COUNTRY STUDY CLIMATE CHANGE SURINAME

WATER RESOURCES

PROFILE

Technical report no. 4a

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I. Climatological Characteristics of the Coastal Area

I.1 General

Suriname is situated on the northern coast of South America and lies just north of the equator. Its climate is largely controlled by the passage of the Inter Tropical Convergence Zone (ITCZ) above the region. The ITCZ is the area where the NE and SE trade winds meet and this area follows the sun in its movement north to about 15^0 latitude or south to about 10^0 latitude over the equator. The ITCZ thus passes twice every year over Suriname, once travelling southwards and once travelling northwards, bringing heavy rainfall when it is overhead.

I.2 Rainfall and climatic seasons

When the ITCZ appears over Suriname in its northward and southward journeys the NE trade winds saturated with moisture meet with the SE trade winds and bring heavy rains over the region, the rainfall amount depending on the degree of moisture saturation and the pressure gradient. When the ITCZ is north or south of Suriname drier conditions prevail. As a result, the year can be divided into four seasons that are classified as follows:

The short wet season: from the beginning of December to the beginning of February. The ITCZ is overhead and travelling southwards. The region lies under the influence of the Atlantic cyclone. The mean monthly rainfall is about 200mm.

The short dry season: from February to the end of April. The ITCZ has passed over the region and is travelling further southwards. The further it is from Suriname the less the probability of heavy rainfall. The mean monthly rainfall is about 100mm.

The long wet season: from the beginning of May to the middle of August. The ITCZ is now travelling northwards and is again over Suriname. It comes into collision with the relief of the country as well as the trade winds from the sea causing its movement over the region to become slower and the wet season is prolonged. The most humid month with a rainfall of about 325mm is observed during this season. In general, the mean monthly rainfall is about 200mm.

The long dry season: from the middle of August to the beginning of December. The ITCZ has already passed over Suriname and is found north, above the Atlantic Ocean. September and October are normally the driest months of the year. The mean monthly rainfall is generally less than 100mm.

The above classification is developed for Paramaribo, the capital of Suriname, but it can be applied to the whole northern part of the country.

Another classification of the climate in Suriname, elaborated by Köppen, is based on the non-uniformity of the rainfall distribution in time. According to this classification, Suriname has a tropical rain climate (A-climate) which is subdivided into the following types:

Af - climate: tropical rainforest climate, always humid and every month has rainfall exceeding 60mm.

Am - climate: monsoon climate. One or more months have less than 60mm rainfall. The deficit is compensated by the annual value of rainfall.

Aw - climate: Humid and dry climate. One or more months have less than 60 mm of rainfall. The deficit is not compensated by the annual value of rainfall.

The northern part of Suriname has an Af - type of Köppen classification. This means that the mean monthly rainfall in the coastal area is always higher than 60mm. However, a small strip along the northwestern portion of the coastal area, including Coronie and Nickerie, might have lower than 60mm rainfall in the driest months. The greater portion of Suriname has an Am - type climate whilst in the southwest the Aw - type climate prevails.

I.3 Rainfall characteristics

Amount and distribution

Average annual rainfall over Suriname is given on the map "Rainfall" compiled by NARENA (Department of Natural Resources and Environment Assessment, Centre for Agricultural Research in Suriname) and shown as Figure 1 in Appendix "B". The rainfall increases from about 1700 mm at a narrow strip along the coast at Coronie and Nickerie to about 3000 mm in the region of Tafelberg in the interior. The rainfall distribution also, is not simultaneously applicable since the rainfall seasons first begin in the east at Albina and begin much later in the west of the country at Nw. Nickerie.

Generally, on the coastal plain rain falls in the form of heavy showers. Rainfall is highest during the long wet season (May-August) which provides 50-70% of the total annual rainfall. The short wet season contributes 17-25% to the total whilst the remainder occurs during the two intervening dry seasons.

Rainfall trends within the coastal zone are illustrated in Figures 2-10 in Appendix "B". Trends are shown in two directions. First in the direction going along the coast more or less parallel to the coastline. For this purpose the stations at Nw. Nickerie, Friendship/Totness, Groningen, Paramaribo, Alliance and Galibi are used. Secondly in the direction going inland and for this purpose the stations at Paramaribo, Lelydorp, Republiek and Zanderij are used. From these figures it can be concluded that whilst the annual rainfall trend is not consistent along the coast, it appears to increase going inland.

Intensity

For station Cultuurtuin k-days rainfall summations are computed and analyzed by Kamerling over the period 1928-1957. He used three methods:

A) Computation with non-overlapping periods
B) Computation with overlapping periods
C) Computation by a method, whereby the top rainfalls are discounted, while the periods are taken as non-overlapping.

Under summations of k-days rainfall is meant the sum of the rainfall in k-days, whereby k is equal to 1 or 2 or 3 or…. n-1. By doing this a new array is created out of which rainfall probabilities of given values are computed. Application of the above methods for determining the rainfall probabilities has shown that by using method A low values are obtained whilst method B gives high values. The values of method C are in between. Method C was therefore used for treatment and processing of rainfall data. Figs. 11-14 (Appendix B) show the rainfall intensities of the stations Nw. Nickerie, Friendship/Totness, Paramaribo and Moengo for the period 1921-1960. Figure 15 (Appendix B) shows intensities at Cultuurtuin for the period 1911-1960 as well as the probability of exceedence of the rainfall intensity for the time periods of 15, 30, 60, 120, 240 and 480 minutes.

H. Ehrenburg summarizes the rainfall intensities determined by various persons/organizations for different periods and stations in Paramaribo. These results are given in Tables 2-13 in Appendix A for purposes of comparison.

I.4. Temperature

Temperatures are high during all seasons and the mean annual air temperature varies only 2^0-3^0C. However, along the coast the daily fluctuations of temperature are about 5^0C whilst in the interior daily fluctuations of 10^0 - 12^0C occur. At Paramaribo the mean air temperature is 27.3 ^{0}C with the lowest occurring in January with a mean of 26.2 ^{0}C and the highest in September and October with a mean of 28.2 ^{0}C. Maximum daily temperatures (average 31 ^{0}C) occur at 1500hrs whilst minimums (average 23 ^{0}C) occur at 0600hrs. The main factors determining temperatures are cloud cover and evaporation. Mean annual soil temperature in the forest at a depth of 2.5m is about 24 ^{0} - 26 ^{0}C.

I.5. Humidity

Humidity averages about 80 - 90% annually in the coastal regions whilst in the central and southern regions daily air humidity is lower and averages about 75%. These values increase during the wet seasons.

In the forest tracts the air humidity largely depends on the entrance of the sun's radiation and at a height of 1.5m. relative air humidity lies between 70 - 100%. In open areas the fluctuation is even greater lying between 50 - 100%. Sharp decreases and increases are observed in the relative air humidity about 10hrs and 17hrs respectively.

I.6. Wind speed and direction

The mean wind speed is 1.3 on the Beaufort scale. Maximum mean windspeeds occur during the dry seasons attaining 1.6 Beaufort in February with a second peak in September and October. Minimum mean windspeeds of 1.0 Beaufort occur in January. Windspeeds of 3 - 4 Beaufort generally occur during the day but during the evening and night, especially in the interior, the windspeeds drop.

I.7 Available data

Table 1 in Appendix A lists meteorological stations situated within the coastal area. The majority of these stations are concentrated around Paramaribo whilst others are located along roads and rivers. For each of these stations mean annual precipitation is computed as the arithmetical mean of the total rainfall of the observed years. Most of these stations have missing and incomplete data. In these cases, the years with missing data have been excluded except for those years where it is possible to obtain this data by correlation. For this purpose the double mass curve method was used.

II. Water Resources in the Coastal Area

II.1. General description

The water resources in the coastal area can be divided into two categories, the surface water resources and the ground water resources. The resources of the first category are generally used for irrigation, aquaculture and other industries whilst the latter is normally used for domestic (potable) purposes.

II.2 Surface water resources

II.2.1 Data available

The open water resources in Suriname can be divided into two major groups as follows:

- rivers, including sea water, and
- swamps, wetlands, lagoons and man-made lakes.

Rivers

Seven main rivers are located within the coastal region of Suriname and are from east to west:

- the Marowijne
- the Commewijne
- the Suriname
- the Saramacca
- the Coppename
- the Nickerie
- the Corantijn.

Table 1 below provides some hydrological characteristics of these rivers. The outfalls of the Commewijne, Saramacca and Nickerie rivers, due to their low discharge, lie in the estuaries of the rivers Suriname, Coppename and Corantijn respectively.

All rivers mentioned in Table 1 flow more or less northward and parallel to each other except within the Young Coastal Plain. Here, due to the movement of mud banks, the Guyana current and their small amount of discharge, the smaller rivers have bent westwards at some period of the Holocene. Table 1 also shows that it is not the specific discharge but the total discharge of a river that determines whether a river has made a westward movement or not. The Marowijne and Corantijn rivers discharge a greater amount of water into the Atlantic Ocean then the

Coppename and Suriname rivers and are therefore hardly or even not influenced by the above mentioned factors.

Table 1. Hydrological characteristics of the main rivers in Suriname

N	Main river	Catchment Area in Km^2	Discharge m^3/s	Specific discharge ($l/s/km^2$)
1	Marowijne	68,700	1,780	25.9
2	Commewijne	6,600	120	18.2
3	Suriname	16,500	426	25.8
4	Saramacca	9,000	225	25.0
5	Coppename	21,700	500	23.0
6	Nickerie	10,100	178	17.6
7	Corantijn	67,600	1,570	23.2

According to their size and shape, the drainage areas of the rivers given in Table 1, can be divided into three groups as follows:

Group I represents the drainage areas of the Corantijn and Marowijne Rivers which have large drainage areas and discharges. The shapes of their drainage areas are nearly the same and correspond to a triangular shape. Also the size of the drainage area is more or less the same. Both rivers are located at the borders of neighboring countries, the Corantijn in the west and the Marowijne in the east. From the middle of the country up to its southern border these rivers have a common watershed.

Group II consists of the drainage areas of the Suriname and Coppename rivers. The shapes of these areas is elongated and spread over central Suriname. They have intermediate drainage areas and discharges. The Coppename drainage area originates in the Wilhelmina Mountains in the south and has common watersheds with the Nickerie in the west and the Saramacca in the east. The Suriname drainage area borders with that of the Saramacca in the west and that of the Commewijne and the Marowijne in the east.

Group III consists of the smallest drainage areas which belong to the Commewijne, Saramacca and Nickerie rivers. These rivers have the smallest discharges and their catchment areas are located between the larger rivers. The Commewijne drainage area is located between the Marowijne in the east and the Suriname in the west and has a circular shape. The Saramacca drainage area is located between the drainage area of Suriname in the east and that of the Coppename in the west and it follows the fault of the Wilhelmina Mountains southward. It has an elongated shape. The Nickerie drainage area is less elongated in shape and is located between the catchment of Coppename river in the east and Corantijn river in the west respectively.

Among the above-mentioned rivers, the Commewijne is the only river, which flows for the larger part within the coastal area. This river, together with the Nickerie, has the lowest specific discharge, about 18 $l/s/km^2$. The other the rivers have higher values of about 23-25 $l/s/km^2$. The rivers in Groups II and III originate in the central mountain ranges in Suriname where the annual average rainfall is the highest in the country.

Conditions, under which these rivers flow, are very similar. Waterfalls and rapids often interrupt their courses in their higher reaches. In the upper part of their basins the water regime of all rivers, including those in the first group, reflects the seasonal character of the rainfall. Their hydrographs show that the beginning and ending of flood waves are closely related to the onset, advance, and end of the rainfall seasons. The long wet season may last from one to four months and usually begins in the month of May. The earliest occurrence of this season is in April and the latest in June.

Annual maximum discharges are also observed to accord with the occurrences of the floods. In the south-west of the country the maximum discharges usually occur in June-July whilst in the center of the country these occur in May – June and in the eastern part of the country the annual maximum discharge is observed in April. High water conditions, therefore, occur earliest in the east and later in the west of the country. The annual maximum discharge in some years occurs at the end of the short rainy season in January or February.

During the dry seasons the amount of water in the rivers is mainly determined by groundwater discharge, individual or isolated rainfall of convective origin and flow from the swamps. The minimum water levels occur in these periods of the year, usually with the lowest levels during the long dry season.

The effect of rainfall on the flood regime of the whole region is, however, not the same. In part of the coastal area the water regime is influenced by the sea water penetration up the rivers as a result of the diurnal tide (see Appendix C: figure1) apart from the rainfall.

Swamps / wetlands / man-made lakes

These open water resources can be divided into two groups:

a). Those with saline and brackish waters, and

b). Those with fresh water.

Group (a) includes swamps/wetlands and lagoons lying within a relatively small strip along the coast. The southern border of this strip is determined by:

- Polderdams and roads in the west, northwest and north of Nickerie, established as a result of rice lands expansion.
- East-west road in the north of Coronie. Prior to the establishment of the east-west road a gradual transition of fresh water to salt water was observed in the swamps. This changed after the road was built. The Coronie district shows a classical example. The northern flow of the swamp water was cut off in 1964

when the east-west road was constructed and the whole water balance of the northern part of the swamp was disturbed. In order to redress this situation a number of sluices and culverts were constructed to supply the northern part of the swamp with fresh water from the southern portion. This also helps to reduce high water levels in the southern swamps and flooding of neighboring rice lands during the rainy seasons.

- Water divide between the fresh and saline waters, especially in the north of Saramacca, parts of Commewijne and Marowijne. This water divide, in contrary to those in Nickerie and Coronie, is dynamic. It moves during the rainy seasons in the northern direction and draws back in the southern direction during the dry seasons. The area wherein the movements of the water divide border occur, form areas of brackish waters also called brackish water swamp.

Group (b) includes most of the swamps located south of the water divide, as defined here above. These swamps contain fresh water, except for a small strip along the tidal rivers, where due to the bank overflows brackish swamp might form. Groups (a) and (b) are linked together as well as by artificial structures as by natural water divide, but due to continuing development, particularly in agriculture, the locations of these links are constantly displaced. An other consequence of this development is that not enough fresh water is being provided to the saline and brackish swamps in the north to maintain the ecological balance of the region.

The fresh water swamps are divided from west to east as follows:

- the Nanni swamp
- the Coronie swamp
- the Coesewijne swamp
- the Surnau swamp

Generally these swamps are poorly drained by discharge through small rivers, creeks and are depleted by evapotranspiration. The northern portion of these swamps is dammed by the east-west road or by dams along irrigation and drainage canals. These dams also function as dykes against high water levels in the swamps during periods of heavy rainfall. In particular, high water levels of the Nanni swamp and the Coronie swamp result often in dam breaks and (large scale) damage of rice crops.

The man-made lake, the Prof. Dr. Ir. Van Blommenstein reservoir, is the largest artificial open freshwater resource in Suriname. It is located in the Suriname river at Afobaka , 194km upriver. The purpose of this reservoir is to provide electricity for the aluminum smelter at Paranam. This man-made lake is located entirely outside the study area and will therefore not be discussed further.

Hydraulic and hydrologic conditions of the coastal zone

Two flood and two ebb tides are observed in the daily movement of the Atlantic Ocean. These semi-diurnal flood tides penetrate, through rivers and creeks, far into the Young Coastal Plain forming salt wedges. The location of the salt wedges are not only a function of the magnitude of the tide but depends also on other factors, among which the fresh water discharge of the river is the most important one. The location of the salt wedge in the rainy periods of the year is closer to the estuaries of the rivers whilst during the dry seasons it penetrates further up the river especially during the long dry season. When the level of salinity in the salt water wedge exceeds 300 mg Cl/l the water is considered unsuitable for irrigation of rice.

During the high water spring tides the salt-water penetration is further upriver and parts of the banks and the coastal shore may be inundated at these times. These inundations are more severe if combined with heavy rainfalls. Inundation of large areas especially in the second half of the rainy season may be caused by rainfall alone. Backwater effects during the spring periods in combination with heavy rainfall may also result in inundations.

Salt water intrusion

The majority of the Young Coastal Plain lies between 0.5m and 1.5m above NSP (national datum, about mean sea level) with the highest points (ridges) reaching 4.0m NSP. Because of this, sea and river defenses are necessary in some regions (among others Nickerie, Coronie, Commewijne) to protect the land from inundation. When these defenses are breached or overtopped, as happens occasionally, tidal flooding by saline water causes damage to agricultural areas as well as to infrastructure such as roads and housing. Apart from this direct inundation, salt water from the sea also intrudes far into the estuaries of the coastal rivers.

The depth of salt intrusion into the estuaries of these rivers primarily depends on the magnitude of the extruding force of the river discharge and the intruding force of seawater with its dissolved salts during the flood tide. Salinity may be expressed as the total weight of salt in grams dissolved in 1000 grams of seawater (‰) or alternatively the term 'chlorinity' is also used to indicate the total mass of Cl-ions found in 1000 grams of seawater. For normal sea water the relation between salinity (S) and chlorinity (Cl) is $S=0.030+1.805Cl$. The mean salinity of seawater is about 34.3‰. As chlorine has been determined in Suriname the "chlorinity" is being used.

All the river estuaries are subject to semi-diurnal tides with tidal ranges increasing from about one meter near the open sea to about 3 meters upriver in the estuaries. Tidal ranges are greatest at spring and lowest at neap. The shape of the channel, its depth, width, obstructions and irregularities in its bed and shoreline, also affects tidal behavior.

In order to find the extent of saltwater intrusion in the estuaries, water samples were taken at high water slack (HWS) when the salinity is at its maximum. HWS occurs when there is no horizontal motion of the water just after the flood current stops and the ebb current has not yet begun. By travelling with a boat upstream at HWS, water samples can be taken a various locations on a river at the same tide. At each location, three samples were taken in a vertical namely at surface, middle and at bottom. The mean chlorinity at each sampling vertical was determined by laboratory analyses. Twice daily water sampling at fixed locations on the tidal rivers is also being done.

The main factor influencing the depth of salt-water intrusion up the rivers is the amount of discharge of the river. The size of the tidal range and the mean river water level also influence the longitudinal displacement of the boundary between fresh and salt-water though to a much lesser extent. So far no simple relationship has been worked out between tidal stage and the chlorinity of the rivers. To establish such relationships would require much more field data than are now available.

Water for irrigating agricultural lands and for aquaculture is taken from the rivers while water for domestic use is taken from ground water aquifers. In case the saltwater boundary moves higher up the river than normally occurs it will mean that less fresh water will be available for industrial domestic and other uses.

On the NARENA (Department of Natural Resources and Environment Assessment, Centre for Agricultural Research in Suriname) map "Waterbodies, Catchment areas and Waterbodies", a value of 200 mg Cl/l is used to indicate how far the salt water intrudes upriver. However, river water for rice cultivation may contain a higher salinity, namely up to 300 mg Cl/l.

Data collection and management

At present, there are several agencies dealing with data collection and management of the water resources in Suriname. These are:

***Ministry of Public Works* (OW)**

Meteorological Service Suriname (MDS).

Hydraulic Research Division (WLA)

***Ministry of Agriculture* , Fishery and Animal Husbandry (LVV)**

Ministry of Natural Resources (NH)

Bureau for Hydropower Works (BWKW)

Suriname Water Company (SWM)

Rural Water Supply Division (DWV)

Ministry of Planning and Development (PLOS)

Waterboards

District Commissioners

Surinam Aluminum Company (SURALCO) and Billiton Maatschappy Suriname (BMS)

Multipurpose Corantijn Canal Project (MCP)

Maritime Authority Suriname (MAS)

Foundation National Rice Institute(SNR)l /Foundation Mechanized Agriculture Suriname (SML)

The Meteorological Service of Suriname deals with data collection of rainfall and other meteorological elements. For a list of their stations see Table 1 in Appendix A. The daily data on rainfall, evaporation, wind speed and wind direction, temperature and humidity are formerly published in Meteorological Annuals.

The Hydraulic Research Division collects hydrologic and hydraulic data of the coastal area, from the estuary up to the first rapids in the rivers in the tidal area. The collected data concerns water levels, discharges, water quality sedimentation and bathymetry of the estuaries. This Division is also carrying out other studies, such as determination of water balances and irrigation capacities, hydraulic and waterquality study, etc. In the Hydrological Annuals water levels, discharges and silt and salt data are published, the last one being for the year 1982.

