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Annexes to the Final Report

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CATCHMENT PROFILES

ANNEX 1 CATCHMENT PROFILES

In the following annexes, information is presented that was derived from the work of the Belize Land Information Centre and its GIS facility. In particular, data is given on the catchment area within Belize's territorial boundaries along with percentage and distribution of slope gradient classes, pollution risk classes and 1989/92 land-use. The first two represent preliminary assessments of the proportion of classes based on a manual estimation of percentage area and distribution from 1:250,000 and 1:200,000 maps prepared by LIC. A detailed analysis has not been undertaken at this time on the assumption that LIC will eventually use its GIS analytical capabilities to produce tables of the occurrence of each slope gradient and pollution risk in each catchment polygon (Noreen Fairweather, personal communication). Note that the estimates made are probably in the order of accuracy of plus or minus 2%. The LIC already produced tables of land-use area in acres using their GIS facility. This was converted into percentage and hectares using Lotus 1-2-3. Other observations on land-use and catchment characteristics have been made based on over-flights of almost the whole country, specifically each of the 16 major catchments of Belize, taken by the consultants along with Mr. Frank Panton in the light aircraft of Project Lighthawk.

The pollution risk classes represent an arbitrary and apparently crude assessment of the potential for a given area to receive agricultural runoff from an area upslope now or in the future. Thus for groundwater recharge zones, and for surface water bodies, it requires that there be:

a. a slope gradient (it is assumed that the classifier adopted the maxim that the greater the slope, the greater the risk),
b. actual application of, or potential future application of fertilizer or pesticides on the upslope location.

Moreover, clearly the risk most important for surface water quality is the risk of direct inflow from an agricultural section of land and its adjacent stream and river system. Thus the contiguity between a land area classified as high risk and a stream channel is the most important characteristic to note for each of the catchments in question in relation to monitoring of water quality in Belize. It must be kept in mind that this is likely to be a very crude index who's veracity and importance has not been established through any type of field-based analysis and ground-truthing to the knowledge of the consultants.

In preparing these profiles, general use was also made of map information and descriptions found in Hartshorne (1984) and the 1981-82 Yearbook of Hydrometeorological Data (GOB, 1982).

Included in Annex 6 of this report are maps at varying scales that indicate the boundaries, topography and land-use of the Belize catchments featured in these profiles.

ANNEX 1.1 CATCHMENT PROFILE OF THE RIO HONDO (AND TRIBUTARIES BLUE CREEK, BOOTH'S RIVER AND RIO BRAVO)

1.1.1 Geography and Topography

The Rio Hondo originates from forested, undulating headwaters in the Northern Peten of Guatemala and the southern woodlands of the State of Campeche, Mexico. It forms the northern border of Belize first as the Blue Creek, and hence following its confluence with Booth's River as the Rio Hondo, a sluggish, broadly meandering river that slowly crosses the northern coastal plain on its way to Corozal Bay. It bisects the coastline between the two growing coastal towns of Chetumal (Mexico), and Corozal (Belize). Chetumal was been designated an area of priority investment for urban expansion by the Mexican government (1982).

The topography of the Rio Hondo catchment is divided between the lowland northern coastal plain and the limestone uplands. The Booth's River and its major tributary, the Rio Bravo, both drain the limestone escarpments named after them, collectively called the Bravo Hills, a karstic region on the northern flank of the central Mayan Mountains. Both rivers extend up towards Gallon Jug and the northern edge of the Yalbac Hills, close to the southern limit of Orange Walk District. The Rio Bravo also extends into the Peten region of Guatemala. The highest point in the Booth's River and Rio Bravo catchments is around 250 meters ASL with the majority lying below 100 meters. Only the very upper headwaters have the higher elevations. The Booth's River and Rio Bravo are separated by the Booth's River escarpment and the Rio Bravo is constrained within this scarp and the more westerly Rio Bravo escarpment. Both valleys have broad areas of low-lying marshy ground probably formed by the slumping of the limestone beds.

Table 1.1.1 Topography of the Rio Hondo Catchment

Slope Class	% Area
Less than 1 degree: plain	20
1 to 5 degree: undulating plain	70
5 to 25 degrees: rolling plain	10
25 to 35 degrees: local relief > 30 m - hills	<1
25 to 35 degrees: steep slopes	<1
>= 30 degrees: karst	<1

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the topographic characteristics illustrated in the previous table.

According to LIC data produced from their GIS, the planar area of the portion of the Rio Hondo catchment within Belize is 2,674 km^2. A further 7,614 km^2 lies within Mexico with the Rio Escondido sub-catchment comprising a total area of 4,582 km^2, and the portion of the Rio Hondo and Rio Azul catchments in Mexico comprising 3,032 km^2. The catchment also extends into Guatemala where it occupies a further 2,671.5 km^2. The total area is therefore roughly 15,075.5 km^2, 17.7% in Belize, 31.8% in Guatemala and 50.5% in Mexico.

1.1.2 Geology and Soils

The topography is largely controlled by the underlying geology which comprises almost completely of the massive but slumped beds of the tertiary limestones known as the Buena Vista and Santa Amelia formations. This in turn, exerts a great influence on the soils of the basin. The soils of the portion of the Rio Hondo catchment in Belize are largely calcareous ranging from stony, sandy soils to highly plastic clays. Consequently, there is considerable variation in drainage characteristics and runoff potential. The soils and the underlying rock from which they are derived will give the river an alkaline chemistry and high background hardness levels. No information has been collected concerning the geology and soils of the non-Belize portion of the catchment but it is expected that they will be broadly similar to those in Belize.

1.1.3 Land-Use

Based on LIC GIS tables of land-use surveyed between 1989/92, 57,076 ha (around 21%) of the portion of the Rio Hondo catchment in Belize is devoted to some type of agricultural activity, mostly sugarcane production, but also pasture and annual crops. Urban land-use is listed as 1,145 ha in total.

According to the 1989/1992 land-use maps produced by LIC, fully 60-70% of the Hondo land-area downstream of August Pine Ridge is devoted to sugar cane or else is too marshy for agricultural use, particularly along the river itself. The sugar cane production is grown by a large number of independent small producers. Further upstream from August Pine Ridge there is a broad belt of annual crops, mainly basic grains and feedstuffs and extensive cattle pasture, continuing up towards the Mennonite settlements around Neustadt. Once away from the main river and the roads and up into the Rio Bravo hills and escarpments, the predominant land-use is broadleaf forest with some savannah. From the air, there appear to be broad patches of milpa slash-and-burn subsistence farming and forestry concessions for the extraction of wood products. However, according to LIC data, the Milpa activity constitutes only 267 ha or 1% of the part of the catchment in Belize. Forestry activity involves development of a broad array of access tracks which are both sources of localized erosion and sediment loss and which provide access for milpa farmers looking for cultivable land. The presence of extensive "thicket" vegetation (6%) is probably a reflection of the past milpa clearing and forest exploitation. The Booths river catchment, in particular, has been a site of forestry activity in its headwaters.

There is hydrocarbon exploration activity in this region associated with potential oil-bearing carboniferous limestone layers deep below the land surface.

Table 1.1.2 Land-Use in the Rio Hondo Catchment

LIC CODE	%	ha	LAND-USE
BF	62.8	167909	BROADLEAF FOREST
SC	6.9	18370	SUGARCANE
SC/SR	5.0	13471	SUGARCANE/SCRUB
SV	4.8	12726	SAVANNAH
MS	3.3	8709	MARSH SWAMP
P	2.8	7356	PASTURE
TH	2.7	7321	THICKET
AC	2.5	6562	ANNUAL CROPS
P/AC	1.9	4968	PASTURE/ANNUAL CROPS
BF/TH	1.8	4770	BROADLEAF/THICKET
SR	1.0	2631	SCRUB
SV/TH	0.9	2288	SAVANNAH/THICKET
AC/P	0.8	2112	ANNUAL CROPS/PASTURE
SV/PF	0.6	1539	SAVANNAH/PINE FOREST
TH/BF	0.4	1101	THICKET/BROADLEAF
UI	0.4	977	URBAN
CF	0.3	849	CLEARING FOR FARMING
WB	0.3	682	WATER
TH/SV	0.2	651	THICKET/SAVANNAH
PF	0.2	465	PINE FOREST
MX	0.2	449	ANNUAL CROPS NON-MECH
SC/TH	0.1	278	SUGARCANE/THICKET
MF	0.1	267	MILPA
BR	0.1	244	BAMBOO/RIPARIAN
MS/TH	0.1	232	MARSH SWAMP/THICKET
MS/TH	0.1	190	MARSH SWAMP/THICKET

LIC CODE	%	ha	LAND-USE
UII	0.1	168	URBAN NON-BUILT UP
O	0.0	79	UNKNOWN
C	0.0	41	CITRUS
MGD	0.0	20	MANGROVE DWARF
RIVER	0.0	18	RIVER
SR/TH	0.0	7	SCRUB/THICKET
P2	0.0	4	PASTURE ?
		267454	

No information was obtained on the land-use characteristics of the Rio Hondo and sub-catchments in Mexico and Guatemala.

1.1.4 Rainfall

The majority of the Rio Hondo catchment area, at least in Belize, receives between 1000-1500 mm of rainfall on average per year since it is of relatively low relief and not subject to the orographic influences of the Maya Mountains.

1.1.5 Hydrology

In Belize, the Rio Hondo is a river of two parts, an upper catchment of branching major tributaries with relatively steep gradients and a trellis pattern of drainage resulting from the constraining scarp geomorphology, and a meandering lower reach moving sluggishly across the subsided northern coastal plain. On the broad floodplain it has few tributaries as it passes northeastward to Corozal Bay. Due to its low gradient, the water is slow moving and the valley subject to periodic inundation. Tidal influence probably extends as far upstream as the town of Cocoyal or even Agua Blanca. No stream discharge data was located.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have suggested installing automatic recording equipment at the following sites: on the main river at Blue Creek Village, Vaqueros, Agua Blanca, Douglas and Santa Elena, on Booth's Creek at San Jose, and on the Rio Bravo at Chan Chich, and Rio Bravo (probably Cedar's Crossing).

In the northern, Mexican half of the catchment, one large sub-catchment, the Rio Escondido, extends north and west into generally low relief but with considerable branching of channels.

1.1.6 Water Quality

There are no known water quality or quantity measurements for the Rio Hondo available in Belize, although based on communications with the Mexican Comisión Nacional del Agua, there are four monitoring or water sampling stations established on the Mexican banks of the main river from which quarterly samples of both stream discharge and quality have been taken since 1982. At the time of preparing this report, the consultants were still awaiting receipt of statistics from the Mexican authorities. As already reported in the main body of this report, the locations of these stations were identified from maps located by the consultants in a US university library. No direct information was supplied by the Mexican government.

According to the 1:250,000 surface water hydrology map of 1988, there are four sampling sites in the main catchment comprising one hydrological station (station 1) at the border bridge crossing west of Chetumal, and three sampling locations at surface water intakes, on the main river Hondo downstream of the Rio Escondido confluence (sampling point 9), on a small channel close to the Caseta de Migración (sampling point 6) near Lago Milagros and at La Unión near the main river Hondo (sampling point 12). There is also a fourth water sampling point on Lago Milagros near Huay-Pix (sampling point 7). There also appear to be three sampling points in the Rio Escondido sub-catchment of the Rio Hondo at Xpujil (sampling point 5), at Veinte de Noviembre (sampling point 10) and Ucum (sampling point 8), the latter just upstream of the confluence with the Rio Hondo. It is not clear whether these three are for surface or groundwater intakes but they are located on or near marked stream or river channels.

Given the characteristics of the catchment area, it is probable that the Rio Bravo, Booth's River and Rio Hondo exhibit similar natural background quality characteristics to the New River, for which some water quality data is available.

1.1.7 Pollution Sources

From an assessment of available data from Belize and from Mexico, there are very few anthropogenic pollution sources in the contributing area of the Rio Hondo (GOM, 1982, 1991). There are no listed industrial facilities nor large settlements along the rivers whose upper courses collectively drain a largely pristine forest area of calcareous hills. The many small towns located along both sides of the river banks are potential sources of domestic contamination since none appear to have any kind of domestic waste treatment. One of the largest is the Mexican town of La Union situated on a sloping bluff above the river. However, many of the rural towns in both Belize and Mexico rely on latrines or septic tanks rather than collection and disposal systems. It is likely then, that BOD and bacterial inputs to this river system from domestic waste are slight by Central American standards. There is, however, potential for contamination from agricultural activities in terms of suspended sediments and the drainage of agricultural chemicals and animal slurry. There is extensive livestock rearing on the Neustadt and Blue Creek plains.

According to the pollution risk map of Belize, the Hondo River catchment exhibits medium pollution risk along its floodplain section (low slope but extensive agrochemical application for sugarcane) with medium risk also along the Rio Bravo tributary but with some localized high risk. Both the Booths River and Blue Creek tributaries exhibit mostly low risk although there is some medium risk on the more hilly areas of the Booths River and along the river on the Blue Creek.

1.1.8 Water Uses

It is not known whether any of the local towns and Mennonite communities use the Rio Hondo as their source of drinking water but the river is used extensively for irrigation and for the generation of 35 kW of hydroelectricity for the Mennonite Community at Blue Creek. According to King et al (1992), at the end of the dry season, the generator is taken out of service because there is insufficient flow to generate power. The greatest part of the catchment is in Mexico and Guatemala.

ANNEX 1.2 CATCHMENT PROFILE FOR THE NEW RIVER

1.2.1 Geography and Topography

The New River almost wholly drains the Northern Coastal Plain that makes up the largest part of Orange Walk and Corozal Districts. Its very southern most tip extends into the edge of the limestone Bravo Hills. Its Irish Creek tributary extends up to drain part of the 200 metre plus Yalbac Hills which divide it from the Belize and Rio Hondo river systems. However, over 99% of its total drainage area lies below 100 meters and forms a broad, floodable lowland landscape above Shipyard and past Hill Bank where the river is in fact a broad (up to 1 km wide) and shallow lagoon and marshy wetland.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.2.1 Topography of the New River Catchment

Slope Class	% Area
Less than 1 degree: plain	75
1 to 5 degree: undulating plain	25
5 to 25 degrees: rolling plain	<1
25 to 35 degrees: local relief > 30 m - hills	<1
25 to 35 degrees: steep slopes	<1
>= 30 degrees: karst	0

According to LIC data produced from their GIS, the planar area of the New River catchment is 1,900.0 km^2.

1.2.2 Geology and soils

Like the Belize portion of the Rio Hondo, the New River is almost wholly Tertiary limestone with a slight portion comprising overlying coastal plain sediments of late Tertiary/early Quaternary age. Slumping most likely gave rise to the broad, straight and shallow nature of the valley as it drains up to Corozal Bay, separating from the marshy lagoonal lands to the east.

1.2.3 Land-use

Based on LIC GIS tables of land-use surveyed between 1989/92, 40,563 ha (around 21%) of the land is devoted to some type of agriculture, mostly sugarcane but also annual cops and pasture. Urban land-use totals 791 ha.

The major agricultural activity in the New River catchment is the production of sugar cane for the export industry. It is estimated that around 24,000 hectares of land is under sugar cane production, producing around 1.1 million metric tonnes each year (King et al, 1993). According to the 1989/92 LIC land-use map, the sugar cane production occupies roughly 30% of the land-area downstream of Shipyard, mostly on the western side of the floodplain, a total of around 15-16% if the scrubby sugarcane area is included. The rest of the floodplain is a broad mix of broadleaf forest (55%), savannah grassland (approx. 14%) and scrub brush and thickets (around 5%). Around Shipyard there is a large concentration of annual crop production giving way to broadleafed forest again. Annual crops and pasture make up almost 5% of the land-use or around 10,500 ha. There is very little milpa in the catchment, only around 143 ha according to LIC figures. The area adjacent to the river and lagoons on the east side is mostly savannah and water marshes.

Table 1.2.2 Land-Use in the New River Catchment

LIC CODE	%	ha	LAND-USE
BF	54.6	104070	BROADLEAF FOREST
SV	13.9	26438	SAVANNAH
SC	12.1	23131	SUGARCANE
MS	3.3	6377	MARSH SWAMP
SC/SR	3.3	6308	SUGARCANE AND SCRUB
AC/P	3.0	5763	ANNUAL CROPS - PASTURE
TH	2.8	5430	THICKET
AC	1.6	3071	ANNUAL CROPS
WB	1.2	2306	WATER
BF/TH	1.0	1975	BROADLEAF FOREST AND THICKET
P	0.8	1531	PASTURE
SR	0.5	999	SCRUB
UI	0.4	783	URBAN
SV/TH	0.4	728	SAVANNAH/THICKET
SC/TH	0.2	427	SUGARCANE/THICKET

LIC CODE	%	ha	LAND-USE
BR	0.2	361	BAMBOO/RIPARIAN
MGD	0.2	333	MANGROVE DWARF
TH/BF	0.1	172	THICKET/BROADLEAF FOREST
TH/SV	0.1	148	THICKET/SAVANNAH
MF	0.1	143	MILPA
CF	0.0	84	CLEARING FOR FARMING
AC/SR	0.0	62	ANNUAL CROPS/SCRUB
MX	0.0	43	ANNUAL NON-MECH
O	0.0	41	UNKNOWN
UII	0.0	8	URBAN NON-BUILT UP
		190731	

1.2.4 Rainfall

The New River catchment receives generally more rainfall from east to west, varying from a long-term average of between 1500-2000 mm per year to between 1000-1500 mm per year

1.2.5 Hydrology

The New River has a dry season flow of around 117,000 m^3/day (1.4 m^3/s) and experiences tidal influences as far upstream as Tower Hill causing reversed flow and the potential transport of pollutants upstream from point sources at Libertad and Orange Walk. The river along most of its length has a highly laminar, slow moving flow pattern with limited mixing and the streaming of pollution concentrations within the hydraulic cross-section (note that this is relevant to the selection of appropriate sampling techniques). There is a Hydrology Department gauging station at Tower Hill toll bridge, close to Orange Walk.

