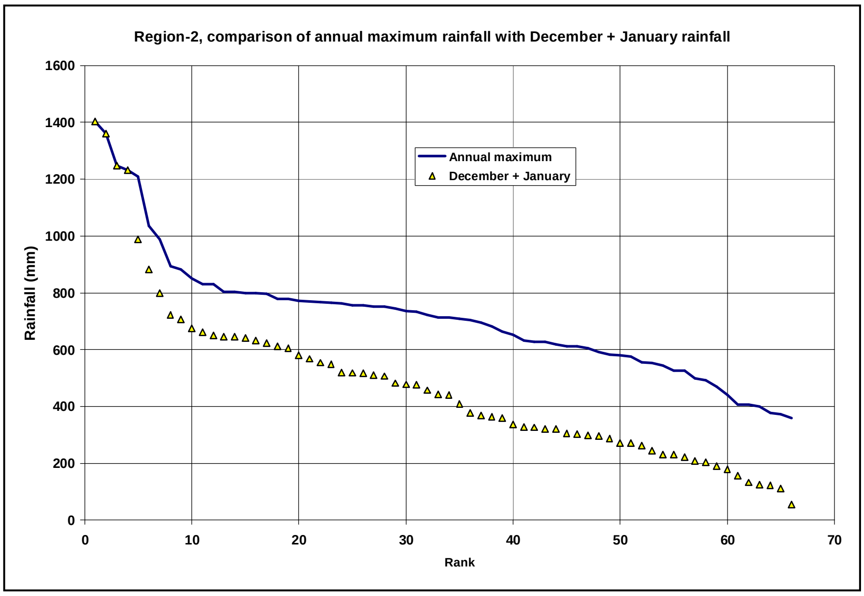

Figure 2.12

Ranked annual maximum two monthly rainfall and December + January rainfall in Region 2, Period 1940-2005

It is noted that differences in rainfall between the coastal zone and the uplands may throw a different light on the above analyses, but in absence of better data, the above estimate gives the best one possible at the moment.

2.6 Capacity of the Ituribisi Water Conservancy outlet

The Ituribisi Water Conservancy outlet is controlled by a structure. The structure has neither been visited by the Mission nor has data been received on the capacity of this outlet structure. The Conservancy Embankment was said to have been overtopped in January 2006 and needs to be heightened and/or the outlet capacity needs to be increased. However, no survey data is available on the elevation - storage capacity curve of the Conservancy to design the required works.

3. Region 3

3.1 Description of the basins

Region 3, see Figure 3.1, is enclosed by the Essequibo River in the west and the Demerara River in the east. The northern part used to be drained by the Boeraserie River, but its waters are now stored in the Boeraserie Conservancy to supply water to the cultivated land near the mouth of the Essequibo, the coastal zone and the lands along the west bank of the Demerara River. This Conservancy catches further the runoff from the Bonasika River in the west and the Kamuni River in the east. The total catchment area of the Conservancy is 436 km^2. At spillway crest level the Conservancy measures 254 km^2. The upper part of the basin is heavily vegetated, and underlain by white sand deposits. Relief is very low, and the stream slope along the longest water course is of the order of 0.00023. The primary flood response will come from precipitation falling on the reservoir area itself, rather than from the natural catchment area (Mott MacDonald, 2005).

The embankment around the Conservancy varies in height between 18.74 m (61.5 ft) and 18.90 m (62.5 ft). There are four flood relief structures on the Boerasirie Conservancy, viz:

- to the Essequibo River via:
  - Waramia Sluice
  - The 8000 ft relief weir
  - Naamryck Sluice
- to the Demerara River via:
  - Potosi Sluice

Their capacities are discussed in Chapter 3.5. For a detailed description of the Boerasirie Conservancy reference is made to Draft Report of Conservancy Flood Management Modelling by Mott MacDonald (May 2005 and Revision August 2005).

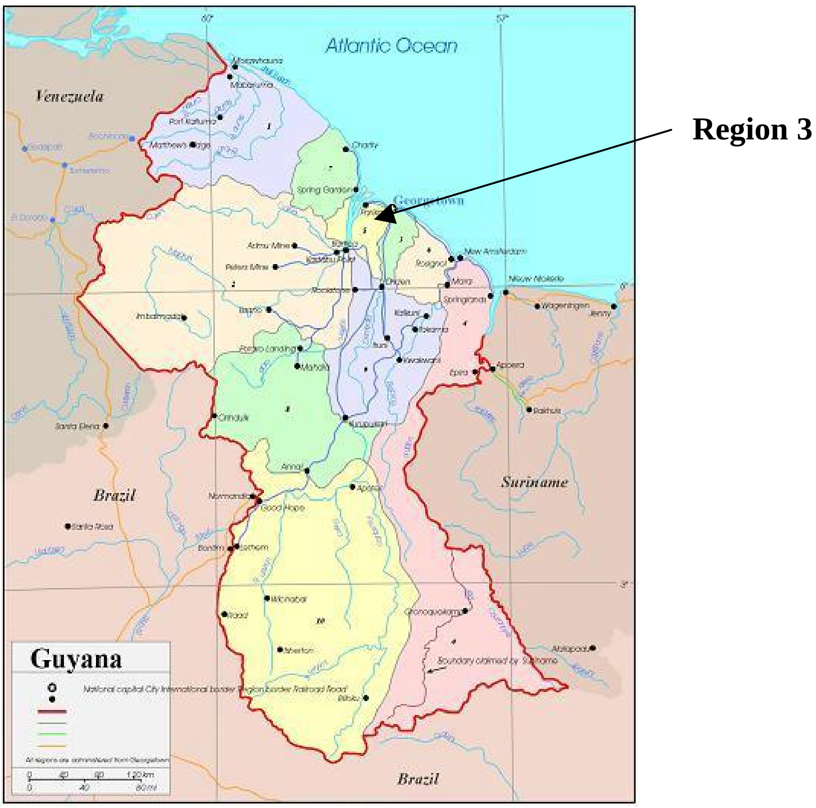

Figure 3.1 Map of Guyana, pointing Region 3

3.2 Rainfall normals

The monthly rainfall normals for Region 3 are presented in Table 3.1 and Figure 3.2. The Region normals are based on an average of the stations Leonora, Boeraserie and Wales. The normals are seen to be highest for the months in the rainy season May to July. The annual total for the Region amounts 2401 mm, which is the highest of the Regions 2 to 6.

Table 3.1 Monthly rainfall normals for Region 3

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Leonora	186.1	76.2	116.5	151.8	296.7	357.5	306.6	197.4	98.1	121.3	193.5	256.0
Boersarie	226.0	113.8	117.6	146.1	336.7	416.4	318.6	198.7	118.7	137.0	184.8	288.1
Wales	207.2	77.6	116.3	151.3	304.4	325.9	227.9	190.6	109.6	109.6	166.3	257.4
Average	206.4	89.2	116.8	149.7	312.6	366.6	284.4	195.6	108.8	122.6	181.5	267.2

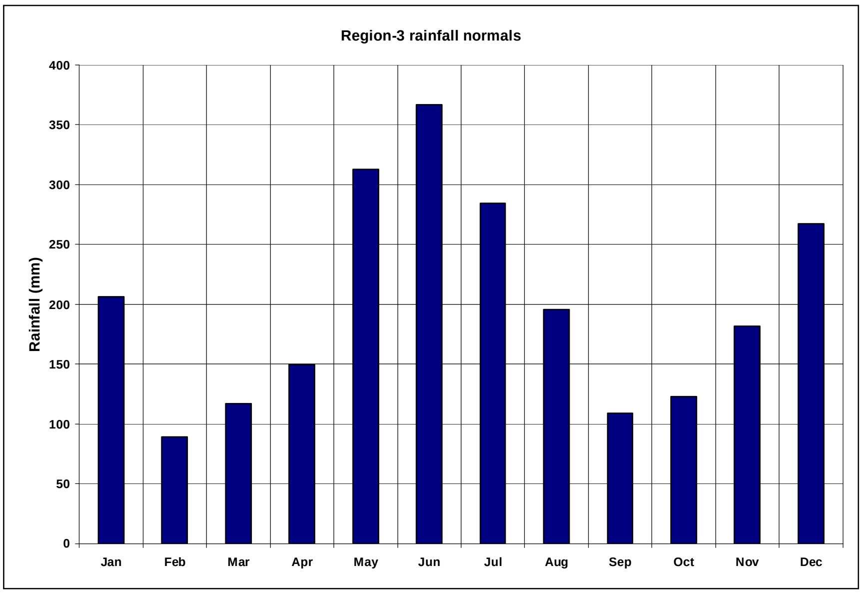

Figure 3.2

Monthly rainfall normals for Region 3

3.3 Rainfall from November 2005 to January 2006

The rainfall normals are used to assess the size of the monthly rainfall relative to average conditions. The results for the months in the rainy season November to January are presented in Table 3.2 and Figure 3.3.

Table 3.2 Monthly rainfall November to January 2005-2006 compared with 2004-2005 and normals in Region 3

Season	November		December		January	
	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal
2004-2005	76.4	42	235.0	88	886.0	429
2005-2006	91.6	50	478.0	222	610.6	296
Normal	181.5		267.2		206.4	

From the Table and the Figure it is observed that the rainfall in November 2005 was below normal, whereas December 2005 reached double the average amount. Most rainfall in this season was experienced in January 2006, with 3 times the region normal. The total of the season amounted 1180.2 mm. This latter amount is about the same as in 2004-2005 when 1197.4 mm was observed. However, in January 2005 the rainfall was more extreme than in the same month in 2006, see Figures 3.4 and 3.5. The heavy rainfall, particularly in the period between 14 and 21 January 2005 caused considerable flood damage. Such extreme intensities are not observed from the 2005-2006 rainfall records. This also reflected in Table 3.3, where the n-daily rainfall totals ($1 \leq n \leq 20$) are compared with the values for Region 3 and 4 for different return periods (statistics from Mott MacDonald, 2004). It is found that particularly for station Wales the return periods of the n-daily totals in December 2004-January 2005 in some cases reached the 500 year return period event, whereas in December 2005-January 2006 the return period of the rainfall sums was close to 5 years, despite the about equal seasonal sums in the two seasons!

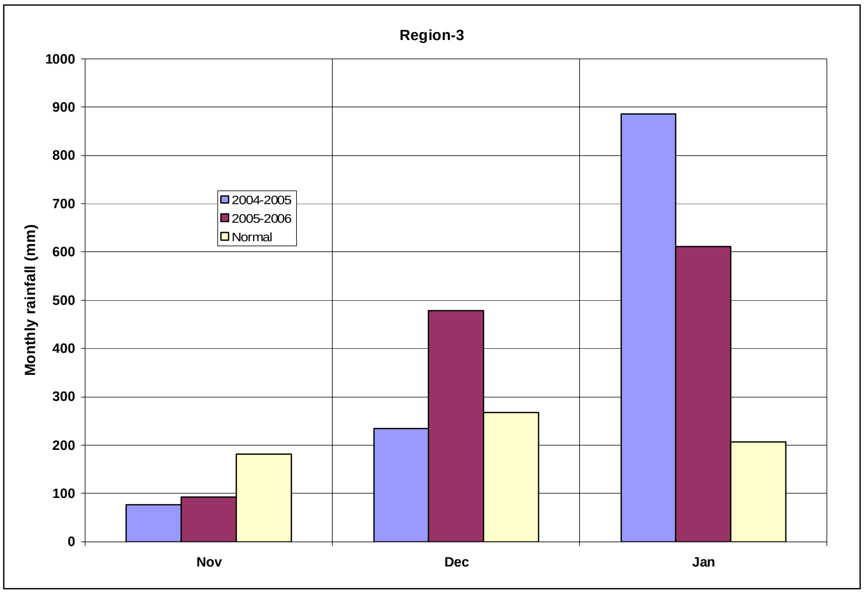

Table 3.3

Monthly rainfall in Region 3 from November to January 2005-2006 compared with previous year and normals

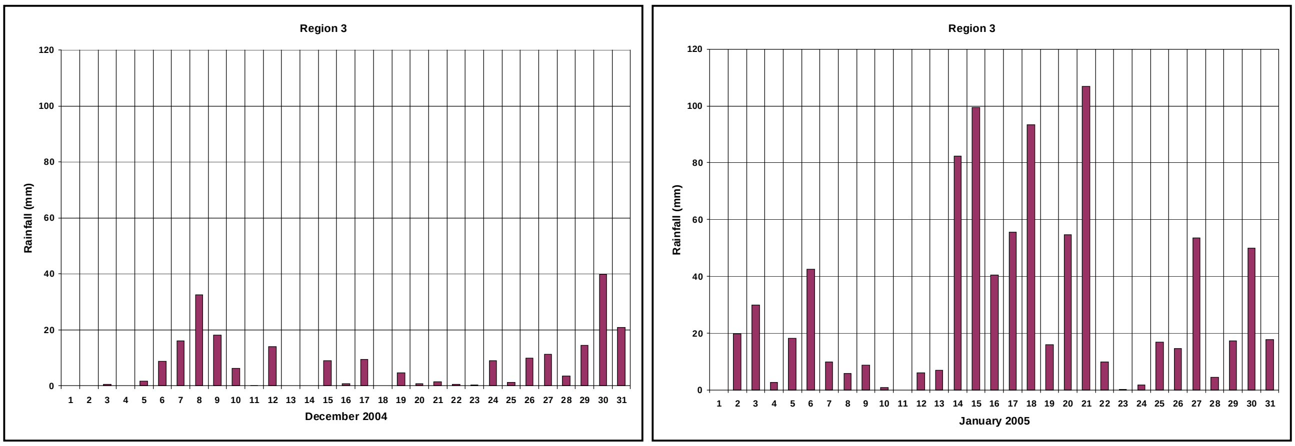

Figure 3.4 Daily rainfall in December 2004 and January 2005 in Region 3

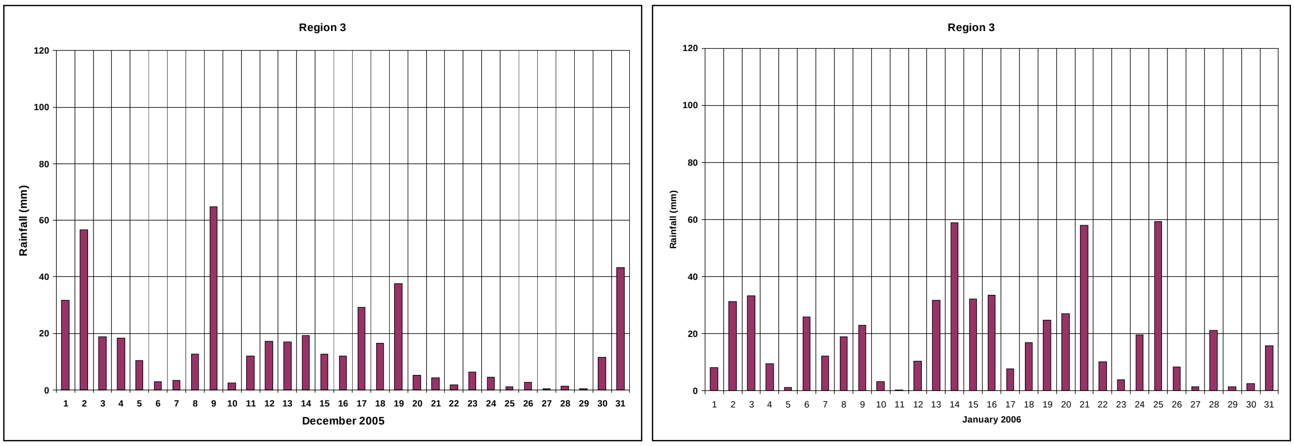

Figure 3.5 Daily rainfall in December 2005 and January 2006 in Region 3

Table 3.3 **Rainfall in period December – January 2004-2005 and 2005-2006 observed at Wales, Boeraserie and Leonora compared with the rainfall for n-daily sums at various return periods valid for Region 3 and 4 (Source: Mott MacDonald, 2005)**

Return Period	Interval in days							
	1	**2**	**3**	**5**	**7**	**10**	**15**	**20**
5	120	175	205	250	295	350	440	520
10	145	195	235	290	325	400	500	600
20	164	215	267	331	382	468	584	687
50	193	245	305	387	445	552	682	795
100	215	267	334	432	493	620	759	877
200	239	288	362	478	543	691	838	960
500	272	315	399	542	611	791	947	1071
1000	298	336	427	593	664	872	1032	1157
10000	397	402	519	778	851	1173	1335	1450
2004-05								
Wales	155.9	253.0	309.1	516.3	632.3	761.9	844.0	926.9
Boeraserie	88.1	153.4	194.5	335.9	425.3	535.2	640.0	745.1
Leonora	84.8	134.2	164.8	261.1	341.2	399.9	480.9	571.2
2005-06								
Wales	94.7	144.7	183.6	232.1	247.1	348.9	428.9	501.7
Boeraserie	73.3	91.0	116.2	160.8	208.5	302.2	409.9	470.4
Leonora	76.4	95.7	127.6	153.2	227.3	281.9	366.9	459.2

3.4 Extremity of December - January rainfall

To investigate the extremity of the recent December and January rainfall a comparison is made with the previous records. Since 1940 rainfall data are available for Region 3. The time series of the December and January rainfall are displayed in Figure 3.6. This series can be compared with the annual maximum monthly rainfall presented in Figure 3.7. The ranking of the annual maximum monthly rainfall is displayed in Figure 3.8, with the position of the January 2005 and January 2006 marked. Particularly, the rainfall in January 2005 was extreme, and has been exceeded since 1940 only two times. From a comparison of Figure 3.6 with 3.7 it is observed that the most extreme values in the plots are the same indicating that the most extreme rainfalls have been experienced in the season November to January, see also Figure 3.9.