Hydrological data of the area from the first rapids to the southern border of Suriname have been collected by BWKW for hydropower purposes. Discharge and water levels were the main hydrological elements observed by this agency. Part of the observed data has been published together with other data of WLA in the Hydrological Annuals and the other part by BWKW itself. Both BWKW and WLA collect and process hydrometric data on the surface waters.

The agencies SWM and DWV deal with collecting, processing and exploitation of groundwater for potable water supply. Groundwater is mainly used for potable domestic purposes. SWM is established in the cities Paramaribo and Nieuw Nickerie and DWV in the rest of the country. The main task of these organizations is domestic water supply. Data on groundwater levels and discharges are not published regularly in Annuals, but are processed in reports and other publications.

The Ministry of Agriculture, Animal Husbandry and Fishery, the District Commissioners, LVV, MCP, and Waterboards are all organizations dealing with maintenance and operation of irrigation systems, whilst the Ministry of Public Works is in charge with the operation and maintenance of the main irrigation and drainage infrastructure. These activities are found mainly in the north-western part of the country.

The Suriname Aluminum Company (SURALCO) and the Billiton Company (BMS) are the main users of hydro-electric power generated at Afobaka. It is therefore very important for them to have up to date data on the water level and the discharge of the Afobaka reservoir. These data are also published in the Hydrological Annuals of the WLA. For performance control these companies also frequently monitor deep wells and surface water levels in and around their active mines and smelters.

Among the observed hydrological and hydraulic elements, the water level, discharge and chlorinity data have the longest record. Most hydrometric stations were opened in the period 1960-1975 and in the years 1986-1988 nearly all the stations were closed. The later was due to the “interior war”. From the 15-20 years of observations nearly all the records contain missing data and, in some cases, even unreliable data. There is no centralized authority to coordinate the above mentioned agencies and overlapping of responsibilities between many agencies occurs.

II.2.2. Rivers

The Corantijn River

Hydrologic and hydraulic studies of the Catchment

The Corantijn River is the most westerly located large river in Suriname and forms the border with Guyana. For Suriname the sources of this river are located in the Acarai Mountains near the boundary with Brazil. The area of the catchment is about 67,600 km^2. Hydrological studies in this catchment started with the establishment of the first hydrometric (waterlevel) station in the Nanni creek at Nanni dam in 1943 to provide data for irrigation purposes. Since then several other hydrometric stations were established and observations have been made for average periods of 20 years along the river. In 1968 Nedeco carried out hydrologic and hydraulic studies in the estuary of the river. Table 2 below, lists these stations and gives the periods of data available.

Discharge characteristics

The discharge characteristics at station Mataway and at the river mouth are given in Table 3 below. The catchment area of station Mataway is about 51,600 km^2, which is 76% of the total catchment of the Corantijn River. At the outfall of the river the characteristics are estimated whilst the discharge at Mataway has been observed.

Table 2. Hydrological data available for Corantijn River

River	Station name	Km	Yrs	Data collected	Period
Corantijn	Clara Sluis	33	17	Water level	1970-1987
	Mac Clemen	72	20	Water level	1966-1986
	Oreala	112	21	Water level	1966-1987
	Apoera	154	23	Water level	1963-1986
	Kabalebo Monding	200	17	Water level	1964-1984
	Mataway	243	15	Water level + discharge	1967-1983
Nanni creek	Nanni dam	-	26	Water level	1943-1969
Nanni swamp	Nanni bekken	-	23	Water level	1967-1986

Water level characteristics

The semi-diurnal tidal movement of the Atlantic Ocean mainly determines the water level in the estuary of the river. Penetration of the seawater upriver depends not only on the magnitude of the tide but also on the different seasons of the year. During the dry seasons, especially, during the long dry season, the tidal effect of penetration of seawater is observed far into the river and the tidal effect reaches Cow Falls about 210 km upstream.

Table 3. Discharge characteristics of Corantijn River.

Discharge characteristics	Discharge in m^3/s at station Mataway	Estimated discharge at the Outfall of the Corantijn river. (m^3/s)
Maximum discharge	5370	7070
Minimum discharge	31	41
Average discharge	1200	1580

On average the range between the annual highest high water and the annual lowest low water at Clara sluis is about 350 cm. An overview of the highest observed annual highest high water (HHW) and lowest observed annual low water (LLW) is given in Table 4 below.

Table 4. Highest observed annual HHW and lowest observed annual LLW in Corantijn River.

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Corantijn	1	Clara Sluis	271	-163
	2	Mac Clemen	267	-122
	3	Oreala	266	-103
	4	Apoera	352	-79
	5	Kabalebo Monding	580	-15
	6	Mataway	1026	104

The highest observed annual HHW and lowest observed annual LLW are graphically expressed in figure 1

Fig. 1. Highest observed annual HHW and lowest observed annual LLW in the Corantijn River

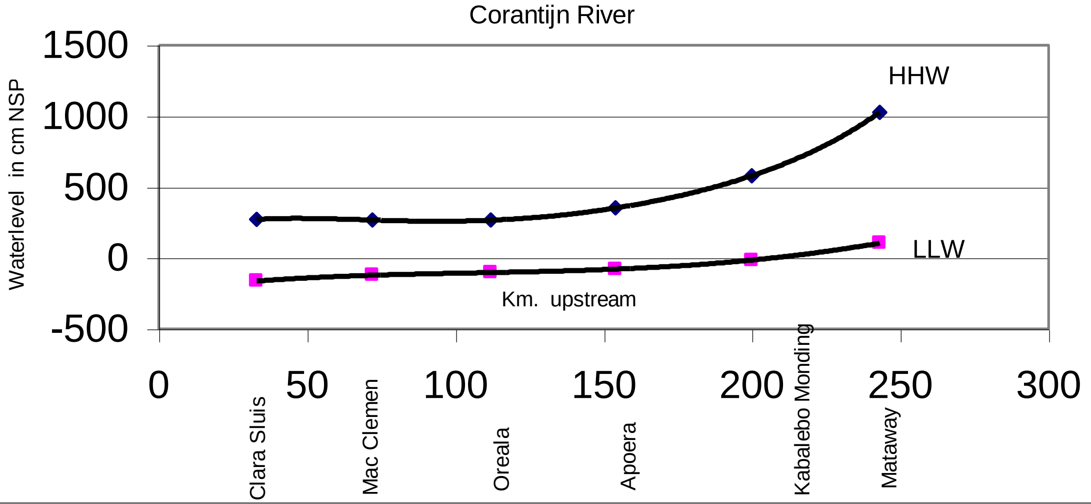
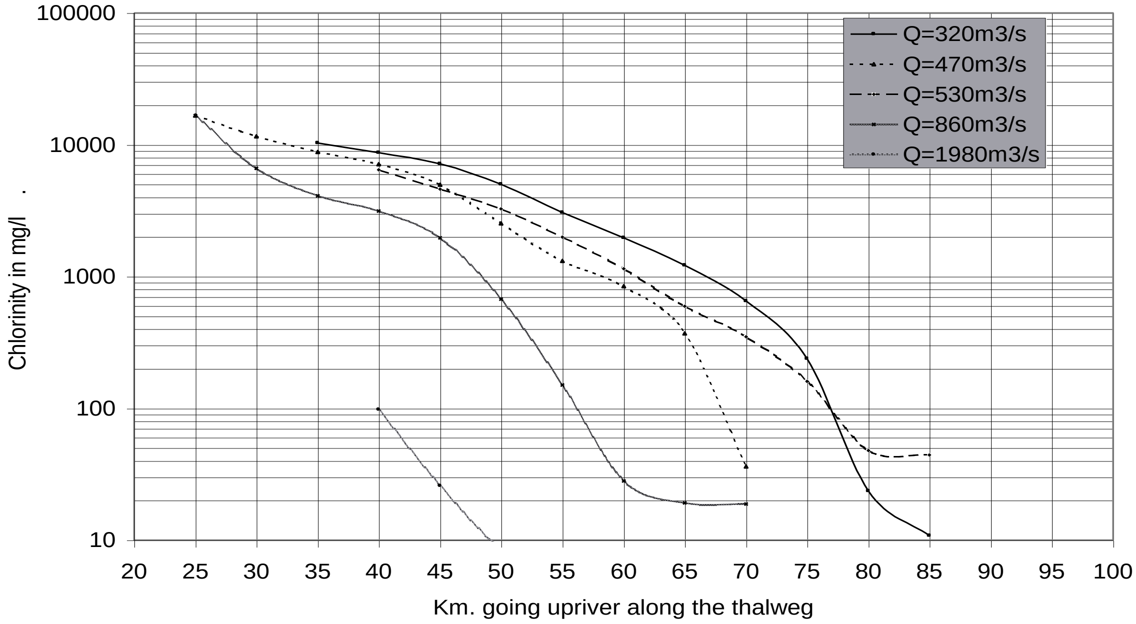


Fig. 2. Chlorinity profiles along Corantijn River for various discharges (Q) at Km. 243



A frequency analysis of the above mentioned water levels has also been done. Gumble's Type 1 Distribution has been used to carry out the analysis. Table 5 below shows the values for the different return periods.

Salt intrusion.

During the dry seasons of the year when the discharge is at its minimum, the tidal effect of the Atlantic Ocean may reach up to the Cow Falls. The salt wedge of 200 mg Cl/l, however, remains far downstream from the falls which is about 75km upstream from the mouth.

Table 5: Estimated values of highest annual HHW and lowest annual LLW for given return periods Corantijn River

(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Corantijn	Clara Sluis	262	280	294	307		-158	-171	-184	-192
	Mac Clemen	250	258	263	269		-117	-123	-127	-132
	Oreala	260	273	282	291		-90	-98	-103	-108
	Apoera	322	352	374	395		-68	-79	-86	-95
	Kabalebo Monding	570	620	655	693		-18	-30	-40	-48
	Mataway	1069	1206	1308	1408		100	50	10	-30

Based on the samples data as described under subsection "saltwater intrusion", chlorinity profiles are given in Figure 2. These profiles show that the chlorinity changes abruptly during periods of peak water flow whilst at low flow the increase of chlorinity is gradual and extends much further upstream.

A pumping station has been established at Wakay, Km 140, on right bank of the river. Its main purpose is to supply the rice polders in this catchment with fresh irrigation water from the Corantijn River. The pumping station has four units, each with a capacity of 7.5 m^3/s giving the station a total capacity of 30 m^3/s. Irrigation water is mostly needed during the dry seasons and extracting water from the river at this time causes the salt wedge to move up the river much higher than normally. No recent data has been gathered to study this effect.

The Nickerie River

Hydrologic and hydraulic studies of the catchment

The source of the Nickerie River lies in the Bakhuis Mountains and mainly it flows northward except in the Young Coastal Area where it flows in a north-westerly direction and finally discharges into the Atlantic Ocean. The area of its catchment is about 10,100 km^2.

The catchment area of the Nickerie River can be divided into three parts as follows:

I. The lower part. Rice polders and human settlements occupy this part. The irrigation and drainage systems of the polders and the settlements mainly depend on the river. Among the rice polders situated along this river Wageningen polder is the largest. It is situated on the right bank of the river at km 73 and at its site a powerful pumping station is established. There is also intensive navigation in this part of the river particularly up to Wageningen polder which uses the river as its main transport route. Two important harbors are situated within this part of the river, first at Nieuw Nickerie, on the left bank of the Nickerie River, at km 22 and the second at Wageningen km 240. This part is affected by the tidal regime of the Atlantic Ocean.

II. The middle part. This part lies between Wageningen and Stondansie Falls. Here the river flows through a swampy area with the Coronie swamp in the east and in the west the Maratakka and the Nanni swamps. The determined watershed between them is based on several factors, among which is data obtained from satellite images. This part also lies in the tidal area.

III. The upper part. This part of the Nickerie catchment is the area of the Stondansie catchment and belongs to the non-tidal area. The first upstream discharge station is located here.

The earliest hydrometric stations established in the river are the stations Klein Henar and Nickerie Monding. Table 6 lists the stations in the catchment and gives their periods of data availability.

Discharge characteristics.

The discharge characteristics of station Stondansie and at the river mouth are given in Table 7 below. The catchment area of station Stondansie is about 5160 km^2, which is 51% of the total catchment. At the outfall of the river the characteristics are estimated whilst the discharge at Stondansie has been observed.

Table 6. Hydrological data available for the Nickerie river

River	Station name	Km	Data collected	Period
Nickerie	Nickerie Monding	20	Water level	1948-1987
	Klein Henar	52	Water level	1947-1987
	Sital	58	Water level+chlorinity	1975-1984
	Premchand		Chloronity	1978-
	Wageningen	73	Water level+chlorinity	1951-1987
	Koffimakka	82.5	Water level	1966-1984
	Akwansa Monding	99	Water level	1966-1967
	Akwansa	111	Water level	1981-1986
	Nova Kreek	157	Water level	1966-1967
	Tapoeripa	157	Water level	1964-1986
	Bostpost	186	Water level	1961-1984
	Duikelaars Kr	213	Water level	1966-1983
	Sopropokampoe	236	Water level	1966-1967
Akwansa	Akwansa Kr.	133	Water level	1970-1977
Maratakka	Morotokko Kr.	125	Water level	1981-1984
	Takomara	162	Water level	1981-1984
	Maurici Zwamp	186	Water level	1981-1987
Nickerie	Stondansie	240	Water level+discharge	1963-1986
	Paris Jacob	335	Water level+discharge	1980-1986
	Mozes Kr.	306	Water level+discharge	1972-1986
Fallawatra	Cremer	273	Water level+discharge	1971-1986
Nickerie	Blanche Marie	358	Water level+discharge	1964-1964

Table 7. Discharge characteristics of Nickerie River

Discharge characteristics	Discharge in m^3/s at station Stondansie	Estimated discharge at the Outfall of the Nickerie river. (m^3/s)
Maximum discharge	450	880
Minimum discharge	1.8	2
Average discharge	78	160

Water level characteristics

The semi-diurnal tidal movement of the Atlantic Ocean mainly determines the water level in the estuary of the river. During the dry seasons especially, during the long dry season, the seawater penetrates far up the river and the tidal effect reaches Stondansie falls, which lies about 240 km upstream. The range of the water level at station Nickerie Monding varies between +263 and – 158 cm NSP.

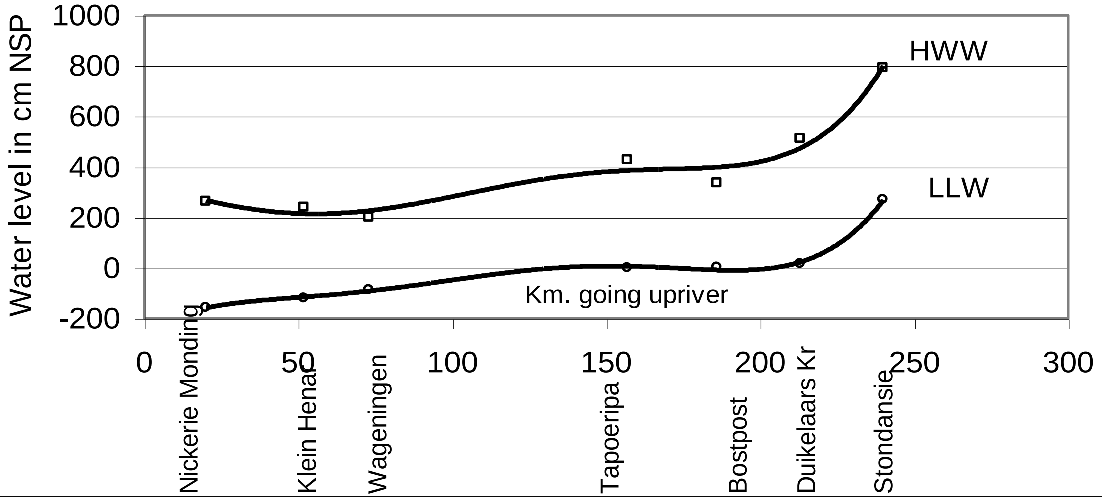
An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest low water (LLW) are given in Table 8 below.

Table 8. Highest observed annual HHW and lowest observed annual LLW in Nickerie River

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Nickerie	1	Nickerie Monding	263	-158
	2	Klein Henar	238	-119
	3	Wageningen	199	-87
	4	Tapoeripa	427	0
	5	Bostpost	335	2
	6	Duikelaars Kr	512	17
Nickerie	8	Stondansie	792	270
	9	Paris Jacob	2146	1420
Fallawatra	10	Cremer	2728	2423
Nickerie	11	Blanche Marie	2793	2195

The highest observed annual HHW and the lowest observed annual LLW are graphically expressed in the Figure 3 below.

Fig. 3. Highest observed annual HHW and lowest observed annual LLW in Nickerie River.



A frequency analysis of the above mentioned water levels has also been done. Gumble,s Type I Distribution has been used to carry out the analysis. Table 4 below shows the values of the different return periods.

Table 9. Estimated values of highest annual HHW and lowest annual LLW for given return periods Nickerie River.

(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Nickerie	Nickerie Monding	237	250	260	270		-155	-160	-164	-168
	Klein Henar	216	227	235	243		-110	-121	-129	-137
	Wageningen	188	196	203	209		-77	-84	-90	-95
	Tapoeripa	280	310	335	360		0	-7	-13	-19
	Bostpost	310	340	360	380		12	0	-10	-18
	Duikelaars Kr	396	415	428	440		24	12	3	-5
Akwansa	Akwansa Kr.	210	226	236	248		-32	-51	-66	-18
Nickerie	Stondansie	760	790	830	860		276	264	255	246
	Paris Jacob	2280	2440	2570	2700		1410	1360	1320	1280
Fallawatra	Cremer	2770	2822	2865	2910		2427	2418	2411	2404
Nickerie	Blanche Marie	2776	2875	2927	3010		2196	2166	2150	2125

Salt intrusion

The intrusion of salt wedge in this river depends on the following factors:

- the tidal effect of the Atlantic Ocean in the estuary
- the freshwater discharge from upstream;
- the amount of water extracted from the river for irrigation purposes;
- the amount of drainage water released into the river from the rice polders into the river.

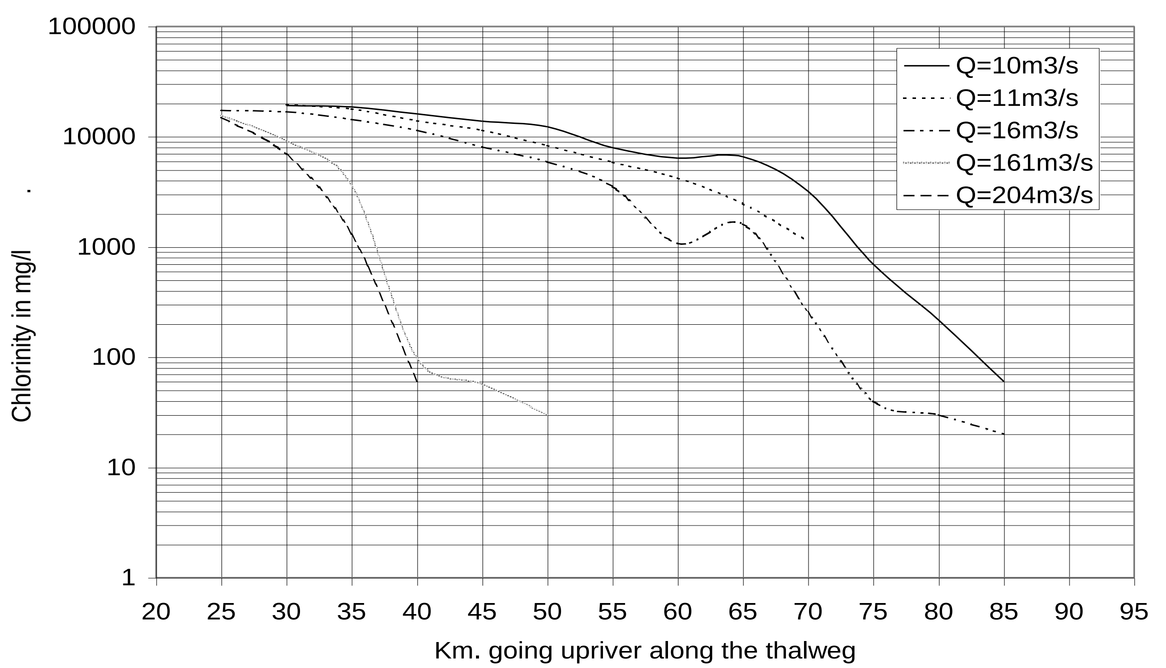
Based on the sampling data as described under subsection “saltwater intrusion”, chlorinity profiles are given in Figure 4 below. These profiles show that the chlorinity changes abruptly during periods of peak water flow whilst at low flows the increase of chlorinity is gradual and extends much further upstream. From Fig. 4 it appears that during the dry seasons when the fresh water discharge is lowest the 300 mg/l chlorinity levels are located further upstream than at Wageningen polder (km 73) and it is at this time when the irrigation needs are highest in the polder.