Table 1.2.3 Flow Gauging Stations on the New River

Station	Tributary	Drainage Area	Hydrology
Tower Hill	New River	1,400 km^2	Drains low lying limestone basin

According to the 1981 Hydrology report, the New River has a drainage area of approximately 1,400

km^2 upstream of Tower Hill where a number of flow measurements were made in 1990 between April and May that showed flow to vary between 3.5 and 10 m^3/s (King et al, 1992). The LIC data indicates that the New River drainage area is 1,900 km^2. The flood peak range has been seen to be about three to four meters creating potential for significant flooding all along the valley. The 1992/93 stage range was recorded as 2.5m from a low of 2.6m and a high of 5.1m. It appears that the flood development is slow, as is the regression of that peak indicating that the river is not flashy but has rather a gradual hydrologic response accumulating runoff and seepage from a broad, low-lying area. In severe floods, roughly every five years or so, the Orange Walk pontoon bridge must be closed when the river rises around 3m or more, with floods persisting for up to 2 months afterwards.

Note that because of the extremely low velocity of flow and tidal influence at Tower Hill, that there is no acceptable stage-discharge relationship established for this station and that accurate measurements of velocity-area are difficult to make. The station equipment was rehabilitated and improved in 1991 (Panton, personal communication) from whence the data can be assumed reliable.

Apart from the existing Hydrological Service gauging station at Tower Hill, the Service has proposed expanding its coverage of gauging stations and has suggested the installation of automatic recording equipment at the following sites on the New River network: Irish Creek, Ramgoat Creek, Shipyard, San Estevan, Libertad and Corozal Bay.

With each of these sites, except at discernable flood stages, measurement of velocity-area and the establishment of stage-discharge relationships will be difficult to achieve due to the very slow flows exhibited by the river.

1.2.6 Water Quality

Based on analyses associated with the sugar refineries, the New River has relatively high background levels of oxygen (varying between 10.5 and 7.0 mg/l), low levels of dissolved salts, in particular low phosphates, nitrates and iron (pollutants present in sugar waste), but high levels of hardness (around 300-350 mg/l) due to the calcareous material in the region where runoff originates (Newell, 1993). Alkalinity is also very high (120-130 mg/l). Potentially this gives the river greater capacity to absorb higher organic loading and pH and maintain physico-chemical conditions in an acceptable range for the support of aquatic life.

1.2.7 Sources of Pollution

The Tower Hill sugar refinery and the La Libertad molasses plant are the main point source pollutants on the New River. They contribute heat (with wastes up to 37-40 degrees celsius), organic material (high BOD and COD), oils, phosphates, nitrates and iron. Sodium hydroxide and hydrochloric acid is used in the cleaning process of boilers, and can be flushed into the river also. The reduction of DO that accompanies the inflow of the organic materials is thought to be responsible for the periodic dieoffs of fish-life in the river.

Upstream of Tower Hill, the background readings for COD have been registered at 19 mg/l (March 1993), with elevated readings for the same period downstream of the Tower Hill refinery and waste discharge point of 44 mg/l (which represented 3 tonnes per day of additional organic material when combined with flow measurements), equal to the domestic waste of a town with 33,000 inhabitants.

Contamination from the Tower Hill factory has been persistent for many years and was first documented by consultants in the 1970s following complaints from Orange Walk residents (Balfour and Sons, 1977). Similar results were observed then as seen in the 1990s, with high upstream dissolved oxygen levels reducing severely downstream of the effluent discharge due to the input of concentrated organic matter with a high oxygen demand.

The Petrojam molasses factory at La Libertad produces a peak discharge of waste of 81,870 m^3/day with a high COD and an equivalent organic loading to the sewage waste of a city of 280,000 people. Its peak discharge is around 22-25 tonnes of organic material per day. It also discharges quantities of oil.

Downstream from the Lamanai Lagoon near Shipyard, a study was made of the DO levels that showed significant and highly fluctuating variation down to the Corozal Bay, caused by the anthropogenic influences of the sugar plants. DO varied from a super-saturation peak of 10.5 mg/l upstream at Lamanai to an anaerobic low of 0.25 mg/l at the mouth of the Corozal Bay, with reduction and recovery after Tower Hill and before La Libertad (Newell, 1993).

Archer (1994) listed other potential and actual sources of contaminant input to the New River, especially of domestic and commercial sewage water. Most of the settlements along the river rely on individual septic systems. At Orange Walk Hospital waste is received by a large septic tank that overflows directly to a public drain feeding the New River. Neither the size of the hospital nor the amount of waste expected to overflow was noted in Archer (1994). It can be expected that hospital waste will be a considerable source of pathogenic organisms as well as the normal assortment of enteric bacteria.

Other sources of direct waste input to the New River in the vicinity of Orange Walk mentioned in Archer (1994) includes:

- the La Mania Inn, which apparently disposes of its solid wastes into the river and its septic tank soakaway drains to the river,
- the San Romain Village, where solid waste is disposed of on the banks of the river,
- the Mi Amor Hotel (Belize Corozal Road) where the septic tank soakaway and laundry drainage flow to the river,
- Victoria Hotel (Belize Corozal Road) where the septic tank soakaway and swimming pool

overflow and filter drainage flow to river.

It is possible that the Cuello Distillery Waste, which flows into a lagoon 3 miles from the bank in Orange Walk, may be a source of contamination to the New River. Its neighbor, the Belize Soap & Detergent Company is thought to be a waste discharger too although it is not in the Archer report (1994).

According to the agricultural pollution risk map of Belize, most of the upper catchment above Shipyard is low risk, however this is a significant zone of high risk immediately adjacent to the river as it flows between Shipyard and San Estevan. The rest of the lower catchment below Shipyard is mostly medium risk. The proportions of high, medium and low for the whole catchment are roughly in the proportion of 5% (or less), 35% and 60%. However, significantly, the high and medium risk zones are each hydrologically close to the river and its estuary, Corozal Bay.

1.2.8 Water uses

The river water is used intensively by the two sugar refineries during their months of operation, which coincide with the months of lowest flow during the summer (January to May). The Tower Hill plant extracts roughly the same volume of water as the dry season minimum flow from the New River when it is operating at peak capacity, roughly 117,000 m^3/day.

ANNEX 1.3 CATCHMENT PROFILE FOR THE BELIZE RIVER (AND TRIBUTARY MACAL RIVER)

Perhaps the most important river in the country is the Belize River which flows close to three of the largest urban settlements in the country; Belize City, Belmopan and San Ignacio.

1.3.1 Geography and Topography

The Belize River touches on each of the major topographic features of the northern half of Belize, the Northern Coastal Plain,the Bravo Hills, the Central Foothills, the Western Uplands and the Maya Mountains. Downstream of San Ignacio, the catchment is all lowland, below 100 meters elevation with a slow-moving, relatively deep river course and low-lying tributaries such as Labouring Creek, Mussel Creek and Black Creek that drain broad, marshy wetland areas and shallow lagoons such as Crooked Tree. Between San Ignacio and Belmopan, several of the contributing tributaries drain up into the lower hills of the calcareous Bravo Hills to the north (150 to 250 meters ASL) and through the central foothills and up into the Mountain Pine Ridge to the south (Barton Creek reaching elevations of up to 600 meters ASL and Roaring creek reaching elevations of up to 1000 meters ASL).

Above San Ignacio, a large portion of the contributing area is in the form of steeply dissected slopes with elevations above 400-500 meters ASL. The Macal River loops around the Mountain Pine Ridge to drain a large section of the more gently sloping western sections of the Mayan Mountains (the metasediments), with the network of undulating, branching valleys sloping up to reach elevations of up to 600-800 meters. The tributaries between the Cacao Camp Creek confluence of the river and San Ignacio, on the other hand, rush incisively down the west of the more steeply sloping and higher Mountain Pine Ridge (the igneous granites), reaching up to elevations of 700-1000 meters, rapidly coalescing onto the broader and shallower transitional zone between the calcareous western uplands (the hilly Vaca Plateau) and the central foothills, at elevations between 300 and 500 meters.

Interestingly, the western branch of the Belize River loops around in similar fashion to the Macal, but on the other side of the 500-600 meter Vaca Plateau and on up to the main divide of the Maya Mountains at around 900 to 1000 meters. This upper section is steeply incised into the metamorphic materials, gradually flattening out as drainage occurs onto the Vaca Plateau where some karstic formations occur leaving a network of relatively shallow, but steeply incised valleys and gorges, for example, the Chiquibul Branch.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.3.1 Topography of the Belize River Catchment

Slope Class	% Area
Less than 1 degree: plain	30
1 to 5 degree: undulating plain	25
5 to 25 degrees: rolling plain	5
25 to 35 degrees: local relief > 30 m - hills	5
25 to 35 degrees: steep slopes	20
>= 30 degrees: karst	25

According to LIC data produced from their GIS, the planar area of the portion of the Belize River catchment within Belize is 6,548 km^2. The portion of the catchment extending into Guatemala (the Mopan branch) comprises 2,891.5 km^2. The total catchment area is therefore 9,434.2 km^2, 69% in Belize and 31% in Guatemala.

1.3.2 Geology and Soils

The Belize River basin contains rocks from the Quaternary back to the Pennsylvanian and all the ages in between. The majority of the headwaters of the catchment are Jurassic limestone, with a smaller proportion of older Bladen granites and metasediments. The middle section of the catchment is a mix of Tertiary and Jurassic limestones, whereas the lower floodplain courses of the river are predominantly over the youngest coastal plain sediments. The igneous geology and siliceous metasediments of the Mountain Pine Plateau of the Maya Mountain Range, which a large portion of the Belize and Macal River drain, are highly leached causing a generally high level of acidity and nutrient deficiencies. Runoff water, particularly baseflow, therefore takes on a relatively low or neutral pH and is also subject to seasonally high suspended solids levels due to the erosivity of the thin soils of the metasediments, especially when cleared of vegetation.

1.3.3 Land-Use

Owing to its considerable size, the Belize River exhibits the largest range of land-use in the country. Moving from the coast to its Maya Mountain origins the land-use changes from being little utilized to intensive farming and back to low intensity uses. The lowland savannah, scrub and marsh around Belize City is increasingly used for urban-related activities - land-fill, construction, waste disposal, and more recently, for shrimp-farming. Based on LIC GIS tables of land-use surveyed between 1989/92, 48,134 ha (7.4%) is devoted to agriculture of some kind. There is a total of 3,217 ha of urban and non-built up urban land use.

The 1989/92 LIC land-use map shows that on leaving Belize City, land-use becomes little-utilized flat, or slightly undulating savannah scrubland without much agriculture. As the river approaches Belmopan, agriculture intensifies with an increasing number of the sloping valley sides under citrus production and under maize and beans, considerable vegetable production and some cattle and rice on the flatter, wetter lands by the river. The vegetable growers of the Belize River valley are responsible for the majority of the fresh produce sold locally in Belize City and Belmopan. Arable crops are produced interspersed with isolate pockets of citrus. Livestock rearing is extensive around the Spanish Lookout area. Past San Ignacio as the river descends from the limestone hills and the siliceous granites and metasediments, the two land-uses of forestry and milpa production is frequently seen although the total hectareage is relatively small and the vegetation remains largely mixed natural forest. Milpa and regenerating milpa probably covers around 6,000 ha. Broadleaf forest covers the majority of the catchment, more than 70% in total, especially on the rolling hills and plateaus. The higher hills of the igneous and metasediment rocks are covered by pine forest, a total or around 5%. Savannah and scrubby vegetation occupies around 10%.

Table 1.3.2 Land-Use in the Belize River Catchment

LIC CODE	%	ha	LAND-USE
BF	69.4	454384	BROADLEAF
PF	5.4	35338	PINE FOREST
SV	5.0	32428	SAVANNAH
TH	2.7	17363	THICKET
P	2.4	15392	PASTURE
SV/TH	2.1	14018	SAVANNAH/THICKET
MS	1.4	9297	MARSH SWAMP
SR	1.2	8164	SCRUB
AC	1.2	7959	ANNUAL CROPS
AC/P	1.1	7377	ANNUAL CROPS/PASTURE
BFO	0.9	6185	OPEN BROADLEAF
BR	0.7	4434	BAMBOO/RIPARIAN
MX	0.6	4212	ANNUAL CROPS NON-MECH
MF	0.6	4011	MILPA
WB	0.5	3495	WATER BODIES
PF/BF	0.4	2934	PINE FOREST/BROADLEAF
MX/SR	0.4	2881	ANNUAL/NON-MECH/SCRUB

LIC CODE	%	ha	LAND-USE
MGT	0.4	2569	MANGROVE TALL
PFO	0.4	2554	OPEN PINE FOREST
MG	0.3	2012	MANGROVE
UI	0.3	1862	URBAN/BUILT
TH/BF	0.3	1848	THICKET/BROADLEAF
BF/TH	0.3	1643	BROADLEAF/THICKET
BF/PF	0.2	1283	BROADLEAF/PINE FOREST
MF/TH	0.2	1281	MILPA/THICKET
P/AC	0.2	1276	PASTURE/ANNUAL CROPS
UII	0.1	835	URBAN/N0N-BUILT UP
C	0.1	745	CITRUS
MX/P	0.1	676	ANNUAL CROPS/NON-MECH/PASTURE
PF/SV	0.1	530	PINE FOREST/SAVANNAH
CF	0.1	524	CLEARING FOR FARMING
UIII	0.1	516	URBAN ?
AC/TH	0.1	464	ANNUAL CROPS/THICKET
SV/PFO	0.1	454	SAVANNAH/OPEN PINE FOREST
TH/PF	0.1	432	THICKET/PINE FOREST
BR/BF	0.1	426	BAMBOO/RIPARIAN/BROADLEAF
AC/AR	0.1	389	ANNUAL CROPS/?
TH/SV	0.1	372	THICKET/SAVANNAH
SP	0.1	364	SALINE SWAMP
SV/BF	0.0	313	SAVANNAH/BROADLEAF
MF/AC	0.0	256	MILPA/ANNUAL CROPS
SR/TH	0.0	256	SCRUB/THICKET
BF/BR	0.0	234	BROADLEAF/BAMBOO/RIPARIAN
P/B	0.0	198	PASTURE/BANANAS
TH/MF	0.0	126	THICKET/MILPA

LIC CODE	%	ha	LAND-USE
BF/MF	0.0	121	BROADLEAF/MILPA
BA	0.0	105	BANANAS
P/SR	0.0	86	PASTURE/SCRUB
O	0.0	80	UNKNOWN
?	0.0	80	UNKNOWN
SR/P	0.0	55	SCRUB/PASTURE
G	0.0	14	SAVANNAH
UII	0.0	4	URBAN/NON-BUILT UP
		654857	

No data was obtained on land-use in the Guatemala portion of the catchment.

1.3.4 Rainfall

The high headwaters of the Belize River receive the most rainfall, between 2000-2500 mm on average each year. The middle headwaters of the central foothills and western uplands receive between 1500-2000 mm per year, reducing to between 1000 and 1500 mm north and west. The mid-section and lower reaches and their drainage areas of low relief receive between 1500 and 2000 mm of rainfall per annum.

1.3.5 Hydrology

As indicated, the lower portion of the catchment is low-lying, undulating ground with broad flat plains. These have shallow groundwater levels and significant standing water, both permanent and seasonal, that give rise to slow-draining lagoons and marshes. These features have slow filling rates and high residence times but probably add little to the stormwater flows that pass through the river from the much larger highland drainage area further south and west which also receives considerably more rainfall. Because of the complex, looping drainage pattern exhibited by the Belize River caused by the presence of a large igneous and metamorphic land-mass within an overall eastward tending landscape, the river is less flashy than it could be given the steep, high-stormwater runoff characteristics of its catchment. The different travel times and lag-times associated with the runoff from the three distinct sub-units:

- the distant north draining Western Branch, passing through Guatemala and entering Belize at Benque Viejo;
- the mid-distant northwest-draining tributaries of the Macal River (Eastern Branch); and

- the short flow-paths to the main body of the river downstream of San Ignacio, from the north (Spanish Lookout), and from the south Roaring Creek and Barton Creek,

results in an overall attenuated flood curve in which the flood peaks, for the size of catchment and amount of rainfall received, are relatively low. Having said this, the flood peak development associated with the Eastern Branch itself and the steep, relatively impermeable, Mountain Pine Ridge and highly dendritic drainage network is intense and gives rise to rapid and enormous changes in discharge and stage which gets concentrated through the steep sided river valley at Cristo Rey (where Hydrology has its monitoring station and recording gauge some 15 meters above normal baseflow levels). This wave attenuates somewhat on its passage downstream onto the flatter valley land but can still give rise to water level changes of over 5 meters and flooding near Belmopan (personal communication, keeper of Banana Bank Station).

The Belize River has a number of installed gauging stations, predominantly in the northern coastal plain but, importantly, up in the headwaters of the eastern branch also. The stations, include Double Run, Bermudian Landing, Big Falls River, Banana Bank, San Ignacio, Benque Viejo, Cristo Rey, Rio On and Rio Frio. According to data from the Hydrological Service and summarized by Hartshorne, the characteristics of the older of these are listed in Table 1.3.3.

Apparently, according to the Hydrology Department data inventory, there are also sampling stations at Mexico Creek, Black Creek Bridge and Mussel Creek on the Belize River, and a tidal station at the Old Customs Wharf on Haulover Creek in Belize Harbour.