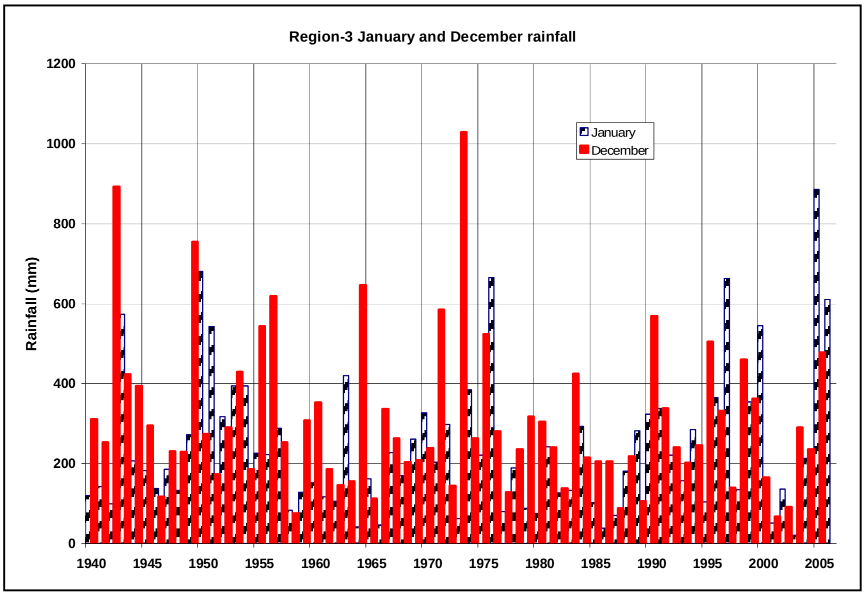

Figure 3.6

January and December rainfall in Region 3, Period 1940-2006

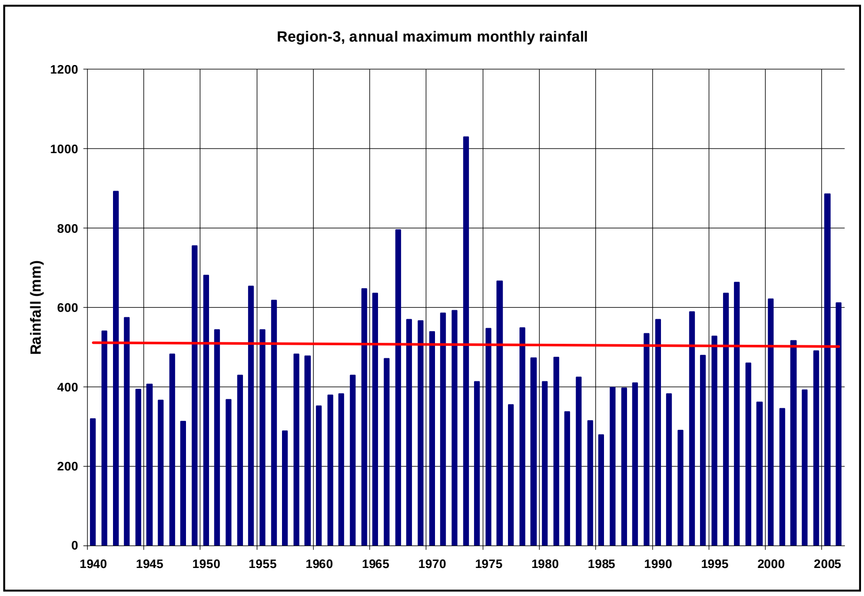

Figure 3.7

Annual maximum monthly rainfall in Region 3, Period 1940-2006, with trend line

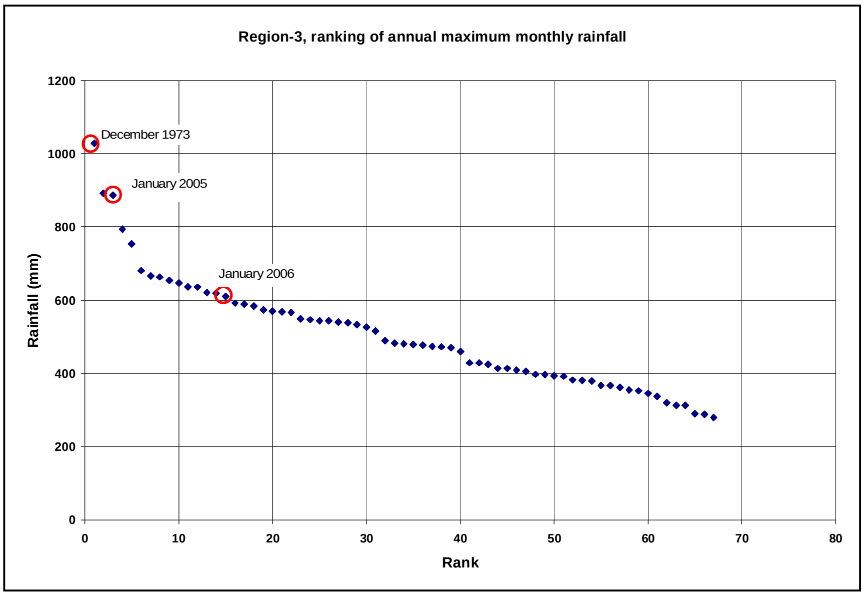

Figure 3.8

Ranking of annual maximum monthly rainfall in Region 3, Period 1940-2006

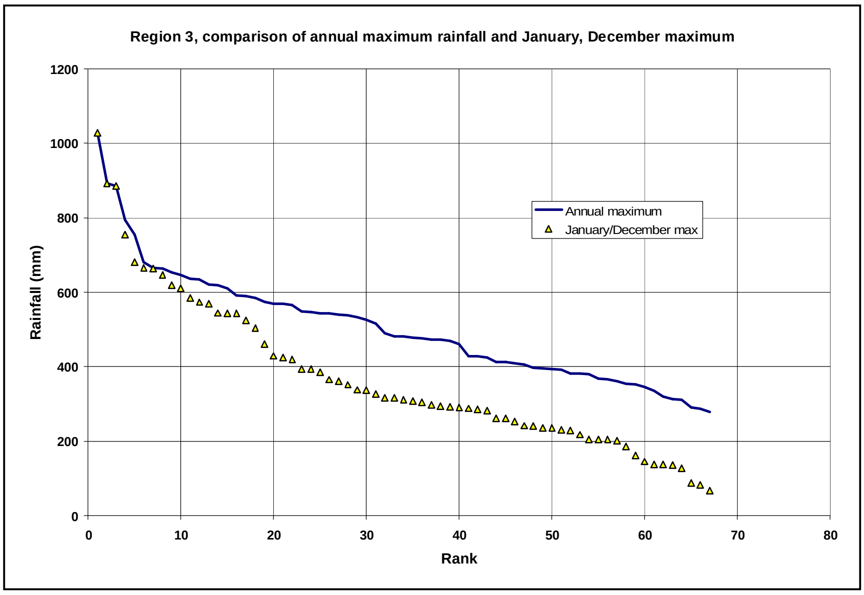

Figure 3.9

Comparison of rank of annual maximum monthly rainfall and maximum January/December rainfall

Similarly, the December + January rainfalls have been compared with annual maximum two monthly extremes. The results are displayed in the Figures 3.10 to 3.12. Comparison of Figures 3.10 and 3.11 shows that in this case a few extremes have been added which do not originate from the November-January rainfall season.

Note also that the monthly as well as the two monthly annual maximum rainfall data do not show any trend in the course of time.

From Figure 3.12 it is observed that the December 2004 – January 2005 and the December 2005-January 2006 rainfall rank respectively 7 and 10 since 1940, whereas the January 2005 rainfall ranks 3, see Figure 3.8. It follows that the monthly rainfall of January 2005 had a return period of about 20 years, whereas a rainfall total as in December 2004-January 2005 can be expected about every 10 years.

It is noted that for the design of relief structures for the Boeraserie Water Conservancy rainfall durations shorter than one month will be decisive on the required capacity.

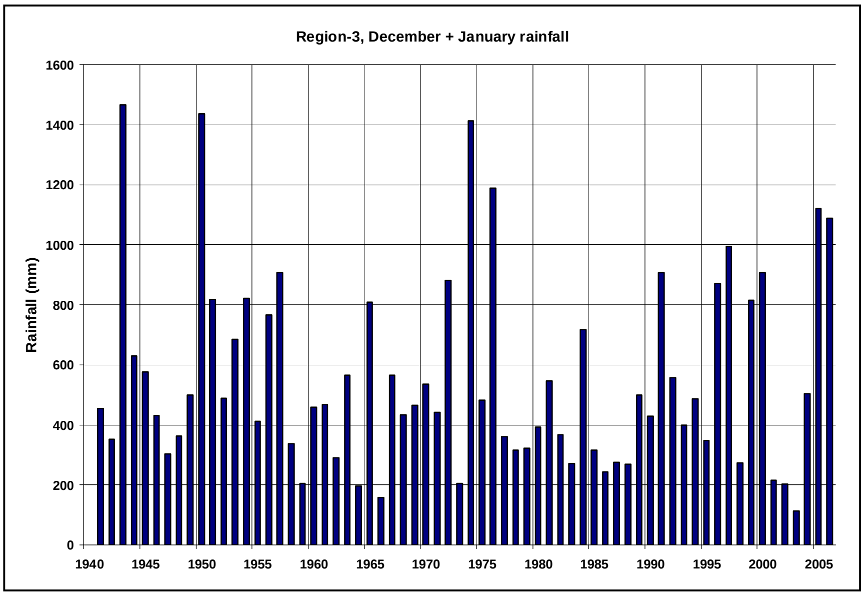

Figure 3.10

December + January rainfall in Region 3, Period 1940-2006

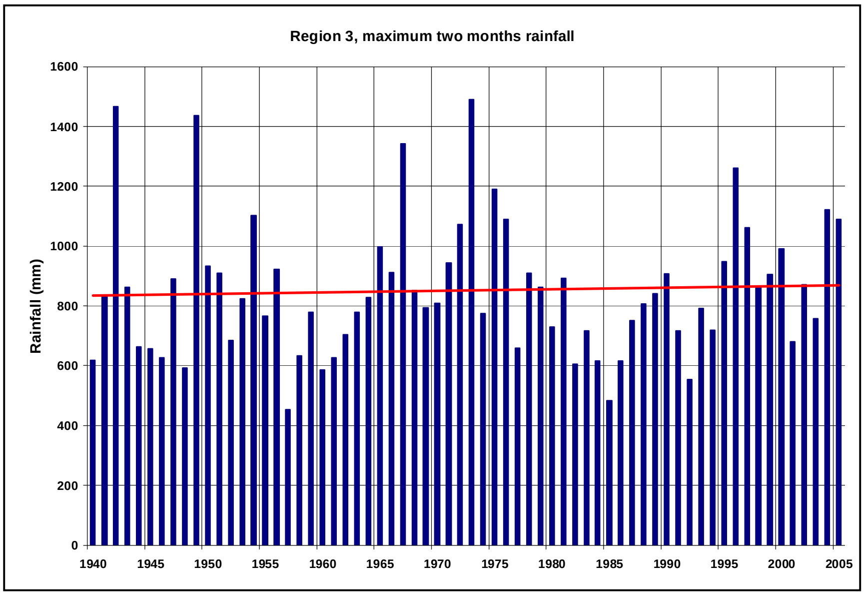

Figure 3.11

Annual maximum two monthly rainfall in Region 3, Period 1940-2006, with trend line

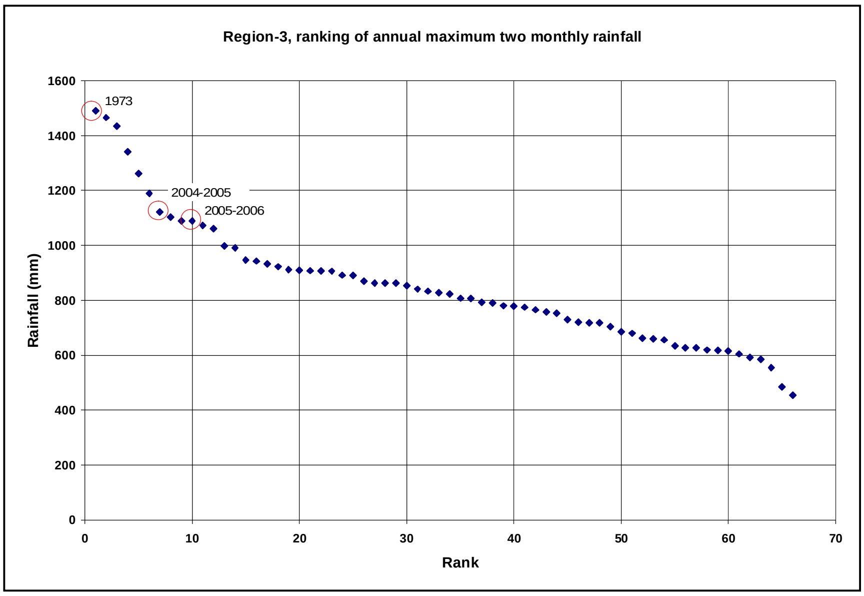

Figure 3.12

Ranking of annual maximum two monthly rainfall in Region 3, Period 1940-2006

3.5 Capacity of the Boeraserie Water Conservancy outlets

In Mott MacDonald (2005) the following details about the Conservancy dam and relief structures are given. "All flood relief sluices have sill levels set at 16.916 m. The 8000 ft weir has a crest elevation of 18.684 m (61.3 ft), and it is when this level is reached that the flood relief sluice gates are opened. Embankment levels around the conservancy are not consistent, and in a number of areas there is very little freeboard. The lowest point on the embankment is reportedly 18.745 m (61.5 ft), and the highest point of the order of 18.898 m (62.5 ft). At its lowest point there is only 60 mm freeboard above the spillway crest, and at its highest point only 214 mm (figures as reported by the Secretary to the Conservancy Board). The current freeboard is quite inadequate. There was extensive overtopping in January 2005, and overtopping in certain sections has been common in the past. No topographic survey exists at present for the crest of the embankment."

The water level record of the Boeraserie Water Conservancy as observed in December 2005 and January 2006 is displayed in Figure 3.13, together with the rainfall as an average of the amounts recorded at the stations Wales, Boeraserie and Leonora. From the graph an immediate response to extreme daily rainfall is apparent. It is observed that the lowest level of the Conservancy Dam has been exceeded almost throughout January 2006 and hence flooding at several locations must have occurred. The drainage capacity is obviously insufficient to control the water level. However, it may not have been as dramatic as the figure indicates in view of slopes of the water table observed during the previous flood event.

The drainage capacity of the four outfalls Waramia sluice, 8000 ft weir, Naamryck sluice and the Potosi sluice are displayed in Figure 3.14 (maximum capacity) and Figure 3.15 (minimum capacity). The actual capacity is determined by the downstream water level. Up to a level of 18.70 m the discharge capacity is at maximum 100 m^3/s or 19.8 mm/day. Only when the 8000 ft weir start operating the capacity increases drastically, but with very little freeboard left. It is also observed from Figure 3.15 that when the downstream levels are high the discharge capacity from the conservancy is virtually nil; the 8000 ft weir capacity reduces when the downstream water level exceeds 18.60 m. In calculating the discharge capacity of the 8000 ft weir it has been assumed that capacity obstructing vegetation on both sides of the weir is removed. Mott MacDonald (2005) carried out a capacity analysis using a hydraulic model of the Conservancy. They concluded that the waterway between Naamryck and the 8000 ft weir and Waramia needs to be significantly improved to permit adequate flow to the 8000 ft weir.