The Coppename River

Hydrologic and hydraulic studies of the catchment

The Coppename River finds its sources in the central highland of the Wilhelmina Mountains and it flows from south to north into the Atlantic Ocean. The area of the catchment is about 21,700 km^2.

Fig. 4. Chlorinity profiles along Nickerie River for various discharges (Q) at Km.240



The catchment area of the Coppename River can be divided into two parts:

I. The lower part, which is the tidal area of the catchment and except for some settlements, hardly has any significant development. On both sides of the river there are large swamp areas. On the left side there is Coronie swamp and on the right side the Coesewijne swamp. The water divide of the different catchment areas through these swamps has been drawn as a broken line indicating the difficulties in determining their watershed (See Figure 1 Appendix C).

II. The upper part. This part of the Coppename basin includes the area of the Maksita catchment, and is a non-tidal area. The first discharge station is therefore located here.

For studying the water regime, water resources and other characteristics of the river hydrometric stations have been established. Table 10 below illustrates the stations and periods of data available.

Discharge Characteristics.

The discharge characteristics of station Maksita are given in table11. The catchment area of station Maksita is about 12,300 km^2, which is 57% of the total catchment. At the outfall of the river the characteristics are estimated.

Table 10. Hydrological data available for Coppename River.

River	Station name	Km	Data collected	Period
Coppename	Boskamp	32	Water level	1961- 1986
	Tibiti	68	Water level	1967- 1986
	Wayambo Monding	95	Water level	1961- 1986
	Heidotie			1961- 1963
Coesewijne	Gr.Borfet Kr.	95	Water level	1969- 1986
	Trilanti			1977- 1981
Wayambo	Cornelis Kondre	122	Water level	1964- 1986
Coppename	Kaaimanston	150	Water level	1964- 1986
Wayambo	Post Venlo	165	Water level	1961- 1986
Coppename	Maksita	175	Water level + discharge	1964- 1986

Table 11. Discharge characteristics of Coppename River.

Discharge characteristics	Discharge in m^3/s at station Maksita	Estimated discharge at the Outfall of the Coppename river. (m^3/s)
Maximum discharge	1,450	2,200
Minimum discharge	4.4	6
Average discharge	319	490

Water level characteristics

The semi-diurnal movement of the Atlantic seawater mainly determines the water level in the estuary of the river. During the dry seasons, especially during the long dry season, seawater penetrates far up the river. In this period the tidal effect reaches Kwintikriki falls at about 172 km upstream. The range of the water level at station Boskamp varies between +293 to – 131 cm NSP.

An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest water (LLW) is given in Table 12 below. The highest observed annual HHW and the lowest observed annual LLW are graphically expressed in Figure 5 below. A frequency analysis of the above mentioned water levels has been done. Gumble's Type I Distribution has been used to carry out the analysis. Table 13 below shows the values for the different return periods.

Salt intrusion

The salt wedge in this river depends on the following factors:

- the tidal effect of the Atlantic Ocean in the estuary
- the freshwater discharge from upstream;

Table 12. Highest observed annual HHW and lowest observed annual LLW in Coppename River.

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Coppename	1	Boskamp	293	-131
	2	Tibiti	360	-123
	3	Wayambo Monding	205	-125
Coesewijne	4	Gr.Borfelt Creek	261	101
Wayambo	5	Cornelis Kondre	574	-37
Coppename	6	Kaaimanston	650	-30
Wayambo	7	Post Venlo	291	-73
Coppename	8	Maksita	1498	610

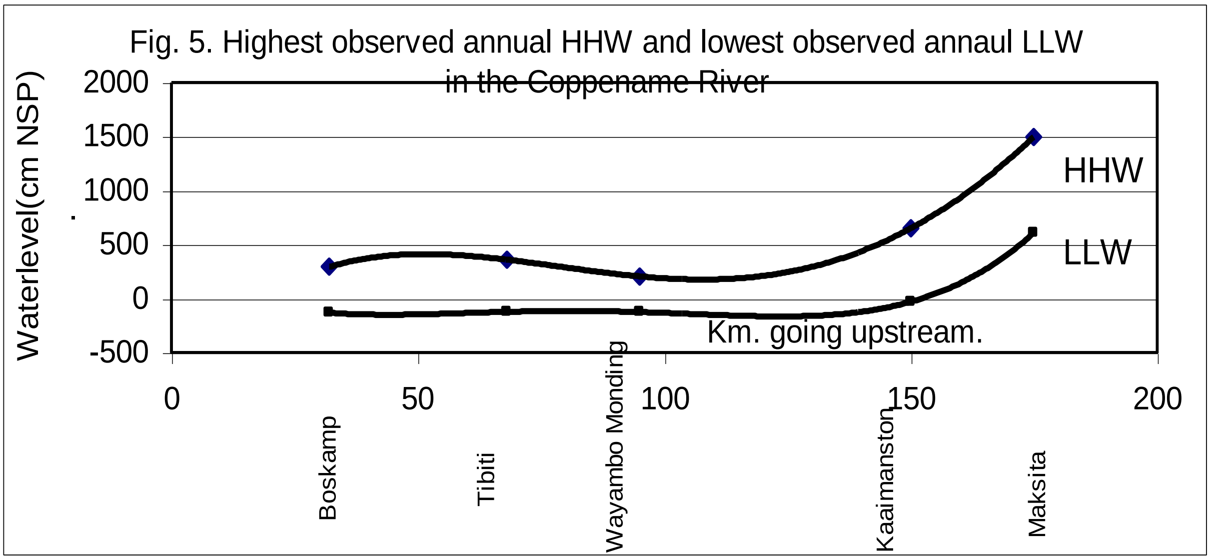


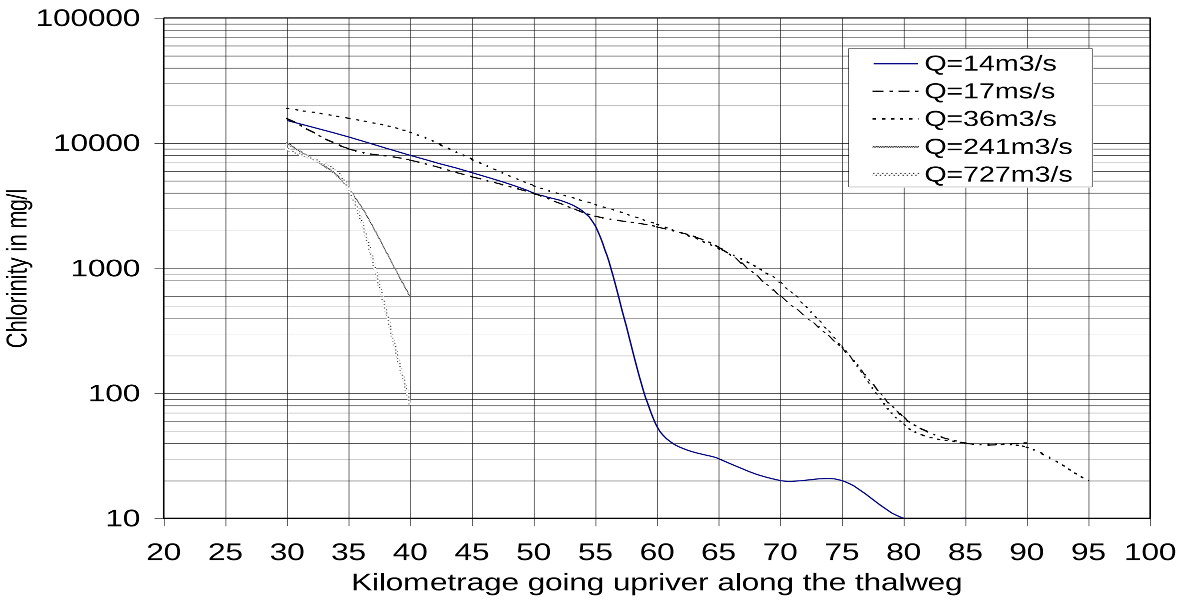
Table 13. Estimated values of highest annual HHW and lowest annual LLW for given return periods Coppename River.

(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Coppename	Boskamp	211	222	229	237		-127	-132	-136	-140
	Tibiti	213	221	229	233		-118	-125	-131	-136
	Wayambo Monding	202	209	215	220		-123	-126	-136	-146
Coesewijne	Gr.Borfet Kr.	198	213	224	235		-16	-22	-27	-32
Wayambo	Cornelis Kondre	212	235	251	290		-86	-95	-102	-108
Coppename	Kaaimanston	590	690	730	795		-23	-30	-36	-40
Wayambo	Post Venlo	299	292	302	315		-60	-71	-80	-88
Coppename	Maksita	1420	1520	1585	1856		621	610	600	565

Based on the sampling data as described under subsection "saltwater intrusion", chlorinity profiles are shown in Figure 6 below. These profiles show that the chlorinity changes abruptly during periods of peak water flow, whilst at low flows the increase of chlorinity is gradual and extends much further upstream.

Fig. 6. Chlorinity profiles along Coppename River for various discharges (Q) at Km. 175



The Saramacca River

Hydrologic and hydraulic studies of the catchment

The sources of the Saramacca River lie in the central highlands of Suriname in the Emma Mountainrange, the Van Asch van Wijk and the Wilhelmina Mountains. The river mostly flows northward except in the Young Coastal Plain where it flows from a northwesterly to a westerly direction and finally discharges into the Atlantic Ocean via the estuary of the Coppename River. The area of the catchment is about 9,000 km^2

The catchment area of the Saramacca River can be divided into three parts as follows:

I. <u>The lower part.</u> This part is affected by the tidal regime of the Atlantic Ocean. Rice polders and human settlements occupy this part of the catchment. The drainage systems of the polders and settlements mainly discharge into the river. For irrigation water the rice farmers depend on the river as well as the local freshwater swamps. On both sides of the lower Saramacca river rice is intensively cultivated where the swamps are also located. Also at Uitkijk water is withdrawn for irrigation of bananas at the Jarikaba plantation (sprinklers in the dry season only).

II. The middle part. This part begins at the settlement Santigron and ends further upstream at Dramhosso, where the tidal effect is not observed. This part of the river passes through the Savanna Belt and the Old Coastal Plain.

III. The upper part. This part of the Saramacca catchment includes the area of the Dramhosso catchment in the Grote Saramacca River and the Anoemafoetoe catchment in the Kleine Saramacca. It belongs to the non-tidal area. The first upstream discharge station is the located here.

For understanding and studying the water regime of the river, hydrometric stations have been established to collect relevant data. Table 14 below lists these stations by name and their periods of data available.

Discharge characteristics

The discharge characteristics at station Dramhosso and at the river mouth are given in Table 15 below. The catchment area of station Dramhosso is about 3520 km^2, which is 39.1% of the total catchment. At the outfall of the river the characteristics are estimated.

Water level characteristics

The semi-diurnal movement of the Atlantic seawater mainly determines the water level in the estuary of the river. During the dry seasons, especially during the long dry season, seawater penetrates far into the river. In these periods the tidal effect reaches more than 240km upstream. The range of the water level at station Carl Francois varies between +208 and –104 cm NSP.

Table 14: Hydological data available for the Saramacca River

River	Station name	Km	Data collected	Period
Saramacca	Carl Francois	43	Water level+chlorinity	1962- 1986
	Huwelijkszorg	53	Chlorinity	1973-
	Tiger Creek	64	Water level+chlorinity	1962-
	Sarah Maria	73	Water level+chlorinity	1962- 1965
	Monkshoop	80	Chlorinity	1966-
	Groningen	85	Water level	1950- 1986
	Uitkijk Sluis	104	Water level+chlorinity	1949- 1986
	Creola	105	Water level	1962- 1986
	Santigron	117	Water level	1946- 1986
	LBB Brug	196	Water level	1970- 1983
	Commissaris Kondre	220	Water level	1961- 1985
Saramacca Canal	Uitkijk Canal		Water level	1949- 1986
	Doorsteek Canal		Water level	1962- 1988
Saramacca	Brokolonko	262	Water level	1961 -1969
	Dramhosso	285	Water level+discharge	1960- 1986
Kleine Saramacca	Anoemafoetoe	282	Water level+discharge	1965- 1986

An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest low water (LLW) is given in Table 16 .The highest observed annual HHW and the lowest observed annual LLW are graphically expressed in Figure 7 below.

Table 15: Discharge characteristics of the Saramacca River

Discharge characteristics	Discharge in m^3/s at station Dramhosso	Estimated discharge at the Outfall of the Saramacca River. (m^3/s)
Maximum discharge	493	1260
Minimum discharge	1.8	4.6
Average discharge	100	255

Table 16: Highest observed annual HHW and lowest observed annual LLW in Saramacca River

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Saramacca	1	Carl Francois	208	-104
	2	Groningen	186	-86
	3	Uitkijk Sluis	195	-64
	4	Creola	180	-62
	5	Santigron	183	-62
	6	LBB Brug	298	-43
	7	Commissaris Kondre	574	-37
	8	Dramhosso	2070	799

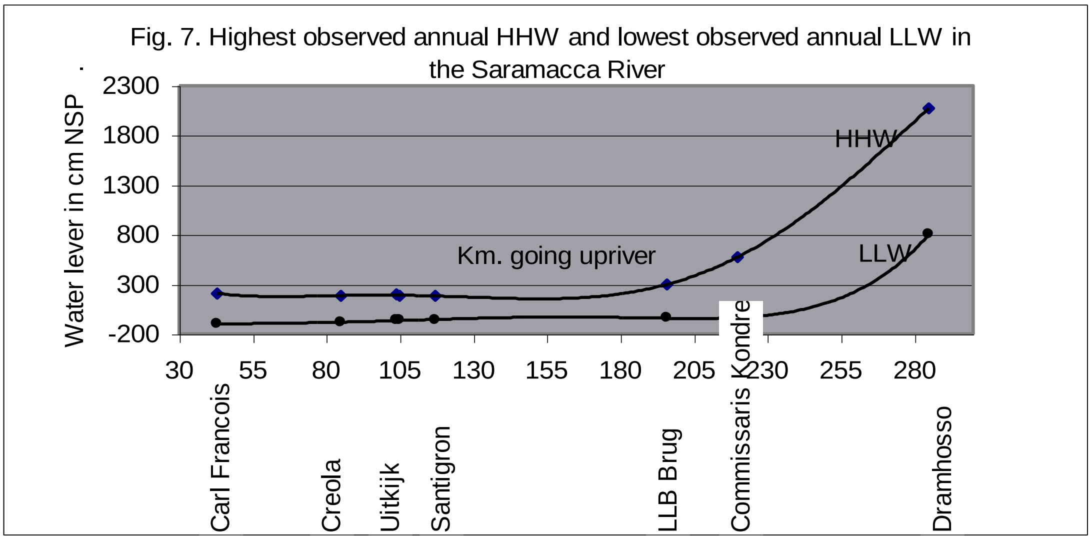


Fig. 7. Highest observed annual HHW and lowest observed annual LLW in the Saramacca River

A frequency analysis of the above mentioned water levels has also been done. Gumble's Type I Distribution was used for the analysis. Table 17 below shows the values of the different return periods.

Salt intrusion.

The salt wedge in this river depends on the following factors:

- the tidal effect of the Atlantic Ocean in the estuary
- the freshwater discharge from upstream;
- irrigation water extracted for rice and banana cultivation
- drainage water from the rice polders and other agricultural land released into the river.

Based on the sampling data as described under subsection "saltwater intrusion", chlorinity profiles are given in Figure 7 below. These profiles show that the chlorinity changes abruptly during periods of peak water flow, whilst at low flows the increase of chlorinity is gradual and extends much further upstream.

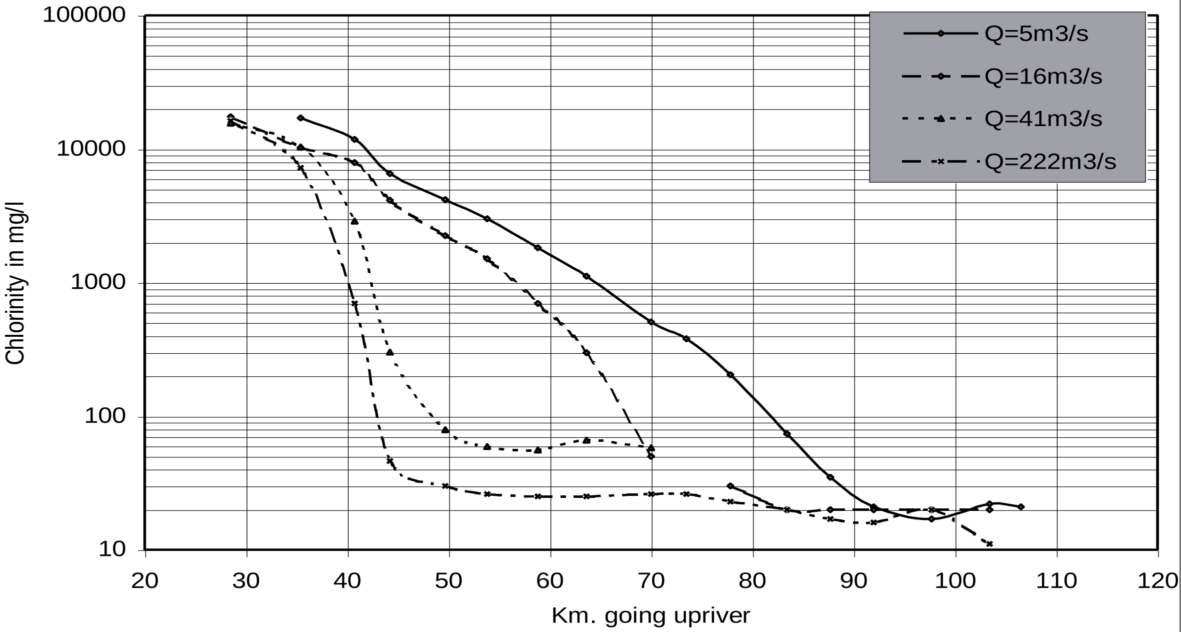
Table 17: Estimated values of the highest annual HHW and lowest annual LLW for given return periods Saramacca River.

(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Saramacca	Carl Francois	203	209	213	217		-100	-107	-112	-116
	Groningen	178	184	189	193		-78	-85	-90	-94
	Uitkijk Sluis	172	182	189	196		-61	-65	-68	-71
	Creola	173	182	189	196		-61	-64	-67	-69
	Santigron	172	182	189	196		-58	-63	-66	-69
	LBB Brug	283	316	340	365		-40	-48	-53	-58
	Commissaris Kondre	520	570	610	650		-12	-31	-43	-60
	Dramhosso	2041	2078	2100	2125		1662	1646	1630	1616

From Fig.8 it appears that during the dry seasons the salt wedge of 300mg/l chlorinity is located just downstream from Groningen at Km 85 so that the rice polders which lie between km 43 and km 75 are well within its range. This implies that during these periods water is taken from the swamps are the only available water resources

Fig. 8. Chlorinity profiles along Saramacca River at various discharges (Q) at Km.285



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The Suriname River

Hydrologic and hydraulic studies of the catchment

The Suriname River finds its sources mainly in the Eilerts de Haan mountain range and to a lesser extent in the Van Asch van Wijck and the Wilhelmina Mountains. The river flows mainly from south to north except in the Young Coastal Plain where it meanders and causes erosion processes at certain locations and finally discharges into the Atlantic Ocean. The area of the catchment is about 16,500 km^2.

The catchment area of the Suriname River can be divided into three main parts:

I. The lower part. This part extends from the outfall to the man-made lake "Brokopondo" upstream and is affected by the tidal regime of the Atlantic Ocean. The capital of Suriname, Paramaribo, with about 150,000 inhabitants is situated on the left bank of the river at km 52. Other settlements including Domburg and the industrial bauxite complex at Paranam are also situated along this left bank. On the right bank of the river, New Amsterdam, the local capital of the district Commewijne, is located. The harbors are also located in this part of the river and navigation on this river is more intense than on the other rivers in Suriname. At km 194, a dam has been constructed in 1964 for generating hydroelectricity and as a result the lower part of the river is now artificially regulated.