Table 1.3.3 Flow Gauging Stations on the Belize River

Station	Tributary	Drainage Area	Estimated Discharge (1981/82)	Hydrology
Rio Frio (no longer in service)	Eastern Branch	19 km^2	0.1 m^3/s 166 mm	Drains western slopes of Mountain Pine Ridge
Rio On	Eastern Branch	70 km^2	2.3 m^3/s 1036 mm	Drains western slopes of Mountain Pine Ridge
Cristo Rey	Eastern Branch	1590 km^2	30.2 m^3/s 1360 mm	Drains Eastern Branch - whole of western slopes of Mountain Pine Ridge, northern Vaca Plateau and western Maya Mountains to the north of Richardson Peak
Benque Viejo *	Main Branch	943 km^2	51.8 m^3/s 1732 mm	Drains Western Branch catchment, mostly in Guatemala

Station	Tributary	Drainage Area	Estimated Discharge (1981/82)	Hydrology
Banana Bank	Main Branch	4022 km^2	95.8 m^3/s 751 mm	Situated on coastal floodplain on main branch.
Big Falls	Main Branch	4926 km^2	99.8 m^3/s 639 mm	Situated on coastal floodplain on main branch.
Bermudian Landing	Main Branch	---- km^2	--- m^3/s --- mm	Situated on coastal floodplain on main branch.
Double Run	Main Branch	5708 km^2	155 m^3/s 858 mm	Situated on coastal floodplain on main branch. Drains over 99% of catchment.

* note that according to the summary in Hartshorne, the portion of the Belize River catchment in Belize is 5,874 km^2 and the portion in Guatemala is 3,238 km^2, a total of 9,112 km^2. The data listed above could be in error therefore (i.e does not include the Guatemala portion), because from an assessment of the 1:250,000 maps, it is impossible for the downstream catchment below Double Run to make up close to 40% of the area and for the catchment above Benque Viejo to be so small. Also note that based on a table of data developed for the measured stages and stream discharge at Rio On from August 1978 through October 1987, the average discharge measure was 1.15 m^3/s with a low of 0.22 and a high of 6.3 m^3/s. Assuming an average flow of 1.15 m^3/s would make the equivalent rainfall runoff equal to 1908 mm, rather than 166 mm which seems very low for the steep igneous catchments with significant rock outcropping and river beds. These upstream catchment area figures should be treated with caution therefore.

Map information consulted for Guatemala indicates that there are, or were, two stations established on the Mopan branch by the National Electric Institute. From an analysis of the Inventario del Recurso Agua en Guatemala, the Atlas Hidrológico Primer Edición (no date), the following hydrological stations were identified from the map "Localización de Estaciones Hidrometricas y Limnimetricas, 1:1,000,000".

CODE	NAME
II.4.1.H	El Arenal
II.4.2.H	El Cruzadero

Both stations are located a short distance inside the Guatemala-Belize border.

Current Status of Belize Stations

According to Panton (personal communication), the Rio Frio station is no longer actively monitored.

The Rio On (1983), Cristo Rey (1969), Benque Viejo (1969), Banana Bank (1969), Big Falls (1969) and Double Run (1981) stations all have an acceptable stage-discharge relationship established that can be used in predicting stream discharge when quality measurements are taken. The Bermudian Landing station has no stage-discharge relation at present, being recently rehabilitated in 1990.

Several items of data on stage and stream discharge were retrieved from Hydrology Dept computer files that can be summarized for the various stations involved.

Rio On

Only one file was retrieved which detailed a stream discharge measurement taken in 1992 (no date), which gave a data set as follows:

STAGE	0.38 m
FLOW*	0.60 m^3/s
VEL	0.04 m/s

Apparently, a rating curve exists for Rio On but no data files were included in the data downloading retrieved from the Hydrology technicians. This data, when available, should be collected and processed as part of the water quality monitoring program, particularly the stage-discharge relation.

Cristo Rey

According to Hydrology Department Data, the Macal River, at Cristo Rey experiences minimum flow depths as low as 1m and maximum flow depths as high as 18m with flows well over 1000 m^3/s. The following represents a summary table of annual average, maximum and minimum values extracted from obtained Hydrology Service files (in units of meters and seconds):

YEAR	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90
STAGE m									
Mean	1.73	1.41	1.88	1.95	2.01	1.73	1.62	1.79	----
Max	4.62	4.50	5.10	4.70	5.42	6.50	5.12	4.70	----
Min	1.01	1.00	1.00	1.07	1.11	0.70	1.01	1.02	----
FLOW m^3/s									
Mean	27	17	34	34	35	33	21	27	35
Max	391	359	541	414	660	1195	548	414	833
Min	4	4	4	5	5	2	4	4	5

YEAR	90/91	91/92	92/93*
STAGE m			
Mean	2.19	1.71	2.07
Max	14.30	3.12	6.34
Min	1.10	1.28	1.16
FLOW m^3/s			
Mean	124	---	266
Max	15790	---	648
Min	5	---	139

(* problems with data set, missing values).

Benque Viejo

According to Hydrology Department Data, the Western Branch of the Belize River which flows out of Belize, into Guatemala and back to Belize at Benque Viejo experiences minimum flows as low as 1 m^3/s and maximum flows as high as 275 m^3/s with a mean between 20 and 40 m^3/s. The following represents a summary table of annual average, maximum and minimum values extracted from obtained Hydrology Service files (in units of meters and seconds):

YEAR	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90
STAGE m									
Mean	0.39	0.30	0.46	0.44	0.22	0.39	0.31	0.46	0.43
Max	1.35	1.63	1.62	1.54	1.25	2.25	1.50	1.84	1.37
Min	0.05	0.01	0.10	0.10	0.02	0.02	0.01	0.06	0.12
FLOW m^3/s									
Mean	---	28	46	43	19	38	28	46	43
Max	---	171	170	161	132	235	158	193	144
Min	---	0.3	6	6	1	1	0.3	3	8

YEAR	90/91	91/92
STAGE m		
Mean	0.45	0.40
Max	2.64	1.59
Min	0.07	0.07
FLOW m^3/s		
Mean	44	39
Max	274	167
Min	4	4

Banana Bank

Only a small amount of stage and flow data was obtained for Banana Bank because the annual files had not yet been computed. Stage data for 1992/93 placed the mean flow depth at 1.61m with a range from 0.6m up to 5.83m. The following stage-discharge test data was retrieved for 92/93:

STAGE m	1.56	1.93	2.15
FLOW m^3/s	55	150	93
VEL m/s	O.5	0.6	0.6

Big Falls

Data for Big Falls shows a considerable flow range in the order of 7m and discharge ratio 10:1:

YEAR	69/70	70/71	71/72	72/73	73/74	75/76	76/77	81/82	82/83
STAGE m									
Mean	3.78	3.33	3.32	3.89	2.94	2.59	4.12	2.37	2.17
Max	9.01	7.69	9.00	8.98	8.94	4.84	8.97	7.55	7.66
Min	1.55	1.92	1.89	1.96	2.94	2.11	2.11	1.01	1.01
FLOW m^3/s									
Mean	---	---	---	---	---	---	---	---	104
Max	---	---	---	---	---	---	---	---	498
Min	---	---	---	---	---	---	---	---	21

YEAR	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92
STAGE m									
Mean	2.51	3.66	1.15	3.21	---	3.28	3.20	3.71	3.29
Max	7.69	8.35	7.14	7.92	---	9.20	8.92	9.60	9.85
Min	2.50	1.56	0.10	1.11	---	1.08	2.01	2.09	2.07
FLOW m^3/s									
Mean	127	205	---	---	139	---	173	211	202
Max	500	554	---	---	573	---	602	659	680
Min	21	68	---	---	21	---	95	100	99

YEAR	92/93
STAGE m	
Mean	3.42
Max	7.94
Min	2.08
FLOW m^3/s	
Mean	187
Max	521
Min	99

Bermudian Landing

Only a small amount of stage and flow data was obtained for Bermudian Landing because the annual files had not yet been computed. The following stage-discharge test data was retrieved for 92/93. Based on data established for the other gauges upstream and downstream, this would suggest that the data is in error(*) because the discharge data is an order of magnitude too low.

STAGE m	4.35	8.65
FLOW* m^3/s	19	44
VEL m/s	0.5	0.5

Double Run

This site of the major freshwater intake for Belize City and Belmopan has recorded peak flows in the range of 550-600 m^3/s with low flows down to 10-20 m^3/s and annual mean flows at around 100-150 m^3/s, similar to Big Falls and Banana Bank.

YEAR	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90
STAGE m									
Mean	1.84	1.63	1.47	1.78	---	1.74	1.31	1.66	1.51
Max	4.56	4.60	4.16	4.20	---	4.47	4.27	4.40	4.30
Min	0.40	0.45	0.45	0.34	---	0.41	0.39	0.42	0.37
FLOW m^3/s									
Mean	153	132	116	147	79	143	100	134	120
Max	436	440	391	395	322	425	403	417	407
Min	17	20	20	13	20	17	16	18	15

YEAR	90/91	91/92
STAGE m		
Mean	1.94	1.53
Max	5.78	5.01
Min	0.50	0.47
FLOW m^3/s		
Mean	164	121
Max	575	486
Min	23	21

Also according to Panton (personal communication), stage and velocity measurements have also been made several times a year at Mexico Creek, Black Creek and Mussel Creek over the last three years.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified possible sites for the installation of automatic recording equipment at: Chapayal, Davis Bank, Guacamallo, Haulover Bridge, Iguana Creek, Labouring Creek, Lemonal, Vaca Falls, and Young Bank.

1.3.6 Water Quality

Over the years between 1982 and 1987, the Hydrological Service took 28 water quality samples from five of the Belize River stations: Rio On, Benque Viejo, Cristo Rey, Big Falls Ranch and Double Run. WASA also take samples of Double Run water, not in situ at the river but through their treatment plant intake. Quality data from the Hydrological Service are included in a subsequent Annex.

Five sample test sheets were located from the Rio On, each showing five to seven days delay between sampling and analysis. Based on recorded stage, the flows probably vary from between 0.4 and 1.5 m^3/s. The water generally shows very low alkalinity, hardness and a varying pH around neutral (but pH will be unreliable because of slow analysis procedures). Total alkalinity varies between 7 and 24 mg/l and total hardness between 4 and 22 mg/l as both calcium and magnesium.

Cristo Rey, on the same eastern branch of the Belize network downstream, exhibits greater hardness and alkalinity. Of four samples, again with analytical delays, total alkalinity was from 33 to 161 mg/l and total hardness from 36 to 101 mg/l. The data are not concurrent with that from Rio On. pH varies from 6 to 8 and chlorides are zero to low.

Benque Viejo, on the western branch of the Belize River, registers the drainage from Guatemala and the southern side of the Vaca Plateau. From five samples, most with delayed analysis, total hardness ranged from 184 to 330 mg/l (discharge not known) and total alkalinity from 110 to 203 mg/l. pH varied from 7.8 to 8.1. One CO_2 level of 114 mg/l was recorded. Sulphate levels, where recorded, are listed in the range of 6 to 10 mg/l. Slight turbidity was recorded with some variation.

Big Falls Ranch has three sample results usually with a week or more between sampling and analysis. Alkalinity is high, with total values between 120 and 170 mg/l and total hardness varied between 220 and 470 mg/l, mostly $CaCO_3$. Sulphate levels ranged between 75-250 mg/l and pH between 7.8 and 8. Flow depths ranged from 1 to 3 meters.

Closest to Belize City, Double Run experienced the most frequent sampling between 1982 and 1987, with 10 samples or almost two per year. Some of the samples were analyzed same day but more often three to five days later. The river exhibits high hardness and as expected, where stage levels are available, they seem to show the highest total hardness, up to more than 500 mg/l, corresponding with the lower stream discharge conditions representative of base flow. During higher flood flows, the total hardness concentrations fall (see following table) due to the diluting effect of carbonate-free surface runoff.

Table 1.3.4 Stage and Total Hardness Data for Double Run

DATE	STAGE	TOTAL HARDNESS
9/5/83	0.575 m	544 mg/l
12/4/83	0.74 m	405 mg/l
2/7/83	2.22 m	220 mg/l
2/11/83	4.10 m	150 mg/l

Alkalinity varies between 90 and 160 mg/l with pH varying between 7.5 and 8. The data for sulfates vary enormously from 12 up to over 300 mg/l and could suggest analytical problems since samples were taken and analyzed by a variety of different people.

1.3.7 Pollution Sources

There is a mining concession issued for river sand and gravel just upstream of Belmopan and 10 km above the gauging station at Banana Bank. This may be a source of high seasonal suspended solids during runoff periods.

It would appear that Haulover Creek, the man-made channel that bisects Belize City, is a major receptacle of both solid and liquid wastes from residents and therefore a major conduit for the transport of land-based pollutants into the Marine environment close to the Belize River outlet (Archer, 1994). Since it is also tidal in nature, it provides a difficult subject for quality monitoring. There is a tidal level monitoring station at Haulover Creek at the Old Customs Wharf. Other sources of domestic wastes close to the coastline include the Biltmore Plaza Hotel where seepage from five septic tanks and soakaways passes into the Belize River (Archer, 1994). The Belize airport is also a likely source of liquid wastes with its high worker population and proximity to the river outlet. Again, due to the tidal nature of the river and its proximity to the coast, it presents a difficult monitoring challenge to the DOE. Clearly the stretch of river between Double Run and the sea is potentially one of the key zones of contamination for the Belize River and its associated city canal system and it would be interesting to be able to monitor the input and output conditions as an aid to the Coastal Zone Management Unit's attempt to promote land source controls.

Downstream of Double Run, in the area between Belize City and around Ladyville, there are a number of factories that are known to discharge point source pollution to the Belize River. These include the Pebco Soft Drink bottling factory, Bradleys Soft Drinks, Travellers Rum and Belikin Brewery that together discharge more than 50,000 gallons per day of BOD and nutrient rich water, much of which makes its way directly or indirectly to the river. This water will also contain significant quantities of caustic soda and chlorine used in the cleaning and sterilizing process. More BOD, nutrients, suspended solids and chlorine are thought to be added by the two Fisherman's cooperatives, which discharge around 7,500 gallons per day of liquid wastes. Oil and other industrial residues are apparently discharged by Shell Belize and Belize Electric directly to the Belize River.

Further upstream, a major source of wastewater related contaminants occurs at San Ignacio Hotels. There are five hotels within 50 to 300 meters of the Macal River with direct discharge from laundry facilities to the water as well as overflows from septic tanks (Archer, 1994). San Ignacio businesses are also thought to contribute contaminants to the river. There are several establishments, a bank, auto-repair shop and gas station from which overflow of septic tanks drains to the Macal River. Belize Electric is known to occasionally spill oils and detergent water into the Belize River. Further downstream, there is an area of concentrated industry out along the road north of the river to Spanish lookout. The industries there, including dairy, food manufacture, feed supplies, poultry and meat processing all drain their waste into nearby creeks. These creeks all flow east and down to the Belize River and although their shallow gradient and dry character in summer months makes them equivalent to leachfields, it can be expected that this waste will route to the Belize River during the rainy season. The factories can all be expected to produce relatively high levels of nutrients, BOD and suspended solids as well as pathogens in the case of the poultry, dairy and meat plants. Some of the plants will use significant amounts of detergents and chlorine as cleansing products.

Between Spanish Lookout and Belmopan, the area around Central Farm also has a number of point sources including the Homestead Poultry and Running W meat plants. Homestead pipes around 10,000 gallons per day of wastewater to the Belize River with expected high levels of BOD and nutrients.

The sewage treatment plant from Belmopan discharges its final effluent directly to the Belize River. The plant is a primary treatment plant designed for the removal of solids only from the wastewater collected from 3,800 people and 1,300 connections. This includes discharge from the distillery at Belmopan. The plant design and its operations allow rapid throughflow of liquids with probably only around 4% removal of BOD and 11% removal of suspended solids. As of July 1993, the effluent, around 158,000 gallons per day, still had extremely high fecal coliform counts and high phosphate and nitrate concentrations together with BOD of 250 mg/l and suspended sediments of 335 mg/l. The input to the Belize River is therefore basically raw sewage (van de Kerk, 1993a). According to the Teachers manual on pollution, there have been instances of isolated algal blooms on the Belize River caused by excesses of nutrients flushing in, probably caused by sewage and agricultural drainage (GOB, 1990). This would be expected given the characteristics of the Belmopan treatment plant.

In the area around Ladyville, there are shrimp farming operations 10 km from Belize City but they discharge their BOD loaded contents and their treated processing waste to the ocean, rather than to the Belize River.

Archer (1994) provides a table of estimated industrial discharge in tons per month to the Belize River for selected industries and contaminants. This is not thought to be inclusive of all the discharges expected from all sources:

Table 1.3.5 Estimated Discharge of Industrial Contaminants in the Belize River Catchment

Industry	BOD	Suspended Solids	Oils
Soft Drink	6.0	8.2	
Seafood	8.1	6.3	
Poultry	35.3	26.3	
Meat	12.2	10.9	6.7
Electricity	18.8	2440	1.3
	80.3	2491.7	8.0

Taken in context, the production of 80 tons of BOD and its output into a river the size of the Belize would not suggest a significant problem. It is probable that the assimilative capacity of the river, even at low-flow conditions, would absorb this loading. The individual large sugar factories on the New River will discharge up to 20 tonnes per day.

One other major source of pollution that may persist for several years to come is the potential sediment load that has been created on the Macal River by the construction of the new hydroelectric run-of-the-river plant due to come on line in 1995. Channel modifications, cut and fill and road construction have each mobilized a considerable volume of sediments that, during future rainstorm and storm-flow events will begin to shunt through the system and down to the Belize River. Seasonally high TSS levels may be expected at Cristo Rey and below for the next two years and possibly much longer. Note that hydroelectric dam construction is also planned or being carried out for the Mopan branch of the Belize River in Guatemala.

According to the agricultural pollution risk map of Belize, the majority of the lower portion of the Belize catchment below San Ignacio is of high and medium pollution risk, except for the largely flat and marshy areas out on the coastal plain east of Crooked Tree Lagoon. Notably, all along the main channel and adjacent floodplain of the Belize the risk is high up to Spanish lookout although not so along the tributaries such as Labouring Creek. The northern draining slopes of the Maya Mountain fringe have a higher risk also.

According to the official pollution risk assessment, the opposite is true for the upper catchment of the western part of the Maya Mountains and the Vaca Plateau. There around 90% of the land area is classified as low risk and the rest as medium risk. Therefore, in terms of agricultural contaminants, one can expect the largest concentration, if at all, to occur below San Ignacio.