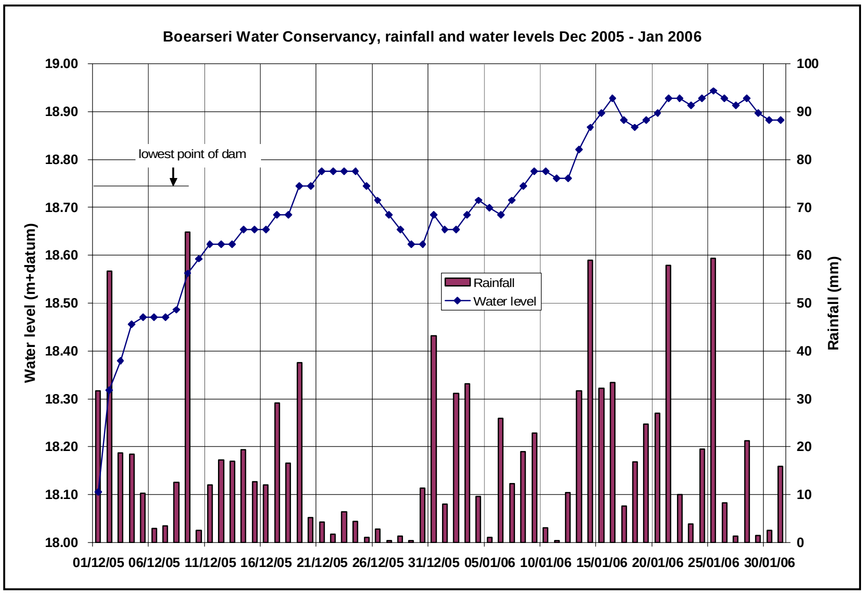

Fig 3.13

Water level in Boeraserie or West Demerara Water Conservancy with daily rainfall in Region 3

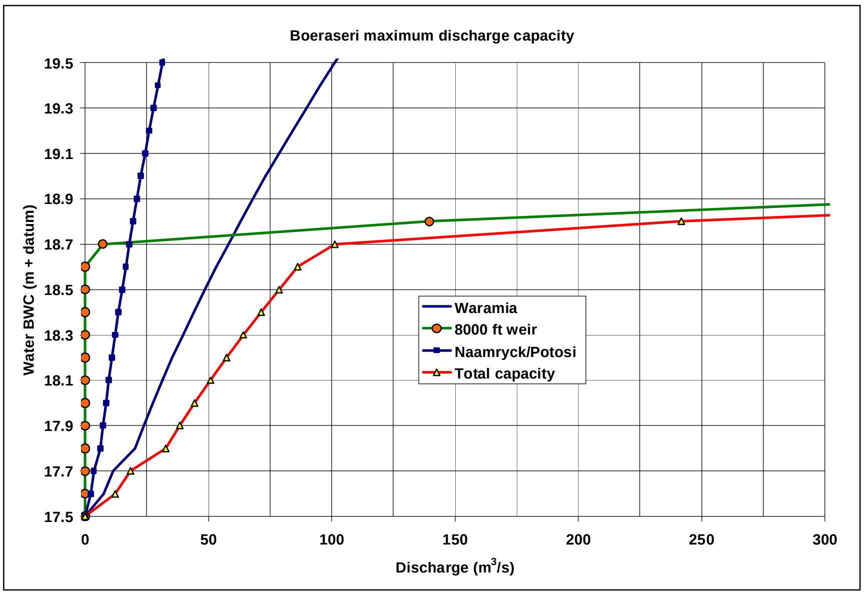

Figure 3.14

Maximum discharge capacity of Waramia, Naamryck and Potosi sluices and of 8000 ft weir.

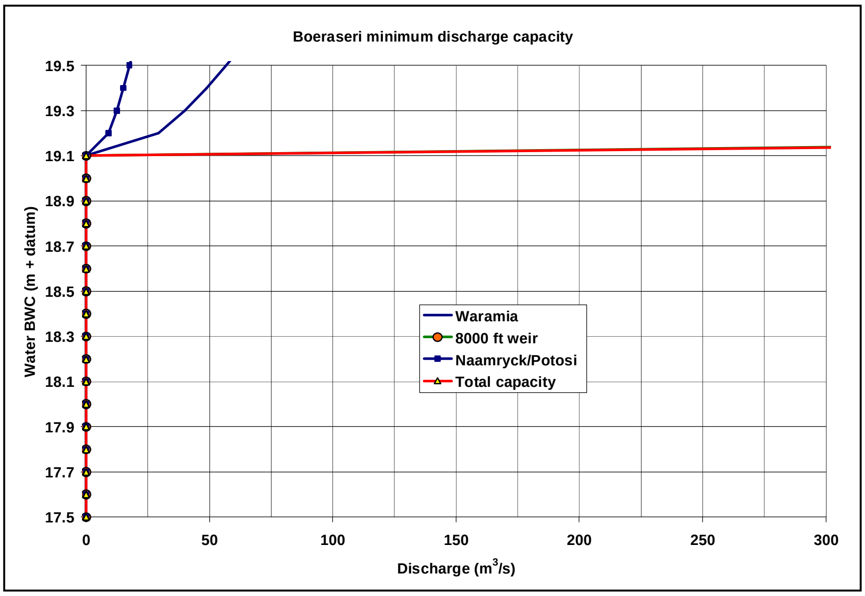

Figure 3.15

Minimum discharge capacity of Waramia, Naamryck and Potosi sluices and of 8000 ft weir.

4. Region 4

4.1 Description of the basins

Region 4 is contained between the Demerara River in the west, the Mahaica River in the east and the Atlantic Ocean in the north. Apart from a small zone along the Demerara River the major part of Region 4 used to drain to the Mahaica River. In the late nineteenth century the East Demerara Water Conservancy Dam was build to supply water to the cultivated lands along the coast and drinking water. This dam with its crest on average at and elevation of 18.29 m+datum (60 ft) captures the water from the west flowing creeks but particularly of the left bank tributaries of the Mahaica River. The catchment area of the East Demerara Water Conservancy measures 582 km^2. The Conservancy at an elevation of 17.98 m covers an area of 520 km^2 and stores 340 Mm^3 of water. The Conservancy Dam and particularly the eastern side of it poses a continuous threat to the people and lands behind the dike when the water levels in the Conservancy rise. Drainage outlets from the Conservancy comprise:

- To the Demerara River (from South to North):
  - The Cunha Sluice
  - The Land of Canaan Sluice, and
  - The Kofi Sluice
- To the Mahaica River (from South to North)
  - The Maduni Sluice, and
  - The Big and Small Lama Sluices.

For a detailed description of the East Demerara Conservancy reference is made to Draft Report of Conservancy Flood Management Modelling by Mott MacDonald (May 2005 and Revision August 2005).

The cultivated lands downstream of the EDWC drain their excess water to the Atlantic Ocean through a number of outfalls.

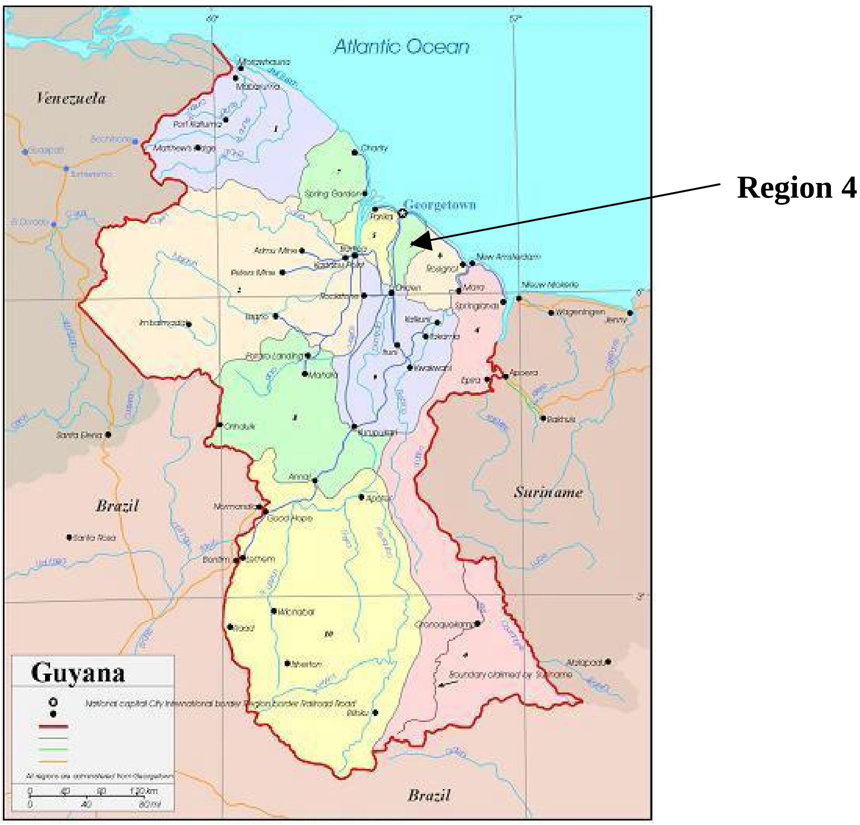

Figure 4.1 Map of Guyana, pointing Region 4

4.2 Rainfall normals

The monthly rainfall normals for Region 4 as an average of the normals of the stations Georgetown Botanical Gardens, Timheri, and Ogle are presented in Table 4.1 and Figure 4.2. There are two distinct wet periods, viz. May to July and November to January, with May, June and July being the wettest months on average. The annual average rainfall in Region 4 amounts 2304 mm.

Table 4.1 Monthly rainfall normals of stations in Region 4

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Georgetown	185.2	91.9	111.0	140.5	285.5	327.7	268.0	201.4	97.5	107.2	185.9	261.9
Timehri	207.3	102.2	134.0	172.0	316.7	337.3	286.0	281.6	132.0	136.6	173.7	233.4
Ogle F	180.4	94.1	102.2	146.5	278.6	306.1	260.6	178.7	86.8	83.8	177.1	241.3
Average	191.0	96.1	115.7	153.0	293.6	323.7	271.5	220.6	105.4	109.2	178.9	245.5

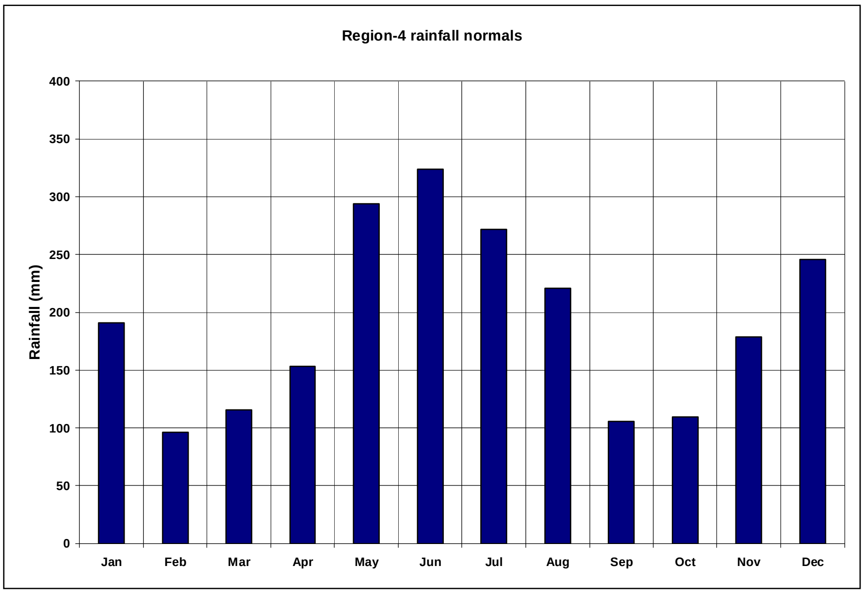

Figure 4.2

Monthly rainfall normals in Region 4 as an average of the Stations Georgetown, Timeheri and Ogle

The normals are used to assess the extremity of the rainfall in the season November 2005 - January 2006.

4.3 Rainfall from November 2005 to January 2006

The monthly rainfall in Region 4 for the months November 2005 to January 2006 as an average of the stations Georgetown, Timeheri and Ogle are presented in Table 4.2 and Figure 4.3, where a comparison is made with the monthly normal and the rainfall in the same months in the previous year.

Table 4.2 Monthly rainfall November to January 2005-2006 compared with 2004-2005 and normals

Season	November		December		January	
	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal
2004-2005	54.8	31	299.1	122	933.3	489
2005-2006	228.3	128	523.2	213	540.2	283
Normal	178.9		245.5		191.0	

From the Table and the Figure it is observed that the rainfall in November 2005 was below normal whereas December 2005 and January 2006 were well above normal with respectively 2 to 3 times the average value for those months. Compared with the previous year it is observed that the November and December totals were considerably higher, but the monthly rainfall of January 2006 was substantially lower than in 2005. The seasonal totals, however, are the same: 1287 mm in 2004-2005 against 1292 mm in 2005-2006. Despite the equal seasonal totals, the reason that the last season did not cause flooding problems in this Region is, apart from some measures taken in the aftermath of the 2004-2005 flood, mainly attributable to the large differences in rainfall intensities. In the 2004-2005 November-January rainfall season the intensities were far more extreme than in the 2005-2006 season. This is observed from a comparison of the daily rainfall pattern in December and January in those two years, presented in the Figures 4.4 and 4.5. This difference is also strongly reflected in the return periods for the 1, 2, 3, 5, 7, 10, 15 and 20 daily rainfall sums measured at the Botanical Gardens in Georgetown for these months in 2005-2006 and in 2004-2005, as shown in Table 4.3. Whereas in January 2005 e.g. the 3-7 days rainfall totals exceeded the 1000 year return period level, in December 2005 and January 2006 none of the rainfall sums came even close to the 5 year return period level.

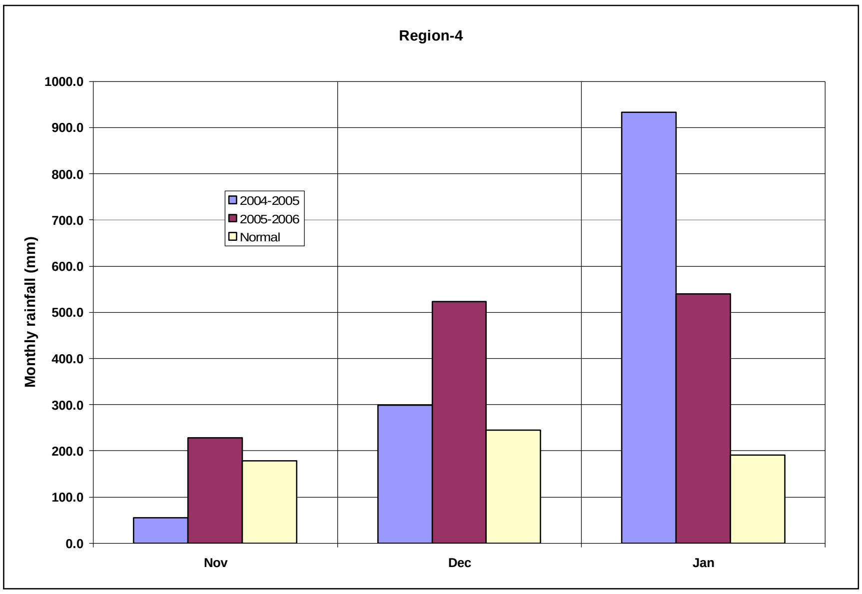

Figure 4.3

Monthly rainfall in Region 4 from November to January 2004-2005 compared with previous year and normals

Table 4.3 **Rainfall in period December – January 2004-2005 and 2005-2006 observed at Georgetown Botanical Gardens compared with the rainfall for n-daily sums at various return periods valid for Region 3 and 4 (Source return period statistics: Mott MacDonald, 2005)**

Return Period	**Interval in days**							
	1	**2**	**3**	**5**	**7**	**10**	**15**	**20**
5	120	175	205	250	295	350	440	520
10	145	195	235	290	325	400	500	600
20	164	215	267	331	382	468	584	687
50	193	245	305	387	445	552	682	795
100	215	267	334	432	493	620	759	877
200	239	288	362	478	543	691	838	960
500	272	315	399	542	611	791	947	1071
1000	298	336	427	593	664	872	1032	1157
10000	397	402	519	778	851	1173	1335	1450
2004-05	166.1	293.1	429.1	649.4	716.5	792.4	855.5	957.1
2005-06	92.5	127.1	157.9	197.1	224.1	293.0	381.7	455.9