II The middle part. The Prof. Dr. Ir. van Blommenstein storage Lake (Brokopondo lake). The area of this lake is about 1600 km^2.

III The upper part. This part of the Suriname River catchment includes the catchment area of Pokigron, which is located at km 273.

The hydrometric stations in the Suriname River are listed in Table 18 as well as the registration period.

Discharge characteristics

The discharge characteristics of station Pokigron and at the river mouth are given in Table 19 below. The catchment area of station Pokigron is about 5,160 km^2, which is 51% of the total catchment. The catchment area of Afobaka is about 12,550 km^2 and is therefore 76% of the total catchment. At the outfall of the river the characteristics are estimated.

Water level characteristics

The semi-diurnal tidal movement of the Atlantic Ocean mainly determines the water level in the estuary of the river. During the dry seasons, especially during the long dry season, seawater penetrates far up the river and the tidal effect reaches to Berg en Dal, which is about 164 km upstream from the outfall.

Table 18. Hydrological data available for the Suriname River

River	Station name	Km	Registration type	Period
Suriname	Geleidelicht	25	Water level	1966- 1987
	Nw.Amsterdam	40	Water level	1966- 1986
	Paramaribo	52	Water level	1960- 1986
	Doorsteek	65	Water level	1962- 1988
	Domburg	69.5	Water level+chlorinity	1966- 1986
	Paranam	88	Water level	1961- 1986
	Torarica	107	Water level	1964- 1969
	Carolina	119	Water level	1969- 1986
	Joden Savanna	120	Water level	1964- 1969
	Phedra	133	Water level	1965- 1986
	Berg en Dal	164	Water level	1966- 1986
	Para Doorsteek		Water level	1965- 1966
	Brug Highway	65	Water level	1972- 1975
	Hanover		Water level	1968- 1975
	Brokopondo	185	Water level+chlorinity	1952- 1983
	Afobaka	194	Water level+chlorinity	1965- 1986

The range of the water level at station Geleidelicht, Km 25, lies mostly between 181 and –223 cm NSP.

An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest low water (LLW) is given in Table 20 below.

Table 19. Discharge characteristics of Suriname River.

Discharge characteristics	Discharge in m^3/s at station Pokigron	Discharge in m^3/s at station Afobaka	Estimated discharge at the Outfall of the Suriname river. (m^3/s)
Maximum discharge	923	756	1800
Minimum discharge	5.8	214	220
Average discharge	224	324	440

The range of the water level at station Geleidelicht, Km 25, lies mostly between 181 and –223 cm NSP.

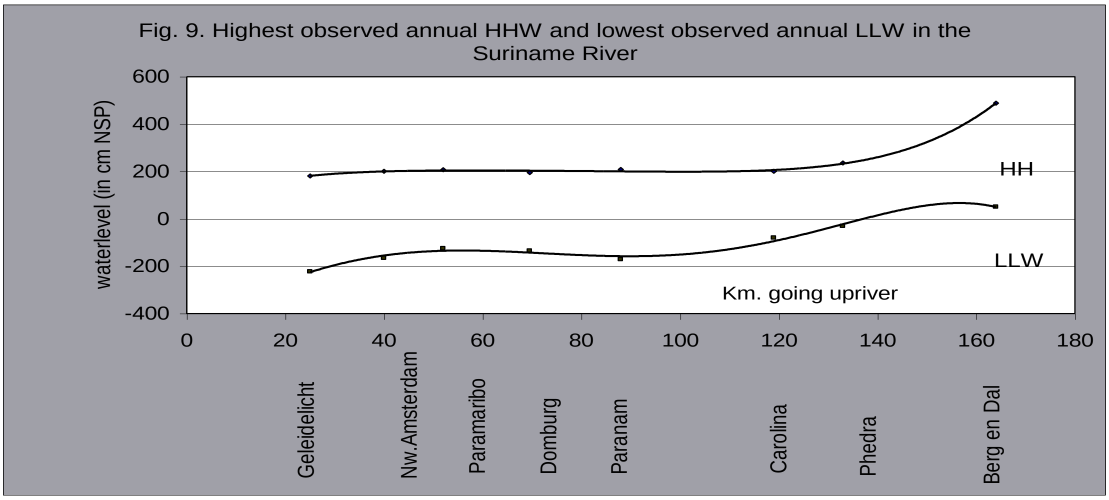
An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest low water (LLW) is given in Table 20 below.

Table 20: Highest observed annual HHW and lowest observed annual LLW in the Suriname River.

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Suriname	1	Geleidelicht	181	-223
	2	Nieuw. Amsterdam	200	-166
	3	Paramaribo	207	-126
	4	Domburg	195	-136
	5	Paranam	208	-172
	6	Carolina	200	-81
	7	Phedra	236	-31
	8	Berg en Dal	488	50

The highest observed annual HHW and the lowest observed annual LLW is graphically expressed in the Figure 9 below.

A frequency analysis of the above mentioned water levels has also been done. Gumble's Type I distribution has been used for the analysis. Table 21 below shows the values of the different return periods.



Salt intrusion

The salt wedge in this river depends mainly on the following factors:

- the tidal effect of the Atlantic ocean in the estuary
- the freshwater discharge from the Brokopondo lake;

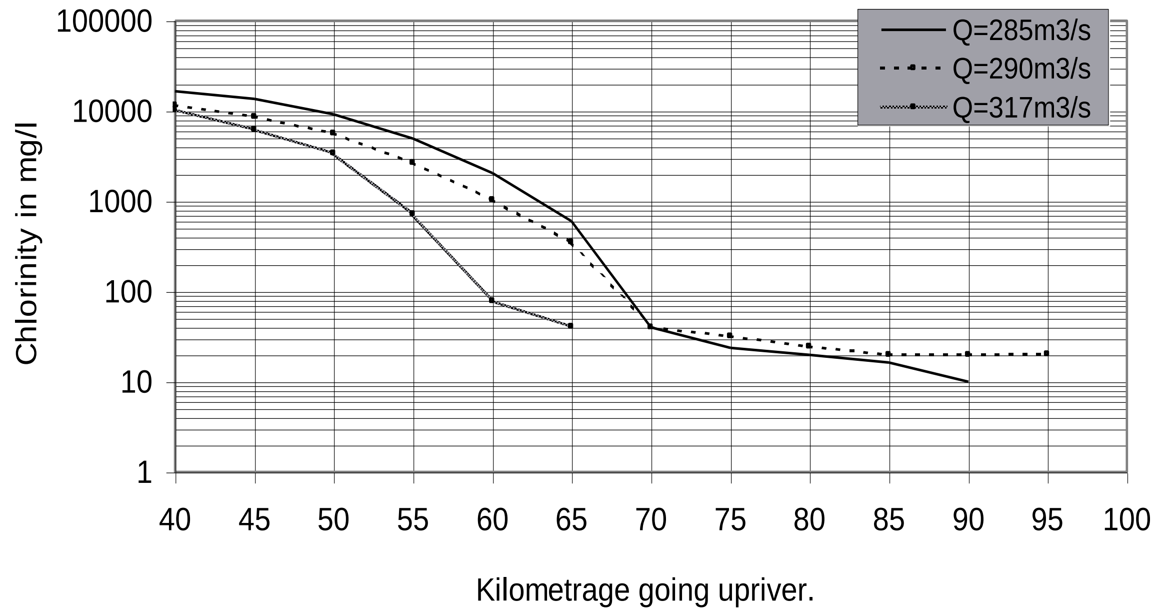
Table 21. Estimated values of the highest annual HHW and lowest annual LLW for given return periods Suriname River.

(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Suriname	Geleidelicht	185	198	207	216		-206	-230	-247	-265
	New. Amsterdam	193	203	210	217		-151	-164	-174	-184
	Paramaribo	201	211	219	226		-124	-129	-133	-137
	Domburg	198	203	207	212		-125	-135	-142	-149
	Paranam	155	175	190	204		-55	-175	-190	-204
	Carolina	196	202	206	210		-80	-86	-90	-94
	Phedra	229	239	246	254		6	-2	-9	-15
	Berg en Dal	382	428	460	496		92	53	30	0

Based on the sampling data as described under subsection “saltwater intrusion”, chlorinity profiles are given in Figure 9 below. These profiles show that the chlorinity changes abruptly during periods of peak water flow whilst at low flows the increase of chlorinity is gradual and extends much further upstream.

Fig.10. Chlorinity profiles along Suriname River for various discharges at Km.194



From Figure 10 it appears that during periods of low fresh water discharge the salt wedge of 300mg Cl/l lies much further upstream than at Paramaribo, at km 52, and almost reaches to Paranam at km. 88.

The Commewijne River

Hydrologic and hydraulic studies of the catchment

The Commewijne River finds its sources in the Hok-A-Hing mountain range near the Brokopondo Lake. It is the only river among the main rivers which flows, for the larger part, through the Old and Young Coastal Plain. The main tributary of the Commewijne River is the Cottica River which, through a bifurcation with the Wane Creek, is connected with the Marowijne River. The Cottica River is also entirely located in the Old and Young Coastal Plain and flows mainly east to west with its branches mostly flowing from the south. Other branches of the Commewijne are the Cassewinica, the Mapane and the Tempati Creeks. The Cassewinica derives its waters mainly from the Surnau swamp. The Mapane and Tempati Creeks have their sources in the Hok -A–Hing mountain range and the Old Coastal Plain. The Commewijne river flows in a northerly direction except in the Young Coastal Plain where is flows first towards the north-west and then bends entirely towards the west. The outfall of the river is in the estuary of Suriname River. The area of the catchment is about 6,600 km^2.

The catchment area of the Commewijne River can be divided into two parts:

I. <u>The lower part.</u> This is the area affected by the tidal regime of the Atlantic Ocean. The upper location of the tidal influence has not exactly been determined yet. It may reach the junction of the creeks Kleine Commewijne and Tempati. Human settlements and infrastructure occupy only the estuarine part of the lower river. Drainage systems of the polders, settlements and abandoned plantations are based on the river tides. On the right bank of the Cottica River at the settlement Moengo, km 190, an important harbor is situated, mainly for shipping bauxite.

II. <u>The upper part.</u> This part of the Commewijne basin belongs to the nontidal area.

III.

Few hydrologic and hydraulic studies have been done in the Commewijne. A preliminary investigation on the irrigation capacity of the river was formulated but there was no follow-up. Other studies concerning water levels and water quality have also been carried out. The hydrometric stations are given in Table 22 below with their periods of data availability.

Discharge Characteristics

There are no discharge stations established in the Commewijne River. The only discharges measured in this river are those of the preliminary investigations for irrigation capacity taken at Destombesburg at km 115. These discharge measurements lasted two weeks to complete a cycle from neap-tide to spring tide. The results of these measurements are given in Table 23 below. The catchment area of station Destombesburg is about 2,990 km^2, which is 45% of the total catchment. At the outfall of the river the characteristics are estimated.

Table 22. Hydrological data available for Commewijne River.

River	Station name	Km	Data collected	Period
Commewijne	Alliance	66	Water level+chlorinity	1963- 1986
Commetewane kreek	Slootwijk		Water level	1964- 1966
Commewijne	Penribo		Chlorinity	1980- 1986
	Stolkertsijver	103	Water level	1966- 1986
	Potribo	109	Water level	1974- 1979
	Cassiwinica	120	Water level	1977- 1978
	Penninica	155	Water level	1974- 1976
	Nieuw Java	164	Water level	1977- 1985
Cottica	Gibbons Bend	125	Water level	1964- 1983
	Koopmans Creek	135	Chlorinity	1975- 1983
	Tamarin	162	Water level+chlorinity	1966- 1986
	Moengo	190	Water level	1933- 1983
Coermotibo	Toekriki	190	Water level	1983- 1983
Pattamacca	Pattamacca	204	Water level	1966- 1983

Table 23. Discharge characteristics of Commewijne River.

Discharge characteristics	Discharge in m^3/s at station Destombesburg	Estimated discharge at the Outfall of the Commewijne river. (m^3/s)
Maximum discharge	97.4	215
Minimum discharge	28.6	-
Average discharge	51.3	113

Water level characteristics

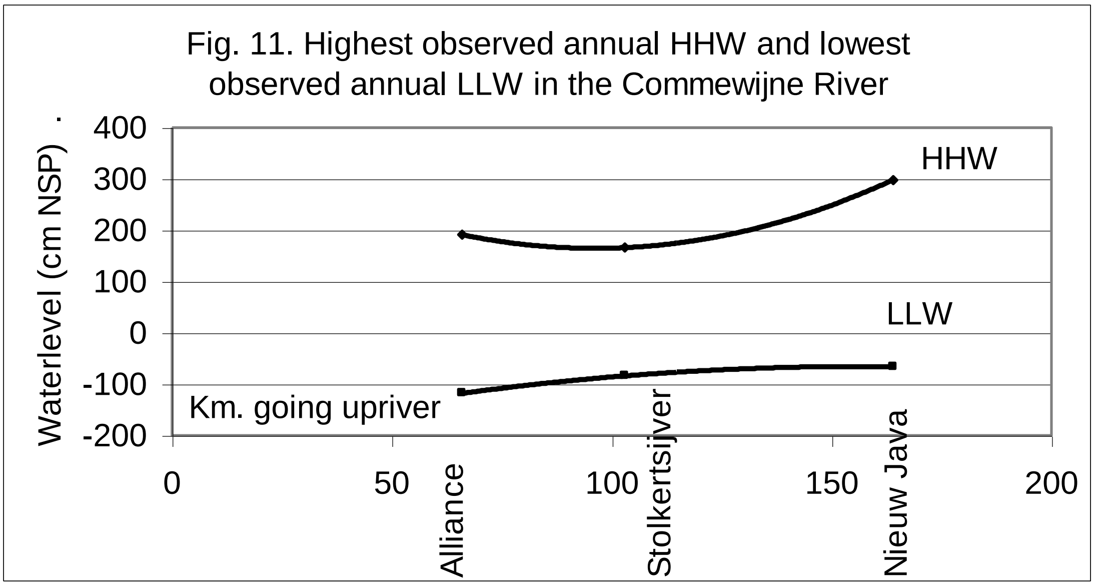
The semi-diurnal movement of the Atlantic seawater mainly determines the water level in the estuary of the river. During the dry seasons, especially during the long dry season, the penetration of seawater is observed very deep up the river.
The range of the water level at station Alliance lies mostly between +191 to -118 cm NSP.

An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest low water (LLW) is given in Table 24 below.

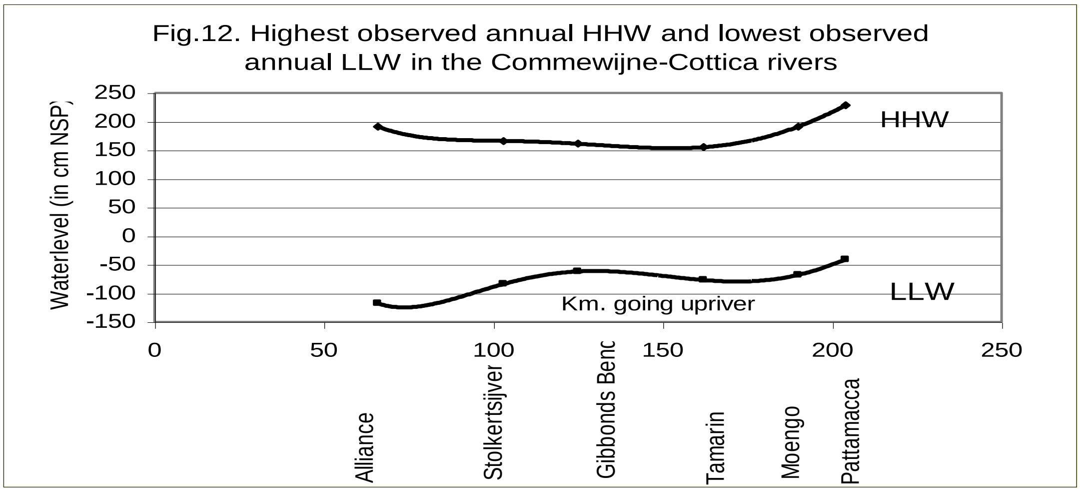
Table 24. Highest observed annual HHW and lowest observed annual LLW of the Commewijne River.

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Commewijne	1	Alliance	191	-118
	2	Stolkertsijver	166	-84
	3	Nieuw Java	298	-66
Cottica	4	Gibbons Bend	161	-62
	5	Tamarin	155	-77
	6	Moengo	191	-68
Pattamacca	7	Pattamacca	228	-41

The highest observed annual HHW and the lowest observed annual LLW on the Commewijne and its major tributary the Cottica are graphically expressed in the figures 11 and 12 below.



A frequency analysis of the above mentioned water levels has also been done. Gumble's Type I Distribution has been used for the analysis. Table 25 below shows the values of the different return periods.



Salt intrusion

The salt wedge in this river depends on the following factors:

- the tidal effect of the Atlantic Ocean;
- the freshwater discharge from upstream;

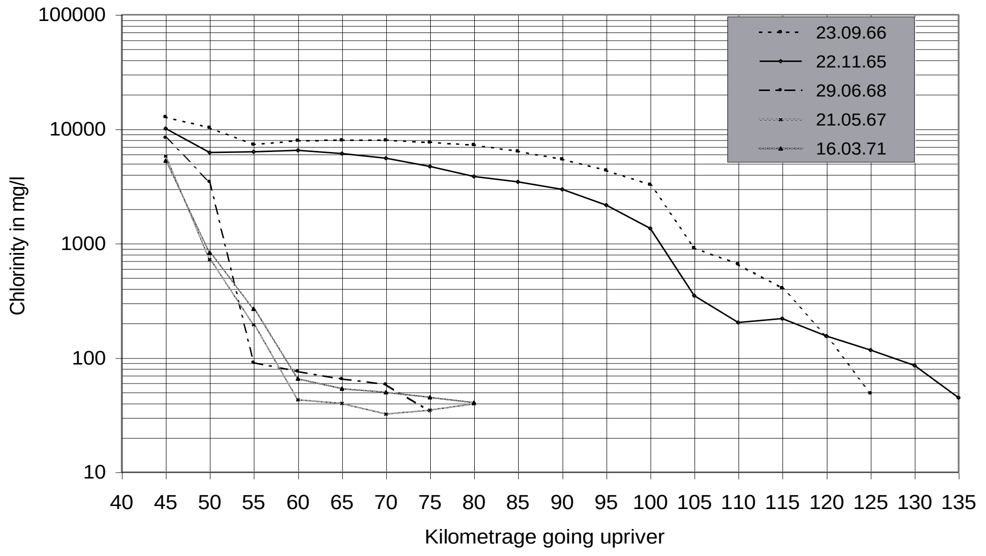
Table 25. Estimated values of the highest annual HHW and lowest annual LLW for given return periods Commewijne River.

(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Commewijne	Alliance	179	193	203	213		-114	-120	-126	-130
	Stolkertsijver	158	165	170	175		-86	-93	-99	-104
Cottica	Gibbons Bend	164	175	183	191		-72	-85	-94	-102
	Moengo	174	193	208	220		-65	-74	-80	-86
Patamacca	Patamacca	240	280	305	334		-45	-53	-59	-65

Based on the sampling data as described under subsection “saltwater intrusion”, chlorinity profiles are given in Figures 13 and 14. These profiles show that the chlorinity changes abruptly during periods of peak water flow whilst at low flow the increase of chlorinity is gradual and extends much further upstream.

Fig. 13. Chlorinity profiles along Commewijne River on given dates



Hydrometric studies in this river started with the first water level observations in 1953 in the Tapanahony River, a large tributary of Marowijne River. In 1968, Nedeco did hydrologic and hydraulic studies in the estuary of the river. A list of hydrometric stations is presented with the periods of data availability in Table 26 below.

Table 26. Hydrological data available for Marowijne River.

River	Station name	Km	Data collected	Period
Marowijne	Galibi	30	Water level	1982-
	Erowarte	49	Chlorinity	1978-
	Albina	57	Water level+chlorinity	1974- 1983
	Bastiaan	88	Water level	1966- 1983
	Lange Tabbetje	134	Water level+discharge	1962- 1985

Discharge Characteristics

The discharge characteristics of station Lange Tabbetje derived from the available records are given in Table 27 below. The catchment area of this station is about 63,500 km^2 that is 92% of the total catchment. At the outfall of the river the characteristics are estimated.