1.3.8 Water Uses

The Belize River is used as a source of treated, potable water supply for the cities of Belmopan and Belize City and the smaller villages of Roaring Creek and Camalote. The towns of San Ignacio and Santa Elena take their water from the river through bankside infiltration galleries. It is also used for irrigation along the good alluvial farmland and valley slopes from San Ignacio to Roaring Creek. In its upper tributary of the Macal River, near the Rio On, it is shortly to be used for the generation of hydro-electricity at the run-of-the-river plant currently under construction. As well as a source of water, it is used as a sink for wastewater, particularly discharge from sewer mains, from wastewater and water treatment plant discharges and from selected small industrial sites as explained.

ANNEX 1.4 CATCHMENT PROFILE FOR THE SIBUN RIVER

1.4.1 Geography and Topography

The Sibun River drains into the sea at Sibun Bar just down the coastline from Belize City. Just inland, it follows a meandering path through mangroves and marshes formed on this low-lying sedimentary northern coastal plain. Downstream of Churchyard, the drainage system is not developed, with a few short tributaries slowly emptying the coastal marshes and lagoons south of the western highway. Upstream of Churchyard, the drainage is more highly developed as the Sibun cuts down trough low limestone formations, with some of its tributaries (such as the Caves Branch) disappearing underground in karst topography. The main Sibun channel flows from a considerable distance back up into the limestone hills and down from the Maya Mountains in the region of the 1,000 metre Baldy Beacon and Baldy Sibun at the northern edge of the Mountain Pine Ridge It cuts down through the steep and narrow Sibun Gorge and passes under the Hummingbird Highway as it flows north before gradually tending eastward to Belize City. Caves Branch, which rushes down from Baldy Beacon before taking a more gentle course as it approaches the settlement of Caves Branch, also passes under the Highway on a parallel course to the main Sibun.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.4.1 Topography of the Sibun River Catchment

Slope Class	% Area
Less than 1 degree: plain	45
1 to 5 degree: undulating plain	4
5 to 25 degrees: rolling plain	2
25 to 35 degrees: local relief > 30 m - hills	2
25 to 35 degrees: steep slopes	35
>= 30 degrees: karst	12

According to LIC data produced from their GIS, the planar area of the Sibun River catchment is 987 km^2.

1.4.2 Geology and Soils

The headwaters of the Sibun River are predominantly the ancient metasediments, folded and intruded by the tectonics that brought the granite intrusions of the Maya Mountain chain. The middle sections of the river comprise the Jurassic limestones and the lower reaches cross the young Coastal Plain Sediments of late Tertiary or Quaternary times. The igneous geology and siliceous metasediments of the Mountain Pine Plateau of the Maya Mountain Range are highly leached causing a generally high level of acidity and nutrient deficiencies. Runoff water, particularly baseflow, therefore will take on a relatively low pH and low hardness and is also subject to seasonally high suspended sediment levels due to the erosivity of the thin soils of the metasediments, especially when cleared of vegetation.

1.4.3 Land-Use

The Sibun River has a broader mix of converted land utilization than the catchments further south that have been developed predominantly for citrus. However, the total area of agricultural land-use is small. Based on LIC GIS tables of land-use surveyed between 1989/92, 2,547 ha (around 2.6%) is devoted to agriculture, mainly citrus but also pasture, cacao, annual crops, bananas and cashew. Urban land-use totals 504 ha.

Based on roadside and aerial observations, the Sibun has areas of milpa farming close to the road and into the headwaters with some production forestry (often the milpa follows the forestry). As indicated in the 1989/92 LIC maps, the upper catchment is predominantly broadleaf forest, especially above the Southern Highway. Along the Highway is a mix of agriculture with citrus and cacao production, which has expanded on the slopes of many of the tributaries and is receiving increasing investment and encouragement from the Government. Hummingbird Hershey has its production on land in this catchment, around 160 hectares of the total 500 plus hectares now under production (King et al, 1993). Note that the LIC (1994) data estimates only 207 ha of cacao to be planted in Belize. Downstream from the road, there is cattle grazing along the riparian zone, with more citrus on both sides of the Western Highway. Citrus is the largest productive land use (1,200 ha) with pasture second (500 ha). Most of the lower catchment is savannah grassland, scrub and closer to the coast, saline swamp and extensive mangrove cover.

Table 1.4.2 Land-Use in the Sibun River Catchment

LIC CODE	%	ha	LAND-USE
BF	64.6	63758	BROADLEAF
SV	11.6	11450	SAVANNAH
TH	6.7	6610	THICKET
SV/TH	2.4	2405	SAVANNAH/THICKET
BR	2.1	2072	BAMBOO/RIPARIAN

LIC CODE	%	ha	LAND-USE
SR	1.3	1284	SCRUB
MG	1.3	1265	MANGROVE
C	1.2	1208	CITRUS
MS	1.0	984	MARSH SWAMP
SP	1.0	948	SALINE SWAMP
PFO	0.9	886	OPEN PINE
BF/TH	0.8	783	BROADLEAF/THICKET
TH/SV	0.6	547	THICKET/SAVANNAH
P	0.5	513	PASTURE
WB	0.5	476	WATER
TH/BF	0.5	453	THICKET/BROADLEAF
BF/PF	0.5	452	BROADLEAF/PINE FOREST
TH/PF	0.3	284	THICKET/PINE FOREST
MGT	0.3	268	MANGROVE TALL
UIII	0.3	256	URBAN ?
CO	0.2	199	COCOA
MF	0.2	187	MILPA
PF	0.2	187	PINE FOREST
UII	0.2	184	URBAN NON-BUILT UP
CF	0.2	158	CLEARING FOR FARMING
MX	0.1	147	ANNUAL CROPS NON-MECH
CV	0.1	134	COASTAL STRAND
BFO	0.1	117	OPEN BROADLEAF
PF/SV	0.1	108	PINE FOREST/SAVANNAH
BA	0.1	75	BANANAS
PF/BF	0.1	68	PINE FOREST/BROADLEAF
BF\PF	0.1	56	BROADLEAF/PINE FOREST
UI	0.1	50	URBAN

LIC CODE	%	ha	LAND-USE
SV/MS	0.0	37	SAVANNAH/MARSH SWAMP
CA	0.0	33	CASHEW
C/P	0.0	27	CITRUS/PASTURE
U11	0.0	14	URBAN NON BUILT-UP
?	0.0	8	UNKNOWN
G	0.0	5	SAVANNAH
WA	0.0	3	WATER
		98701	

1.4.4 Rainfall

The Sibun River headwaters receive an average annual rainfall of between 2,000-2,500 mm, with some slopes receiving an average of as much as 3000 mm. The foothill and coastal plain sections of the river receives only 1500-2000 mm.

1.4.5 Hydrology

The Sibun River catchment exhibits significant karst formations on its limestone geology with numerous springs and subsurface flows that result in discontinuous surface flows, especially in the dry season when the majority of flow may be underground. Deep and steep valleys are cut into the limestones (collapsed karst) and into the metamorphosed sediments also.

According to Hydrological Service data summarized in Hartshorne (1984), the Sibun River catchment covers 1,222 km^2 whereas the LIC GIS database indicates a planar area of 987 km^2. There were two gauging stations in existence on the Sibun River, both at sites on the lowland coastal plain downstream of the majority of the steep and long catchment area. The Freetown Sibun station, on the other hand, has a well-established stage-discharge relationship. The uppermost gauge was at Churchyard (Norland Farm - 17188604) roughly 20 km inland and perhaps 30 km upstream from Sibun Bar. The second gauging site is less than 10 km from the sea at Freetown Sibun (17188604), along the secondary road from Hattieville. According to Panton (personal communication), the Churchyard Station has been out of commission since 1984. According to the Hydrological Service, the Norland Farm station collected from the upland 749 km^2 of the catchment and recorded an average daily discharge of 35.9 m^3/s based on 1981/82 data. Freetown Sibun collects from the lower portions of the catchment comprising a total of 1,059 km^2 of the whole basin, with an estimated average discharge of 50.5 m^3/s based on 1981/82 records. Longer-term records show stage to range from 1 to 4m with mean daily flows between 35 and 65 m^3/s and recorded highs and lows of 250 and

1.8 m^3/s respectively.

Table 1.4.3 Flow Gauging Stations on the Sibun River

Station	Tributary	Drainage Area	Estimated Discharge (1981/82)	Hydrology
Churchyard (no longer in service)	Sibun River main branch	749 km^2	35.9 m^3/s 1511 mm	Drains upper catchment
Freetown Sibun	Sibun River main branch	1,059 km^2	50.5 m^3/s 1504 mm	Drains majority of basin area including lowlands

The following summary table of stage and stream discharge data was prepared for Freetown Sibun from data files collected from the Hydrological Service of Belize:

YEAR	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90
STAGE m									
Mean	1.71	1.69	1.70	1.70	1.70	1.70	---	1.53	1.60
Max	3.83	3.83	3.84	3.84	3.84	3.84	---	3.80	3.95
Min	1.03	0.94	1.02	1.02	1.02	1.02	---	0.93	1.01
FLOW m^3/s									
Mean	45	45	47	68	42	38	37	34	39
Max	189	189	190	250	127	245	189	186	199
Min	4	2	3	5	0	2	2	2	3

YEAR	90/91	91/92	92/93
STAGE m			
Mean	1.71	1.55	1.59
Max	3.92	3.88	3.80
Min	0.96	1.06	1.02
FLOW m^3/s			
Mean	46	35	38
Max	196	193	186
Min	2	5	4

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have suggested installing automatic recording equipment at the following additional sites: Caves Branch, Sibun Camp, Crosslanding and Sibun Estuary.

1.4.6 Water Quality

Five water quality samples were taken by the Hydrological Service between 1983 and 1987 at different months. Delays of five and up to 20 days were recorded between taking and analyzing the sample. For two only, water stage was recorded. Total hardness varied from 116 to 250 mg/l, mostly in the form of CaCO3, with total alkalinity varying from 65 to 120 mg/l. Chlorides varied from 22 to 45 mg/l and sulfates from 10 to 85 mg/l. Generally, pH was basic, varying between 7.6 and 7.9 although given the sampling delays, these are probably not very meaningful.

1.4.7 Pollution Sources

According to Geology and Petroleum permit data, there are two licensed mineral extractions from river sections in the Sibun catchment, one at Churchyard Run and the other on both the main branch and Caves Branch of the Sibun upstream of their confluence. It is not known how significant this production is, but it likely provides a source of suspended sediments, especially during times of high water. At other times, it may lead to greater downstream channel erosion. According to Archer, one of these two plants is discharging around 4000 gallons per day of suspended solid-rich water to the river.

Similarly to its neighboring Belize River catchment, the Sibun exhibits two characteristic parts in relation to calculated agricultural pollution risk. The lower half of the catchment exhibits considerable pollution risk, particularly along the river channel and the adjacent floodplain areas. Roughly 60% of the lower half of the catchment is classified as high risk, 15% medium and 25% low. The majority of the low and medium zones are further up the catchment.

1.4.8 Water Uses

Water from the river is probably used for washing sand and gravel. There are a number of settlements along the river in the catchment including Gracy Rock Bank, Cedar Bank and Freetown Sibun, but it is not documented whether the river has significant commercial or domestic uses for these communities.

ANNEX 1.5 CATCHMENT PROFILE FOR THE MANATEE RIVER

1.5.1 Geography and Topography

The Manatee River drains from the central foothills and into the southern lagoon north of Gales Point (where there is a tidal monitoring station). From the high point of the Middlesex mountain (575 meters ASL) that separates the Mullins River, Manatee River and North Stann Creek, the Manatee river curves west and north to link up with Big Creek and Soldier or Plantation Creek as they drain the 400 metre high plateau of the eastern-most extension of the central foothills.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.5.1 Topography of the Manatee River Catchment

Slope Class	% Area
Less than 1 degree: plain	40
1 to 5 degree: undulating plain	<1
5 to 25 degrees: rolling plain	<1
25 to 35 degrees: local relief > 30 m - hills	<1
25 to 35 degrees: steep slopes	30
>= 30 degrees: karst	30

According to LIC data produced from their GIS, the planar area of the Manatee River catchment is 484 km^2.

1.5.2 Geology and Soils

The northern tributary headwaters of the Manatee drain the Jurassic limestones of the remnant Yucatan plateau whereas the southern tributary headwaters drain the metamorphosed sediments of the older Maya Mountains. The lower to middle reaches of the main river drain across the younger Tertiary and Quaternary coastal sediments.

1.5.3 Land-use

Based on LIC GIS tables of land-use surveyed between 1989/92, 1,052 ha (around 2.2%) of land is devoted to agricultural production with only 5 ha of urban land. Like many of the other catchments to the south, the Manatee River has seen some conversion to citrus orchard and bananas through a process of clear-cutting, usually right down to the river banks of the various tributary valleys.

According to the 1989/92 LIC land-use maps, the extent of citrus conversion is very small, along some of the major tracks only. Around 156 ha is citrus and up to 774 ha has some degree of banana production. Mangos are present on around 78 ha. Predominantly there is broadleaf forest (70%) and savannah (12-14%) with some pine forest (1-2%). Broadleaf forests dominate the upper catchment. Around the lagoons are mangroves, and saline swamps.

Table 1.5.2 Land-Use in the Manatee River Catchment

LIC CODE	%	ha	LAND-USE
BF	70.6	34192	BROADLEAF
SV	11.7	5675	SAVANNAH
TH	5.7	2742	THICKET
MG	2.0	955	MANGROVE
SU	1.6	770	UNKNOWN
SV/TH	1.2	566	SAVANNAH/THICKET
SV/BA	1.1	548	SAVANNAH/BANANA
PF/TH	0.9	449	PINE FOREST/THICKET
BFO	0.7	335	OPEN BROADLEAF
TH/SV	0.6	276	THICKET/SAVANNAH
CU	0.5	226	UNKNOWN
TH/PF	0.4	213	THICKET/PINE FOREST
PFO	0.4	213	OPEN PINE FOREST
PF	0.4	187	PINE FOREST
WB	0.4	184	WATER
MS	0.3	168	MARSH SWAMP
BA	0.3	164	BANANA
C	0.3	156	CITRUS
MGT	0.3	131	MANGROVE TALL
M	0.2	78	MANGO
BA/SV	0.1	62	BANANA/SAVANNAH
TH/BF	0.1	61	THICKET/BROADLEAF
BA/TH	0.1	44	BANANA/THICKET

LIC CODE	%	ha	LAND-USE
CV	0.1	41	COASTAL STRAND
WA	0.0	5	WATER
U1	0.0	5	URBAN
SR	0.0	4	SCRUB
		48448	

1.5.4 Rainfall

The headwaters of the Manatee River receive on average between 2000 and 2500 mm of rainfall each year, decreasing to between 1500 and 2000 mm as it drains towards the coastline and the southern lagoon.

1.5.5 Hydrology

The Manatee river has a heavily asymmetrical drainage pattern with only two northern tributaries but a large number of parallel southern tributaries draining northeast out of the hills. The Manatee river is the major contributor to the Southern Lagoon which is connected by Main Creek to the larger Northern Lagoon. The southern lagoon is drained to the ocean by the continuation of the Manatee river directly across from its inflow point, some 3-4 km to the west. There is a tidal station at Gales Point that measures water levels in the lagoon resulting from the joint influences of marine inflow and freshwater runoff but there has been no river gauging station to date. No stream discharge data therefore exists on this system.

There are few major road crossings over the Manatee River although there is a small settlement at Government Landing 3-4 km upstream from the Southern Lagoon inflow. Note that the Hydrology Department has proposed expanding its coverage of gauging stations and they have identified possible sites for the installation of automatic recording equipment at: Manatee Cave, Government Landing, Soldier Creek, Manatee Bridge and Big Creek.

1.5.6 Water Quality

There is no river monitoring station on the Manatee and no water quality data seems to have been sampled.

1.5.7 Pollution Sources

Based on permit maps obtained from the Geology and Petroleum Department, there is a sand and gravel extraction permit issued for Soldier or Plantation Creek near Government Landing, which could result in periodic flushes of silt and sand into the main channel and downstream to the sea. The workings are accessed by a dirt track navigable by a pick-up or lorry.

According to the Belize agricultural pollution risk map, the Manatee catchment exhibits low pollution risk in the upper and main portion of the catchment with high pollution risk along the river channels and on the inland side of the lagoon. If this is correct, the presence of agricultural contaminants would not be expected at an upper or mid-system sampling site but at the outflow end of the catchment by the coast.

1.5.8 Water Uses

The river water will probably be used for the washing of sand and gravel. There are few settlements along the river or in the waters suggesting that other uses are few.

ANNEX 1.6 CATCHMENT PROFILE FOR THE MULLINS RIVER

1.6.1 Geography and Topography

The Mullins River is a small short catchment draining the northern edge of the eastern foothills and across the central coastal plain north of Dangriga. The river is crossed by the road between Melinda Forest Station and Gales Point with a bridge on the main channel just downstream of the inflow point of Wagner Creek (possible gauging site). The road branches off just after the bridge to the community of Mullins River. The river descends steeply from a 300 metre plateau, east of mount Middlesex, forming Hell Gate Falls in the process, and then shallows out to meander across the fresh sedimentary soils and mangroves of the coastal plain.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.6.1 Topography of the Mullins River Catchment

Slope Class	% Area
Less than 1 degree: plain	30
1 to 5 degree: undulating plain	15
5 to 25 degrees: rolling plain	10
25 to 35 degrees: local relief > 30 m - hills	0
25 to 35 degrees: steep slopes	45
>= 30 degrees: karst	0

According to LIC data produced from their GIS, the planar area of the Mullins River catchment is 157 km^2.

1.6.2 Geology and Soils

The upper half of the Mullins river drains the edges of the eroded ancient metasediments before draining over the flatter and younger Tertiary coastal sediments.