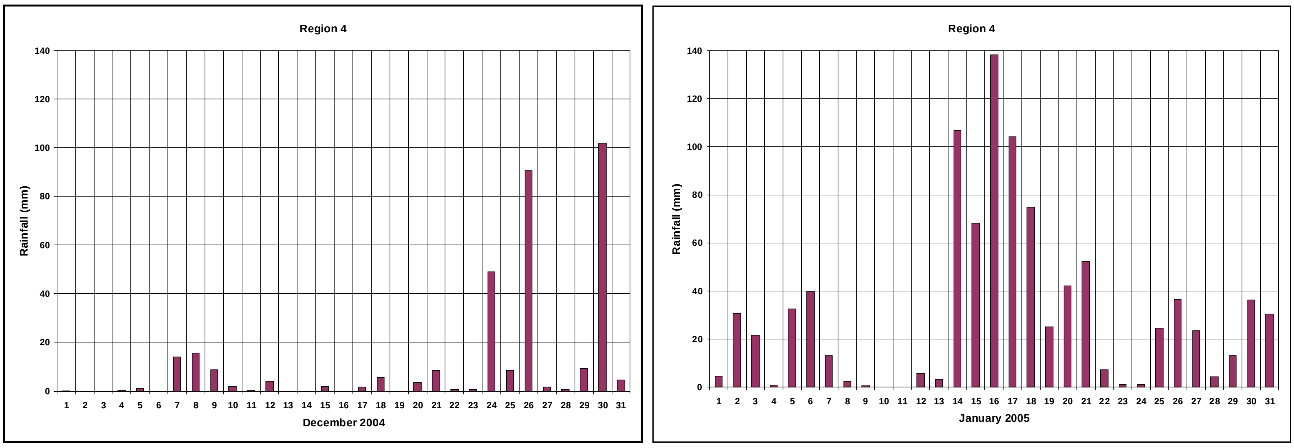

Figure 4.4 Average daily rainfall in Region 4 in December 2004 and January 2005

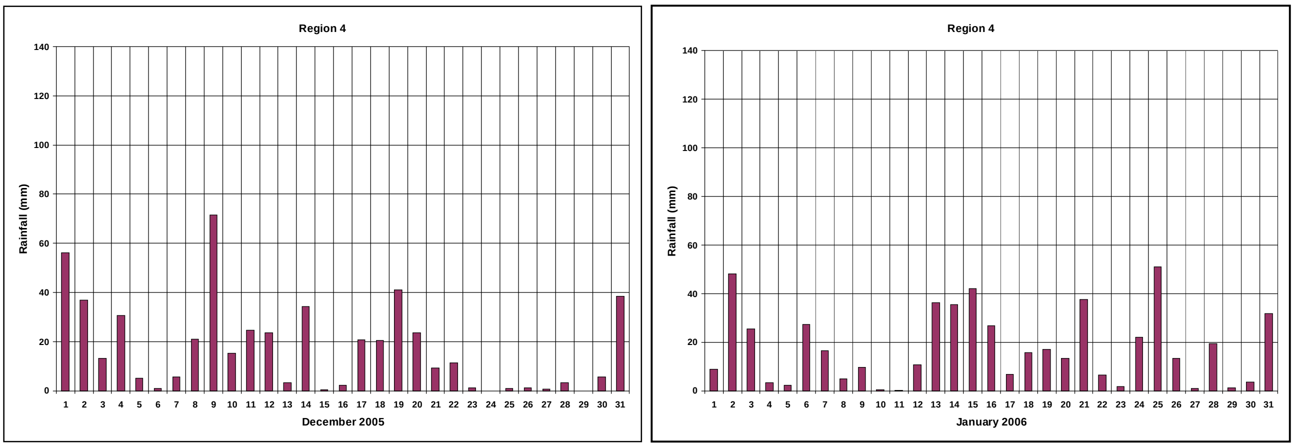

Figure 4.5 Average daily rainfall in Region 4 in December 2005 and January 2006

4.4 Extremity of the December-January rainfall

The time series of the rainfall in the months January and December is displayed in Figure 4.6 and of the annual maximum monthly rainfall in Figure 4.7. The ranking of the annual maximum monthly rainfall is shown in Figure 4.8. From the latter it is observed that the January 2005 rainfall was the one but largest in the series of observations, whereas the January 2006 rainfall has been exceeded in 110 years time 22 times. So the return periods of these monthly totals are respectively about 50 and 5 years. The former is seen to be considerably less than the return period for the short duration events as shown in Table 4.3.

In Figure 4.9 the ranking of the annual maximum monthly rainfall is compared with the ranking of the maximum rainfall in January, December. It is observed that the most extreme monthly rainfall is with almost no exception observed in the second rainy season from November to January.

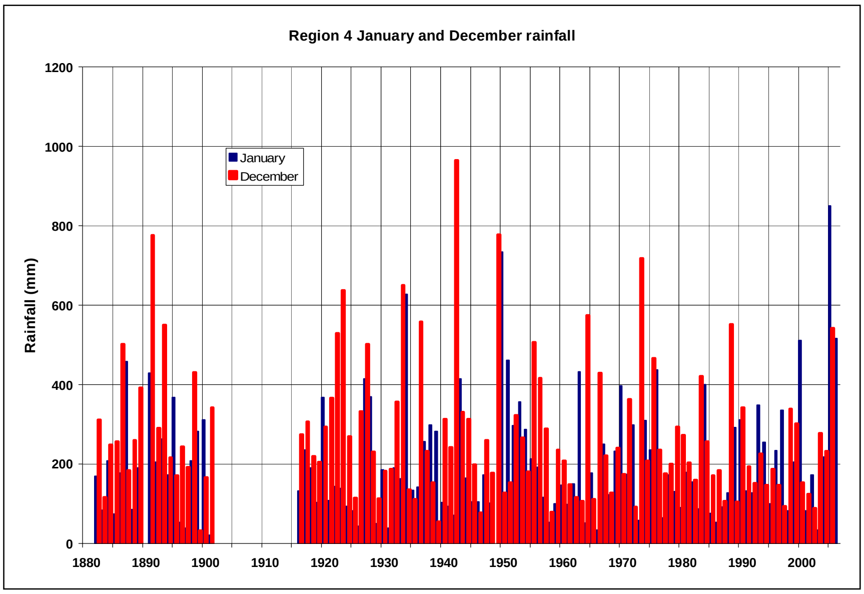

Figure 4.6

January and December rainfall in Region 4, Period 1882-2006

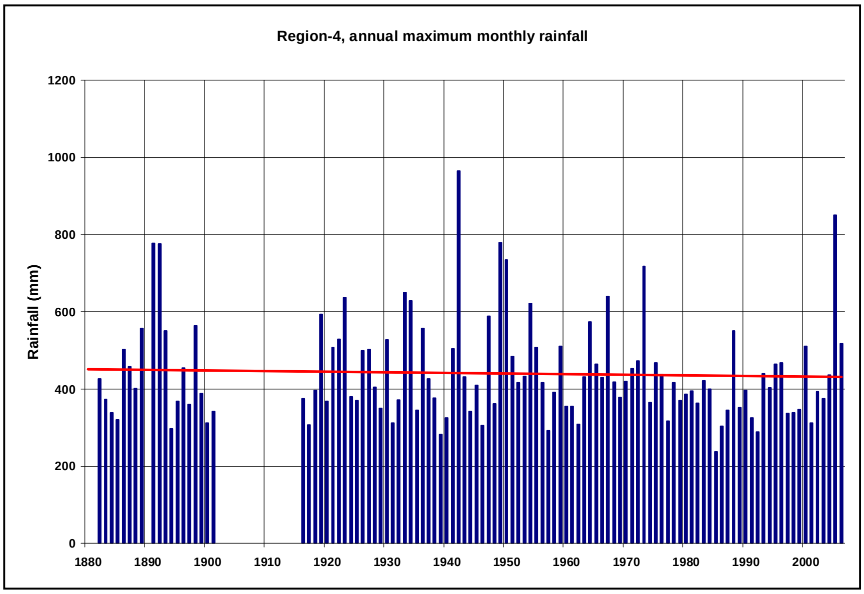

Figure 4.7

Annual maximum monthly rainfall in Region 4, Period 1882-2006

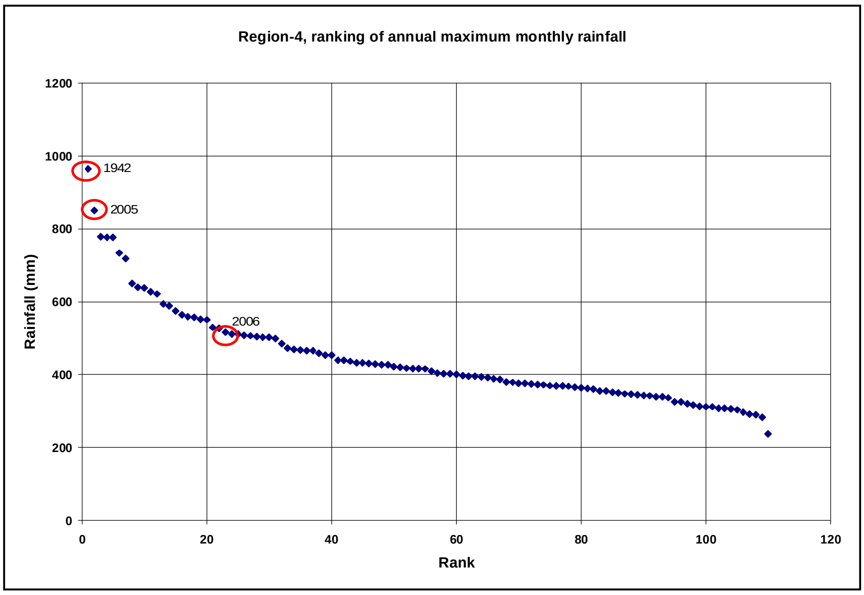

Figure 4.8

Ranking of annual maximum monthly rainfall in Region 4, Period 1882-2006

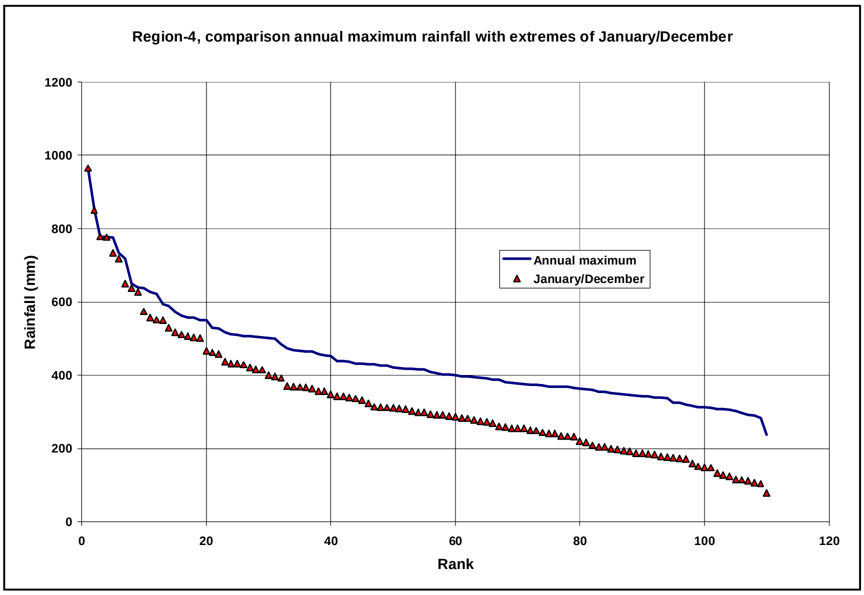

Figure 4.9

Comparison of ordered maximum annual monthly rainfall with maximum January/December rainfall in Region 4, Period 1882-2006

The time series of the December + January rainfall and of the annual maximum two monthly rainfall are presented in the Figures 4.10 and 4.11. The ranking of the two monthly extremes is shown in Figure 4.12. The latter Figure shows that the December-January totals of 2004-2005 and 2005-2006 rank respectively 6 and 8, which gives them a return period of about 15 years. For the 2004-2005 December – January rainfall it implies that the larger the duration is taken the less extreme the rainfall become, whereas for the 2005-2006 rainfall the opposite applies. A comparison of Figure 4.10 and 4.11 shows that the largest extremes take place in the December-January rainy season.

From Figures 4.7 and 4.11 it is observed that the annual maximum monthly and two monthly rainfalls do not exhibit a trend.

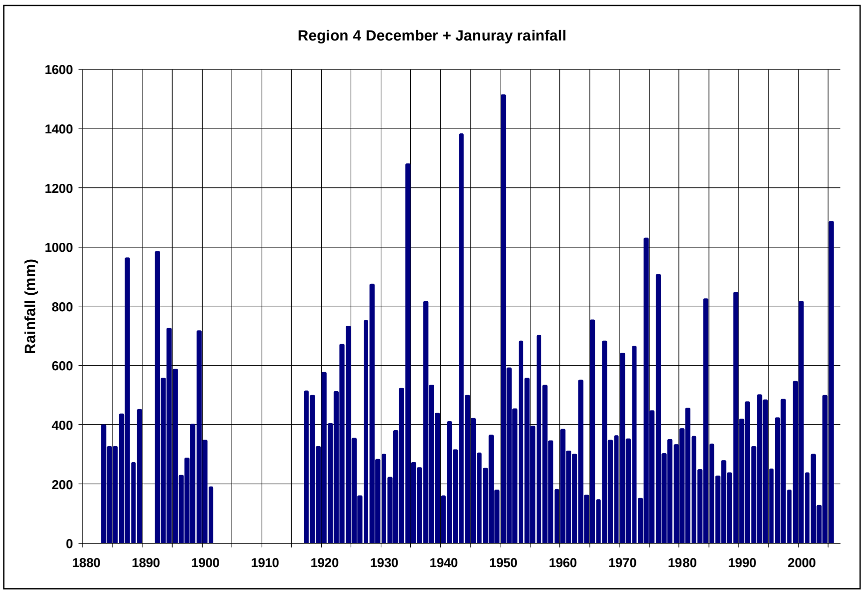

Figure 4.10

December + January rainfall in Region 4, Period 1882-2005

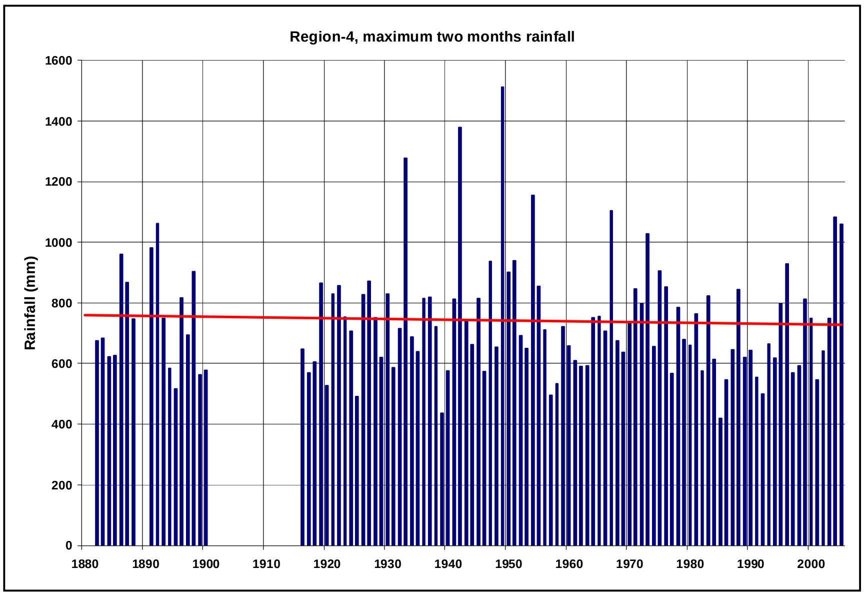

Figure 4.11

Annual maximum two monthly rainfall in Region 4, Period 1882-2005

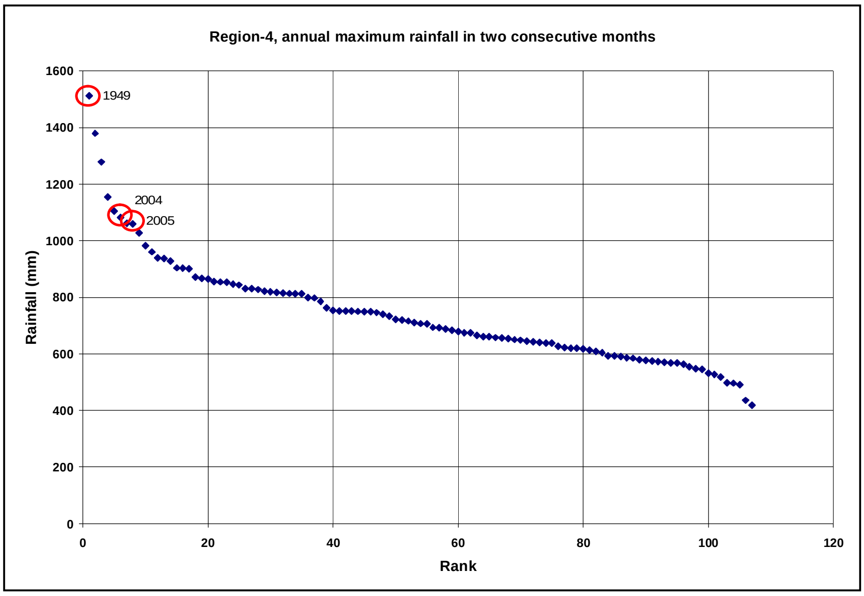

Figure 4.12

Ranking of annual maximum two monthly rainfall in Region 4, Period 1882-2005

4.4 Capacity of the East Demerara Water Conservancy outlets

The crest of the EDWC dam varies in level. From the hydraulic model studies report by Mott MacDonald (2005) it is revealed that the average crest elevation is at 18.29 m (60 ft) but that its lowest point is well below that level: 17.70 m. Comparing these elevations with the water level observed at Flagstaff from December 2005 to February 2006 as presented in Figure 4.13, it is observed that the Conservancy Dam would have been overtopped at several locations as from 14th January 2006 onward. When flying over the Conservancy on 15-02-2006, the Mission saw that at locations, particularly on the eastern part of the dam, clay bags had been put on top to heighten the dam. From Figure 4.13 it is also observed that the water level stayed well below the average crest level; a maximum water level of 17.95 m was observed on 21st January 2006. Thereafter the rain continued, but the water level in the Conservancy dropped by applying the sluices.