Table 27. Discharge characteristics of Marowijne River.

Discharge characteristics	Discharge in m^3/s at station Langa Tabbetje	Estimated discharge at the Outfall of the Marowijne river. (m^3/s)
Maximum discharge	5670	6160
Minimum discharge	45	48
Average discharge	1650	1785

Water level characteristics

The semi-diurnal movement of the Atlantic seawater mainly determines the water level in the estuary of the river. During the dry seasons, especially during the long dry season, the penetration of seawater is observed far up the river.

The range of the water level at station Galibi lies mostly within +212 and –98 cm NSP.

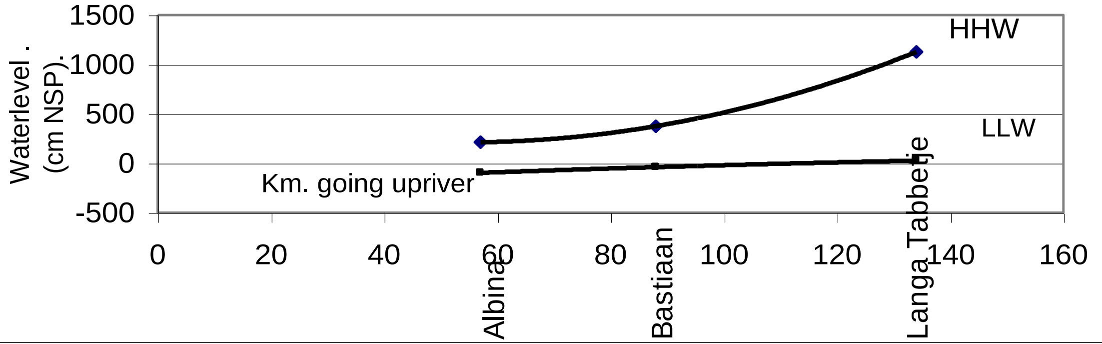
An overview of the highest observed annual highest high water (HHW) and lowest observed annual lowest low water (LLW) is given in Table 28 below.

Table 28. Highest observed annual HHW and lowest observed annual LLW in the Marowijne River.

Catchment	No	Station	HHW (in cm NSP)	LLW (in cm NSP)
Marowijne	1	Albina	212	-98
	2	Bastiaan	375	-40
	3	Lange Tabbetje	1126	26

The highest observed annual HHW and lowest observed annual LLW are graphically expressed in the figure 15 below

Fig.15. Highest observed annual HHW and lowest observed annual LLW in the Marowijne River



A frequency analysis of the above mentioned water levels has also been done. Gumble's Type I Distribution has been used to carry out the analysis. Table 29 below shows the values of the different return periods.

Table 29. Estimated values of the highest annual HHW and lowest annual LLW for given return periods Marowijne River.
(T_{10} = once every 10 years etc.)

Catchment	Station	Annual HHW in cm NSP					Annual LLW in cm NSP			
		T_{10}	T_{25}	T_{50}	T_{100}		T_{10}	T_{25}	T_{50}	T_{100}
Marowijne	Albina	204	214	220	227		-89	-99	-108	-113
	Bastiaan	328	360	383	406		-40	-47	-53	-58
	Lange Tabbetje	1035	1100	1155	1210		80	50	20	0

Salt intrusion

The salt wedge in this river depends on the following factors:

- the tidal effect of the Atlantic Ocean in the estuary

- the freshwater discharge from upstream;

Based on the sampling data as described under subsection “saltwater intrusion”, chlorinity profiles are shown in Figure 16 below. The profiles show that the chlorinity changes abruptly during periods of high water flow whilst at low flow the increase of chlorinity is gradual and extends much further upstream.

From Figure 16 it appears that the salt wedge of 300 mg Cl/l chlorinity during the dry seasons can occur upstream of Albina at km 58.6.

II.2.3. Swamps / Wetlands

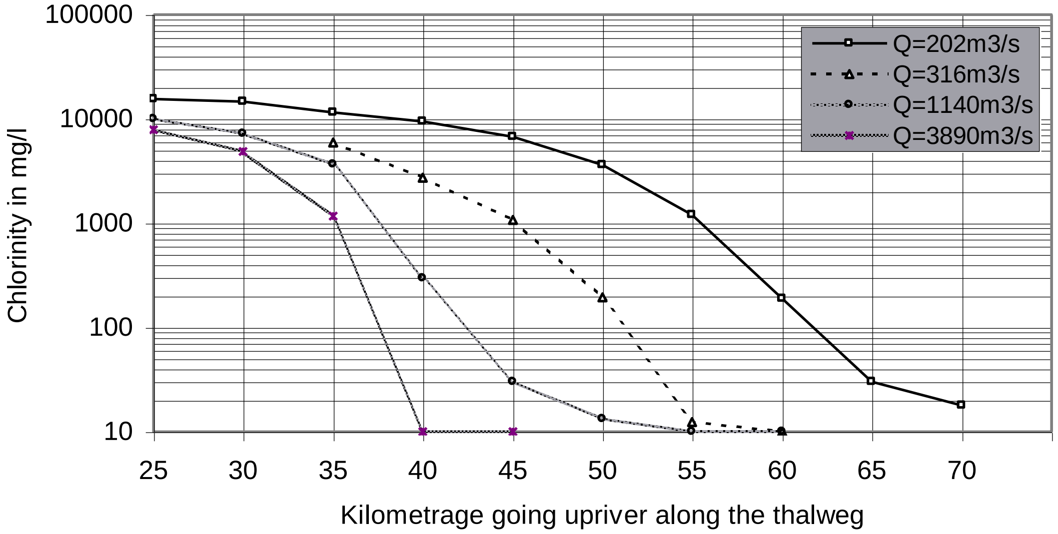
The coastal area of Suriname, in particular the Young Coastal Plain, is very low and flat with elevations of between the 0 - 10m. Swamps cover a major part of this area and the four largest are located from west to east as follows (see Figure 1 Appendix C):

- Nanni swamp;
- Coronie swamp;
- Coesewijne swamp;
- Surnau swamp.

These swamps have the following common characteristics:

- They have similar borders - in the south with the Zanderij formation and the Old Coastal Plain (except for Coronie swamp which borders with Wayambo River), in the north with the land-use activities of people and in the east and west by rivers.
- They are divided in two parts: the northern part, which is mainly flat with relief variations between 0-5m NSP, and the southern part where the relief variations exceed more than 10 meters.
- Except for the Nanni and Coronie swamps, the other two are poorly studied and little is known about them.
- The swamps all function as potential large freshwater reservoirs.

Fig. 16. Chlorinity profiles along Marowijne river for various discharges (Q)) at Km.134



The Nanni swamp

The Nanni swamp is currently one of most important fresh water resource in northwest Suriname. This swamp supplies irrigation water for about 18,000 ha of agricultural lands, mostly for the rice culture. According to Sevenhuysen (1977) the area of Nanni swamp is very low and flat, as a result of which swamp vegetation has developed. This type of vegetation together with the peat reduces the stream velocity and consequently the discharge flow of the area. At the same time due to the very low surface and subsurface flow, the inundated area is increasing. This area is largest during the long wet season and smallest at the end of the long dry season. Agricultural lands for rice culture are expanded during the long dry season when large areas of the swamp are becoming dry. In this way the total area of the Nanni swamp has been reduced through the years by expansion of the rice lands.

In general the Nanni swamp is enclosed in the east by the Maratakka river, in the south by Kapouri creek, in the west by the Corantijn canal and in the north by the east and west conservancy dams. The last are constructed to protect agricultural lands lying beyond the swamp against flooding, especially during the rainy season when the water levels are high. Consequently a reservoir is created to retain rainfall for irrigation purposes during the dry seasons.

The total area of the swamp is about 1,550 km^2 and is divided in two parts; the northern and the southern swamp. The area of the northern swamp is about 650 km^2 and that of the southern swamp 900 km^2. The division is based on the location of ridges within the swamp. The connection of these two parts and so the water flow takes place along depressions through the ridges. Natural drainage has been impeded by construction of east and west conservancy dams and the Corantijn canal. In the west and in the south the boundary between the swamps and that of the adjoining rivers depends on the water level in the swamp. The table 30 below illustrates the relation between the water level and the inundated area. It is taken from R.L.Heesbeen / E.H.Shaap (1990).

Table 30. Relationship water level and inundated area Nanni swamp

Water level in meters N.S.P. in the northern swamp	3.44	1.54	1.94	2.14	2.44	2.94
Area in km^2	40	90	128	290	480	560
Waterlevel in meters NSP in the southern swamp	1.94	2.14	22.9	2.44	2.94	3.44
Area in km^2	24	29	37	50	160	320

Table 31 below shows some observed maximums of high water in meters NSP in the northern part of the swamp at station Nanni Bekken.

Table 31. Observed annual maximum water level Nanni bekken

Year	1970	1972	1973	1974	1975	1976	1977	1978	1979	1981	1984
Water level in m	280	2.87	2.97	2.90	2.84	3.11	2.61	2.51	3.16	3.08	3.02

A depression, the Nanni lake, is located within the southern swamp. It is fed by the rainfall and runoff from the Old Coastal Plain. The depression has an area of about 330 km^2. Due to the inaccessibility of the area detailed data of water levels are missing.

The only source of water available for the swamp is the rainfall and the inflow from Zanderij formation and the Old Coastal Plain. There might be a small contribution of groundwater flow from the Old Coastal Plain into the Nanni swamp but it is not registered or measured yet. Percolation decreases with the depth and the two main ways of water depletion from the swamp is by evapotranspiration and surface flow, through the creeks and small watercourses. These small watercourses arise spontaneously after rainfall leading to quick drainage of the water to the deeper part of the swamp. The Nanni creek drained the main part of the swamp before it was dammed up to provide additional irrigation water to the rice fields and other agriculture.

The swamp itself can be divided into three types:

- Swamp areas with low lying ground (areas between the ridges). These parts of the swamp are inundated during the whole year.
- Swamp areas with intermediate ground elevations (ridges). These areas are seasonal swamps and are not inundated during the whole year.

- Swamp areas with high ground (south portion of the Nanni swamp). These types are only inundated during the rainfall periods.

Each of these types has its own specific characteristics and so its own value of evapotranspiration. The direction of the streams is generally from south to north .In the south the stream velocity is very low.

A water balance, based on the above mentioned characteristics and values of the relevant parameters, shows that in a year with average rainfall the discharge is 12.5 m^3/s. In an extreme wet year discharge increases to 16.8 m^3/s., and in an extreme dry year the discharge falls up to 9.5 m^3/s. These variations in discharge determine the level and irrigation capacity of the swamp. This swamp is one of the main water resources for the rice cultivation in northwest Suriname. Sudden changes in the water quantity and/or water level rise may cause flooding of large areas, whereby dam breaks and serious damage in the production structure may occur, which in turn will have negative impacts on the social and economic development in the region. In the past this problem has been registered many times.

The Coronie swamp

The Coronie swamp is bordered in the north by the E-W road, in the east by the Coppename River, in the south by the rivers Arawarra and Wayambo, in the west by the Nickerie River. The total area of this swamp is about 70,000 ha, which is mainly flat and low-lying. Like the Nanni swamp, the Coronie swamp can be divided into northern and southern parts by ridges and the border between the Old and the Young Coastal Plain as borders. The relief in the northern part varies from 0-5m NSP. In the south it may rise up to about 10m NSP. Above the swamp soil there is a layer of peat about 4m or thicker. This layer floats in the vertical direction depending on the water level in the swamp. During the dry seasons when the water level is low this layer rests on the bottom of the swamp and drastically reduces the stream velocity. An important characteristic of this layer is its high water conservancy capacity.

The pattern of water flows within the swamp is from the “middle” of the swamp radial, to all directions. The middle of the swamp, see “Vegetation map” compiled by NARENA, is free from vegetation. In the northern part of the swamp the main stream flows in the northwesterly direction and a minor stream flows to the northeast. The main water stream in this part of the swamp is the Koffimakka creek. In the southern part of the swamp the main direction of water flow is towards the south into the Wayambo. The main stream here is the Pereko creek.

The swamp water flowing eastward discharges water from the northern part of the swamp by sluices and culverts into the Atlantic basin. This is ecologically very import for the various flora and fauna of the basin. The swamp water flowing in the western direction benefits the rice culture along the Nickerie River.

The Coronie swamp has always been considered as an unlimited source of good quality water. This water is extracted from the northern part of the swamp for irrigation, mostly for rice production. An area of about 4,000 ha is being supplied with irrigation water. A detailed water balance for this swamp, however, has never been established yet for the following reasons;

- the swamp is very difficult to access.
- there are no data on rainfall and evaporation within the swamp;
- determination of discharge is very difficult both in the rainy as well as in the dry season;
- lack of financial means.

Flooding of the agricultural areas due to dam breaks are caused by prolonged rainfalls mostly during the rainy season. Extensive expansion of the agricultural lands in the north of the swamp and the reduction of the natural drainage ways from the swamps might (suddenly) increase the risks of flooding the area. Several dam breaks have been reported in the last 8 years.

The annual highest high waters at station Zoetwaterkanaal in the swamp is given in the table 32 below:

Table 32. Highest high waters at station Zoetwaterkanaal.

Year	Water level in cm NSP		Year	Water level in cm NSP
1970			1971	257
1972	259		1973	265
1974	262		1975	273
1976	272		1977	271
1978	276		1979	289
1980	281		1981	281
1982	277		1983	289
1984	275		1985	280
1986	285		1987	253

The Coesewijne swamp

The Coesewijne swamp is mainly drained by the Coesewijne River, The Coesewijne River finds its sources in the Zanderij formation, the Old Coastal Plain and flows through the Coesewijne swamp area in a south to north direction. In the Young Coastal Area it flows from a northwesterly to a westerly direction and finally discharges into the Coppename River. The tidal influence penetrates far high up the river, about 20-25 km upstream the hydrometric station Grote Borfelt. The catchment area of the river is about 1,100 km^2.

The Coesewijne swamp includes the lower part of the catchment of the Coesewijne River and part of the lower area between the Coppename River and the Coesewijne River. The area of the swamp depends on its water level. During the rainy season it may extend over 800-900 km^2. During this period of time large areas are inundated. In the dry season the area of the swamp may reduce drastically. The borders of this swamp may therefore be taken as: in the south the Tibiti river and the

Old Coastal Plain, Zanderij Formation, in the west the Coppename River, in the north and in the east the watershed of Coesewijne and Saramacca rivers.

The swamp is also considered as a potential source of fresh irrigation water. The first hydrologic measurements in this river were made in April 1969 as part of the study of fresh water availability for agricultural purposes. Since then some further measurements have been made on water levels, chlorinity and discharges. The last has been carried out in both the tidal area at Grote Borfelt as well as beyond the tidal range. By using a deterministic model, discharge at Grote Borfelt in the Coesewijne River is estimated at 22.1 m^3/s. The lowest and the highest measured discharges at Grote Borfelt are respectively about 8.0 and 68.0 m^3/s.

The runoff value depends mainly on two factors: rainfall and groundwater flow (from the Zanderij formation). The latter is the main source during the dry seasons.

The annual highest high water at Grote Borfelt, which is located at km 79, is given below in table 33.

Table 33. Highest high waters at Grote Borfelt

Year	Water level in cm NSP		Year	Water level in cm NSP
1970	182		1971	174
1972			1973	158
1974	153		1975	178
1976	203		1977	156
1978			1979	164
1980	157		1981	187
1982	182		1983	201
1984	159		1985	158

Except from these few studies no other data is available.

The Surnau swamp

The Surnau swamp lies between two major rivers, the Commewijne River in the north and east and the Suriname River in the west. The Old Coastal Plain forms the southern border of the swamp. The swamp therefore, functions as a fresh water source for both rivers. Rainfall and groundwater flows from the Old Coastal Plain are the main water resources of the swamp.

Water resources of this swamp have not been studied yet. No hydrological data on this swamp is available and therefore little is known about it except for some tributaries of the Commewijne River such as the Cassewinica creek, which has its sources in the Surnau swamp.

II.3 Groundwater

II.3.1 General

The aquifers of Suriname are in the coastal basin, which are built up of unconsolidated sediments consisting of a sequence of clay, sands, sandy clay, clayey sands, gravel, with more or less kaolin content, and thin bed organic compound. The geological age is ranging from Createaceous and Tertiary to Holocene. These aquifers which have been classified based on the geological ages are : Nickerie, Onverwacht, A-sand, Coesewijne, Zanderij, Coropina and Demerara. The most important freshwater aquifers are the A-sand aquifers (Oligocene age), the Coesewijne aquifers (Miocene age) and the Zanderij aquifers (Plio-Pleistocene age).

The oldest extensively outcropping aquifer is the Zanderij aquifer in the savanna area. The older aquifers (Nickerie, Onverdacht, A-sand) terminate southward against the rising basement. Exceptions are the upper Coesewijne aquifers, which are in contact with the overlying Zanderij aquifer and the proper Zanderij which crops out southwards. Towards the seaward end the formation is overlain by thick clay deposits (Demerara) while and the aquifers sealing them selves from salt-water intrusion.

There is an abundance of groundwater which is contained in the coastal basin. This water is confined under artesian conditions with high waterlevel close to the ground surface. The aquifers consist mainly of graded coarse-grained angular quartz sand, more or less koalinitic. Generally the hydraulic conductivity vary up to about 100 m/day and exceptionally it may be more than 300 m/day.

Based on groundwater age and flow the coastal basin is divided into two parts .The south which is an active system is recharged directly from rainfall and coincides with the savanna and old coastal plain. In the upper sections recharge is discharged rapidly. However regional flow is slow, at rates up to 6 m/day and the groundwater age is up to 2,000 years BP. To the north the groundwater is more or less static and coincides with the Young Coastal Plain. Groundwater ages varies from about 13,000 to 20,000 BP. It is suspected that an active flow system is extended throughout the basin during the Pleistocene and early Holocene time when the ocean level was lower. As a result of ocean loading during the Holocene transgression the flow was reversed (inland).

The annual recharge is estimated at 480 and 200 mm in the savanna area west of Zanderij and in the Old Coastal plain at Rijsdijk respectively, based on observation wells records. Extensive areas of the savanna have a clay surface, where recharge decreases towards the North in the Old Coastal Plain.

Generally the salinity increases towards the coast. The water in the Zanderij aquifer is fresh thoughout the Old Coastal Plain, and brackish in the Young Coastal Plain, particularly adjacent to the rivers. The change is abrupt. In the Coesewijne aquifers freshwater continues farthest north. Higher salinity extends farthest inland along concealed lines in the A-sand. Brackish groundwater is wide spread in the coastal area of the Commewijne and apparently in the area of the Coppename river mouth.

II.3.2 Nickerie aquifers

The Nickerie aquifers is of the Cretaceous age and is the oldest and deepest lying aquifers. These aquifers start a depth of 330 m at the North of Paramaribo and at a depth of 500 m at Nickerie. They are not suitable for water supply purposes, since the sand and gravel layers in this formation contain brackish water.

II.3.3 Onverdacht aquifers

General Descriptions

The Onverdacht aquifers are in the formation of the lower Tertiary (Eocene and Paleocene) and are overlying the Nickerie formation. It is a more or less continuous downfaulted coastal unit confined beneath younger Tertiary sediments, ending against the rising basement, immediately north of the Bauxite belt. These aquifers include the sand members of the Onverdacht formation.

In the Paramaribo the top of these aquifers is at a depth of 120-450 m., whilst at Meerzorg it is at a depth of 170 m. The thickness of individual aquifers appears to be up to 30m. However zones with a thickness up to 50m. occur with only interbedded clays. In most areas the aquifers constitute between 30 and 50 % of the formation, whilst in the Saramacca-Coppename rivermouth area this ratio is 60%.

At higher levels in the Bauxite belt a more or less discontinuous unit is present. Locally it crops out. However it is buried and surrounded by Coesewijne, Zanderij and Coropina aquifers.

Aquifer parameters

At Onverdacht the average transmissivity is 75 m2/day. The thickness is about 10m and the average hydraulic conductivity is 8 m/day. The aquifer is under leaky artesian conditions, whilst the storativity is in the order of 10^{-3} to 10^{-4}

The hydraulic conductivity has been estimated from 5 to 40 m/day at the East of Paramaribo. At Meerzorg the hydraulic conductivity increases at 5 to 38 m/day with increasing depth from 161 to 188m.