1.6.3 Land-use

Based on LIC GIS tables of land-use surveyed between 1989/92, 799 ha (around 5%) of this catchment is devoted to agriculture, with 28 ha of urban land. Natural forest lands have been converted to citrus orchards through a process of clear-cutting. Based on aerial reconnaissance from Lighthawk, the catchment is still predominantly covered in broadleafed forest. As shown on the

1989/92 LIC land-use maps, the headwaters of the basin are predominantly broadleaf forest with a small amount of citrus land midway along the river and a large plantation area to the south of the river on the road to Gales Point. These plantations of citrus in total appear to occupy around 671 ha. The only other agricultural uses registered for the catchment is aquaculture, with 50 ha of the lowlands used for this purpose, and 50 ha of milpa and 4 ha of pasture. The lower catchment is mostly savannah and scrub apart from this.

Table 1.6.2 Land-Use in the Mullins River Catchment

LIC CODE	%	ha	LAND-USE
BF	73.8	11598	BROADLEAF
SV	10.1	1583	SAVANNAH
C	4.3	671	CITRUS
BFO	3.0	471	OPEN BROADLEAF
PF	2.4	375	PINE FOREST
MG	1.5	238	MANGROVE
TH	1.4	224	THICKET
TH/SV	0.6	98	THICKET/SAVANNAH
SR	0.6	97	SCRUB
SF	0.5	74	SHRIMP/AQUACULTURE
MF	0.3	50	MILPA
TH/PF	0.3	47	THICKET/PINE FOREST
MS	0.3	46	MARSH SWAMP
WB	0.3	40	WATER
BR	0.2	35	BAMBOO/RIPARIAN
CV	0.2	30	COASTAL STRAND
UI	0.2	28	URBAN
P	0.0	4	PASTURE
		15707	

1.6.4 Rainfall

The majority of the catchment of the Mullins River receives between 2000 and 2500 mm of rainfall, with the headwaters receiving between 2500 and 3000 mm.

1.6.5 Hydrology

Little is known about the Hydrology of the Mullins River. There is no hydrological gauging site and no water quality data as yet. It is probable that the river has similar flow conditions and water quality to the Manatee. The river descends relatively steeply from the hills as a series of whitewater riffles and deeper pools.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and has identified possible sites for the installation of automatic recording equipment at: Mullins Bridge and Mullins River Estuary. Also note that the Hydrology Department also has identified a possible site for a river gauging station on the small Big Creek situated between Mullins River and North Stann Creek at the Big Creek Bridge on the road from Melinda Forest Station to Gales Point.

1.6.6 Water Quality

No known water quality data exists for the Mullins River.

1.6.7 Pollution Sources

It has been thought that the Mullins River catchment is already a prime zone for citrus production expansion but based on aerial assessment during 1994, it appears that it is largely still forested. As such, agricultural pollution prospects are expected to be low, due to the low number of potential non-point source zones. Nevertheless, according to the Belize pollution risk map, the Mullins catchment exhibits around 20% of its area in the high risk class, again notably along river channels and along the coast, with around 5% medium and the rest, particularly the upper, higher sections, with low risk.

1.6.8 Water Uses

Due to the relative absence of settlements within this catchment, water uses are likely to be limited from this river. Actual uses have not been documented.

ANNEX 1.7 CATCHMENT PROFILE FOR THE NORTH STANN CREEK

1.7.1 Geography and Topography

The North Stann Creek is a relatively asymmetrical river system with a straight main branch incising deeply into the easily erodible granites between the 400 meters plus Middlesex Peak and the harder rocks of the 800 meters plus Arthurs Seat. The valley head forms a saddle divide between the Sibun River and North Stann Creek. It continues to exploit this eastward drainage line, emerging out of the valley between Macaroni Hill and Blue Mountain onto the coastal plain and past the flow gauging site at Melinda Forest Station. On the southern side of the catchment, a sequence of branching contributing channels extend up into the steep hard-rock basin (200 to 900 meters) between Arthurs Seat and Mount Mossy, draining down north-eastward from these steep high slopes of the Maya Mountains and curving through the northern-most edges of the lowly fringing eastern foothills that break up the transition to the coastal plain. The valley is filled with good quality, recent alluvium (King et al, 1993).

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.7.1 Topography of the North Stann Creek Catchment

Slope Class	% Area
Less than 1 degree: plain	30
1 to 5 degree: undulating plain	0
5 to 25 degrees: rolling plain	0
25 to 35 degrees: local relief > 30 m - hills	0
25 to 35 degrees: steep slopes	70
>= 30 degrees: karst	0

According to LIC data produced from their GIS, the planar area of the North Stann Creek catchment is 279 km^2.

1.7.2 Geology and Soils

The headwaters of North Stann Creek and north draining tributaries largely drain the ancient granites and metasediments of the Maya Mountains. The valley continues eastward to emerge out between hills of metasediments onto the Tertiary sediments of the coastal plain. The soils of the eastern foothills are easily eroded, particularly when slopes are cleared for agriculture such as the introduction of citrus.

1.7.3 Land-use

The predominant productive land-use of the North Stann Creek valley and its tributaries is for citrus, with continuing expansion of the number of hectares through a clear-cutting process followed by grading to produce tree rows and drainage lines. Over 6,200 ha have been converted to orchards. A total of 7,383 ha (around 26.4%) of the land is devoted to agricultural activity, with 251 ha of urban land according to 1989/92 figures.

Although milpa production is widespread throughout the country, the highly visible new milpa tracts on the steep slopes along the Hummingbird Highway are frequently cited as course for concern, with loss of protective forest and widespread instability and loss of topsoil. It would appear that about 700 ha or more of the catchment shows milpa or milpa-type activity based on the presence of mixed land-use, non-mechanized annual cropping, etc.

Based on aerial reconnaissance from Lighthawk, conversion of forest to orange grove was still actively continuing as of May 1994. The 1989/92 land use data shows that 22.3% of the catchment area all along the Creek and up along tributary valleys and their lower to middle slopes has been placed under citrus production, with windrowed plantations common. The steeper slopes and headwaters are largely broadleaf forest (over 70%) with some pine.

Recent construction work for the widening and renovation of the Hummingbird Highway have produced new cut and fills and mobilized an enormous quantities of sediments draining off into the North Stan Creek. This should be only of a temporary nature but may give rise to relatively high background TSS levels for the next few years as this increased loading reaches equilibrium within the river system, much of it shunting out to the inner channel during high flow conditions.

Table 1.7.2 Land-Use in the North Stann Creek Catchment

LIC CODE	%	ha	LAND-USE
BF	69.6	19431	BROADLEAF
C	22.3	6230	CITRUS
MX/BF	1.3	350	ANNUAL CROPS NON-MECH/BROADLEAF
MX/TH	1.2	328	ANNUAL CROPS NON-MECH/THICKET
UI	0.8	221	URBAN
BF/PF	0.8	214	BROADLEAF/PINE FOREST
P	0.7	205	PASTURE
MG	0.7	196	MANGROVE
SR	0.7	184	SCRUB

LIC CODE	%	ha	LAND-USE
TH	0.6	163	THICKET
CF	0.5	130	CLEARING FOR FARMING
MX	0.3	87	ANNUAL CROPS NON-MECH
PF	0.2	63	PINE FOREST
MF	0.2	53	MILPA
MS	0.1	29	MARSH SWAMP
UII	0.1	22	URBAN NON-BUILT UP
BFO	0.0	10	OPEN BROADLEAF
CV	0.0	8	COASTAL STRAND
U11	0.0	8	URBAN NON-BUILT UP
		27932	

1.7.4 Rainfall

The headwaters of the North Stann Creek extend up into the orographically induced belt of rainfall that produces between 2500 and 3000 mm on average per year. In the eastern and lower half of the catchment, closer to the coast, rainfall reduces to an average of 2000 to 2500 mm per year.

1.7.5 Hydrology

There were two gauging stations on the North Stann Creek, both located at bridges of the newly renovated Hummingbird Highway which runs parallel for most of the length of the North Stann Creek down to Dangriga town which is bisected by the river. The first was at the Middlesex town bridge (17088511) which drains a relatively small upland part of the catchment between Arthurs Seat and Mount Middlesex. The second was at Melinda Forest Station (17088312) about 4-5 km east of the point at which the Stann Creek Valley opens out onto coastal plain. However, according to Panton (personal communication) both gauges have been discontinued because of channel silting problems probably due to road construction and soil erosion from orange grove clearance. Sand extraction has also proven a problem at the gauge sites. The Middlesex site was discontinued in 1993, and the Melinda station in 1983. There are no significant tributaries downstream of this point. The Hummingbird Highway and several of the feeder roads now branching off into the citrus growing region that has grown up along the branching channels of the fringing central foothills, offer the opportunity of other gauging sites that can isolate one or more of the contributing areas draining these hills.

Table 1.7.3 Flow Gauging Stations on the North Stann Creek

Station	Tributary	Drainage Area	Estimated Discharge (1981/82)	Hydrology
Middlesex (bridge) (now out of service)	North Stann Creek main branch	65 km^2	6.9 m^3/s 3347 mm	Drains small upper part of catchment
Melinda Forest Station (bridge) (now out of service)	North Stann Creek main branch	256 km^2	15.4 m^3/s 1897 mm	Drains majority of basin area above outflow onto coastal plain

According to Hydrological Service data published in Hartshorne (1984), Middlesex station drains only 65 km^2 of the overall 518 km^2 catchment, whereas the downstream Melinda station drains 256 km^2 (although this figures seems somewhat low based on an interpretation of the 1:250,000 topographic map). Based on 1981-82 flow data, the average runoff is 6.9 m^3/s at Middlesex and 15.4 m^3/s at Melinda. This signifies a runoff equivalent to 3347 and 1897 mm of the average rainfall received respectively. Particularly the Middlesex estimate seems unreasonably high unless the catchment is receiving significant subterranean flow from other catchments adjacent to the North Stann Creek, passing in from outside the topographic divide on which the area calculations are based.

Flow depth averaged at around 0.55m at the old Middlesex station from a low of 0.1m to a high of around 3.9m. The following is a summary of stage data recorded for Middlesex by the Hydrology Service and extracted from their computer files:

YEAR	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	90/91
STAGE m									
Mean	0.20	0.70	0.77	0.57	0.46	0.48	0.52	0.51	0.59
Max	0.70	3.90	1.79	3.34	1.50	2.51	1.85	1.40	2.41
Min	0.07	0.10	0.57	0.17	0.01	0.08	0.22	0.20	0.22

YEAR	91/92
STAGE m	
Mean	0.66
Max	1.95
Min	0.29

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified possible sites at: Hope Creek, Big Eddy, Dangriga Town. Note that because of the fact that North Stann Creek has seen so much land-use change and road construction over the last ten years, there appears to be a great deal of erosion and deposition within the river system that has made the establishment of a rating curve for river stations a difficult prospect.

1.7.6 Water Quality

The North Stann Creek has generally low alkalinity and low hardness, draining mostly the silicious materials of the granite and metamorphosed igneous sediments of the Maya Mountain foothills. Hardness was measured as low as 12 mg/l as CaCO3 by Newell (1993) and 8-40 mg/l total hardness by the Hydrological Service between 1982 to 1987. Similarly, total alkalinity for the seven analyses taken at the upstream Middlesex station ranged from 10-40 mg/l with pH between 6.7 and 8.6 but mostly over 7. Chlorides of between 3-15 mg/l were recorded over the five years with only two paired stage (from which flow can be calculated) and quality measurements. Data taken by the CZMU at the mouth of the river and summarized in van de Kerk (1994b) show dissolved oxygen levels to vary between 5 and 10 mg/l with temperatures between 25 and 30 degrees centigrade.

According to Newell (1993) rivers such as the North Stann Creek have very little capacity to absorb even low levels of organic waste.

1.7.7 Pollution Sources

According to King et al (1993), it is suspected that in the North Stann Creek catchment in particular, freshwater contamination with agrochemicals is increasing to a level of concern. This cannot be judged based on available water quality data although tests in 1990 at Dangriga have yielded phosphate and nitrate maximum concentrations of 0.2 mg/l and 1.8 mg/l respectively (King et al, 1993). Neither of these are particularly high.

In terms of specific land-based sources of marine pollution on the North Stann Creek, there is a concentration in the coastal town of Dangriga. Archer (1994) mentions the Jungle Huts Motel (Ecumenical Drive) which has five septic tanks with their overflow draining to the Creek. He also mentions Hubbs Guest House, the River View Hotel, the Bank of Nova Scotia, Soffies Hotel and an Auto Repair Shop that leach their septic tanks and overflows of sewage and greywater to the North Stann Creek. This all takes place within a short distance of the ocean outlet along the tidal stretch of the river. The fact that the Hydrological Service has difficulty maintaining their rating curves and integrity of their stations at Middlesex and Melinda Forest Station suggests heavy sediment loads to be moving through the system.

As far as industrial pollution, the two citrus processing plants, one at Pomona and one further up at Alta Creek, provide significant opportunities for heavy inputs of low pH, high BOD drainage into the Creek due to storage lagoon overflows, direct discharge and runoff of leachate from peel dumps.

Stann Creek is meant to be one of the areas where numerous patch reefs have been seen to be affected by the outwashing of nutrients and other pollutants into the nearshore environment (Archer, 1994). According to the pollution risk map of Belize, around 40% of the North Stann Creek exhibits a high risk of pollution from agricultural sources, notably all along the coastline and along the main

North Stann Creek channel and floodplain where chemical-intensive orange cultivation is carried out. With only a tiny percentage of medium risk, the rest of the upland parts of the catchment and its tributary channels exhibit apparent low pollution risk.

1.7.8 Water Uses

The town of Dangriga takes its water from the North Stann Creek approximately 3 km west of the town after which it is clarified, filtered and chlorinated (WASA, 1992). The two citrus processing plants also probably are users of river water further upstream although this is not well documented.

ANNEX 1.8 CATCHMENT PROFILE FOR THE SITTEE RIVER

1.8.1 Geography and Topography

The Sittee river occupies an eastward draining, relatively narrow and deep basin that cuts back into the Maya Mountains through the fringe of the coastal foothills and up to the main divide between Mount Mossey and the Cockscomb Range's Victoria Peak. The vertical extent of the catchment is high, from less than 100 meters elevation at Kendall up to 800 meters at the back of the basin and rising to 1000 meters and more at the leading edges of the basin sides. Within this relatively narrow basin, the topography is a series of parallel, yet still branching contributory creeks including the Cocoa, Pull Shoes and Blackwater Branches of the main channel. These are separated by generally 300-400 metre interfluves made up of small plateaus and steep valleys.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.8.1 Topography of the Sittee River Catchment

Slope Class	% Area
Less than 1 degree: plain	18
1 to 5 degree: undulating plain	0
5 to 25 degrees: rolling plain	0
25 to 35 degrees: local relief > 30 m - hills	0
25 to 35 degrees: steep slopes	80
>= 30 degrees: karst	2

According to LIC data produced from their GIS, the planar area of the Sittee River catchment is 449 km^2.

1.8.2 Geology and Soils

The dissected headwaters of the Sittee River have formed up into the fringing metasediments surrounding the granitic intrusions of the ancient Maya Mountains. The lower and middle reaches of the river flow across the younger Tertiary coastal sediments. The soils of the metamorphic eastern foothills are easily eroded, particularly when slopes are cleared for agriculture such as takes place with the introduction of citrus.

1.8.3 Land-use

The primary productive land-use of the Sittee River basin is citrus, occupying the rolling land around the various river channels and gradually being expanded up the less suitable interfluves through a slash-burn and grading process. The citrus orchards occupy a broad swath of land on both sides of the highway, penetrating up the individual tributary valleys and thinning out onto the flatter, poorly drained coastal plain. Aerial views from Lighthawk confirmed that as of May 1994, new clearance of groves onto steeper valley slopes in the vicinity has been extensive. LIC data from 1989/92 (LIC, 1994), shows citrus to occupy 711 ha of the catchment. In total, 1,422 ha (around 3.2%) of land is devoted to agriculture with 66 ha of urban land.

Upstream of Kendall, there is largely broadleaf forest in the headwaters and mid-sections of the catchment with the major expansion of citrus down along the various subsidiary channels toward the coast. There appears to be some cattle grazing also between the highway and the coast amongst the savannah, scrub and pine. This totals around 395 ha while milpa activity is slight, probably less than 100 ha if one includes the non-mechanized annual crop production. Mechanized annual crop production is around 150 ha.

Table 1.8.2 Land-Use in the Sittee River Catchment

LIC CODE	%	ha	LAND-USE
BF	88.3	39700	BROADLEAF
SV	2.3	1033	SAVANNAH
C	1.6	711	CITRUS
TH	1.6	699	THICKET
MG	1.1	497	MANGROVE
BR	1.0	438	BAMBOO/RIPARIAN
P	0.9	395	PASTURE
PF	0.9	392	PINE FOREST
MS	0.5	230	MARSH SWAMP
SV/TH	0.4	181	SAVANNAH/THICKET
BFO/TH	0.4	178	OPEN BROADLEAF/THICKET
AC	0.3	150	ANNUAL CROPS
CF	0.1	67	CLEARING FOR FARMING
MX/TH	0.1	61	ANNUAL CROPS NON-MECH/THICKET
UI	0.1	54	URBAN

LIC CODE	%	ha	LAND-USE
BFO	0.1	52	OPEN BROADLEAF
SR	0.1	38	SCRUB
MX	0.1	28	ANNUAL CROPS NON-MECH
CV	0.1	23	COASTAL STRAND
UII	0.0	12	URBAN NON-BUILT UP
MF	0.0	10	MILPA
		44946	

1.8.4 Rainfall

The majority of the catchment area of the Sittee River drains land receiving an average of 2500-3000 mm per year whereas the coastal section downstream of Guana Church Bank receives between 1500 and 2500 mm per year.

1.8.5 Hydrology

The Sittee River is crossed by the Southern Highway as it skirts the low, hilly fringe of the steeply rising Maya Mountain front. A gauging site is located at Kendall bridge (16888413) just after the turnoff to Regalia, High Sand and Middle Bank. These small villages offer other access sites to the Sittee River. According to Panton (pers.comm., 1994), the Kendall stage recorder is currently out of action.