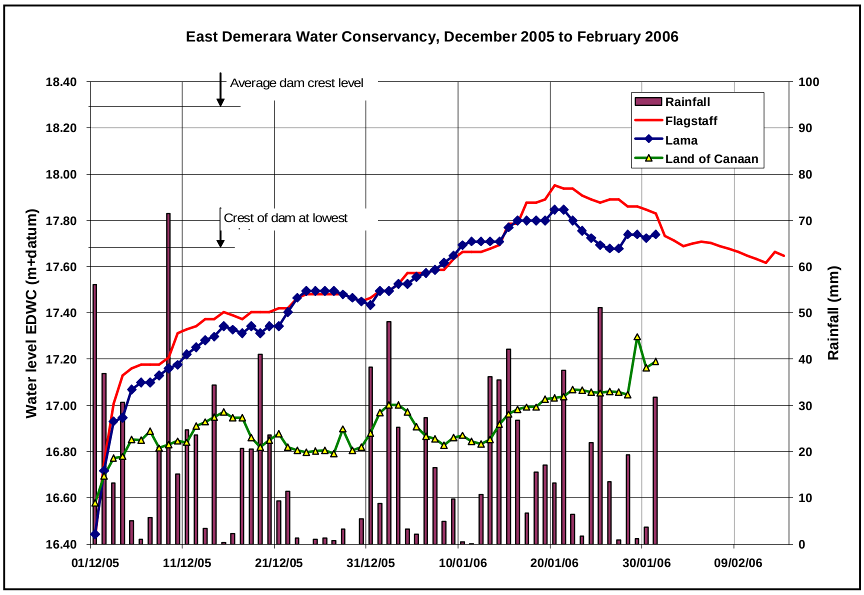

Figure 4.13

Rainfall and water levels observed in the East Demerara Water Conservancy, Period December 2005 to February 2006

The drainage outlets from the Conservancy comprise the Cunha, Land of Canaan and Kofi sluices to the Demerara River and Maduni and the Big and Small Lama sluices to the Mahaica River. The capacities of the sluices may be affected by the downstream water level. An overview of the maximum and minimum capacities of the sluices is presented in Table 4.4 and Figure 4.14. To get an impression of how much water will be spilled over the Conservancy Dam if the water levels raise too high Figure 4.15 is added. It is observed that a small amount would have crossed the dam had the clay bags not been applied.

Table 4.4 Maximum and minimum capacities of the relief structures along EDWC, with distinction in west flowing and east flowing outfalls

H-EDWC	Total-max	Total-min	Total-max	Total-min	West-max	West-min	East-max	East-min
m+datum	m^3/s	m^3/s	mm/day	mm/day	m^3/s	m^3/s	m^3/s	m^3/s
17.80	344	241	51	36	205	156	140	85
17.90	364	263	54	39	217	170	147	93
18.00	383	285	57	42	230	184	153	101
18.10	404	316	60	47	244	198	160	118
18.20	424	338	63	50	257	213	167	126
18.30	445	360	66	53	271	227	174	133

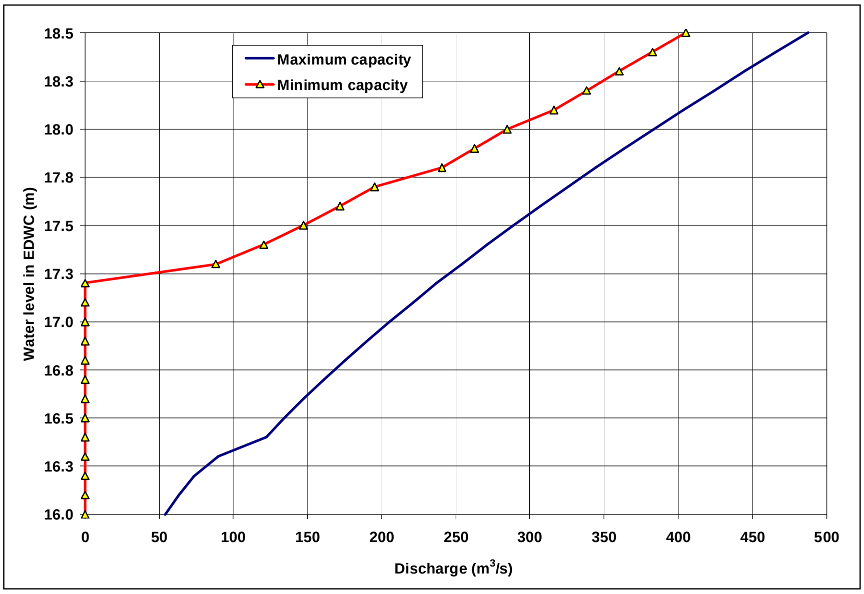

Figure 4.14

Maximum and minimum capacities of relief structures along EDWC

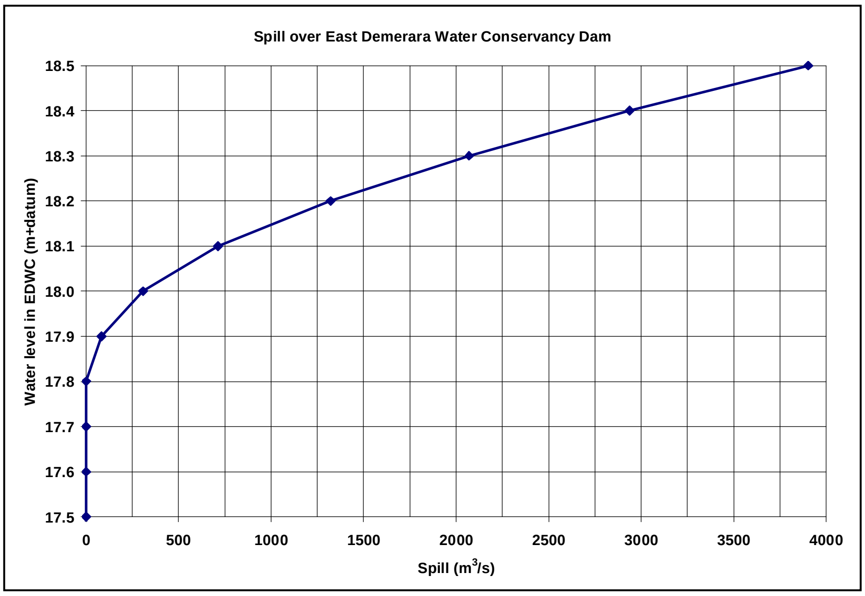

Figure 4.15

Capacity of EDWC Dam

In Table 4.4 it is also indicated how much water can be drained to the Demerara and how much to the Mahaica. Particularly the latter is of interest as drainage to the Mahaica aggravates the flooding in Region 5. This is also shown in Figures 4.16 and 4.17.

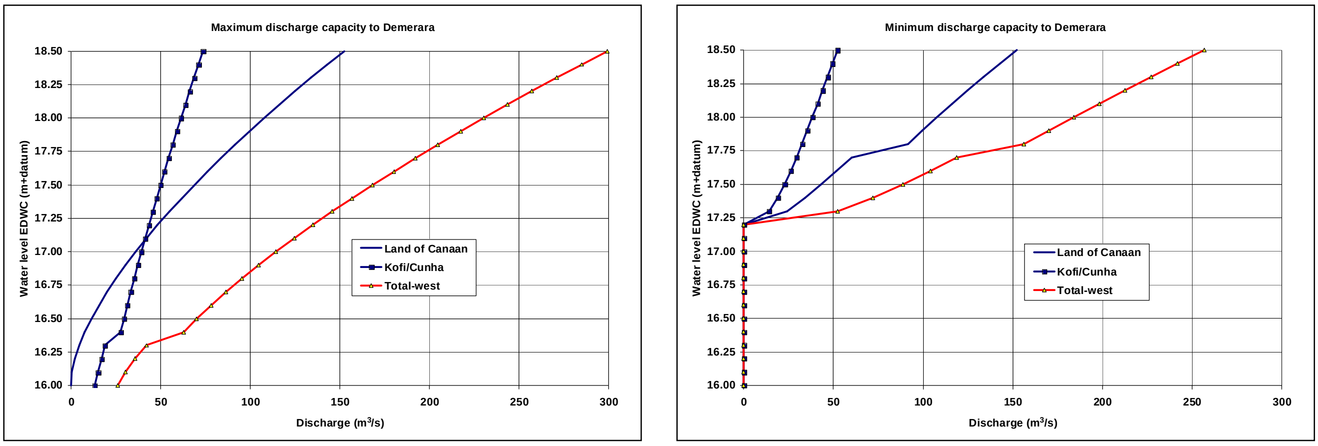

Figure 4.16 Maximum and minimum capacities of sluices draining to Demerara River

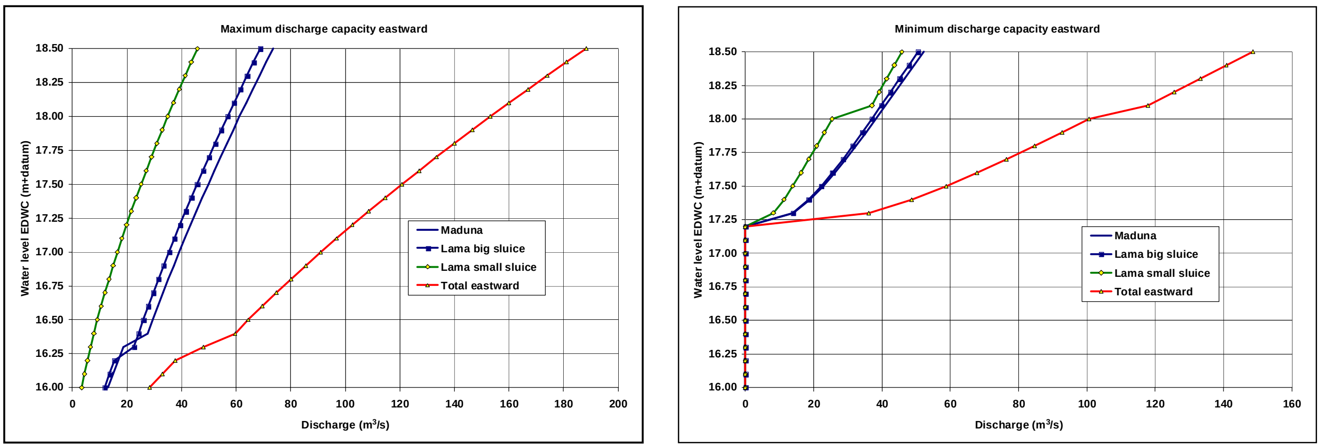

Figure 4.17 Maximum and minimum capacities of sluices draining to Mahaica River

On 20 January 2006 the water level at Lama sluices attained a level of 17.85 m. If a similar level is applied for the Maduni sluice it implies that dependent on the downstream water level between 90 and 145 m^3/s was discharged to the Mahaica River. The capacity of the Mahaica was, based on cross-section parameters and assumed flow velocities, estimated at about 450 m^3/s, see Chapter 5. It means that between 20 and 32 % of the Mahaica capacity was consumed by release of water from the EDWC. It is obvious that this has contributed to the flooding in that region.

Mott MacDonald (2005) concluded based on hydraulic model analyses of the East Demerara Water Conservancy that an appropriate margin of safety cannot be assured for a 10,000 year flood with the present outlet works and that additional outlet must be provided as soon as possible. Furthermore, in view of the negative effects of release of water to the Mahaica River additional capacity to the Demerara River and/or to the Atlantic Ocean should be implemented with priority.

5. Region-5

5.1 Description of the basins

Region 5 is drained by 4 rivers, viz.:

1. in the west by the Mahaica River, which also drains the south-eastern part of Region 4
2. in the middle by the Mahaicony River,
3. further to the east by the Abary River, and
4. in the east by the Berbice River

The catchment of Mahaica river as recorded in the Hydrological Yearbooks is 958 km^2. This is likely exclusive of the part controlled by the East Demerara Conservancy, which used to drain to the Mahaica River, via the Lama Creek and Mahuni River. With the latter included the total drainage area becomes about 1450 km^2. Unfortunately, neither discharge nor water level stations ever existed on this river. The cross-section of the river near the mouth measures approximately 50 x 6 = 300 m^2. At present the EDWC spills to the Mahaica River via the Lama Big and Small sluices and the Mahuni sluice, see Chapter 4.

The catchment area of the Mahaicony River measures 1398 km^2 and the Abary River 1289 km^2, which is slightly less than the area drained by the Mahaica River. The river widths near their mouths are respectively 45 and 30 m. On both rivers water level gauging stations are operated by the MMA (Mahaica Mahaicony Abary Authority).

The runoff from the upper reaches of the Abary River (808 km^2) is stored behind the dam of the Abary Water Conservancy in the Mahaica Mahaicony Abary Water Control Project (MMA Phase I, completed in the mid eighties). The outflow from the conservancy is controlled by the Abary Control Sluice (capacity 113 m^3/s), the Main Canal Head Regulator and a spill-weir (design capacity 538 m^3/s) to the Berbice River. The Conservancy is operated by the MMA. The MMA Phase III plan comprises an extension of the conservancy to the Mahaicony and Mahaica Rivers to fully control the runoff from the upper reaches of the basins to benefit flood control and irrigation water supply.

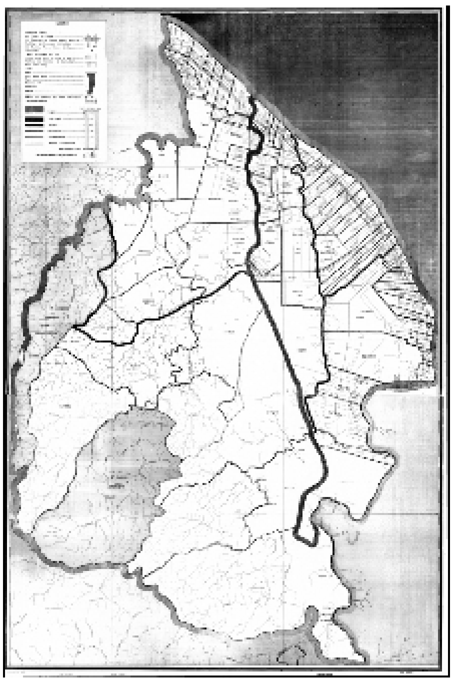

Figure 5.1 Drainage area map of Region 5

5.2 Rainfall normals

The monthly rainfall normals for Region 5 as an average of the normals of the available stations Blairmont and Mards are presented in Table 5.1 and Figure 5.2. It is observed that there are two distinct wet periods, viz. May to July and November to January, with May, June and July being the wettest months on average. The annual average rainfall amounts 1955 mm.

Table 5.1 Monthly rainfall normals in Region 5

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Blairmont	179.2	86.9	109.6	157.6	248.2	290.7	250.2	170.9	69.6	68.4	129.4	196.7
Mards	183.8	82.7	109.3	149.3	251.5	266.7	264.4	164.4	73.9	67.7	123.5	215.0
Average	181.5	84.8	109.5	153.5	249.9	278.7	257.3	167.7	71.8	68.1	126.5	205.9

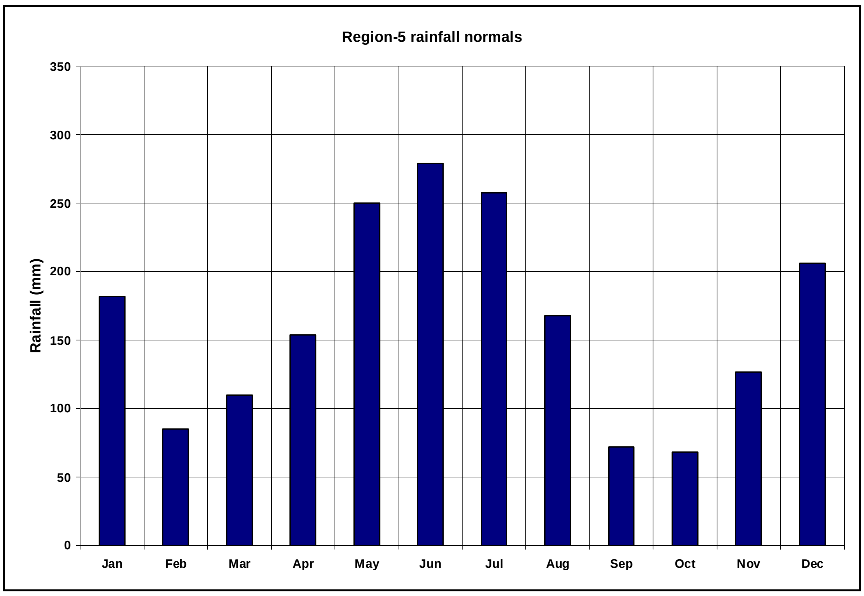

Figure 5.2 Monthly rainfall normals for Region 5 as the average of the Stations Blairmont and Mards

5.3 Rainfall from November 2005 to January 2006

The rainfall in Region 5 in the months November 2005 to January 2006 is shown in Table 5.2 and Figure 5.3. In the Figure a comparison is made with the rainfall normals and the rainfall in the season one year ago.