It is assumed that throughout the coastal area non-leaky confined conditions is prevailing, with the high kaolin content, where the effective porosity is less than 0.1

Water quality

The water at Onverdacht is low in dissolved solids. It is essentially a sodium chloride water with a dry residue of 75 ppm, chlorides of 19 ppm, and without sulphates. The pH ranges between 5.5 and 6.0, whilst iron is only 0.1 ppm. The occurrence of brackish water in the North has been reported.

The water in the coastal area at the east and north-east of Paramaribo is mainly brackish with chlorides generally exceeding 1,500 ppm. At Meerzorg the chloride ranges between 323 to 590 ppm with increasing depth from 161 to 188 m.

Water at Livorno suspected to origin from Onverdacht has a chloride content of only 111 ppm. The water is brackish from Calcutta to Totness along the North-West flank of the Bakhuis zone, and is fresh from Totness towards the basin centre.

Waterlevels

From old data it appeared that the original water level was at an elevation of about 2m NSP in the bauxite belt in Groot Chatillon.

It is likely that at Onverdacht the original level was higher than at Chatillon and higher than in the surrounding Zanderij aquifer, since it is overcropping nearby at an elevation higher than 20m NSP. The piezometric surface has declined later on because of dewatering in nearby mines. In the supply wells the water level is between -22 and -27m NSP. In nearby observation wells the water level was about -12m NSP, whilst about 2 km to the north the open cast mines are dewatered to depths of about -25 m NSP. In this area the water is flowing towards the mines and locally towards the wells.

In the coastal area the highest water level was recorded at Nw.Amsterdam (5m NSP). Farther inland the water level is lower. At Jaglust it is about 3m NSP, at Meerzorg 2.7m NSP and at Tamanredjo 2.0m NSP. There is evidence of apparent inland flow of groundwater.

Recharge and Utilization

Quantitative information on recharge in the bauxite belt is lacking. Local recharge at Onverdacht is likely due to leaky artesian conditions and the fact that in the south the aquifers are cropping out. The area is disturbed by mining operations. Since water is perched at the surface of the worked out areas it is likely that the infiltration is slow.

In the coastal area the aquifers are everywhere confined to the inland slope of the piezometric surface, and water levels higher than in the overlying aquifers exclude possible modern recharge.

Currently there is extensive withdrawal from this aquifer for drinking water purposes.

II.3.4 A-sand aquifers

General Description

The A-sand aquifer corresponds with the A-sand formation, consisting of coarse and fine grained angular sand and at some locations of coarse angular sand and fine round gravel. The aquifer is present in the coastal plain north of the Bauxite belt. It thins inland and ends against the rising basement or intervening Eocene sediments. The aquifer is confined by the Coesewijne clay (top) and the Onverdacht formation (bottom). There is locally contact with the lowest Coesewijne aquifer and the sands of the Onverdacht formation. The top of the aquifer is relatively uniform, sloping gently with a gradient of about 0.003 m/m to the north. However the floor is irregular.

There is an eastern and western unit, which are separated by an area which coincide with the Bakhuis zone. In this zone the floor is higher and the aquifer is thinner or missing.

The eastern unit is extending inland south of Paramaribo to the northern edge of the Bauxite Belt. This unit is not continuing East beyond the Suriname river in areas south of Meerzorg. In the south the aquifer is at a depth of 120m and near the coast 160m of which the thickness is a few meters to 60m respectively. A relative thick section of the aquifer is extending inland flowing the SE Bauxite fault.

The western unit begins at the west of the Bakhuis zone in the vicinity of the Coppename river and continues westward to Guyana. Probably this aquifer is extending inland from 30 to 50 km respectively. The top of the aquifer is in the Nickerie area at a depth of 350 m with a thickness of up to 80m.

The two unit is connected in the coastal strip by the Saramacca river near Calcutta and Tambaredjo and it is not known how far offshore the aquifer continues. The aquifer as it is known onshore is not in open contact with the ocean.

Aquifer Parameters

The aquifer is everywhere confined. Before withdrawals near Paramaribo the aquifer had artesian conditions. Currently probably in the West this artesian conditions exists.

In Paramaribo the storage coefficient have been determined in the range of 10^{-4} to 10^{-5}, while near Leysweg (West of Paramaribo) to the West this parameter ranges from 10^{-3} to 10^{-4} .

In Zorg & Hoop the hydraulic conductivity has been estimated at between 80 and 190 m/day with an average of 116 m/day. The transmissivity at Leysweg has been estimated at between 2,300 and 4,100 m2/day, with a rounded average of 3,200 m2/day. The thickness of the aquifer has not been determined yet, but it is believed to be about 10m. In this case the hydraulic conductivity would be about 320m/day, which is quite high. Hydraulic conductivity values, estimated from old incomplete data are mainly between 30 and 80 m/day, with an exceptionally high value at Koewarasan (Wanica). Dissolved carbon dioxide has been reported from 60 to 100 ppm, with a highest value of 127 ppm.

The pH value is generally between 6.0 and 7.0. At Zorg & Hoop it varies between 6.5 and 7.0, and in the West at Uitkijk it and Koewarasan it is 6.0. The values, namely 7.0 and 7.4 were reported in Nieuw Amsterdam and Jaglust.

The iron is high and varies up to 17.5 ppm.

The total hardness is mostly in excess of the bicarbonate hardness, however at some locations these two are equal. The total, hardness varies from 60 to 534 ppm. Where the dissolved solids are high, these values are high. The bicarbonate hardness is varying from 5.0 to 5.5 ppm. Also in this case the values are higher where the dissolved solids are high. This value ranges at Zorg & Hoop between 53 and 100 ppm, however an extreme value of 7 ppm has been reported.

The water is extreme aggressive.

The dissolved solids content increases Northward towards the coast. The isochlors bulge inland to the Southwest in the vicinity of Koewarasan, following the trend of the SE Bakhuis fault zone.

Relative fresh water is indicated in Western Suriname. However as an exemption at the mouth of the Saramacca river a sand formation exists, which may be the A-sand, with a relative high salinity of 850 ppm as NaCl. The salinity indicated in this section are only relative.

Water quality

Near the south of Paramaribo (Pont) and in Wanica between the southern boundary near Lelydorp, and the Saramacca canal the water has a chloride content of 120-150 mg Cl/l.

Further Westward, near Jaricaba and Santo the aquifers contain water of good quality. However at West Nickerie (Sidoredjo, Corantijnpolder, Clarapolder, Nannipolder) the A-sand water is brakish (> 600 mg Cl/l).

Water Levels

Water levels are only known in the Eastern basin in the area near Paramaribo. The piezometric surface was lower than in the underlying Onverdacht aquifers and higher than in the overlying aquifers before withdrawals. The piezometric surface was generally above groundlevel. There are no data of western Suriname. It is assumed that the piezometric level will be above ground level as in Guyana.

Recharge and Withdrawals

There is no evidence of recharge, at least in the eastern basin. There are significant withdrawals from this aquifer for drinking water purposes. About 32% of the drinking water supply is withdrawn from the A-sand aquifers.

Average withdrawal rates are as follows:

1. Zorg & Hoop	13,000 m3/day
2. Livorno	10,000
3. Leysweg	5,400
4. Meerzorg	3,600
5. Helena Cristina	4,800
6. Koewarasan	2,400
Total	***39,200***

II.3.5 Coesewijne aquifers

General Description

The Coesewijne aquifer zone is equivalent to the Pollen Zone E and F above the A-sand. This zone is largely composed of clay and sandy clay with interbedded sand aquifers. It appears that these sand aquifers are hydraulically interconnected. In the Suriname and Saramacca rivers this zone has a thickness up to 100m, and in Nickerie Area up to 120m, where the top is about 230 m below ground surface.

The Zanderij aquifer is overlying the Coesewijne quifer zone. Outcrops of the zone are not known. The zone is absent in the Bauxite belt at locations where the buried hills of the Onverdacht formation rise to elevations higher than the top of the zone.

Generally the aquifers make up 30 to 50% of the entire zone. In the east the aquifers appear more frequently in the upper section, coinciding approximately with Pollen Zone F. Normally individual aquifers are up to 10m thick. However locally they form complexes of two or more thin clay partings.

The NNW dip of the zone is greater than that of the Zanderij aquifer, and thus there is contact between them in the Bauxite belt and immediately to the North where water in the Zanderij aquifer contains brackish water and subsurface outcrops of the Coesewijne aquifers along the sides of the buried valley are in contact with it.

There is contact between the lowest aquifer and the A-sand at some locations in the coastal area.

Aquifer parameters

The aquifer is everywhere confined. However in the extreme south of basin local exceptions may exist, where there is contact with the Zanderij aquifers at locations where it is confined. The storage coefficient is generally in the range of 10^{-4} to 10^{-5} which reflects confined conditions of the aquifers.

The hydraulic conductivity is estimated at a range between 10 and 130 m/day. The west values are for aquifers with a substantial clay content. The highest value was estimated for the supply well for the Kwatta-Leidingen project. The aquifer here is relatively free of clay and is thick. Probably it represent a complex of more than one sand body.

The average of the hydraulic conductivity of the lower aquifers is estimated at 43 m/day and for upper aquifers at 70 m/day. The distribution of the values is patchy, reflecting varied conditions in the several aquifer unit within the zone. In the lower aquifers the values are between 40 and 70 m/day between the Suriname and Saramacca rivers. At the west of the Suriname river it decreases to 24 m/day (Kampong Baroe) and 15 m/day (Groningen). The values for the upper aquifers are more variable.

In the western part of the country hydraulic conductivities of 10 and 42 m/day have been estimated for the aquifer at Paradise and Groot Henar.

Effective porosity has been estimated from disturbed samples at about 8% to 13%. An overall value of 10% is assumed.

Water quality

The Coesewijne aquifer is at the East of Nickerie at a depth between 240-280 m. and contains water of very good quality (15 - 70 mg Cl/l). In the Western part of Nickerie (Sidoredjo, Corantijnpolder, Clarapolder and Nannipolder) the water is brackish (> 600 mg Cl/l).

Recharge and Utilization

About 31% of the drinking water supply is withdrawn from the Coesewijne aquifers. Average rates are as follows

Leysweg	3,000m3/day
Kwatta	9,600
Koewarasan	4,300
Helena Christina	3,800
Tijgerkreek	1,400

Tambaredjo	1,400
Groningen	1,400
Kampong Baroe	1,400
Coronie	2,500
Wageningen	3,000
Henar	1,400
Paradise	3,800
Total	***38,000***

II.3.6 Zanderij aquifer

General Description

The Zanderij formation is equivalent to the sandy layers of the Zanderij formation. In the savanna belt the aquifer crops out. It continues northward and dips gently and is confined beneath the Coropina clays and above the Coesewijne formation. It is not known how far this coarse sand aquifer extends offshore. At about 100 km it is equivalent to silly and sandy clay and clay.

The distribution of the aquifer is very irregular in the savanna belt. At some locations there are no clear sands. Usually these sands are highly kaolonic, where present. The conditions improve northward. In the bauxite belt the aquifer is present everywhere except locally, where buried hills rise to higher elevations.

The bottom of the aquifer is irregular and corresponds to the post-middle Miocene erosion surface. The valley of this surface is filled with the coarsest sand and is the thickest aquifer section.

The top of the main sand body is taken as the upper limit of the main sand body. However at some locations the upper limit is difficult to define because of overlying Quartenary sands.

The thickness is generally between 10 and 20m in the bauxite belt and in the savanna belt this varies up to 20 m. The aquifer begins in the coastal area of eastern Suriname at a depth of about 30 to 40m, whilst the thickness attains 40 to 50 m in the buried valleys. This is approximate the locations of the present rivers. In western Suriname (Nickerie) the top of the aquifer is at a depth of about 50m with a thickness of about 165m, probably including some overlying Coropina sands.

Aquifer Parameters

The aquifer is confined beneath Coropina and Demerara clays in the coastal area. Locally the overlying Coropina sediments become more arenaceous southward and leaky artesian and unconfined condition exist.

Between the Saramacca and Suriname rivers confined artesian conditions prevail at least far south as Sidodadie weg, west of Lelydorp. This condition prevail also at de Craneweg. In the Rijsdijkweg there are indications of local leaky artesian conditions, where the water level fluctuates seasonally.

The savanna belt areas bordering to the north vary from artesian to water table. At Republic the conditions are leaky artesian to water table as well as artesian with a boundary.

The hydraulic conductivity in the savanna belt and adjacent area to the north is low. At Republic calculated transmisivities ranges between 24 and 126 m2/day, with an average of 83 m2/day. It is likely that the equivalent hydraulic conductivity is in the order of 15 to 20 m/day. To the south a higher transmisivity of 352 m2/day is evident.

An average transmisivity of 880m2/day was calculated for Rijsdijk. The aquifer thickness is 20 m and the conductivity is 44m/day. At Sidodadi the transmissivity ranges from 894 to 1,120m2/day, with an average of 1,007 m2/day. The hydraulic conductivity here is 75m/day.

The hydraulic conductivity in the coastal area is estimated at up to 140m/day. For both the east and west coastal area the average of these estimates is 72m/day. It is likely that much higher values prevail locally.

The specific yield at Republic is 13%.

Water quality

In the savanna and bauxite belts the groundwater is fresh. However northward the salinity increases toward the coast.

The cat-ions are grouped to a certain extent with alkaline earth only just exceeding alkalis and with magnesium slightly higher than calcium. The waters with higher dissolved solids maintain more or less the same proportion, but are grouped in the field of primary and secondary salinity.

In the savanna area the water is very low in dissolve materials. Dissolved solids of 46 and 86 ppm have been determined for samples taken in the Zanderij-Matta area and to the east near Powakka. The pH is low and it appears to be the lowest at shallow depth. A pH of less than 6.8 generally prevails in the savanna area.

At Republiek, immediately to the north of the savanna area the pH is still low, ranging from 5.0 to 5.6. Dissolved solids is up to 66 ppm and iron content ranges from 0.3 to 1.3 ppm. North from Republiek freshwater continues. However in the Onverdacht area very high chloride values of up to 448 ppm have been reported in the Onverdacht area.

The Northern limit of fresh ground water is varying considerably. The change to brackish water may be quite sharp. Between the Suriname and Saramacca rivers water with low dissolved solids continues north of Sidodadi weg (222 ppm).

Near the Northern limit for fresh water the groundwater contains dissolved solids between 50 and 250 ppm. The higher values are from the area west of the bauxite mines, where the fresh water extend further to the north. The chlorides are between 15 and 30 ppm. The pH varies between 5.5 and 8.0, and the iron between 0.2 ppm and 4.1 ppm, which is high.

Farthest inland brackish water is found immediately north of the bauxite area of Onverdacht. The salinity of the brackish water is caused mainly by sodium chloride. However there is relatively more magnesium and sulfate than in the sea water. In the thickest part of the aquifer the salinity is the highest and dissolved solids are here between 2,000 and 5,000 ppm. In the Groningen-Domburg section the salinity decreases westward to a dissolved solids content of 1,174 ppm at Uitkijk. The eastern part of the aquifer contains water more than 5,000 ppm dissolved solids.

Water levels

Water levels of almost 10 m NSP have been observed in the savanna area. Here water levels are the highest.

At Republiek immediately north of the savanna area the water level generally fluctuates between 0 and 2.5 m NSP, with an average of 1.25m NSP. Here the water level is slightly influenced by pumping.

Northward to the area of Helena Christina Weg where the water level is about sea level, the level is declining, then increases again. Towards the north water level fluctuation diminish.

Originally the water level in the Nickerie area were 2 to 4 m NSP. At Nannipolder approximately 2 km to the south the water level would be approximately 2.5 m NSP.

Recharge and Utilization

It is likely that the Zanderij aquifer is the only aquifer in the basin that receives recharge directly by the infiltration of rainfall, taking mainly place in the savanna area and immediately to the north. Seasonal fluctuations of groundwater level have been measured as far as north as the Crane Weg. It likely is close to the Northern limit of recharge.

Currently about 37% of the drinking water supply is withdrawn from the Zanderij aquifers. Average withdrawals are as follows (1986) :

1.	Paranam	20,000 m3/day
2.	La Vigilantia	2,400
3.	Republic	11,100
4.	Lelydorp	1,400
5.	Biliton	1,100
6.	Wonoredjo/Cottica Rivier	2,000
7.	Albina/Erowarte	1,000
8.	Alliance/Wanhatti	4,000
9.	Nieuw Nickerie	2,500
10.	Sidoredjo	3,100
11.	Apoera	6,000
	Total	***45,600***

II.3.7 Coropina/Demerara aquifers

The Coropina and Demerara formations which are of the Pleistocene and Holocene age are overlying the other formations except the Zanderij outcrops at the South. Sand and predominantly clay layers are found in lenticular form in this area. Since the aquifers contain brackish water, it is not suitable for water supply.

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APPENDIX A

Table 1: List of meteorological stations in the coastal area of Suriname

Station name	Geographical coordinates		Period	Average annual rainfall in mm
109 Coeroeni	03N22min	57W20min	1960 - 1986	2105
1010 Wakay	05N16min	57W13min	1968 - 1986	2436
1020 Apoera	05N13min	57W13min	1914 - 1986	2116
1060 Mac Clemen	05N34min	57W10min	1971 - 1986	2269
1070 Clara sluis	05N56min	57W00min	1972 - 1980	2419
110 Kabalebo	04:24'N	057:13'W	1961 - 1986	2158
2010 Nw Nickerie	05N56min	57W00min	1904 - 1986	1824
2020 Paradise	05N20min	56W27min	1953 - 1986	1920
2030 Pr.Bernhard pld	05N50min	056:53'W	1950 - 1987	1788
2040 Wageningen	01:01'N	054:00'W	1961 - 1971	1738
2050 Groot Henar	05:51'N	056:52'W	1961 - 1987	1831
2060 Arawarra	05:20'N	056:27'W	1953 - 1987	2270
2070 Nanni afdamming	05:48'N	056:59'W	1958 - 1987	1599
2080 Gemaal Nanni	05:53'N	057:02'W	1958 - 1987	1789
209 Nickerie	05N57min	57W02min	1956 - 1986	1707
210 Stondansie	05N07min	56W31min	1963 - 1986	2100
2110 Koningin Juliana	05:51'N	056:53'W	1961 - 1984	1778
2150 Fossibergi	05:49'N	056:52'W	1961 - 1975	2283
217 Tapoeripa	05:22'N	056:33'W	1969 - 1987	2503
2400 Wageningendorp	05N45min	56W41min	1951 - 1986	2052
3010friendshiptotness	05N52min	56W20min	1904 - 1986	1598
3020Sarah	05:53'N	056:23'W	1912 - 1977	1569
305 Cocos polder	05N53min	56W16min	1959 - 1986	1398
3090 Coro				1873
4030Boskamp	05N46min	55W53min	1953 - 1986	2358
404 Coppenamepunt	01:00'N	054:00'W	1961 - 1971	2118
4110 Tibiti Monding	05:53'N	055:54'W	1915 - 1977	1923
4130 Wayambo monding	05N26min	56W20min	1965 - 1986	1908
4190 Raleighvallen	04N44min	56W45min	1971 - 1986	2314
420Goliat	05N16min	55W36min	1970 - 1986	2147
5110kwak	05N47min	55W29min	1912 - 1986	2190
5010 Groningen	05N50min	55W46min	1924 - 1986	2160
5020Carl Francois	05N45min	55W24min	1949 - 1986	2024
506k Dirkshoop	05:46'N	055:25'W	1961 - 1976	2177
5070Kwatta LVV	05:52'N	055:19'W	1978 - 1986	2085
5110 Kwakoegron	05N15min	55W21min	1910 - 1986	2176
5120 De Jong Noord	05N08min	55W16min	1920 - 1986	2137
513k Tabelberg	03:47'N	056:09'W	1959 - 1986	2956
5160 Locuskreek	05:30'N	055:22'W	1953 - 1968	2103