Table 1.8.3 Flow Gauging Stations on the Sittee River

Station	Tributary	Drainage Area	Estimated Discharge (1981/82)	Hydrology
Kendal (bridge)	Sittee River main branch	383 km^2	13.9 m^3/s 1144 mm	Drains upper portion of catchment above coastal plain

The Kendall gauge has a stage-discharge relationship established and has been in service since 1981.

According to Hydrological Service data (Hartshorne, 1984), the catchment occupies 474 km^2 of Belize, with the portion upstream of Kendall bridge draining 383 km^2 (81%). The estimated average discharge of the basin upstream of Kendall is 13.9 m^3/s based on 1981-82 data. Mean daily stage for this year was 1.31m with a high and low of 4.00m and 0.67m respectively. This represents an accumulated runoff equivalent to 1144 mm of the annual rainfall received by the catchment. Data used to establish the stage discharge relationship contains the following recorded data limits (in units of meters and seconds):

STAGE	0.76	1.35
FLOW	2	30
VEL	0.06	0.42

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and has identified possible sites at: Commerce Bight Village, Boom Creek and Freetown.

1.8.6 Water Quality

A single water quality sample is available for the Sittee River from the Hydrological Service and taken in April of 1983 with a relatively low stage of 0.76 meters indicating mostly dry season baseflow. The water exhibited a relatively low total alkalinity of 30 mg/l and a low total hardness at 27 mg/l and indicates the difference between these more acidic metamorphic catchments and the more basic, calcareous catchments and runoff to the south.

1.8.7 Pollution Sources

The lower Sittee catchment and gentle footslopes have significant citrus production but few settlements. Locally then, one would expect some potential agricultural contamination from runoff and very little contamination from domestic sources. The Belize pollution risk map indicates that the riverine zone in the lower quarter of the catchment is of high and medium risk categories while around 85% of the catchment including almost all of the highland area is of low pollution risk.

1.8.8 Water Uses

Sittee River has very few communities along its course and in its catchments and thus probably has few abstractive uses, although locally it may be used for citrus irrigation.

ANNEX 1.9 CATCHMENT PROFILE FOR THE SOUTH STANN CREEK

1.9.1 Geography and Topography

The South Stann Creek drains the eastern half of the Cockscomb Basin which is separated from the coastal plain by the 300-500 metre Cabbage Haul hills through which the Creek exits onto the coastal plain over the Long Falls gap. The Sittee Branch of the Creek cuts around the northern side of Victoria Peak but the other tributaries branch out radially, draining down towards the main channel in the basin centre at Locust Bank. The majority of the basin is actually below 200 meters elevation and very little of the catchment is in the higher metamorphic zones. Rather the rest of the Cockscomb Basin is confined to the 200-400 metre high slopes of the metasediments.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.9.1 Topography of the South Stann Creek Catchment

Slope Class	% Area
Less than 1 degree: plain	30
1 to 5 degree: undulating plain	5
5 to 25 degrees: rolling plain	5
25 to 35 degrees: local relief > 30 m - hills	0
25 to 35 degrees: steep slopes	60
>= 30 degrees: karst	0

According to LIC data produced from their GIS, the planar area of the South Stann Creek catchment is 258 km^2.

1.9.2 Geology and Soils

The headwaters of the South Stann Creek drain the igneous and metamorphosed sedimentary rocks of the ancient Santa Rosa Group whereas the lower reaches drain out across the much younger Tertiary sediments that form the shallow edge slopes and coastal plain. Accordingly, the soils of the region are generally acid and leached of nutrients. The soils of the igneous eastern foothills are easily eroded, particularly when slopes are cleared for agriculture such as the introduction of citrus.

1.9.3 Land-use

Based on LIC GIS tables of land-use surveyed between 1989/92, 580 ha (around 2.2%) of the South Stann Creek is devoted to agriculture, with 130 ha of urban land. The productive land-uses are for citrus and banana. Starting out on the rolling and gentle slopes along the valleys, increasing numbers of smaller farming concerns are expanding their citrus plantations up onto the thin and highly leachable soils on the steeper slopes. This was confirmed by aerial reconnaissance from Lighthawk which showed extensive clearance in progress. The citrus orchards occupy a broad swath of land on both sides of the highway, penetrating up the individual tributary valleys and phasing out onto the flatter, poorly drained coastal plain. According to 1989/92 data, they still only occupy around 229 ha. There are some banana plantations alongside several of the river sections. Together, these comprise around 328 ha. The Cockscomb Basin is partially protected as the Jaguar Preserve and will remain forested. Broadleaf forest occupies over 90% of the catchment. There is evidence of extensive wildfire damage of forest lands over previous years. The foothills along the inland side of the southern highway appear, from the air, to be subject to some milpa clearing. According to the LIC data, there is only 6 ha of milpa, but based on evidence from the Lighthawk flights this would seem an underestimate.

Table 1.9.2 Land-Use in the South Stann Creek Catchment

LIC CODE	%	ha	LAND-USE
BF	88.5	22814	BROADLEAF
BFO	2.6	659	OPEN BROADLEAF
PF	2.1	552	PINE FOREST
B	1.1	293	BANANAS
SV	1.0	246	SAVANNAH
C	0.9	229	CITRUS
PFO	0.9	222	OPEN PINE FOREST
TH	0.8	201	THICKET
TH/PF	0.8	195	THICKET/PINE FOREST
UI	0.5	130	URBAN
CV	0.4	100	COASTAL STRAND
BR	0.3	75	BAMBOO/RIPARIAN
CF	0.1	27	CLEARING FOR FARMING
BA	0.1	25	BANANA
SR	0.1	19	SCRUB

LIC CODE	%	ha	LAND-USE
MF	0.0	6	MILPA
		25792	

1.9.4 Rainfall

The Cockscomb Basin headwaters of the South Stann Creek receive between 2500 and 3000 mm of rainfall on average each year. The coastal sections east of Locust Bank receive 1500 to 2500 mm of rainfall per year, reducing towards the sea as elevation is lost.

1.9.5 Hydrology

As with each of these east-draining short and steep catchments, the South Stann Creek is crossed by the southern highway at the transition between the eastern foothills and the low central coastal plain. The National Hydrological Service has established a gauging station at this bridge location. South Stann Creek is also easily accessible upstream and downstream of this point at Locust Bank and at a minor road crossing respectively.

The bridge gauge site has a stage-discharge relationship and has been in service since 1984 (Panton, personal communication). According to data in Hydrological Service computer files, the stage discharge curve data set (1987/92) used to establish the empirical relationship exhibits the following range:

STAGE	0.94	4.35
FLOW	4	110
VEL	0.39	0.80

No expansion of gauging sites were considered in the Hydrological Service's plans for a Belize hydrometeorological network.

1.9.6 Water Quality

The runoff water will tend to be somewhat acid with low hardness due to the drainage of leached soils and siliceous bedrock. There are no known water quality measurements available on this river although it is possible that members of the citrus orchards may have data. It can be expected that the water quality will be somewhat similar to the Sittee and North Stann Creek rivers.

1.9.7 Pollution Sources

There are no settlements in the South Stann Creek basin except for isolated households along the highway. Pollution potential exists from agricultural drainage from the newly cleared orange groves and sediment input from milpa burning and uncontrolled forest fires. According to the pollution risk map for Belize, only the lower quarter of the catchment exhibits high risk of agricultural pollution, and then only along the river channel with medium risk elsewhere on the coastal plain. Around 75% of the catchment is low risk, with the 10% high and 15% medium mostly on the lower sections.

1.9.8 Water Uses

Apart from local water use by citrus growers, there are few, if any, apparent abstractive uses in this catchment.

ANNEX 1.10 CATCHMENT PROFILE FOR THE MONKEY RIVER

1.10.1 Geography and Topography

The Monkey River is the largest of the catchments draining the east side of the Maya Mountains and the karst of the southern foothills. The Swasey Branch of the Monkey River drains the steep metamorphic hillslopes of the western portion of the Cockscomb Basin that steeply descend to the fringing slopes between 100-200 meters from the main divide at 800 meters and more. The Swasey has a largely radial branching pattern focusing in on Double Fall. As it passes out from the dissected, metamorphosed sediments, the river tumbles over a number of falls as it seeks out sea level through the eroded ridges and bluffs.

The Bladen Branch is an asymmetrical drainage system that adopts a trellis pattern, forced northeast by the southern foothills, probably formed in the discontinuity between the metamorphic, steeply eastward sloping Maya Mountain ridge and the fringing Jurassic limestone. On reaching the edge of these low hills near Chun Bank, the river takes a sharp 90 degree turn south east to flow across the south end of the Central Coastal Plain and join up with the Swasey Branch to form the main Monkey River. The slopes from the main divide down to the Bladen are very steep, losing up to 800 meters in less than 5 km of horizontal distance. The main Bladen channel loses elevation less rapidly, but nevertheless is potentially very flashy. The trellis form of the Bladen drainage contrasts markedly with the radial, more bifurcated branching of the Swasey. The relief is more markedly steep, with short, incised channels separated by steep, narrow interfluves rather than broad sweeping banks.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.10.1 Topography of the Monkey River Catchment

Slope Class	% Area
Less than 1 degree: plain	35
1 to 5 degree: undulating plain	5
5 to 25 degrees: rolling plain	<1
25 to 35 degrees: local relief > 30 m - hills	<1
25 to 35 degrees: steep slopes	40
>= 30 degrees: karst	20

According to LIC data produced from their GIS, the planar area of the Monkey River catchment is 1275 km^2.

1.10.2 Geology and Soils

The southern half of the Monkey River catchment, drained by the Swasey, has developed back into the metasediments and granites of the Santa Rosa Group, flowing out in its middle and lower sections across the broad expanse of younger sediments that comprise the coastal plain. The Bladen too drains mostly the granites and metasediments of the ancient Santa Rosa Group, but also the Jurassic limestone which it has exploited to form its asymmetrical valley form and karstic landscape.

1.10.3 Land-use

Based on LIC GIS tables of land-use surveyed between 1989/92, the Monkey River and its two major tributaries contain 2,769 ha (around 2.2%) of agricultural land, mostly banana but also mango, milpa, annual crops, pasture and citrus. Urban land-use totals 76 ha.

The two sub-catchments differ significantly. The broad igneous basin of the Swasey is used for forestry and locally for cattle on the more rolling, less steep slopes between river channels. The LIC 89/92 land-use data shows only 34 ha as pasture land although on the hillsides, cattle are likely to graze thickets and open forest lands also. The low foothill valleys and coastal plain have been cleared for banana, mango and a little citrus. On the steeper metamorphic geology of the Bladen Branch, there has been less forestry activity and little cattle grazing. However, both of the upper catchment of each is largely under broadleaf forest (LIC, 1994). The shallower slopes and valleys are planted with citrus, banana and mangos, particularly on the Bladen up from the bridge. Bananas are planted alongside most of the river channels, particularly on the lowlands. The most extensive banana planting is at Cowpen on the Swasey.

The Cockscomb Basin is partially protected as the Jaguar Preserve and will remain forested. The foothills along the inland side of the southern highway appear, from the air, to be subject to some milpa clearing. The higher hills are mostly covered with mixed forests. Milpa appears to occupy only 305 ha, with annual crops another 250 ha. The presence of significant thicket vegetation would indicate that perhaps milpa has cleared extensive areas previously that are regenerating. Broadleaf forest occupies around 85% of the catchment and savannah and thicket 10%. The 1989/92 land-use maps (LIC, 1994) show the lower catchment to be mostly savannah.

Table 1.10.2 Land-Use in the Monkey River Catchment

LIC CODE	%	ha	LAND-USE
BF	84.1	107338	BROADLEAF
SV	6.5	8337	SAVANNAH
TH	2.2	2803	THICKET
PF	1.8	2238	PINE FOREST
BF/TH	1.2	1530	BROADLEAF/THICKET
B	1.0	1317	BANANA
M	0.5	665	MANGO
BR	0.5	657	BAMBOO/RIPARIAN
TH/PFO	0.4	485	THICKET/OPEN PINE FOREST
BFO	0.4	473	OPEN BROADLEAF
MF	0.2	305	MILPA
PFO	0.2	271	OPEN PINE FOREST
AC	0.2	253	ANNUAL CROPS
TH/PF	0.1	191	THICKET/PINE FOREST
CF	0.1	186	CLEARING FOR FARMING
PFO/SV	0.1	160	OPEN PINE FOREST/SAVANNAH
CV	0.1	136	COASTAL STRAND
UII	0.0	63	URBAN NON-BUILT UP
TH/P	0.0	53	THICKET/PASTURE
MS	0.0	40	MARSH SWAMP
P	0.0	34	PASTURE
UI	0.0	13	URBAN
C	0.0	9	CITRUS
		127558	

1.10.4 Rainfall

Both the Swasey and the Bladen headwaters receive rainfall between 2500 and 3000 mm per year as does the coastal plain over which the Monkey River meanders down to the sea.

1.10.5 Hydrology

The Swasey Branch has been gauged at the crossing of the Southern Highway just upstream of Logans Bank on the coastal plateau. The Bladen Branch is instrumented at an equivalent location where the highway crosses just upstream of Melvins Bank. Apparently, the station is only one year old, sited at a fairly straight section of a river meander downstream of orange and banana plantations. In both cases, there is negligible contributing area downstream of these sites, with minimal lateral drainage and few tributaries. Monkey River flows off the coastal plain and into the nearshore marine zone at Monkey River Town. From the air, it appears that the Monkey River has extensive sand and gravel bar formations and is used for extraction.

According to Panton (personal communication), both gauges have been functioning adequately for only the last couple of years and there are no stage-discharge calculations established for either site. Bladen Branch stream discharges of 16-20 m^3/s have been recorded for the average annual daily flows of 1.2-1.8m depth and an annual stage range between a low flow of 0.7m and high flow of 4.6m (1992/93). Similar stream discharges were recorded for the Swasey Branch with a recorded annual stage range from 1.1 to 2.2m in 1992/93. The combined Monkey River flow is expected to be a daily average of around 35-40 m^3/s.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified Monkey River Town as a desirable site for the installation of automatic recording equipment.

1.10.6 Water Quality

There are no available water quality measurements taken by the Hydrology Service that could indicate the background quality conditions to be expected in the river water. Although the Bladen Branch receives some limited drainage from the Tertiary/Jurassic Toledo limestones, and may receive significant karstic inflow from calcareous subterranean sources, it is likely that the base condition will be one of slightly acid runoff, between a pH of 6 and 7, with low total alkalinity, low hardness and low overall levels of dissolved salts. However, iron levels may be higher.

1.10.7 Pollution Sources

Sediment losses from newly cleared citrus groves with their lateral drains and from banana plantations established right down to the river bank can be high, with particularly high sediment and organic material loads during flood conditions when the absence of riparian vegetation causes the washing away of materials. The Swasey Branch, in particular, is prone to flooding.

According to King et al (1993), it is suspected that in the Monkey River catchment in particular, freshwater contamination with agrochemicals is increasing to a level of concern. Based on available water quality evidence, this cannot be judged but is highly likely given the southward and upslope expansion of production agriculture. Both the Swasey and Bladen Branch catchments exhibit low agricultural pollution risk according to the map produced from the LIC GIS except for the last five or so kilometers of each river and its adjacent land which show a high risk. Over 85%, almost the entirety of the upper catchment, exhibits low risk although most of the lower catchment of the main Monkey River on the coastal plain exhibits high risk. For the selection of sites for analyzing agrochemical contamination, it would be important to consider these characteristics, concentrating more on the Monkey River channel itself and less on its main tributaries.

1.10.8 Water Uses

The river and its tributaries are probably extensively used by banana growers to irrigate plantations, particularly at Cowpen. There are only minor settlements upstream in the catchment, excluding Monkey River Town which is located at the coastal outlet of the main branch. Non-agricultural abstraction will therefore be minimal.

ANNEX 1.11 CATCHMENT PROFILE FOR THE DEEP RIVER

1.11.1 Geography and Topography

Like its southern neighbor, the Golden Stream, the Deep River is a largely coastal plain system that extends up into the limestone foothills isolated from the Maya Mountains by the headwater capturing effect of the Bladen Branch. The highest points of the catchment are between 400-500 meters with the majority less than 100 meters and the hilly headwaters mostly between 200 and 400 meters. The Deep River flows into a low-lying lagoonal system at the north end of Port Honduras bay.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.11.1 Topography of the Deep River Catchment

Slope Class	% Area
Less than 1 degree: plain	45
1 to 5 degree: undulating plain	40
5 to 25 degrees: rolling plain	<1
25 to 35 degrees: local relief > 30 m - hills	5
25 to 35 degrees: steep slopes	<1
>= 30 degrees: karst	10

According to LIC data produced from their GIS, the planar area of the Deep River catchment is 347 km^2.

1.11.2 Geology and Soils

The majority of the Deep River basin is calcareous. Its headwaters mostly drain from the karstic Jurassic limestones of the Buena Vista and the Tertiary Toledo formations, with a small part draining the southern end of the older metamorphosed sediments. A short final section of the river levels out over the fringing plain of Tertiary coastal sediments.

1.11.3 Land-use

Based on LIC GIS tables of land-use surveyed between 1989/92, it appears that only 102 ha of agricultural land is found in the Deep River catchment, or around 0.3% of the total area. Urban land-use is 20 ha. Based on flights in Lighthawk in 1994, there appears to be significant banana production in the catchment. This does not appear in the 1989/92 LIC land-use data. From the vantage of 1994 Lighthawk overflights, the rest of the catchment seemed to be under forest cover, with signs of some burning along the highway. This is confirmed by the 1989/92 land-use maps which show the majority of the catchment to be savannah to the east and broadleaf forest to the west with some pine forest. A small amount of livestock grazing is shown close to the coast, according to LIC, around 8 ha . Milpa farming appears to occupy around 94 ha, but may also occur in some lands classified as thicket. Broadleaf forest occupies around 60%, savannah around 22% and thickets 12%.