Table 5.2 Region 5, Monthly rainfall November to January 2005-2006 compared with 2004-2005 and normals

Season	November		December		January	
	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal
2004-2005	13.9	11	112.1	52	468.8	255
2005-2006	154.1	122	569.0	265	566.8	308
Normal	126.7		215.0		183.8	

From the Table and the Figure it is observed that the rainfall in December 2005 and January 2006 amounted 2.5 and 3 times the monthly normal. In comparison with the rainfall in the same months one year before it is shown that though the January totals are almost the same, a difference is particularly observed for December, which was below normal in 2004 whereas in 2005 it was well above. For the entire rainy season the rainfall in last one was almost 700 mm higher than in the previous one.

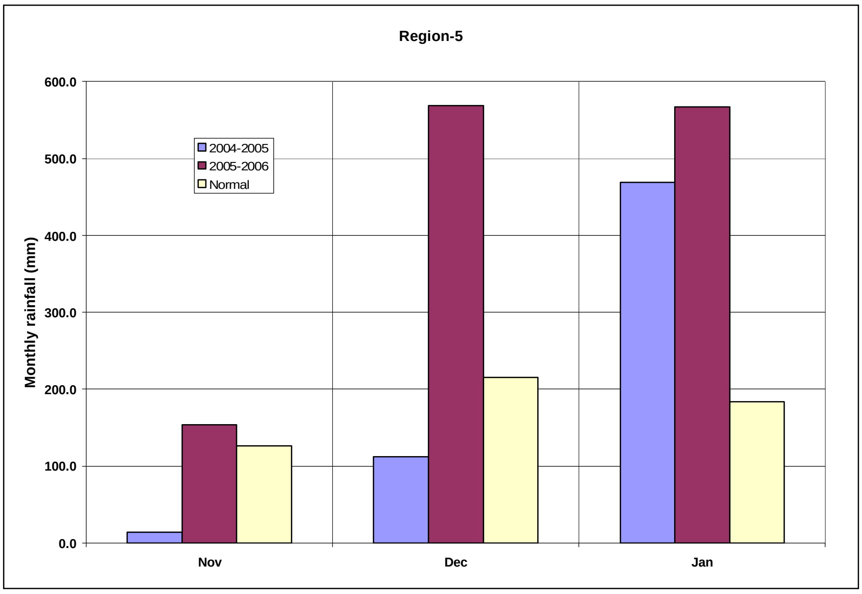

Figure 5.3

Monthly rainfall in Region 5 from November to January 2005-2006 compared with previous year and normals

The difference between the last two rainy seasons is clearly observed from a comparison of Figure 5.4, which shows the daily rainfall patterns of December 2004 and January 2005, and Figure 5.5 presenting the rainfall for the same month one year later. The figures show that in the last rainy season the rainfall has been almost continuous, without becoming very extreme.

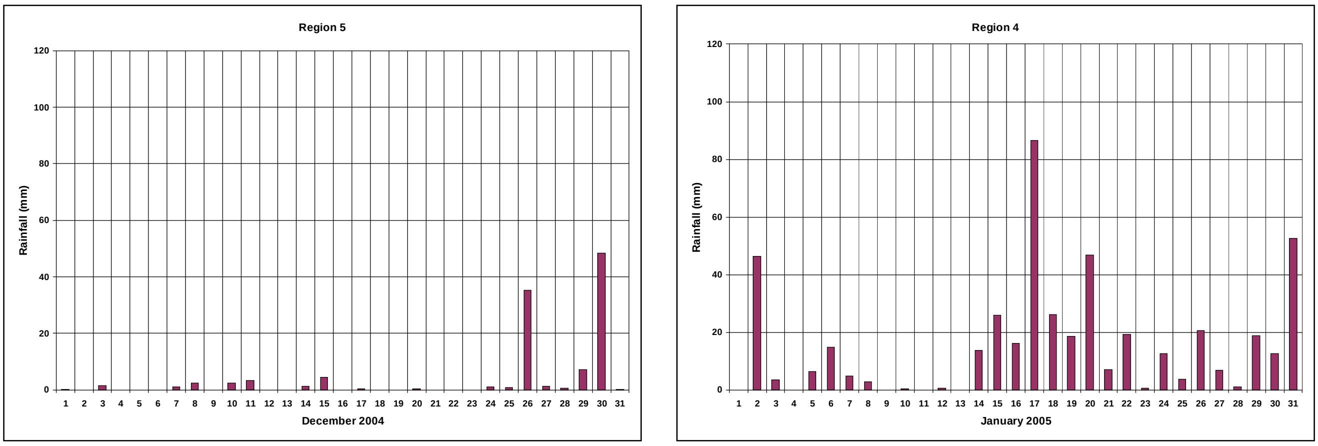

Figure 5.4 Region 5: Daily rainfall of December 2004 and January 2005

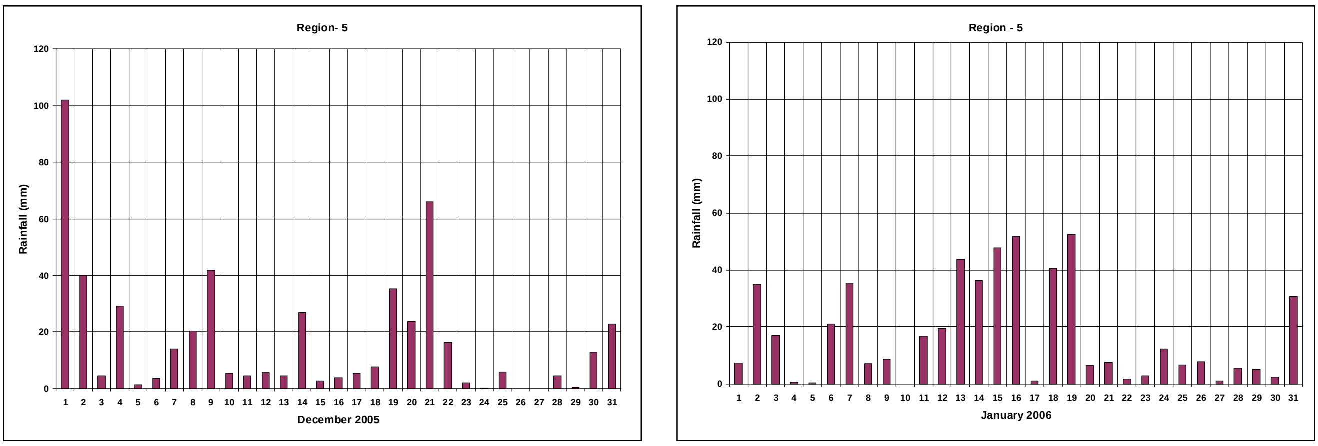

Figure 5.5 Region 5: Daily rainfall of December 2005 and January 2006

5.4 Extremity of the December 2005-January 2006 rainfall

In absence of any flow data for this Region a first assessment of the severity of the flooding can be obtained from an analysis of the rainfall. The rainfall in the months December and January are displayed in Figure 5.6. It is observed that the January 2006 rainfall is the highest on record for that rainy season. Four times more since 1974 a rainfall of similar nature have been experienced. Special about the last rainy season is that now the extreme rainfall covered two month in a row. This is observed from Figure 5.7 where the sum of the December and January rainfall is displayed. The last rainy season shows to be the largest on record, only once approached in the mid seventies.

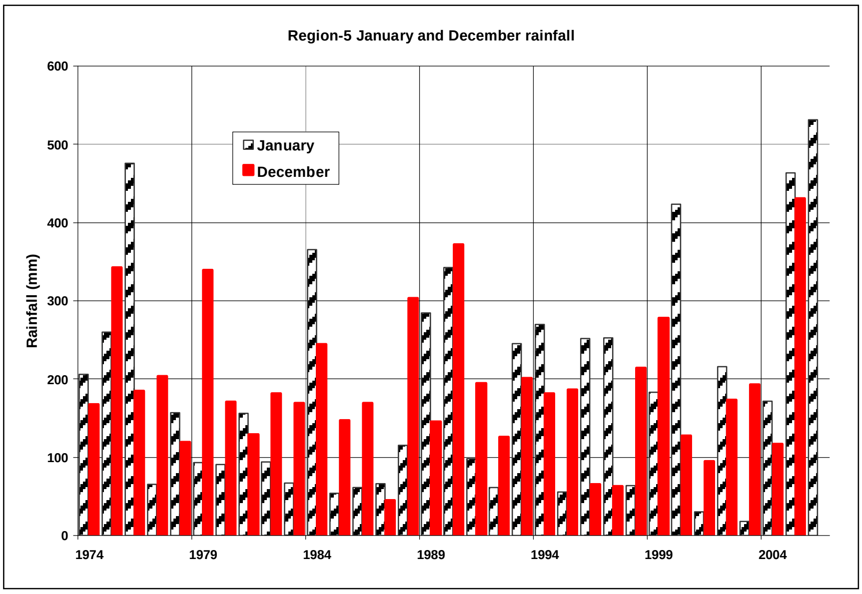

Figure 5.6

Region 5: January and December rainfall in the period 1974-2006

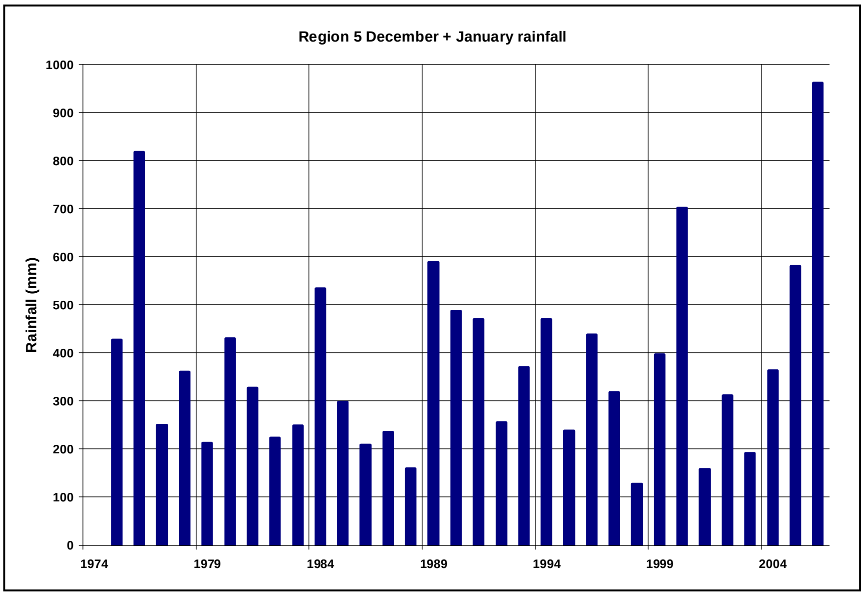

Figure 5.7

Region 5: sum of December and January rainfall in the period 1974-2006

The series is, however, too short to estimate a recurrence interval for such extreme rainfall events. Regions 3 and 4 for example showed even more severe rainfall conditions between 1930 and 1950 than experienced in recent years.

Since extreme rainfall can also be expected in the main rainy season from May to July, the extremity of the December 2005 and January 2006 has been compared with the annual maximum monthly and two monthly rainfall time series for Region 5. The results are presented in Figures 5.8 and 5.10, based on the monthly records of the stations Blairmont and Mards. The Figures show that the January 2006 rainfall has been the highest monthly value on record since 1974, see also Figure 5.9. Similarly, the rainfall from December 2005 to January 2006 exceeds all previous two monthly rainfall records by about 110 mm, see Figure 5.11. The last time serious flooding was experienced in Region 5 was in 1996, when the two monthly rainfall amounted about 800 mm. It is observed that 6 rainfall events exceed this threshold, which would indicate that on average every 5 years flooding could be expected.

Comparison of the two monthly extremes in Figure 5.10 with December+January rainfall in Figure 5.7 shows that the number of extremes has increased substantially, see also Figure 5.12. It implies that not only the rainy season November to January poses a threat to flooding but also the main rainy season from May to July scores high.