5170Oryza	05N48min	55W19min	1958 - 1986	1938
5180 Fernandes	05:50'N	055:19'W	1958 - 1977	1794
519 Utkijk	05:46'N	055:21'W	1962 - 1987	2041
5200 Santobomapompgemaal	05:46'N	055:16'W	1961 - 1987	1987
5230 KAE	04N49min	55W43min	1932 - 1986	1953
5240 Pakka- Pakka	04:41'N	055:39'W	1960 - 1987	1884
5250 Boslanti	04N20min	55W47min	1960 - 1986	2243
5290 Polder weg naar Zee	05N53min	55W15min	1963 - 1986	1375
530 Jarikaba	05:49'N	055:20'W	1969 - 1987	2218
5330 Moeoroekreek	05:23'N	055:25'W	1958 - 1986	2068
5410 Poika	05:26'N	055:30'W	1969 - 1987	2197
546 Coebiti	05N25min	55W29min	1971 - 1986	2202
602k Cultuurtuin	05N50min	55W10min	1847 - 1986	2198
603 ‘s Landsboerderij	05:47'N	055:16'W	1953 - 1975	1859
604k Zorg en Hoop	05:48'N	055:11'W	1961 - 1987	2066
607k Celos	05:47'N	055:13'W	1968 - 1987	2181
6110 Maretraite	05:51'N	055:09'W	1954 - 1987	1748
6120Geyersvlijt	05:50'N	055:08'W	1959 - 1987	2027
614 Morgenstond	05:51'N	055:08'W	1916 - 1987	2098
6150 Nw Amsterdam	05:53'N	055:05'W	1928 - 1987	2022
6160voor	05N53min	55W05min	1928 - 1986	2067
6170Mijnzorgweg	05:43'N	055:15'W	1960 - 1987	2158
6180 Palisadeweg	05:40'N	055:14'W	1961 - 1987	2267
6190 Helena Christina	05:40'N	055:14'W	1961 - 1987	2030
6200 Perpot	05N48min	55W09min	1929 - 1986	2237
6320 Houttuin	05:45'N	055:11'W	1959 - 1987	2056
6330 Java weg	05:41'N	055:16'W	1972 - 1986	2341
6310 Republiek	05N30min	55W13min	1906 - 1986	2075
6340 Domburg	05N41min	55W05min	1909 - 1986	2107
6350 Sectie oost	05:19'N	055:16'W	1910 - 1987	2154
6360 Lelydorp	05N41min	55W13min	1912 - 1986	2182
6380 Groot Chatilion	05:36'N	055:02'W	1912 - 1969	2054
6400 Onverwacht	05:37'N	055:09'W	1943 - 1984	2110
642 Kamp8	05N25min	54W47min	1957 - 1986	2223
643k Zanderij	05N27min	55W12min	1939 - 1986	2207
6550 Brownberg	04:56'N	055:11'W	1972 - 1986	1985
6630Kasbelstation	01:00'N	054:00'W	1910 - 1963	2250
6640 Brownsweg	05N01min	55W09min	1910 - 1987	2362
6650 Sisakamp	01:00'N	054:00'W	1911 - 1963	2199
6660 Dam	01:00'N	054:00'W	1913 - 1972	2224
66640 Brownsweg	05:01'N	055:09'W	1910 - 1987	2317
667 Brokkobakka	05:03'N	055:01'W	1969 - 1984	2809
670 Pokigron	04:30'N	055:22'W	1953 - 1986	2335
676 Blakawatra	05N24min	54W55min	1957 - 1986	2278

677 Klaaskreek	05:11'N	055:05'W	1972 - 1986	2591
6790 Zanderij1	05:28'N	055:12'W	1930 - 1987	2212
699Victor	05:03'N	054:59'W	1970 - 1987	2498
701k Moengo	05N37min	54W24min	1919 - 1986	2381
703 Patamacca	05N32min	54W25min	1966 - 1986	2263
7150 Zoelen	05:53'N	055:04'W	1952 - 1987	2111
7160Backdam	05N50min	55W03min	1952 - 1986	1899
7170Tambaredjo	05:47'N	055:03'W	1964 - 1987	1909
721kAlliance	05N53min	54W53min	1906 - 1986	2181
722 Berlijn	01:00'N	054:00'W	1906 - 1965	2092
723k Slootwijk	05:53'N	054:52'W	1969 - 1987	2002
725k Marienburg	05:52'N	055:03'W	1914 - 1987	2105
7260spieringshoek	05:51'N	054:58'W	1958 - 1987	2190
7270Wederzorg	05N51min	54W59min	1920 - 1986	2195
7290 Rust en Werk	05N54min	55W04min	1953 - 1987	2165
730k Matapica	05N58min	54W52min	1953 - 1986	1661
7400Perica	05N54min	54W38min	1972 - 1986	2532
803k Albina	05N39min	54W03min	1915 - 1986	2366
8040Galibi	05N44min	54W00min	1928 - 1986	2006
805k Stoelmanseiland	04N21min	54W25min	1959 - 1986	2515
8060Langetabbetje	05N00min	54W26min	1967 - 1986	2555

Table 2: Summary of rainfall intensities in Paramaribo by various persons / organizations

Table 1. Amount-duration rainfall (in mm),
of Landbouwproefstation (Cultuurtuin 1965)

Duration (min)	Return period (years). 10	5	3	2	1	0.5	0	0.1
15	38	35	33	31	26	24	20	17
30	50	48	47	44	39	35	26	20
60	63	62	57	54	49	44	31	24
120	70	69	66	62	55	47	35	28
240	72	70	68	66	58	52	39	32
480	86	80	76	72	68	56	44	36

Table 2. Amount-duration rainfall (in mm),
according to Verdeyen en Moenaert (1970)

Duration (min)	Return period (years). 10	5	3	2	1	0.5	0	0.1
15	36	35		32	28	24	20	
30	50	49		44	39	34	28	
60	63	61		54	48	42	34	
120	71	68		61	54	46	38	
240	76	72		64	58	52	40	
480	88	83		72	63	55	45	

Table 3. Amount-duration rainfall (in mm),
of Cultuurtuin according to Sescon-Group.

mm.

Duration (min)	Return period (years). 10	5	3	2	1	0.5	0	0.1
15	35				26			20
30	48				37			24
60	63	59			47			30
120	70	65			52			34
240	71	68			56			37
480	81	75			64			42

Table 4 Amount-duration rainfall (in mm),
of Zorg en Hoop according to Hille (1982).

Duration (min)	Return period (years). 10	5	3	2	1	0.5	0	0.1
15	28	27	27	25	22	19	15	11
30	52	46	45	43	34	30	23	17
60	77	65	64	59	46	37	27	21
120	87	78	69	66	55	44	32	25
240	93	83	78	77	65	51	36	28
480	94	89	85	82	68	58	42	31

Table 5. Amount-duration rainfall (in mm), of Cultuurtuin according to Hille (1982).

Duration (min)	Return period (years).							
	10	5	3	2	1	0.5	0	0.1
15	50	31	31	24	19	17	19	11
30	70	53	43	38	31	26	22	17
60	92	70	58	50	42	34	28	21
120	113	90	71	59	51	41	32	25
240	126	111	90	69	63	50	35	28
480	132	113	92	84	66	55	39	32

Table 6 Amount-duration rainfall (in mm), of Paramaribo according to Meteo Service (1982).

Duration (min)	Return period (years).							
	10	5	3	2	1	0.5	0	0.1
15	32	29		25	23	20	16	13
30	50	45		39	34	29	22	17
60	63	57		49	42	35	26	20
120								
240								
480								

Table 7. Comparison of the rainfall with the various sources at a return period of 10 year.

Duration (min)	Table number.					
	1	2	3	4	5	6
15	38	36	35	28	50	32
30	51	50	48	52	70	50
60	63	63	63	77	92	76
120	70	71	70	87	113	
240	72	76	71	93	126	
480	92	86	81	94	132	

Table 8. Comparison of the rainfall with the various sources at a return period of 5 year.

Duration (min)	Table number.					
	1	2	3	4	5	6
15	35	35		27	31	29
30	48	49		46	53	45
60	62	61	59	65	70	57
120	69	68	65	78	90	
240	70	72	68	83	111	
480	80	81	75	89	113	

Table 9. Comparison of the rainfall with the
Various sources at a return period of 2 year.

Duration	Table number.					
(min)	1	2	3	4	5	6
15	31	32		25	24	25
30	44	44		43	38	39
60	54	55		59	50	49
120	62	61		66	59	
240	66	64		77	69	
480	72	72		82	84	

Table 10. Comparison of the rainfall with the
various sources at a return period of 1year.

Duration	Table number.					
(min)	1	2	3	4	5	6
15	26	28	26	22	19	23
30	39	39	37	34	31	34
60	49	48	47	46	42	43
120	55	55	52	55	51	
240	60	58	56	65	63	
480	64	63	64	68	66	

Table 11. Comparison of the rainfall with the
various sources at a return period of 0.5 year.

Duration	Table number.					
(min)	1	2	3	4	5	6
15	24	24		19	17	20
30	35	34		30	26	29
60	44	42		37	34	35
120	47	46		44	41	
240	52	52		51	50	
480	56	55		58	55	

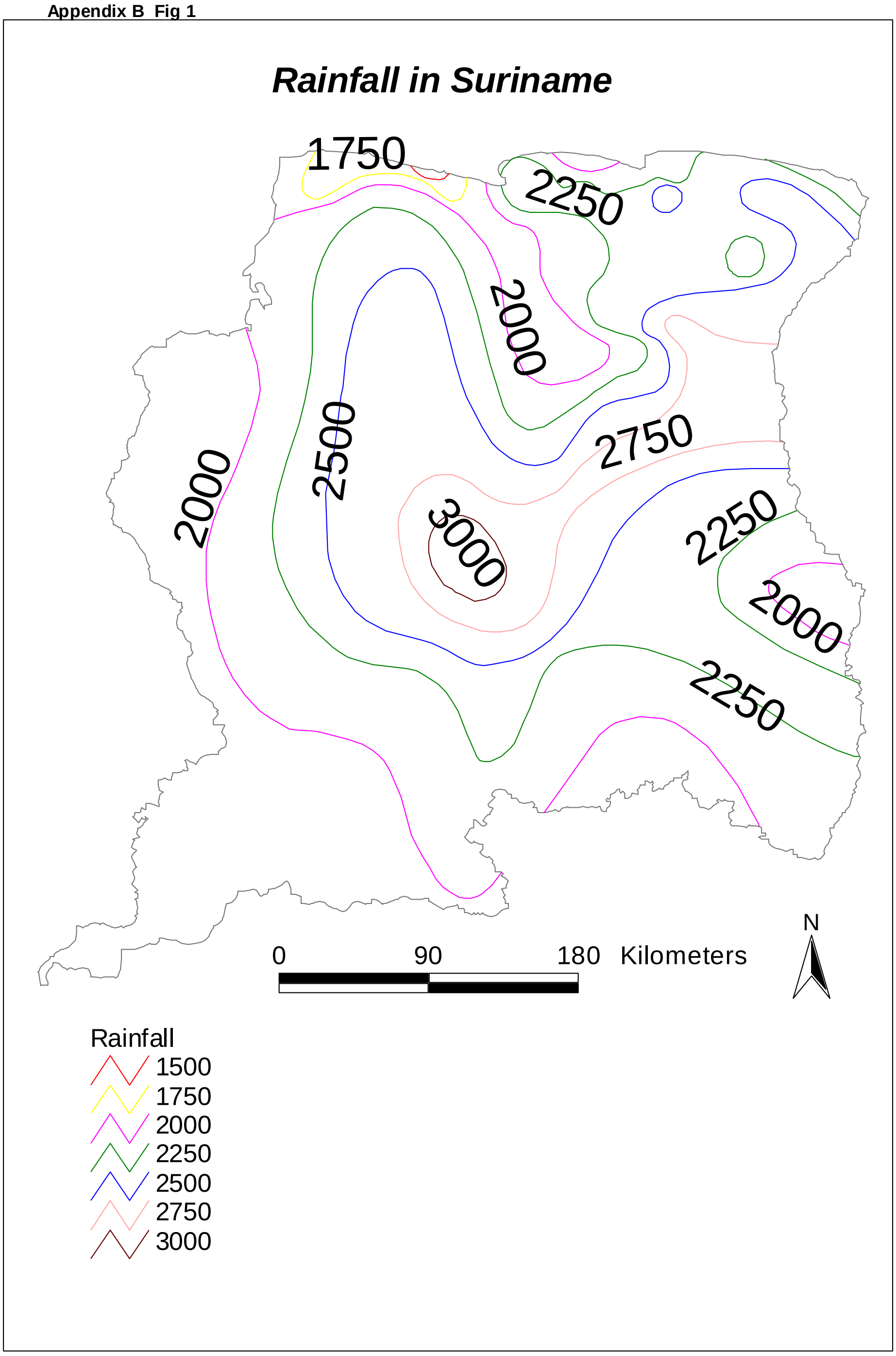
Table 12. Comparison of the rainfall with the
various sources at a return period of 0.1year.

Duration	Table number.					
(min)	1	2	3	4	5	6
15	17		20	11	11	13
30	20		24	17	17	17
60	24		30	21	21	20
120	26		34	25	25	
240	32		37	28	28	
480	36		42	31	32	

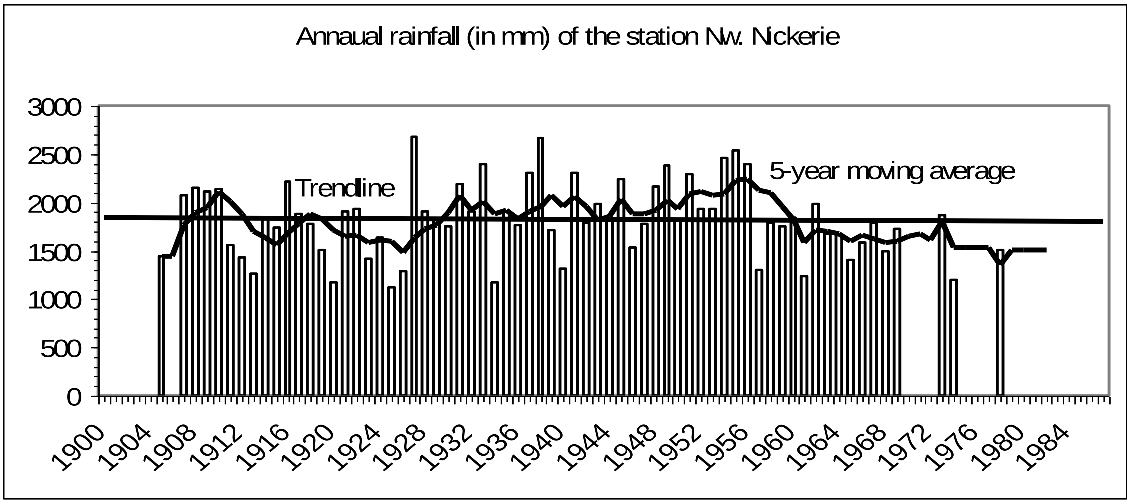
APPENDIX B

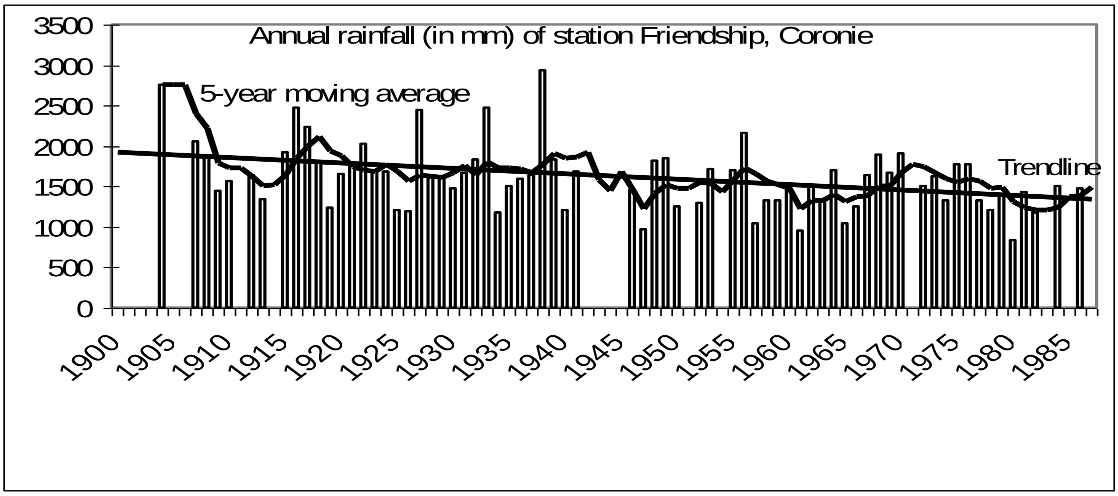
Figure 1: Rainfall map of average annual rainfall over Suriname compiled by NARENA

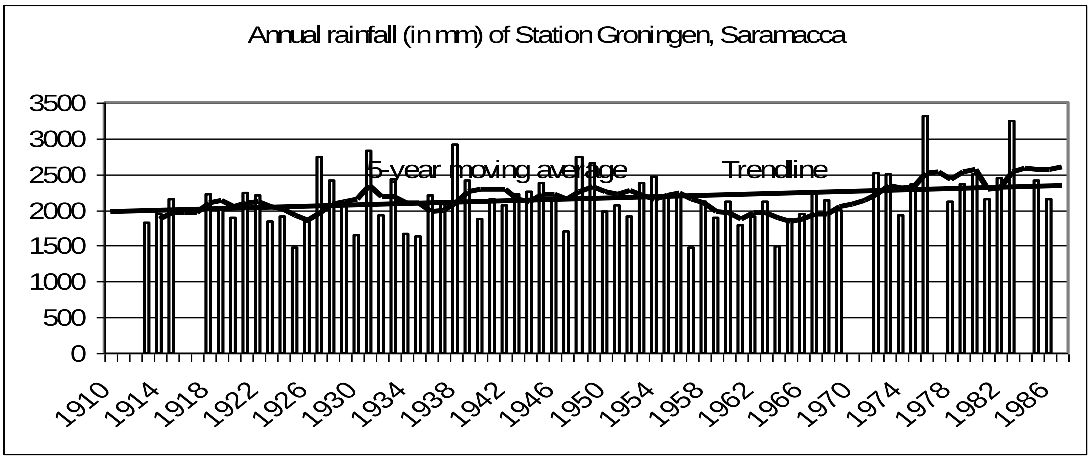
Appendix B Fig 1

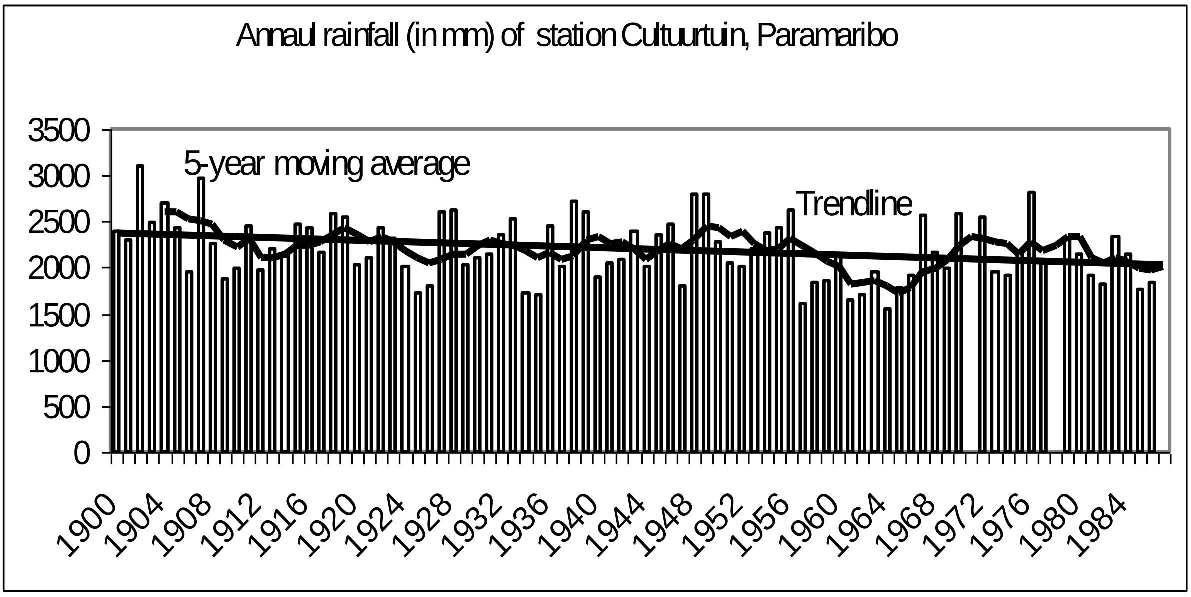


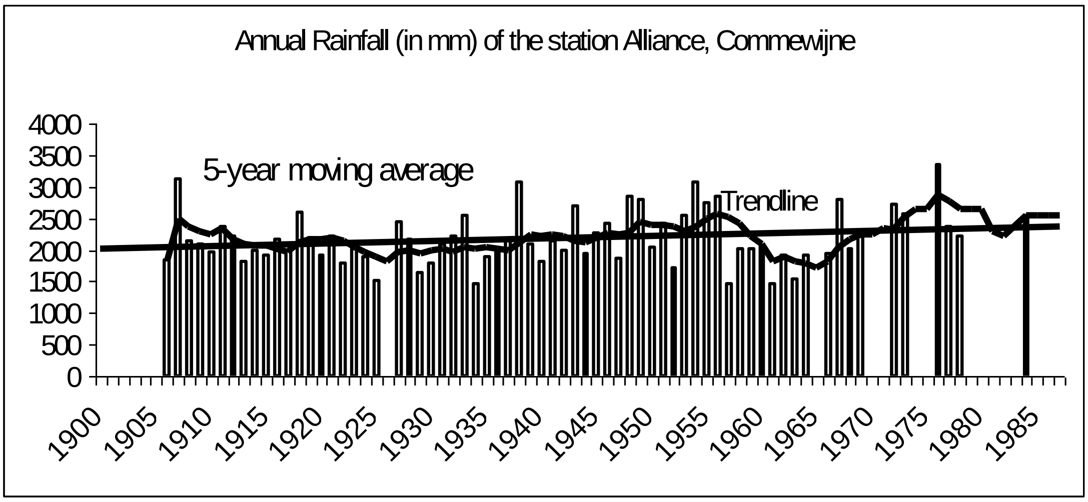
Figures 2-10: Rainfall trends at stations Nw. Nickerie, Friendship / Totness, Groningen, Paramaribo, Alliance, Galibi, Lelydorp, Republiek and Zanderij