Table 1.11.2 Land-Use in the Deep River Catchment

LIC CODE	%	ha	LAND-USE
BF	57.0	19785	BROADLEAF
SV	21.4	7413	SAVANNAH
BF/TH	5.3	1834	BROADLEAF/THICKET
TH	4.8	1651	THICKET
MG	2.7	942	MANGROVE
PF	1.9	662	PINE FOREST
PF/TH	1.9	647	PINE FOREST/THICKET
MS	1.7	591	MARSH SWAMP
MGT	1.0	351	MANGROVE TALL
WB	0.9	323	WATER
SV/TH	0.6	205	SAVANNAH/THICKET
MF	0.3	94	MILPA
TH/P	0.2	52	THICKET/PASTURE
PFO	0.2	52	OPEN PINE FOREST
CV	0.1	43	COASTAL STRAND
SR	0.1	25	SCRUB
UI	0.1	20	URBAN
MGF	0.0	11	MANGROVE ?

LIC CODE	%	ha	LAND-USE
P	0.0	8	PASTURE
		34709	

1.11.4 Rainfall

The headwater areas of the catchment receive an average of between 2500 and 3000 mm of rainfall per year, with part of the catchment receiving between 3000-3500 mm.

1.11.5 Hydrology

Tributaries of the Deep river are crossed four times by the southern highway, at Big Dry Creek, Machaca Creek, the Deep River main channel and Warrie Creek. According to Panton (personal communication), a gauging station was installed in April at Medina Bank. No flow data was recovered from Hydrological Service files for this station as yet. There is also access to the river on a side road near Beattie Pen. The Deep River drains into a coastal lagoonal system.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified potential site to install automatic recording equipment at Deep River Bridge.

1.11.6 Water Quality

There are no known water quality data indicating the types of water quality conditions to be found in the river. It can be expected that the water has similar chemical qualities to the Moho River - heavily alkaline, high hardness and fairly neutral pH.

1.11.7 Pollution Sources

Due to the largely forested and uninhabited nature of the upstream catchment, anthropogenic pollution sources are not expected. There is minimal population in the catchment and no concentrated settlements. According to the agricultural pollution risk index map, only the coastline zone and the area immediately adjacent to the main lowland channel exhibit high risk. Most of the hills between tributaries and the headwaters show low risk while the catchment around the tributaries and side slopes show medium risk. Around 15% of the catchment appears high, 50% medium and 35% low risk overall.

1.11.8 Water Use

There are no known abstractive uses from the river system.

ANNEX 1.12 CATCHMENT PROFILE FOR THE GOLDEN STREAM

1.12.1 Geography and Topography

Golden Stream, like Deep River, flows out of the low limestone hills at the edge of the Maya Mountains at the transition to the southern foothills of the Toledo region. Golden Stream's contributing area is mostly below 200 meters but stretches up into the dissected hills near Raspaculo Hill which locally extend up to 500 meters. The river has only a few tributaries and flows onto the southern coastal plain near Hellgate, where the southern Highway crosses.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.12.1 Topography of the Golden Stream Catchment

Slope Class	% Area
Less than 1 degree: plain	15
1 to 5 degree: undulating plain	55
5 to 25 degrees: rolling plain	<1
25 to 35 degrees: local relief > 30 m - hills	10
25 to 35 degrees: steep slopes	5
>= 30 degrees: karst	15

According to LIC data produced from their GIS, the planar area of the Golden Stream catchment is 204 km^2.

1.12.2 Geology and Soils

Almost the whole of the catchment is calcareous with only a very short lower reach flowing over the mixed coastal plain sediments. The very upper reaches of the river extend into the Jurassic limestones of the old Yucatan plateau formations but the majority drain off the karstic Tertiary limestones of the Toledo formation.

1.12.3 Land Use

Based on LIC GIS tables of land-use surveyed between 1989/92, 2,636 ha (around 12.9%) of the Golden Stream catchment is devoted to agriculture with 20 ha of urban land. The lower river seems prone to flooding with what appears from the air to be extensive riparian meadow-type vegetation. The 1989/92 land use maps indicate around 10% of the land to be involved in milpa and non-mechanized annual crop production (1,861 ha), largely north and south of the main highway, with some recovery as secondary forest regrowth. This extent of land conversion was not noted from the Lighthawk flight. A significant level of livestock pasture is also noted along with banana production. The catchment is mostly placed as broadleaf forest with some scrub and mangroves on the coastal side of the highway.

Table 1.12.2 Land-Use in the Golden Stream Catchment

LIC CODE	%	ha	LAND-USE
BF	73.8	15060	BROADLEAF
MX	9.0	1844	ANNUAL CROPS NON-MECH
TH	4.9	991	THICKET
BF/TH	3.7	764	BROADLEAF/THICKET
MG	3.2	662	MANGROVE
P	1.7	350	PASTURE
B	1.1	232	BANANA
BR	0.5	111	BAMBOO/RIPARIAN
BA	0.4	91	BANANA
CF	0.3	55	CLEARING FOR FARMING
MGT	0.3	52	MANGROVE TALL
AC	0.2	47	ANNUAL CROPS
SV	0.2	44	SAVANNAH
SR	0.2	42	SCRUB
MS	0.1	21	MARSH SWAMP
UIII	0.1	20	URBAN ?
MF	0.1	17	MILPA
?	0.0	7	UNKNOWN
G	0.0	3	SAVANNAH
WB	0.0	2	WATER
		20414	

1.12.4 Rainfall

The Golden Stream catchment extends up into the belt of rainfall that typically yields an annual total of between 3000-3500 mm.

1.12.5 Hydrology

At the Southern Highway bridge, near Hellgate village, there is a gauging station established by the Hydrological Service. The gauge has only been installed since 1994 and therefore, no stage-discharge relationship has been established for the site. No stage or stream discharge data was obtained from the Hydrological Service computer files for this station.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and has identified the following site to install automatic recording equipment at the Bob Creek Confluence. Bob Creek does not appear on the 1:250,000 series map.

1.12.6 Water Quality

No water quality data is available for this river although it can be expected to be similar to the group of limestone draining rivers that make up the catchments south of the Monkey River.

1.12.7 Pollution Sources

Because of the largely pristine nature of this catchment, no anthropogenic point or non-point source pollutants are expected. The agricultural pollution risk index, probably taking into account the potential for future milpa and banana expansion, classifies the majority of the catchment as medium risk, with the headwaters low and isolated high risk along the coast and isolated sections of the river system. Around 75% seems medium, 25% low and less than 5% risk.

1.12.8 Water Uses

There are no known abstractive uses for this river or its tributaries.

ANNEX 1.13 CATCHMENT PROFILE FOR THE RIO GRANDE

1.13.1 Geography and Topography

The Rio Grande is much more extensive than its northern neighbors and extends back up into the Maya Mountain range and eastern slopes of the 900 metre plus Little Quartzite Ridge. The river is highly branched as it winds and divides through the limestone fringe of the 200-400 metre southern foothills, with extensive karst formation that sees surface rivers disappear underground and reemerge some 50 to 100 meters below as part of the same branching network that drains to the broad southern coastal plain. There the Rio Grande meanders slowly down to its estuary around 5 km north of Punta Gorda. The Rio Grande and its various tributaries are crossed in many places by the Southern Highway and secondary roads. The upland drainage is quite complex, mostly below 600 meters, but extending up into a broad, dissected ridge of 600 to 700 meters elevation into which the Little Quartz ridge intrudes.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.13.1 Topography of the Rio Grande Catchment

Slope Class	% Area
Less than 1 degree: plain	20
1 to 5 degree: undulating plain	25
5 to 25 degrees: rolling plain	10
25 to 35 degrees: local relief > 30 m - hills	5
25 to 35 degrees: steep slopes	20
>= 30 degrees: karst	20

According to LIC data produced from their GIS, the planar area of the Rio Grande catchment is 718 km^2.

1.13.2 Geology and Soils

The catchment of this river is almost entirely calcareous with only the very tips of the drainage network extending up into the metamorphic and igneous rocks of the Maya Mountain chain. The river flows down off the Jurassic limestones, across the Tertiary Toledo formation and onto a short section of the younger fringing coastal sediments.

1.13.3 Land-use

The Toledo catchments are largely forested with many small areas of clearing for milpa cultivation of corn and beans, or in areas of suitable flat land and water, for rice cultivation. Based on LIC GIS tables of land-use surveyed between 1989/92, 15,874 ha of the catchment, around 22%, is devoted to agricultural activity with 225 ha of urban land. Milpa and non-mechanized annual crop production are the largest productive land-uses.

Because of the overuse of milpa farming on the flatter valley bottoms, there is a tendency to expand milpa up into the surrounding steep, less fertile and shallow limestone bedded slopes draining to the rivers (King et al, 1993). According to aerial evidence from Lighthawk flights in 1994, the catchment is still largely forested right down to the riverside with broadleafed species. The 1989/92 land-use maps (LIC, 1994) indicate that non-mechanized annual crop production and milpa occupies around 18% or 13,348 ha of the catchment especially on the main river between San Jose and Big Fall and that it extends towards the coast in the crook of the Southern Highway. This extent of milpa was not obvious from the air. Mechanized annual crop production occupies 653 ha. Some isolated banana and citrus farming appears along the main road as well as livestock pasture, both well below 1% of the catchment. Together they occupy some 215 ha. The tributaries up above Jimmy Cut and Resumadero are largely in pristine condition with universal broadleaf cover. Pasture and scrub grazing occupy close to 1,800 ha of land, around 2.3%.

Table 1.13.2 Land-Use in the Rio Grande Catchment

LIC CODE	%	ha	LAND-USE
BF	68.0	48827	BROADLEAF
MF	7.8	5611	MILPA
TH	5.0	3568	THICKET
MX/MF/TH	4.3	3065	ANNUAL CROPS NON-MECH/MILPA/THICKET
MX	4.2	3033	ANNUAL CROPS NON-MECH
P	1.6	1166	PASTURE
MX/TH	1.6	1154	ANNUAL CROPS NON-MECH/THICKET
SR	1.0	687	SCRUB
BF/TH	0.9	660	BROADLEAF/THICKET
AC	0.9	653	ANNUAL CROPS
TH/SR	0.9	614	THICKET/SCRUB
P/TH	0.7	512	PASTURE/THICKET

LIC CODE	%	ha	LAND-USE
MF/TH	0.6	465	MILPA/THICKET
MG	0.5	393	MANGROVE
BF/BFO	0.5	325	BROADLEAF/OPEN BROADLEAF
UI	0.3	218	URBAN
SV	0.3	195	SAVANNAH
PF	0.3	183	PINE FOREST
C	0.2	163	CITRUS
TH/PFO	0.1	82	THICKET/OPEN PINE FOREST
BFO	0.1	60	OPEN BROADLEAF
BA	0.1	52	BANANA
SR/TH	0.0	27	SCRUB/THICKET
PFO	0.0	23	OPEN PINE FOREST
WB	0.0	19	WATER
UII	0.0	7	URBAN NON-BUILT UP
MGT	0.0	4	MANGROVE TALL
		71764	

1.13.4 Rainfall

The headwaters of the Rio Grande generally receive less rainfall than the coastal belt. The steeper sloping upland tributaries receive around 2500-3000 mm per year whereas the more gentle coastal tributaries receive 3000-4000 mm per year on average.

1.13.5 Hydrology

Viewed from the air, the Rio Grande occupies a highly meandering course, especially over the coastal plain. There are two gauging stations established on the Rio Grande, one upstream on the southern Columbia Branch tributary network at San Pedro, and the other on the main channel some 8 km downstream where the Southern Highway crosses at Big Falls (16388914). According to Hydrological Service data published in Hartshorne (1984), the catchment is 772 km^2 in total area with the area upstream of Big Falls South comprising 536 km^2. Based on runoff from 1981-82, the estimated average stream discharge at this location is 24 m^3/s which represents an accumulated runoff of 1412 mm per year. The river is very flashy with large diurnal changes in stage and stream discharge.

There are some gaps in the Big Falls and San Pedro hydrological records (Panton, personal communication) but both sites have stage-discharge relationships well established.

The following data sets were extracted from Hydrological Service computer files for the two gauging sites:

San Pedro:

Yearly summary of conditions:

YEAR	91/92	92/83
STAGE m		
Mean	1.84	1.24
Max	3.62	4.07
Min	0.86	0.84

Selected stream discharge measurements from 1991-1993:

STAGE m	0.82	0.85	1.08	1.11	1.32	1.43	1.49
FLOW m^3/s	1	2	5	4	12	13	14
VEL m/s	0.4	0.4	0.7	0.6	1.0	1.1	1.0

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified Big Hill and Resumadero as suitable sites to install automatic recording equipment.

1.13.6 Water Quality

The limestone basins of the headwaters and karstic formations will cause runoff water, particularly low flows, to be alkaline with a relatively high hardness in the form of calcium and magnesium carbonates. pH will also be fairly high. Expansion of milpa farming up onto the hillside slopes can cause significant nutrient and sediment loss. Use of chemical fertilizers on the upper part of the catchments, if practiced, results in their washing away since they usually are not fixed the soil mass. Consequently, where citrus production is expanding into the hills of the Toledo limestone formations, the potential for agricultural runoff of nutrients is high. In fact two water samples exist for Big Falls, one from February 1984 (at a stage of 0.94 meters) and the other from August 1986 (no stream discharge data).

The February data will represent more the low baseflow conditions and points to a high alkalinity

(185 mg/l) and relatively high total hardness at 180 mg/l (66% calcium), sulfates at 20 mg/l, low to zero iron and chlorides and with a pH of 8.2. The August data which will exhibit wet-season higher flows shows lower alkalinity (60 mg/l) a similar total hardness (190 mg/l), more sulphate (60 mg/l), low iron, higher chlorides (15 mg/l) and pH nearer neutral (7.2).

1.13.7 Pollution Sources

Anthropogenic point source and non-point source pollutants are expected to be low in this catchment due to the slight degree of conversion to alternative land-uses to forestry. According to the agricultural pollution risk map, which takes into account potential future uses, the catchment is patch with a relatively even mix of risk categories, with a slight majority low risk. The upland catchment exhibits low risk while the mid part of the channel network showing high risk. The coastal plain north of the river shows medium risk and the southern low risk.

1.13.8 Water Uses

Due to the small amount of settlements and lack of agriculture and industry in the catchment, little abstraction is expected.

ANNEX 1.14 CATCHMENT PROFILE FOR THE MOHO RIVER

1.14.1 Geography and Topography

The Moho River has a relatively large catchment area that extends up through the karstic Toledo foothills and into Guatemala, draining the southern extension of the Maya Mountains. The major Moho channel drains north east out of Guatemala, combining with the south east channels draining off the eastern slopes of the stepped plateau that flanks the Little Quartz Ridge. It is a trellis network, constrained on its southern side by a series of low 100-200 metre hills running parallel to the Maya Mountain divide and perpendicular to its trend. A large part, the northern portion, of the catchment drains into the Agua Caliente swamp formed behind the low hills of Crique Antonio that rise out of the southern coastal plain. The basin is crisscrossed by a series of secondary roads that like the river branches, stretch on up into the karstic limestone hills, skirting around the swampy basin floor.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.14.1 Topography of the Moho River Catchment

Slope Class	% Area
Less than 1 degree: plain	40
1 to 5 degree: undulating plain	10
5 to 25 degrees: rolling plain	10
25 to 35 degrees: local relief > 30 m - hills	10
25 to 35 degrees: steep slopes	10
>= 30 degrees: karst	20

According to LIC data produced from their GIS, the planar area of the portion of the Moho River catchment within Belize is 813 km^2. The portion of the catchment in Guatemala comprises 376 km^2. The total catchment area is roughly 1,188.5 km^2, 68.4% in Belize and 31.6% in Guatemala.

1.14.2 Geology and Soils

Within the Belize borders, the catchment comprises interspersed exposures of the Jurassic and Tertiary limestones of the Campur and Toledo groups followed by a relatively short traverse across the younger coastal sedimentary rocks underlying the coastal plain. The limestone rocks probably comprise the lions share of the Guatemalan headwaters also.

1.14.3 Land-use

The Moho River basin most frequent agricultural use is for milpa maize and beans production and for rice. According to LIC 1989/92 data, milpa and other non-mechanized annual crop production occupy around 16,000 ha of the catchment or some 20%. Agricultural land in total occupies 17,612 ha (around 21.7%). Urban land-use is 405 ha. It can be expected that more milpa will be found in the Guatemalan portions of the Moho catchment also.

The largest portion of the basin, particularly the limestone slopes and karst areas, is under forest and large swampy areas remain with coastal shrubs and mangroves. Milpa is concentrated so that roughly 50% of the Rio Blanco/Blue Creek tributary is under milpa production. Because of the overuse of milpa farming on the flatter valley bottoms, there is a tendency to expand milpa up into the surrounding steep, less fertile and shallow limestone bedded slopes draining to the rivers (King et al, 1993). On the undulating inter-channel sections of the coastal plain, there have been moves to plant citrus plantations. Only minor amounts of citrus and banana were noted in the 1989/92 LIC survey. Riparian vegetation lines the floodplains along broad sections of the river network. There is a some cattle pasture indicated also. Broad sections of the lowland catchment is also under milpa but the broadest land-use on most of the coastal plain and headwater slopes not under milpa is broadleaf forest.

Table 1.14.2 Land-Use in the Moho River Catchment

LIC CODE	%	ha	LAND-USE
BF	67.8	55109	BROADLEAF
MF	18.0	14613	MILPA
TH	6.9	5577	THICKET
MF/TH	1.4	1173	MILPA/THICKET
P	0.9	737	PASTURE
BR	0.8	622	BAMBOO/RIPARIAN
AC	0.7	577	ANNUAL CROPS
TH/BF	0.6	479	THICKET/BROADLEAF
PF	0.4	344	PINE FOREST
UI	0.4	328	URBAN
MX/MF/TH	0.4	286	ANNUAL CROPS NON-MECH/MILPA/THICKET
MS	0.3	263	MARSH SWAMP
PFO	0.2	149	OPEN PINE FOREST

LIC CODE	%	ha	LAND-USE
SV/TH	0.2	133	SAVANNAH/THICKET
TH/PFO	0.2	131	THICKET/OPEN PINE FOREST
SR/MF	0.2	122	SCRUB/MILPA
MGT	0.1	121	MANGROVE TALL
CY	0.1	114	UNKNOWN
BFO	0.1	109	OPEN PINE FOREST
UII	0.1	77	URBAN NON-BUILT UP
TH/SR	0.1	70	THICKET/SCRUB
MX	0.1	58	ANNUAL CROPS NON-MECH
WB	0.0	40	WATER
CF	0.0	35	CLEARING FOR FARMING
SR	0.0	19	SCRUB
MS/TH	0.0	8	MARSH SWAMP/THICKET
BA	0.0	8	BANANA
MG	0.0	5	MANGROVE
MI	0.0	3	UNKNOWN
C	0.0	3	CITRUS
SV	0.0	1	SAVANNAH
		81317	

No data was obtained on the land-use in the Guatemala portion of the catchment.