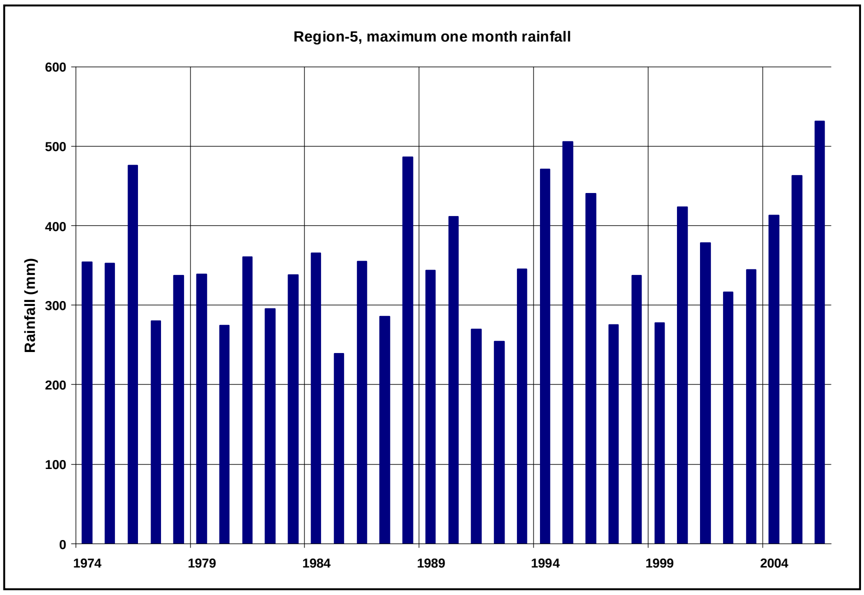

Figure 5.8

Annual maximum monthly rainfall in Region 5, Period 1974-2006

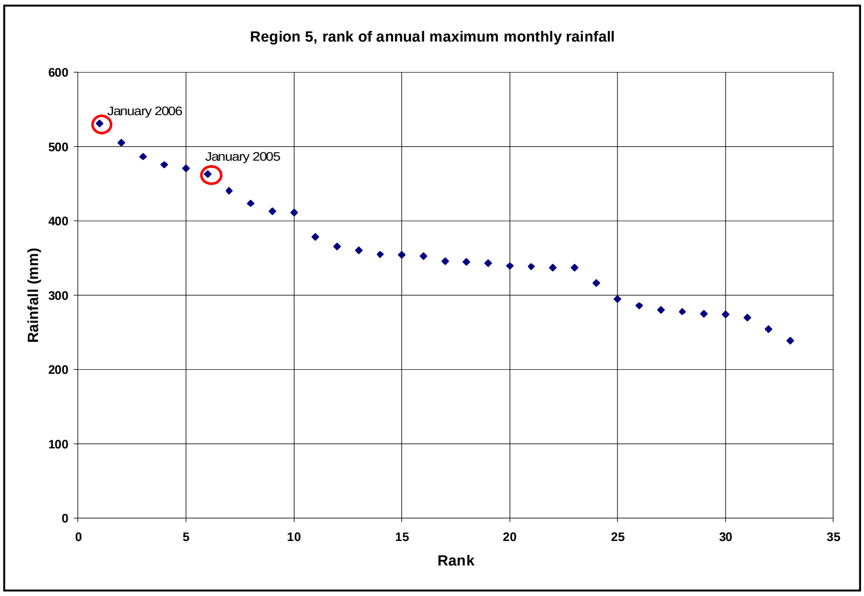

Figure 5.9

Ranking of annual maximum monthly raoinfall in Region 5, Period 1974-2006

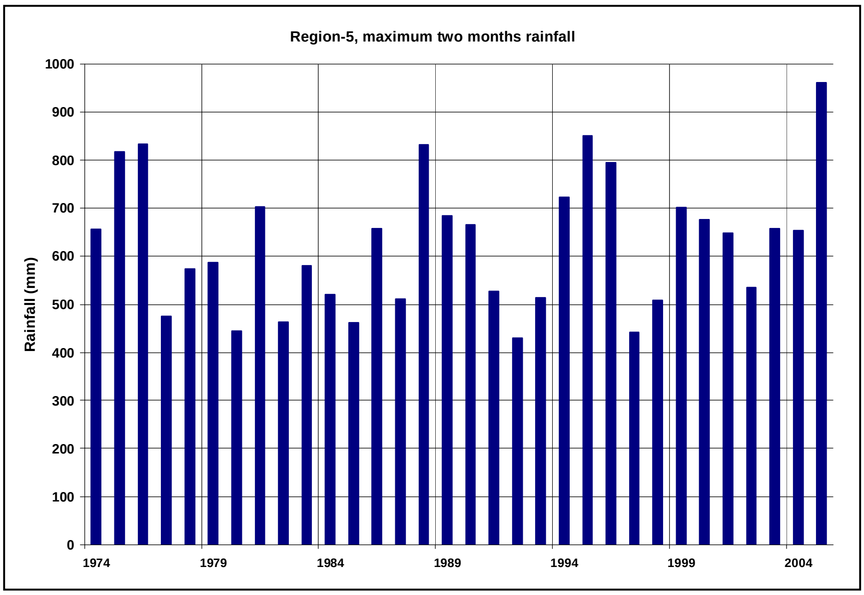

Figure 5.10

Annual maximum two monthly rainfall in Region 5, Period 1974-2005

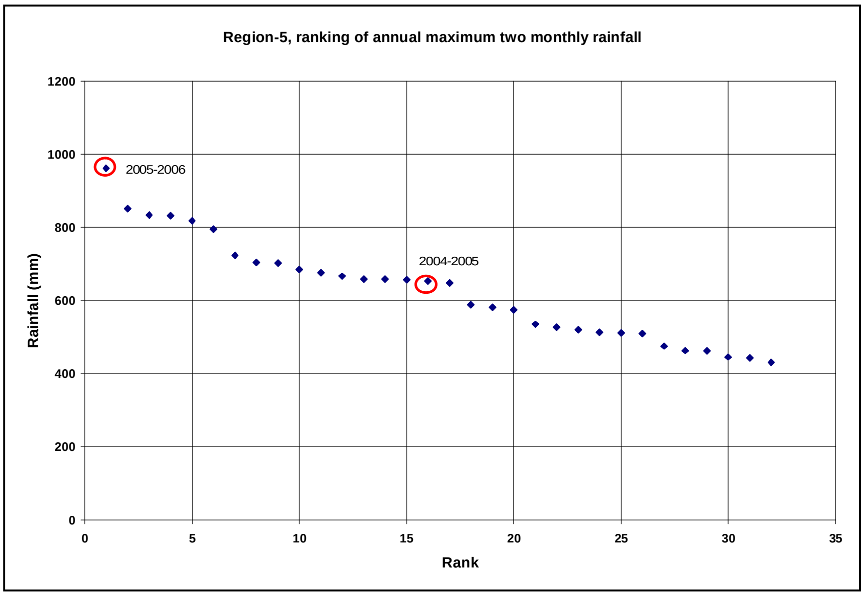

Figure 5.11

Ranking of annual maximum two monthly rainfall in Region 5, Period 1974-2005

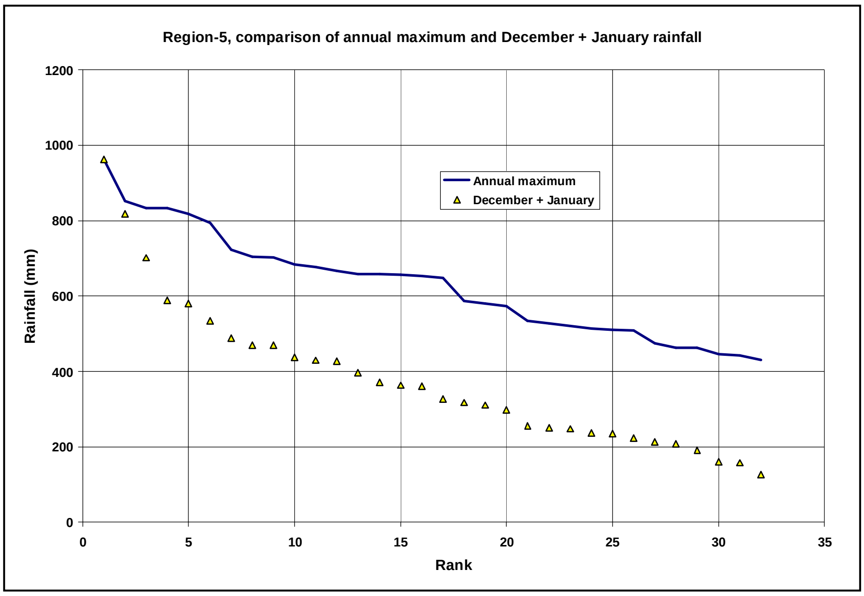

Figure 5.12

Comparison of ranking of annual maximum two monthly rainfall and December + January rainfall in Region 5, Period 1974-2005

5.5 East Demerara Water Conservancy outlet to Region 5

At present the EDWC spills to the Mahaica River via the Lama Big and Small sluices and the Mahuni sluice, see Chapter 4. Near the mouth the cross-section of the river measures about 50 x 6 = 300 m^2. Assuming a flow velocity of 1.5 m/s the discharge capacity becomes about 450 m^3/s. At a water level in the EDWC of 18.00 m (59 ft) the total discharge capacity of the Lama and Mahuni sluices amounts 100-150 m^3/s, dependent on the Mahaica water levels. This is about 20 to 30% of the capacity of the river at its mouth. When the EDWC water level would reach the average crest level of the Dam then the outfalls from the Conservancy would even be able to discharge 30 to 40% of the conveyance capacity of the Mahaica. Hence, the spill from the EDWC really contributes substantially to the flow in the Mahaica and subsequently to flooding along its banks when the river is already in flood.

The total volume of rainfall in December 2005 and January 2006 over the catchment exclusive of the conservancies amounted 3.2 BCM. It would require a continuous drainage capacity of 600 m^3/s to release this in two month time. Such capacity is apparently by far not available. Dredging the lower reaches of the rivers would certainly help to increase the drainage capacity, but its sustainability is questionable. Assessment of its extent and effectiveness needs test dredging, recurrent surveying, flow and sediment transport measurements and hydraulic modelling.

It is regrettable that neither conveyance capacity nor discharge records are available for the rivers in this Region. Such data, together with a mathematical hydraulic model is indispensable to solve the drainage problems in this Region. Therefore, immediate actions are required to establish the required monitoring network, execute the necessary surveys and develop the hydraulic model.

6. Region-6

6.1 Description of the basins

Region 6 is enclosed by the Berbice River in the west and the Corantyne River in the east, see Figure 6.1. The main river that drains the region is the Canje River and tributaries (drainage area about 2700 km^2), which debouches close to the mouth of the Berbice River. In the coastal zone and along the lower reaches of the Berbice and Corantyne rivers nearly 70,000 ha is used for agriculture where predominantly rice and sugar cane is grown, irrigated by pumped abstraction from the Canje River. The water resources of the Canje is augmented by the Torani Canal linking the river with the Berbice. Further details can be found in Mott MacDonald (2004).

Figure 6.1 Map of Guyana, pointing Region 6

6.2 Rainfall normals

The monthly rainfall normals for Region 6 based on the normals of the stations New Amsterdam and Skeldon are presented in Table 6.1 and Figure 6.2. It is observed that the rainfall in the months of the primary wet season May to August is highest on average. The average annual rainfall amounts 1905 mm, which is the lowest of the regions considered.

Table 6.1 Monthly rainfall normals for Region 6

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New Amsterdam	180.4	85.1	115.1	155.2	245.9	286.6	231.3	233.9	71.1	70.3	87.5	201.6
Skeldon F	172.5	108.8	102.2	146.9	248.7	267.9	224.5	154.6	91.3	71.7	106.4	149.6
Average	176.5	97.0	108.7	151.1	247.3	277.3	227.9	194.3	81.2	71.0	97.0	175.6

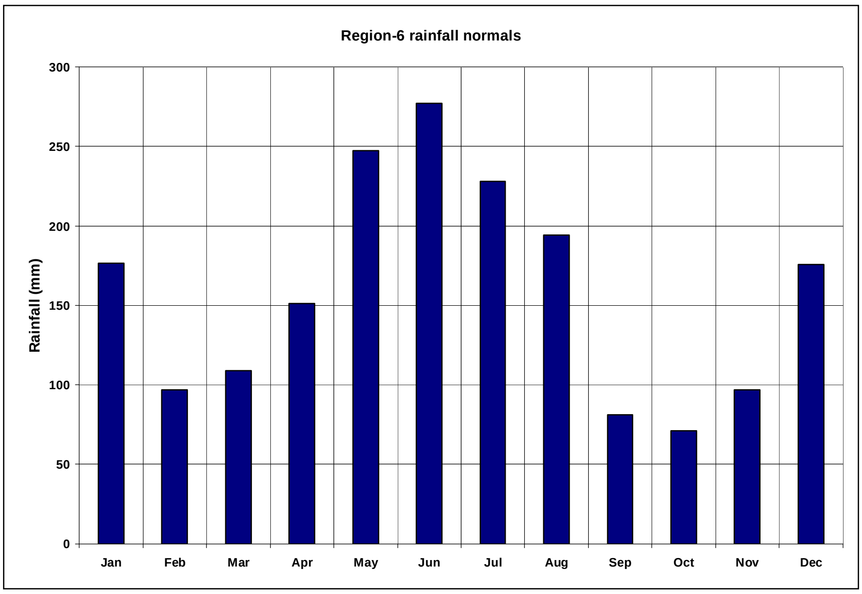

Figure 6.2

Rainfall normals of Region 6, based on Stations New Amsterdam and Skeldon

6.3 Rainfall from November 2005 to January 2006

The rainfall in Region 6 in the season November 2005-January 2006 is presented in Table 6.2 and Figure 6.3. From a comparison with the normals it is observed that the rainfall in all months have been considerably above normal. The season has also been much wetter than in the previous year: 1109.8 against 581.0 mm; in the previous year only January 2005 was above normal.

Table 6.2 Region 6, monthly rainfall November to January 2005-2006 compared with 2004-2005 and normals

Season	November		December		January	
	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal	Rainfall (mm)	Percentage of normal
2004-2005	46.4	48	194.7	111	339.9	193
2005-2006	165.2	170	479.0	273	465.6	264
Normal	97.0		175.6		176.5	

The daily rainfall in the months December 2005 and January 2006 is displayed in the Figures 6.4 and 6.5. It may be observed that the rainfall was almost continuous without reaching high daily intensities.

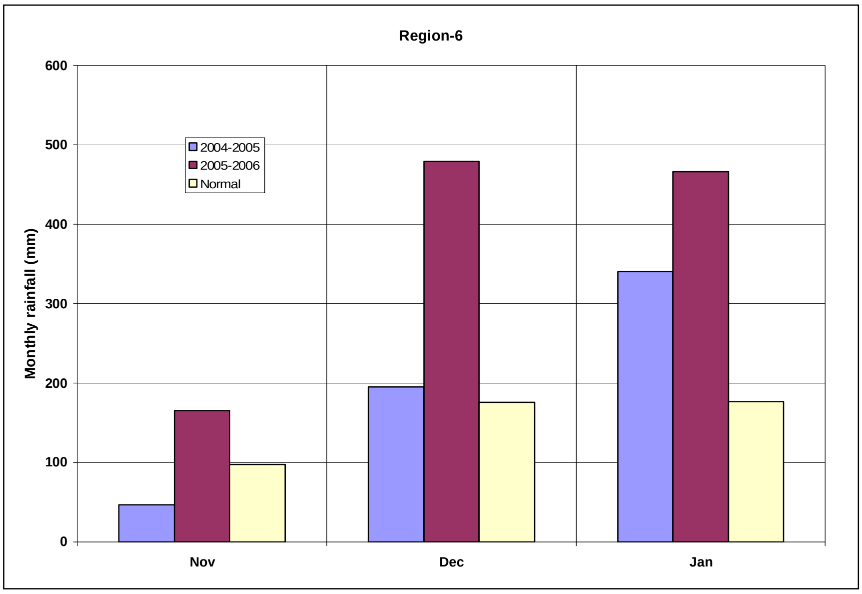

Figure 6.3

Monthly rainfall in Region 6 from November to January 2005-2006 compared with previous year and normals

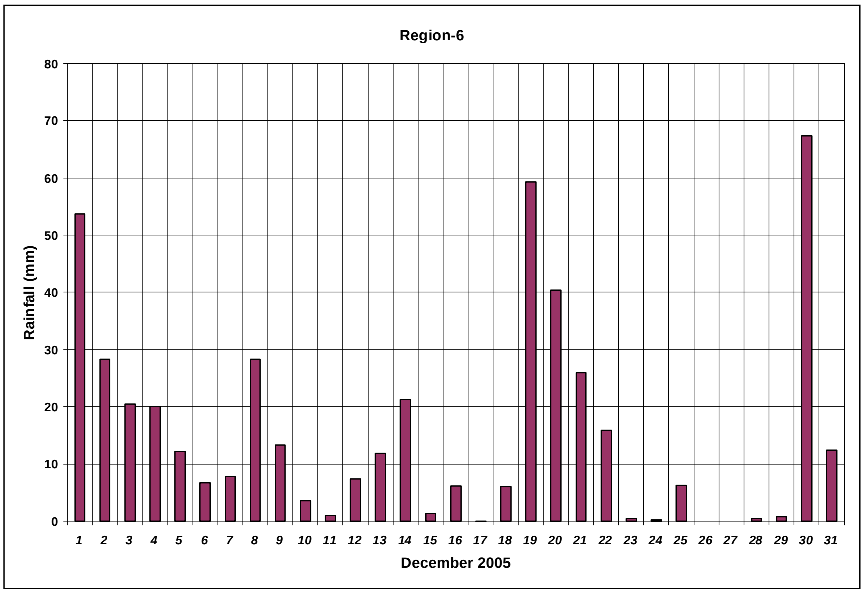

Figure 6.4

Daily rainfall in Region 6 in December 2005

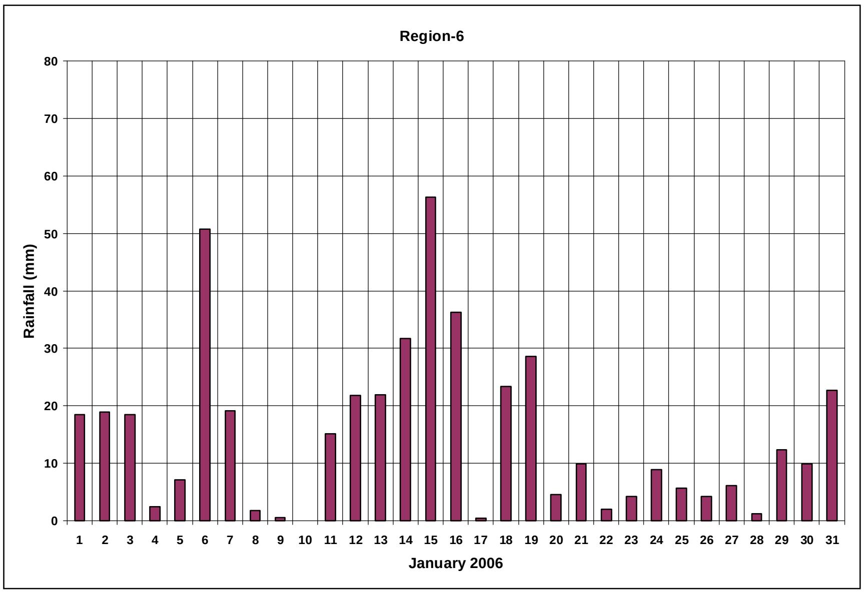

Figure 6.5

Daily rainfall in Region 6 in January 2006

6.4 Extremity of the December-January rainfall

Monthly rainfall in January and December and the annual maximum monthly rainfall in Region 6 is displayed in the Figures 6.6 and 6.7. The ranking of the annual maximum monthly rainfall is presented in Figure 6.8 and in comparison with the maximum monthly rainfall in the December-January period in Figure 6.9. It is observed that the rainfall in December 2005 and January 2006 has been the highest on record, see Figure 6.8. It is also observed from Figure 6.9 that the rainfall in the months December and January generally constitute the most extreme monthly rainfall events. With four such events in 33 years the return period of such extreme monthly rainfall is about 8-10 years.