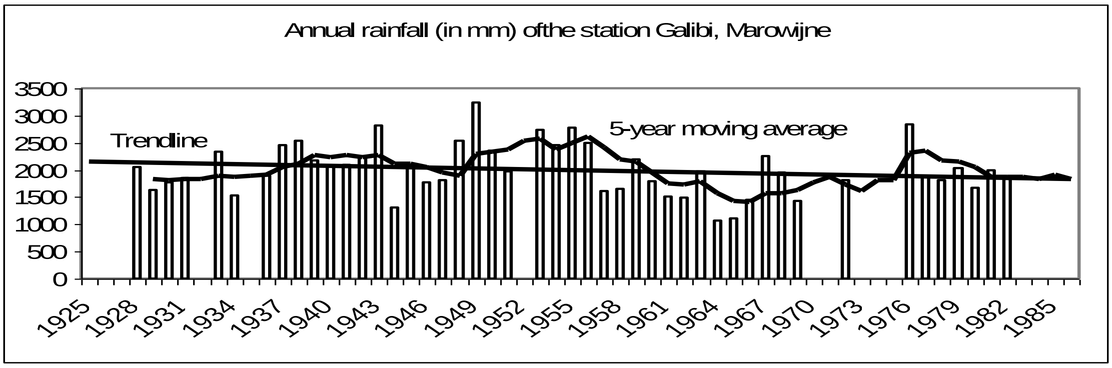



Annual rainfall (in mm) of Station Groningen, Saramacca
3500
3000
2500
2000
1500
1000
500
0
5-year moving average
Trendline
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986

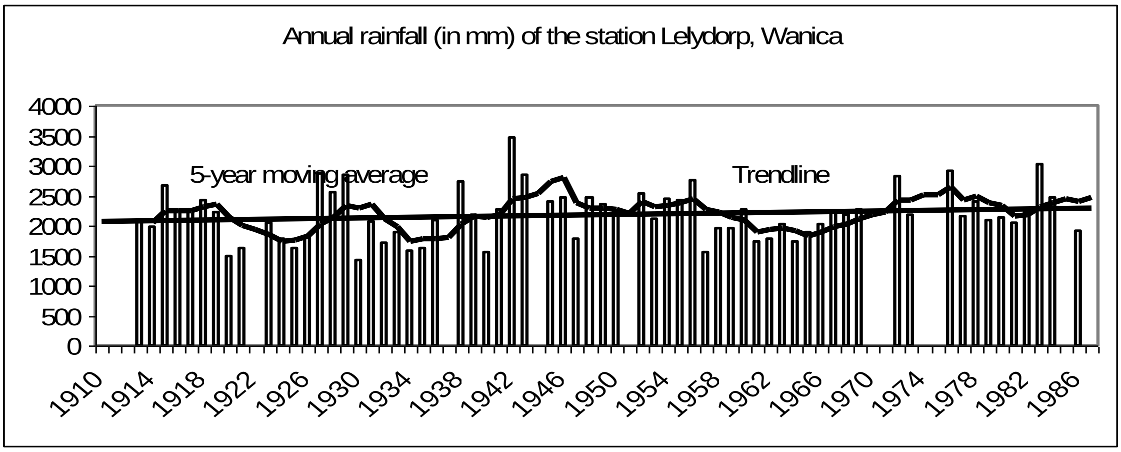

Annaul rainfall (in mm) of station Cultuurtuin, Paramaribo
3500
3000
2500
2000
1500
1000
500
0
5-year moving average
Trendline
1900
1904
1908
1912
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984

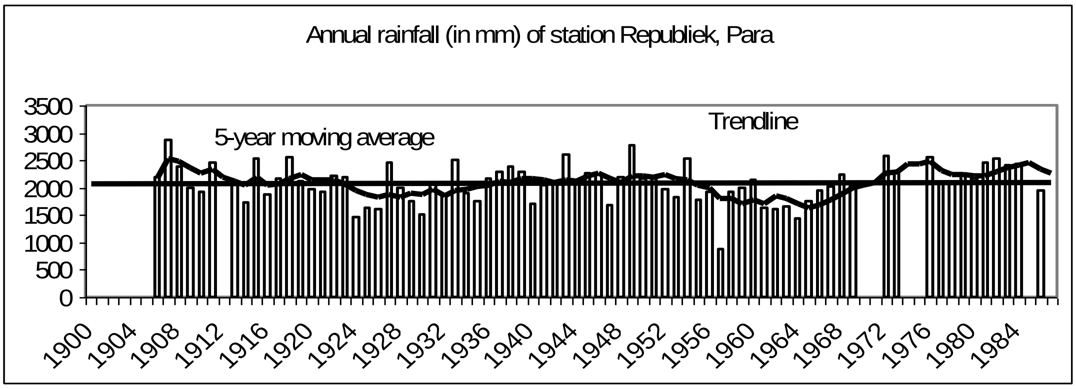


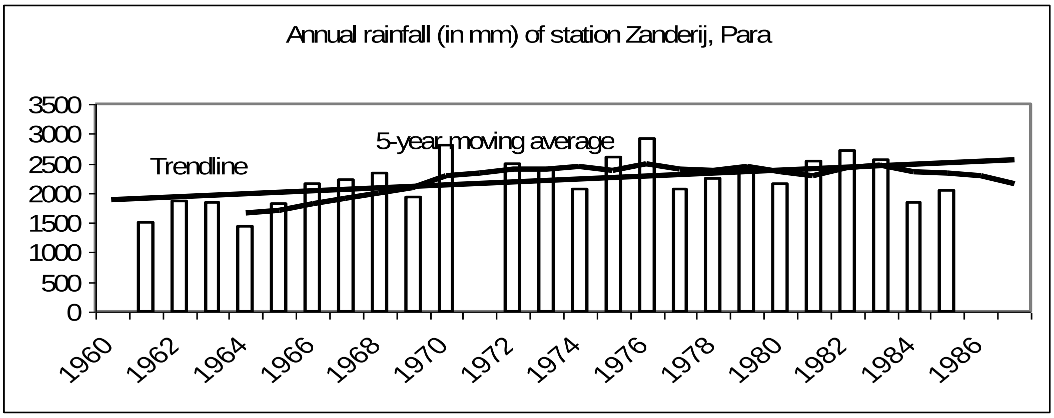
Annual Rainfall (in mm) of the station Alliance, Commewijne
5-year moving average
Trendline
4000
3500
3000
2500
2000
1500
1000
500
0
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985



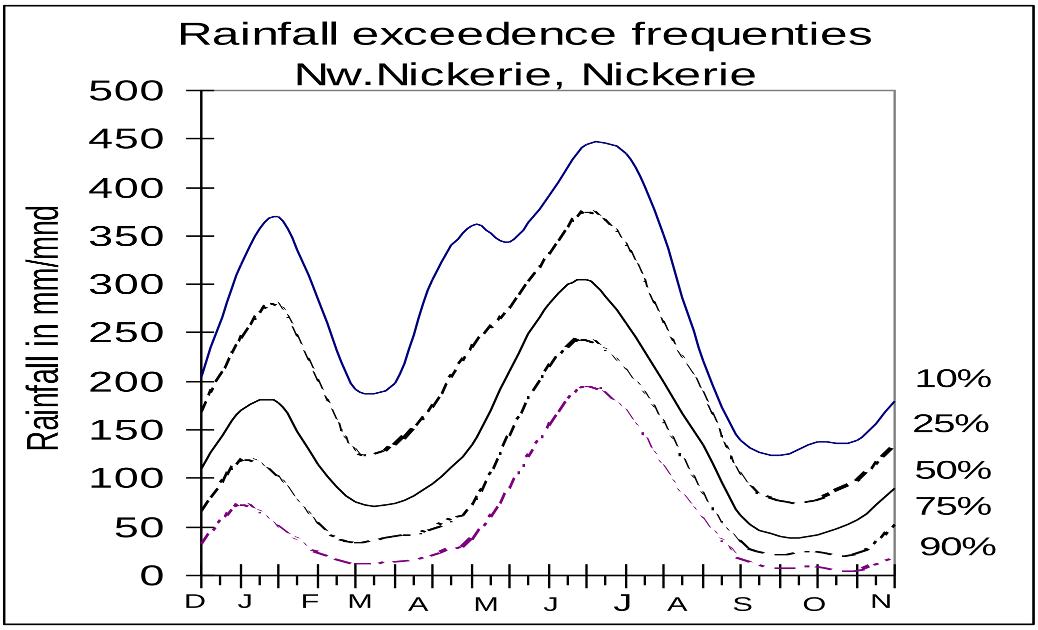
Annual rainfall (in mm) ofthe station Galibi, Marowijne
Trendline
5-year moving average
3500
3000
2500
2000
1500
1000
500
0
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985

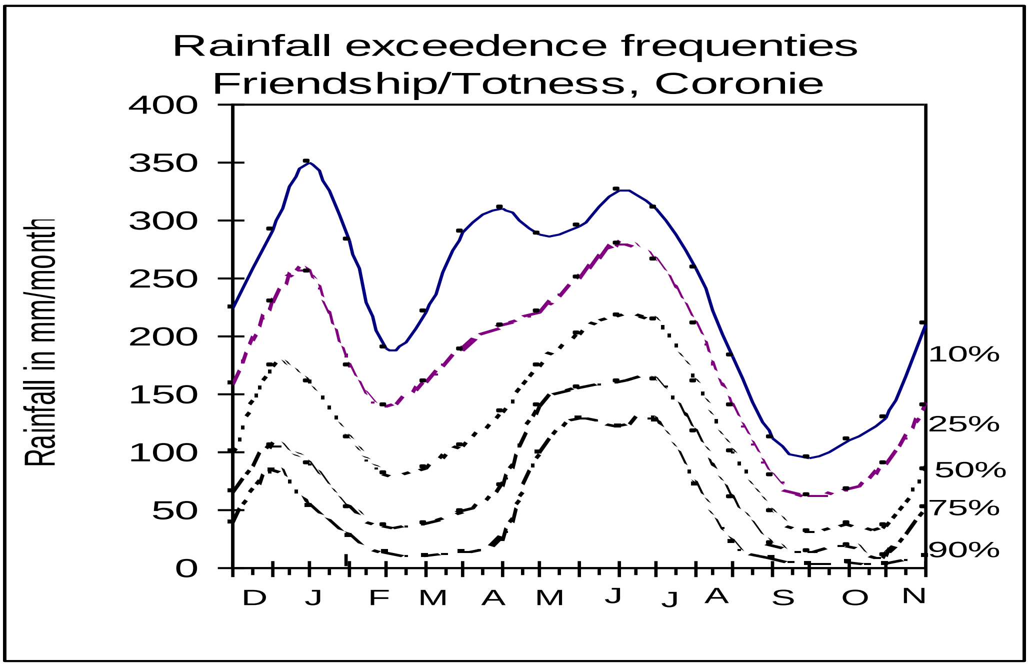

Annual rainfall (in mm) of the station Lelydorp, Wanica
4000
3500
3000
2500
2000
1500
1000
500
0
5-year moving average
Trendline
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986

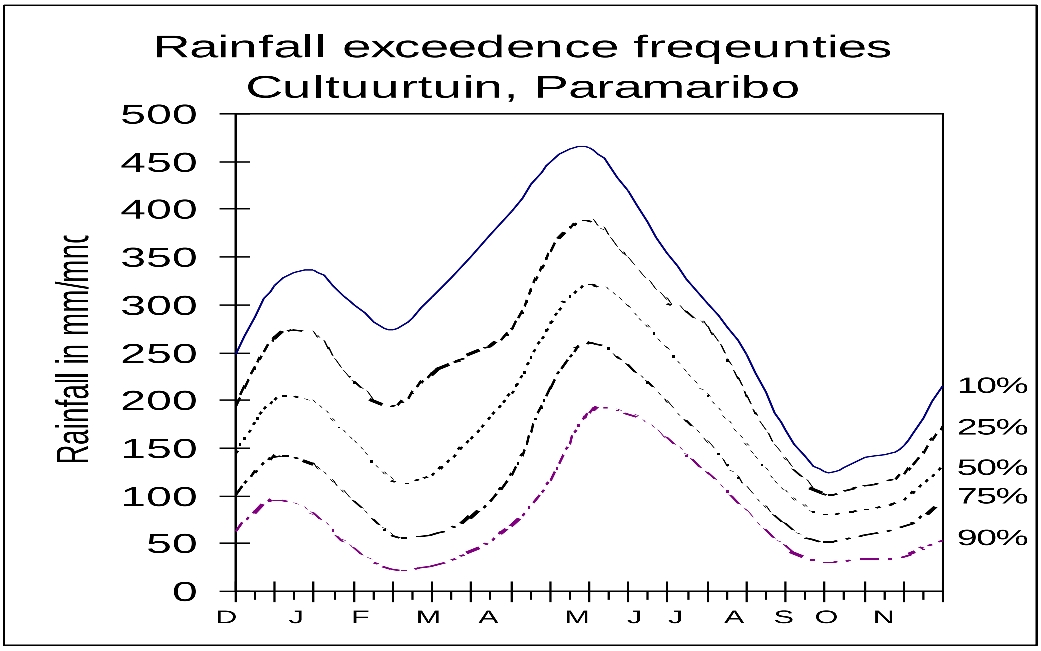

Annual rainfall (in mm) of station Republiek, Para
3500
3000
2500
2000
1500
1000
500
0
5-year moving average
Trendline
1900
1904
1908
1912
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984


Annual rainfall (in mm) of station Zanderij, Para
3500
3000
2500
2000
1500
1000
500
0
Trendline
5-year moving average
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986

Figures 11-14: Rainfall intensities at the stations Nw. Nickerie, Friendship / Totness, Paramaribo and Moengo (1921 - 1960)






Rainfall exceedence freqeunties Cultuurtuin, Paramaribo
Rainfall in mm/mnc
500
450
400
350
300
250
200
150
100
50
0
D J F M A M J J A S O N
10%
25%
50%
75%
90%

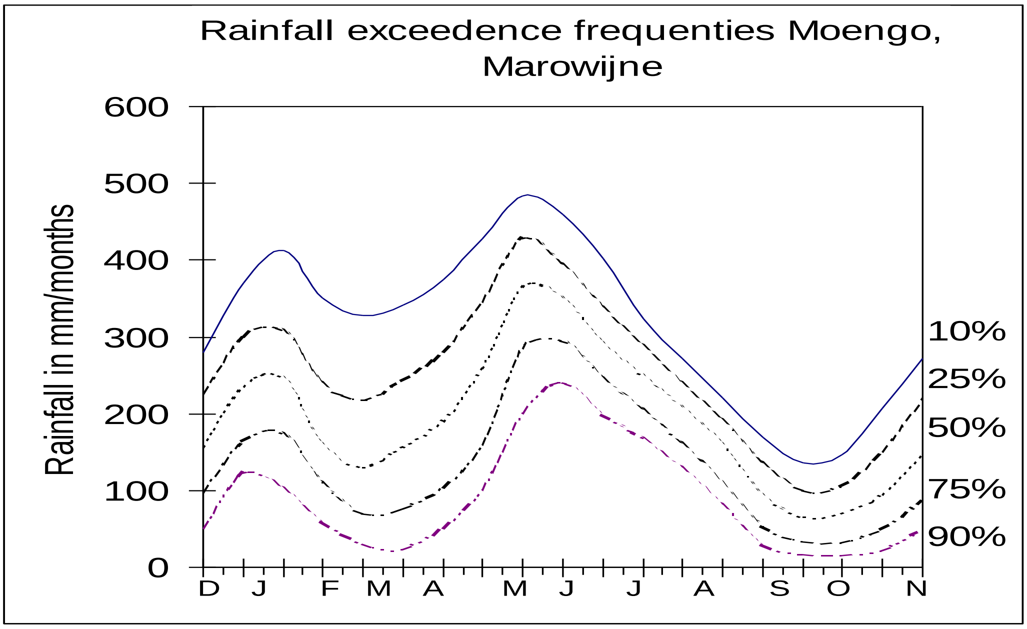
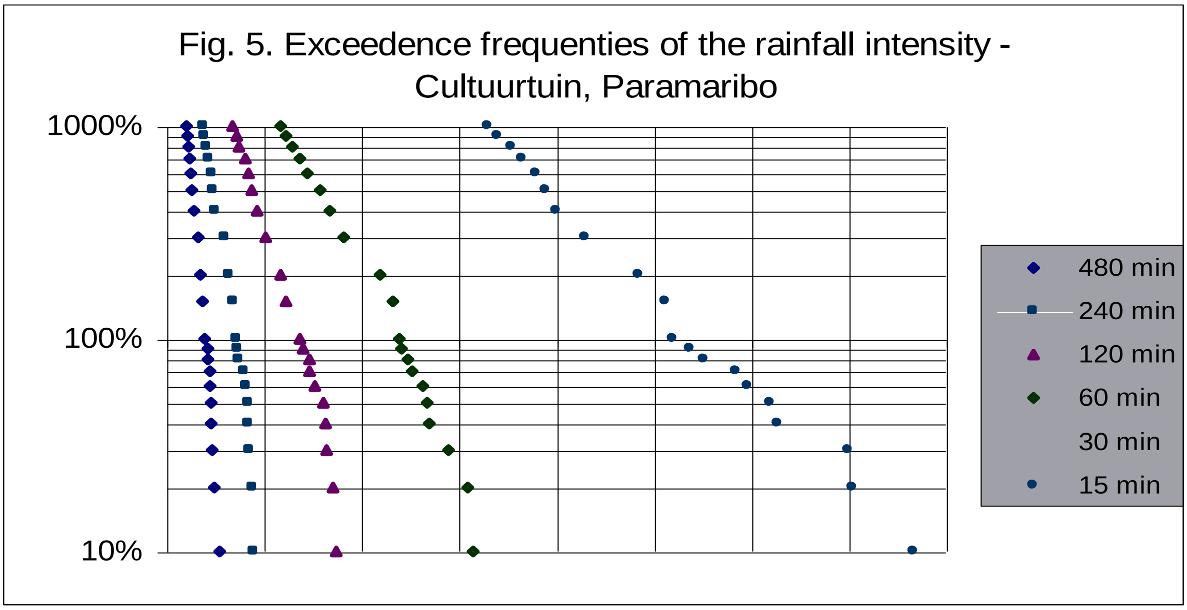

Rainfall exceedence frequenties Moengo, Marowijne
Rainfall in mm/months
600
500
400
300
200
100
0
D J F M A M J J A S O N
10%
25%
50%
75%
90%

Figure 15: Rainfall intensities and their probabilities of exceedence at the station Cultuurtuin (1911 - 1960)



APPENDIX C

Figure 1 Surface water resources Suriname