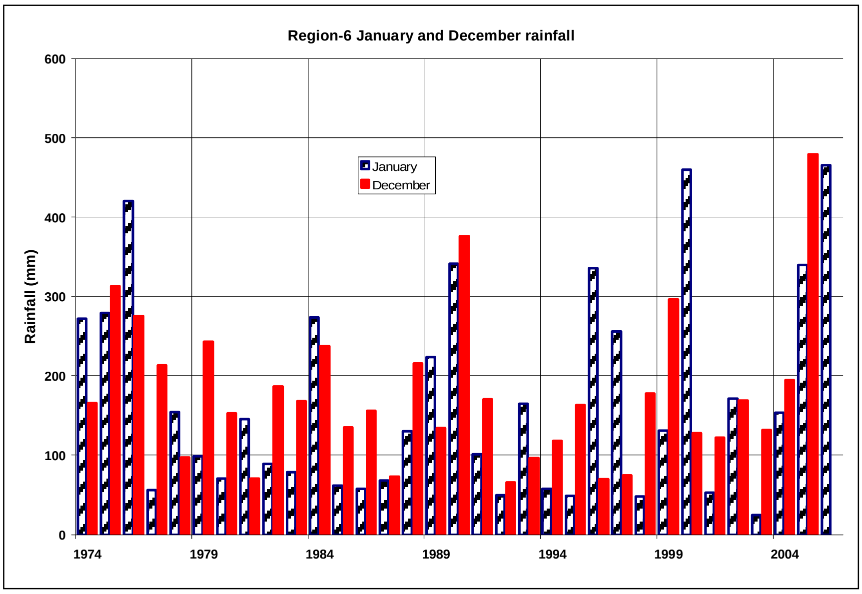

Figure 6.6

January and December rainfall in Region 6, period 1974-2006

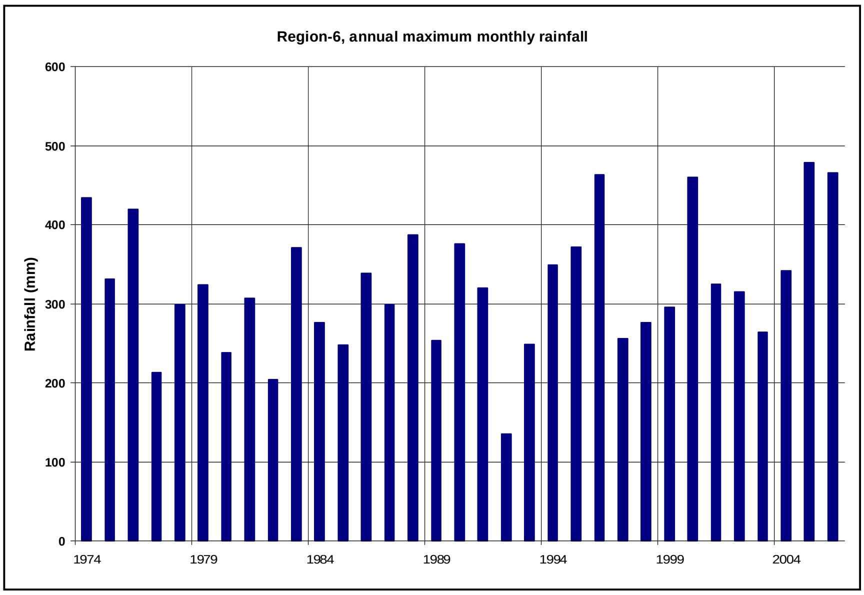

Figure 6.7

Annual maximum monthly rainfall in Region 6, Period 1974-2006

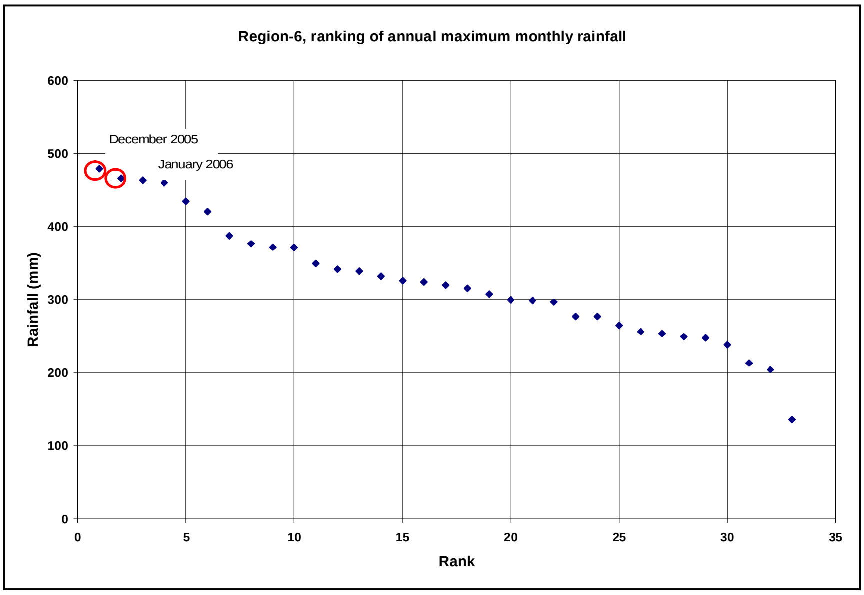

Figure 6.8

Ranking of annual maximum monthly rainfall

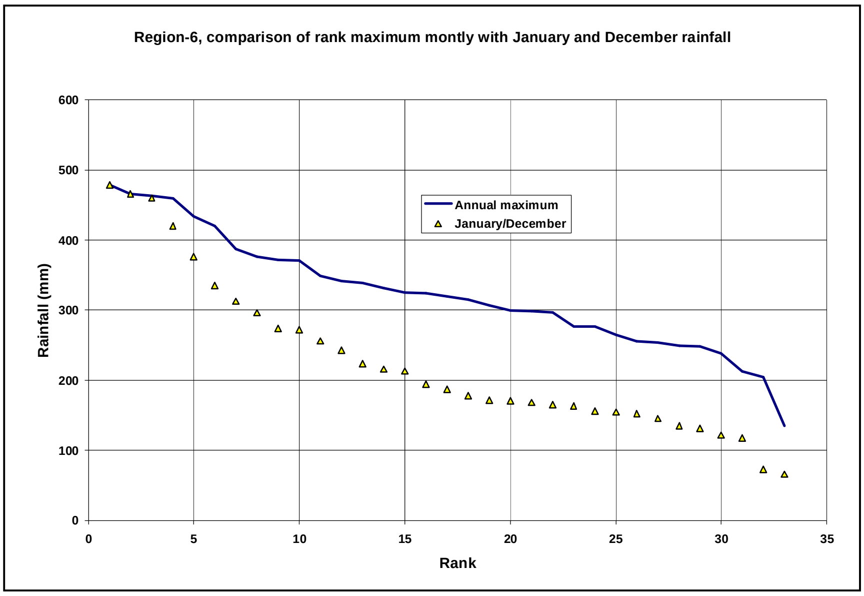

Figure 6.9

Ranking of annual maximum monthly rainfall in comparison to January and December rainfall

In a similar fashion as for the monthly rainfall extremes the two monthly rainfall values have also been considered in view of the size of the Canje catchment. The results are displayed in the Figures 6.10 to 6.12. From 6.12 it is observed that with one exception the most extreme two monthly rainfall is also experienced in the second wet season. Given only two extremes of the size of the December 2005 + January 2006 rainfall in a period of 33 years gives the latter a return period of about 15 years.

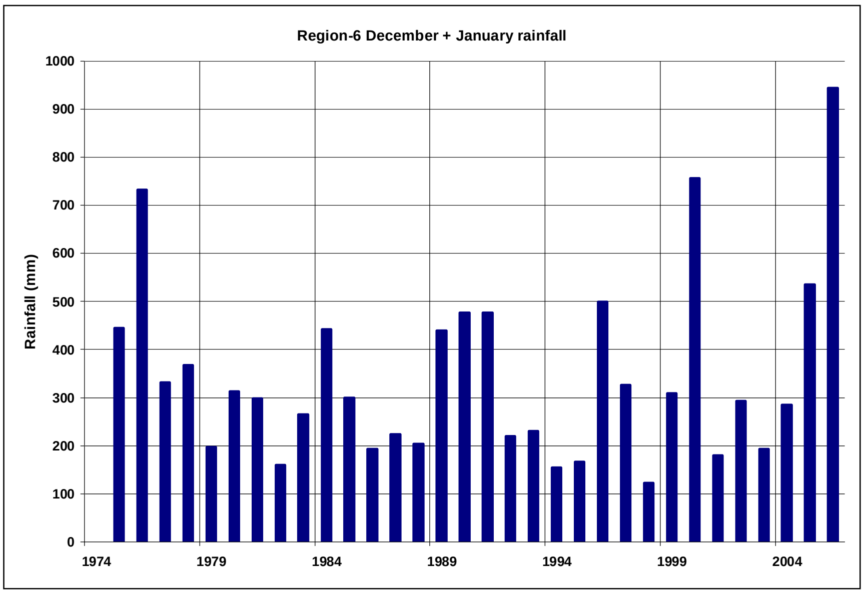

Figure 6.10

December + January rainfall in Region 6, Period 1974-2005

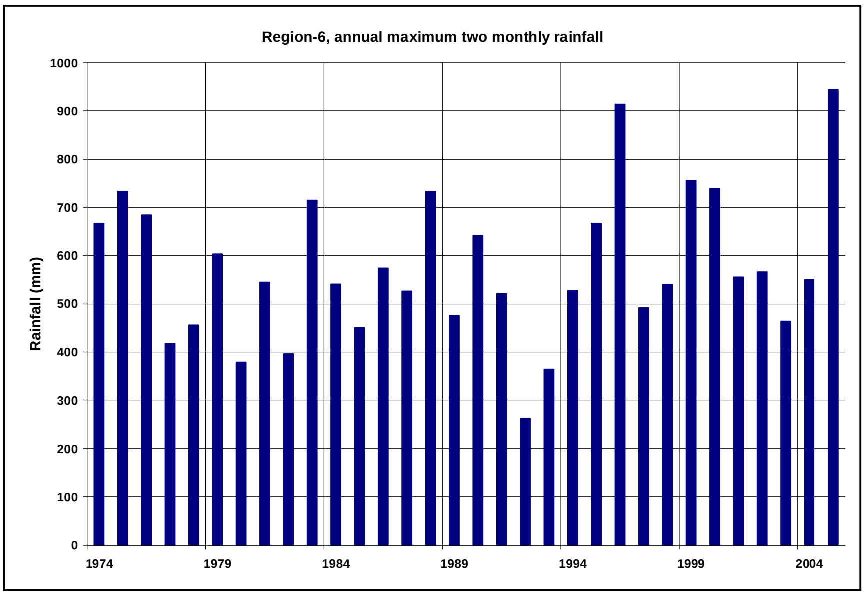

Figure 6.11

Annual maximum two monthly rainfall in Region 6, Period 1974-2005

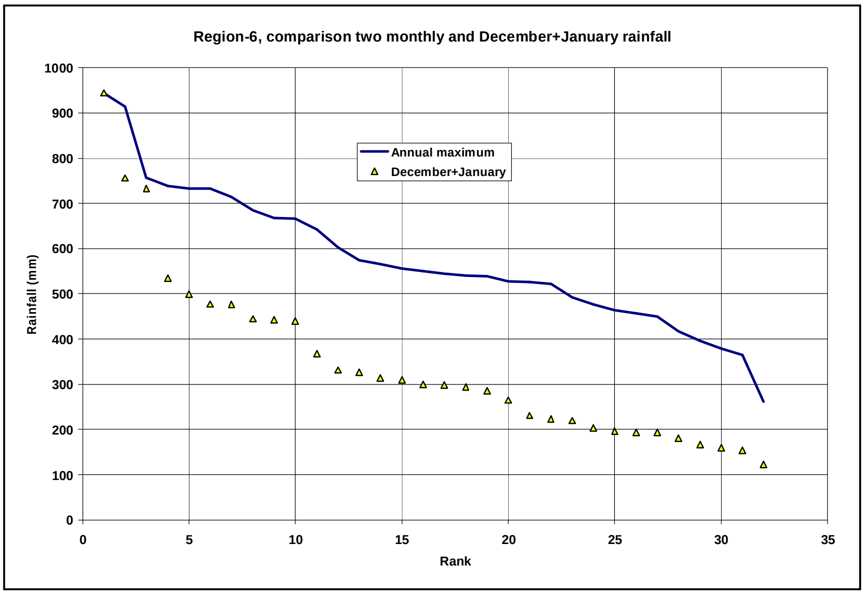

Figure 6.12

Ranking of annual maximum two monthly rainfall in comparison with December + January rainfall

7. Conclusions

From the analyses in this Appendix the following conclusions can be drawn.

General

1. Most extreme monthly rainfalls are generally experienced in the months December and January of the secondary wet season running from November to January, though on average the rainfall in the primary wet season from May to July is higher.
2. There is a distinct El Nino effect on the rainfall in the secondary wet season November to January, whereas no such effect exists with rainfall in the primary wet season. Extremes are more likely during a La Nina. Consequently, for those regions were flooding is generally produced by the rains in the period November to January the SOI provides a proper indicator for an extra flood preparedness status.

Region 2

3. Prolonged heavy rainfall in December 2005 and January 2006 caused flooding along the lower Pomeroon River. The flooding started in December by the incapacity of the drainage system to release the local rainwater, followed by overtopping of the embankment along the river when the river flow became high in January 2006.
4. The mouth of the Pomeroon River is partly silted up, which negatively affects the discharge capacity. However, the scale of it and its effect on the flood levels are difficult to assess as neither hydrographic surveys nor hydrologic monitoring results are available
5. The rainfall in December 2005 and January 2006 was the largest since 1940, though 4 events of similar nature have been observed. All but one occurred in the secondary rainy season.
6. Heavy rainfall in two consecutive months is required to get flooding from the Pomeroon. Since 1940 five times such conditions occurred; this gives flooding along the Pomeroon a return period of 10-15 years. For assessment of flooding in the coastal zone rainfall statistics of much shorter rainfall durations are required.
7. There is no distinct trend in the development of annual maximum monthly and two monthly rainfall in Region 2.
8. In January 2006 the dam of the Ituribisi Conservancy was overtopped and the area adjacent to its outlet was flooded. No further flooding was reported.

Region 3

9. Seasonal rainfall in the 2005-2006 secondary rainy season equalled the amount for the same season in 2004-2005, however the short duration rainfall amounts (1-20 days) were much smaller (< 5 years return period now versus 200-500 years return period one year before). Consequently, the flood damages were less severe than one year before.
10. There is no trend in the development of annual maximum monthly and two monthly rainfall amounts.
11. The water levels in the Boeraserie Conservancy exceeded the lowest point of the conservancy dam by about two decimetres. Sufficient drainage capacity is available at the 8000 ft weir (though with little freeboard), provided that the waterways to this weir are significantly improved. The high water levels in the conservancy indicate that this is still to be done.

Region 4 and Georgetown

12. Seasonal rainfall in the 2005-2006 secondary rainy season equalled the amount for the same season in 2004-2005, however the short duration rainfall amounts (1-20 days) were much smaller (< 5 years return period now versus 500 – 1000 years return period before). Consequently, the little flood damages were experienced in January 2006, particularly in Georgetown

13. Extreme monthly and two monthly rainfalls are generally experienced in the secondary rainy season.
14. There is no trend in the development of annual maximum monthly and two monthly rainfall amounts.
15. The maximum water level in the EDWC in January 2006 remained 0.35 cm below the average crest level of the conservancy dam, but exceeded the lowest level by over two decimetres. To prevent overtopping of the crest at various locations clay bags were applied.
16. It is estimated that at maximum a discharge of 90 – 145 m^3/s has been released towards the Mahaicony, which aggravated the flooding in that region. The outfall capacity to the Demerara River was improved since Janury 2005 by opening of the Cunha and Kofi sluices.
17. The capacity of the relief structures of the EDWC dam to the Demerara and/or the sea needs to be enlarged to improve the safety of the area downstream of the dam and to reduce flooding in Region 5. Furthermore, improvement of the conservancy dam between Non Pareil and Flagstaff needs urgent attention.

Region 5

18. The rainfall in Region 5 in the secondary rainy season of 2005-2006 was 700 mm larger than one year before, which caused wide spread flooding in the region. The rainfall in January 2006 was highest since the start of the rainfall measurements in 1974.
19. An areal rainfall of about 800 mm is required to cause flooding in Region 5. The return period of such events is about 5 years.
20. The flooding in Region 5 in Region 5 is wide spread due to insufficient drainage capacity. The flooding is aggravated by:
    a) Release of water from the EDWC through the Maduni and Lama sluices
    b) Sedimentation in the river mouths of the rivers draining Region 5, to an unknown scale

    It is claimed that the flooding was further enhanced by leakage of water from the Abary Conservancy, for which no clear evidence was found. This needs further investigation
21. The absence of surveys data, conveyance capacities, discharges, etc and the non-availability of a hydraulic model of the hydraulic infrastructure of Region 5 severely hampers a sound design of flood relief measures.

Region 6

22. Rainfall in the months January 2006 and December 2005 were the highest on record since 1974. The rainfall in these months was almost continuous without reaching high daily values.
23. Rainfall of similar magnitude generally occurs in the secondary rainy season and has a return period of about 8-10 years.