1.14.4 Rainfall

The rainfall of the Moho Basin varies between 2500 and 4000 mm, between 2500-3000 mm in the higher headwater areas and 3,000-4,000 mm along the southern coastal plain and the edges of the foothills.

1.14.5 Hydrology

Data published in Hartshorne (1984) indicates that the Moho River catchment is approximately 927 km^2 (although it is unclear whether this is just the portion in Belize only).

There are three gauging sites on the Moho River, the most downstream being Jordan Village just below the last major confluence below the join between the Moho and its swamp-filled northern Black Creek sub-basin. Two other road crossings provide other gauging points upstream, one in the northern sub-basin on the Blue creek (16289015) and the other near Aguacate on the Aguacate Creek (16289116). According to Panton (personal communication), the Aguacate Creek station was discontinued in 1985. Both Blue Creek and Jordan Village have stage-discharge relationships established, although the data record for Jordan Village has some gaps in its record since 1969. Aguacate Creek runs south from the Maya Mountain ridge, just flowing into Guatemala and then veers back east onto the southern coastal plain where it flows into the Moho River. Both the Aquacate and Blue Creek stations mark the junction between the limestone hill mid-sections of the tributary networks and the final coastal plain section of the river.

Table 1.14.3 Flow Gauging Stations on the Moho River

Station	Tributary	Drainage Area	Estimated Discharge (1981/82)	Hydrology
Blue Creek	Blue Creek branch	168 km^2	7.8 m^3/s 1464 mm	Drains northern sub-catchment
Aguacate Creek	Aguacate Creek branch	186 km^2	5.1 m^3/s 864 mm	Drains Maya Mountain ridge and part of Guatemala
Jordan Village	Moho River main branch	--- km^2	50 m^3/s	Drains majority of basin area including lowlands

Data published in Hartshorne (1984) indicates that the portion of the Moho catchment upstream from Blue Creek station is 168 km^2 (18%) and upstream from Aguacate station is 186 km^2 (20%). The annual average flow through the two catchments based on 1981-82 data was listed as 7.8 m^3/s and 5.1 m^3/s, which represents the total accumulated runoff of 1464 mm and 864 mm of rainfall respectively over a 12 month period. More recent data from the Hydrological Service suggest a flashy discharge range of over 500 m^3/s with minimum flows down to 1 m^3/s and maximum flows of more than 600 m^3/s. Recorded mean daily flow ranges from 30 to 80 m^3/s and flow depths of 20cm to 5m at the Jordan station. The tributary Blue Creek mean flow depths have varied between 0.7m and 1.5m with an annual daily recorded low flow level of 0.24m and a high of 6.5m. Aguacate Creek stage discharge curve suggests a normal flow range from 0.3 to 13.7 m^3/s, depths from 0.07 to 0.8m and velocities from 0.5 to 0.7 m/s. This would suggest Blue Creek to be a major contributor. From files obtained from the Hydrology Service, the following data can be summarized for Jordan Village and

Blue Creek:

Jordan Village

YEAR	82/83	.83/84	85/86	86/87	92/93
STAGE m					
Mean	1.15	1.11	0.97	1.69	0.91
Max	4.01	3.34	3.12	5.00	3.20
Min	0.34	0.34	0.42	0.80	0.17
FLOW m^3/s					
Mean	48	41	31	90	---
Max	376	261	227	585	---
Min	1	1	3	15	---

Blue Creek

YEAR	71/72	72/73	74/75	75/76	76/77	77/78	78/79	79/80	81/82
STAGE m									
Mean	1.54	1.52	1.69	1.41	1.49	1.48	1.50	1.73	0.66
Max	4.83	6.03	6.50	4.20	4.56	3.16	3.90	3.23	1.85
Min	1.08	1.17	1.13	1.14	1.18	1.22	1.17	1.23	0.30

YEAR	85/86	86/87	90/91	91/92	92/93
STAGE m					
Mean	0.73	0.72	0.76	0.71	0.69
Max	2.28	3.30	2.68	2.45	2.28
Min	0.38	0.30	0.25	0.24	0.26

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified possible sites at: Aguacate confluence, Black/Roaring Creek confluence and San Antonio.

1.14.6 Water Quality

Only two water quality samples from 1986 are known for the Moho River basin, one at Jordan Village and one at Blue Creek, neither accompanied by a volumetric discharge (note there were 5 days between sampling and testing). Quality at both stations was similar with high total alkalinity (150/155 mg/l), high hardness (330/350 mg/l - 85% calcium), high sulfates (120/125 mg/l), slightly basic pH and chlorides at 35 mg/l. These values are not unexpected given the calcareous origins of the runoff although the values have poor reliability.

1.14.7 Pollution Sources

Expansion of milpa farming up onto the hillside slopes can cause significant nutrient and sediment loss. Use of chemical fertilizers on the upper part of the catchments, if practiced, results in their washing away since they usually are not fixed in the soil mass.

In the Punta Gorda region, between the Rio Grande and Moho Rivers, much of the domestic and commercial developments are along the coastline rather than up the rivers and the pollution sources are assumed to be few.

According to the agricultural pollution risk map, the majority of the catchment is low risk, around 70%. Only along the coast and within around 200 m - 500m of the main channel are high risk zones located, around 20% of the total area.

1.14.8 Water Uses

There are no expected to be any significant demands or abstractions from the Moho River system.

ANNEX 1.15 CATCHMENT PROFILE FOR THE TEMASH RIVER

1.15.1 Geography and Topography

The Temash River occupies a relatively long and thin basin that flows down into the swampy Temash lagoon and thence into the sea. The Belize portion of the catchment is almost exclusively below 100 meters in elevation with a few isolated hills penetrating out of the broad southern coastal plain. The headwaters extend out from the Guatemalan extension of the Toledo foothills.

Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.15.1 Topography of the Temash River Catchment

Slope Class	% Area
Less than 1 degree: plain	90
1 to 5 degree: undulating plain	1
5 to 25 degrees: rolling plain	2
25 to 35 degrees: local relief > 30 m - hills	3
25 to 35 degrees: steep slopes	2
>= 30 degrees: karst	3

According to LIC data produced from their GIS, the planar area of the portion of the Temash River catchment within Belize is 360 km^2. The portion of the catchment in Guatemala comprises 115 km^2. The total catchment area is roughly 474.6 km^2, 75.8% in Belize and 24.2% in Guatemala.

1.15.2 Geology and Soils

The catchment comprises interspersed exposures of the Jurassic and Tertiary limestones of the Campur and Toledo groups followed by a broad traverse across the younger coastal sedimentary rocks underlying the coastal plain.

1.15.3 Land-use

Out of the portion of the Temash catchment in Belize, according to 1989/92 data, 5,259 ha (around 14.6%) of land is devoted to agriculture, with 180 ha of urban land. The majority of agricultural land is for milpa and it can be expected that more will be found in the Guatemalan portions of the catchment also.

On the wetter, more fertile sections of the coastal plain, there is some rice production by the regions farmers, otherwise the major agricultural land-use is slash-and-burn clearing for milpa farming on the shallow slopes and valley bottoms of the incised foothills. Land not yet cleared for milpa, largely the steeper slopes, still remain under forest cover. Fallowed milpa have a low scrub cover. Because of the overuse of milpa farming on the flatter valley bottoms, there is a tendency to expand milpa up into the surrounding steep, less fertile and shallow limestone bedded slopes draining to the rivers (King et al, 1993). The 1989/92 land-use maps (LIC, 1994) place the majority of the catchment still under broadleaf forest (70%) with some mangroves along the main channel at the Temash lagoon and riparian vegetation in the flooding zones near Crique Sarco. There appears to be a small amount of pasture use (less than 1% or 263 ha) and broad bands of milpa from Crique Sarco back towards the Guatemalan border occupying around 13-14% or so of the total area. Thickets and scrub occupy around 10% of the catchment suggesting prior clearance.

Table 1.15.2 Land-Use in the Temash River Catchment

LIC CODE	%	ha	LAND-USE
BF	70.0	25161	BROADLEAF
MF	11.5	4142	MILPA
TH	3.8	1383	THICKET
SR	3.8	1371	SCRUB
TH/BF	2.6	923	THICKET/BROADLEAF
TH/MF	1.9	691	THICKET/MILPA
BR	1.3	459	BAMBOO/RIPARIAN
BF/BR	1.0	373	BROADLEAF/BAMBOO/RIPARIAN
MG	0.9	326	MANGROVE
P	0.7	263	PASTURE
UI	0.5	180	URBAN
CV	0.3	113	COASTAL STRAND
BFO	0.3	105	OPEN BROADLEAF
BF/TH	0.2	89	BROADLEAF/THICKET
MGT	0.2	89	MANGROVE TALL
CF	0.2	65	CLEARING FOR FARMING
MF/TH	0.1	53	MILPA/THICKET
WB	0.1	51	WATER

LIC CODE	%	ha	LAND-USE
AC	0.1	45	ANNUAL CROPS
SV	0.1	31	SAVANNAH
MS	0.0	16	MARSH SWAMP
PFO	0.0	4	OPEN PINE FOREST
TH/SV	0.0	3	THICKET/SAVANNAH
		35936	

No data was obtained on land-use in the Guatemala portion of the catchment.

1.15.4 Rainfall

The Temash basin receives a relatively high annual rainfall averaging more than 3500 mm per year.

1.15.5 Hydrology

Like the Moho and Rio Grande rivers, the Temash leaves the Toledo foothills to cross a relatively flat coastal plain seasonally subjected to flooding and the formation of alluvial wetlands. They have a swampy appearance with highly developed micro-drainage networks like mudflats draining tidal estuaries, with multiple, sinuous, branching meanders interspersed by low hummocks of vegetated sediments. With flooding, new sediments are deposited and organic material and nutrients picked up as the water drains away back to the main Temash channels and to the Gulf of Honduras.

Note that the Hydrology Department has proposed expanding its coverage of gauging stations and have identified two possible sites to install automatic recording equipment: Crique Sarco and the inflow to the Temash Lagoon.

1.15.6 Water Quality

There are no known water quality data for the Temash River, but based on its geology and soil type it can be expected that hardness levels and alkalinity are both high, with low pH and seasonably varying suspended sediment content. Hardness and alkalinity levels will drop significantly during flood periods. Where expansion of milpa farming up onto the hillside slopes has taken place, it can cause significant nutrient and sediment losses that will show up as increased BOD and TSS in river water. Use of chemical fertilizers on the upper part of the catchments, if practiced, results in their washing away since they usually are not fixed the soil mass. Expansion of Cacao and Citrus into the region, as is suggested, could therefore result in the flow of agrochemical nutrients into the coastal nearshore.

1.15.7 Pollution Sources

There is expected to be a diversity of agricultural production, albeit on a small scale, in this catchment. Agricultural runoff and sediments could thus result. According to the agricultural pollution risk index map of Belize, over 85% of the catchment appears in the low risk category, with less than 15% high risk along the rivers up to around 8-10km inland and along the immediate coastline.

1.15.8 Water Uses

There are some small villages and agricultural production such as rice which will require water. How much and where is not documented.

ANNEX 1.16 CATCHMENT PROFILE FOR THE SARSTOON RIVER

1.16.1 Geography and Topography

The Sarstoon river forms Belize's southern border as it meanders across the broad coastal lowlands formed by the Tertiary and Quaternary sediments that lie over the slumped limestone fringe around the Maya Mountain intrusions on its way to the Gulf of Honduras. This border section of the river is approximately 45 km long after which the Sarstoon then extends more than 80-100 km into Guatemala, occupying a broad, flat valley between the south-western extension of the Maya Mountain chain and the more elevated eastward running Sierra de Chama of Guatemala.

The area of the Sarstoon catchment within Belize is mostly flat with marshy ground and some local relief associated with channel terraces and occasional limestone geomorphology. Based on a preliminary assessment of the LIC Slope Gradient Map printed from the Belize GIS, the catchment exhibits the following topographic characteristics.

Table 1.16.1 Topography of the Sarstoon River Catchment

Slope Class	% Area
Less than 1 degree: plain	97
1 to 5 degree: undulating plain	1
5 to 25 degrees: rolling plain	0
25 to 35 degrees: local relief > 30 m - hills	0
25 to 35 degrees: steep slopes	0
>= 30 degrees: karst	2

According to LIC data produced from their GIS, the planar area of the portion of the Sarstoon River catchment within Belize is 194 km^2. The portion of the catchment in Guatemala comprises 2,023.5 km^2. The total catchment area is roughly 2,217.5 km^2, 91.2% in Belize and 8.8% in Guatemala.

1.16.2 Geology and Soils

Within Belize, the catchment comprises interspersed exposures of the Jurassic and Tertiary limestones of the Campur and Toledo groups followed by a broad traverse across the swath of younger coastal sedimentary rocks underlying the coastal plain.

1.16.3 Land-use

The predominant productive land-use in the Sarstoon River basin is milpa farming, with maize and bean production by individual families largely for subsistence production. According to 1989/92 data, 767 ha (4%) of land is devoted to agriculture although it can be expected that more milpa farming takes place in the Guatemalan portion of the catchment. There is no documented urban land-use.

Because of the overuse of milpa farming on the flatter valley bottoms, there is a tendency to expand milpa up into the surrounding steep, less fertile and shallow limestone bedded slopes draining to the rivers (King et al, 1993). The 1989/92 land-use maps (LIC, 1994) indicate that milpa and its associated areas of secondary regrowth occupy around 3-4% and around 8-10% of the catchment respectively. Riparian vegetation, swamp and mangroves occupies around 18-20% of the catchment. The rest of the catchment is mostly broadleaf forest with some patches of savannah.

Table 1.16.2 Land-Use in the Sarstoon River Catchment

LIC CODE	%	ha	LAND-USE
BF	64.6	12473	BROADLEAF
BR	5.8	1126	BAMBOO/RIPARIAN
BF/BR	5.7	1103	BROADLEAF/BAMBOO/RIPARIAN
TH	4.2	804	THICKET
MS	4.1	800	MARSH SWAMP
MG	2.7	512	MANGROVE
SV	2.6	494	SAVANNAH
TH/SV	2.5	475	THICKET/SAVANNAH
MF	2.2	427	MILPA
SR	1.9	373	SCRUB
TH/MF	1.4	277	THICKET/MILPA
BFO	0.9	176	OPEN BROADLEAF
TH/BF	0.6	114	THICKET/BROADLEAF
CV	0.4	79	COASTAL STRAND
CF	0.2	32	CLEARING FOR FARMING
AC	0.2	31	ANNUAL CROPS
BF/TH	0.1	13	BROADLEAF/THICKET
WB	0.1	10	WATER
		19320	

No data was obtained on land-use in the Guatemala portion of the catchment.

1.16.4 Rainfall

Close to the coast, the lower Temash basin experiences the highest average rainfall in the country, over 4000 mm per year.

1.16.5 Hydrology

Other than basic descriptive and geographical data that can be gleaned from available topographic and thematic maps, little data exists on the stream discharge and quality of the Sarstoon River. There are no monitoring stations on the Belize portion of the river nor ad-hoc field data derived from temporary gauging or sample sites. Quality conditions are expected to similar to those rivers to the north.

Due to the remote nature of this river and absence of road connections through the Toledo District, no stations were proposed in the hydrometeorological network expansion by the Hydrological Service.

From an analysis of Guatemalan hydrometeorological maps, it appears that there are two monitoring stations, probably for flow rather than quality, established by the National Electric Institute on the Sarstoon River and its tributaries in Guatemala. The Atlas Hidrológico Primer Edición (no date), shows the following hydrological stations on the map "Localización de Estaciones Hidrometricas y Limnimetricas, 1:1,000,000".

CODE	NAME
II.9.1.H	San Pedro Cardenas
II.9.3.H	Modesto Méndez

Both stations are located where the main highway north from Lago de Izabal to Flores crosses river channels.

1.16.6 Water Quality

No known water quality data exists for the Sarstoon River.

1.16.7 Pollution Sources

Expansion of milpa farming up onto the hillside slopes can cause significant nutrient and sediment loss. Use of chemical fertilizers on the upper part of the catchments, if practiced by milpa farmers, results in their washing away since they usually are not fixed the soil mass.

According to the agricultural pollution risk map of Belize, the immediate coastal plain and area along the channels in the catchment exhibit high risk of contamination should agrochemicals be applied whereas the rest of the Belize portion of the catchment, around 70% shows low risk.

1.16.8 Water Uses

The river is probably used by Maya farmers on both sides of the border for water, waste disposal and other assorted domestic, traditional uses such as laundry. It is also used for navigation. No notable abstraction of water from this river is expected.

ANNEX 2

LIST OF AGROCHEMICALS IMPORTED BY PROSSER, BELIZE (1993)

ANNEX 2

LIST OF AGROCHEMICALS IMPORTED BY PROSSER, BELIZE (1993)

HERBICIDES	FUNGICIDES	INSECTICIDES	FERTILIZERS	NUTRIENTS
Paraquat	Mancozeb	Methomyl	Sulphate of Potash	Bayfolan
2,4-D Amine	Copper Hydroxide	Bacillus Thuringienses	Muriate of Potash	Nutri-Leaf
Diuron	Benomyl	Diazinon	Sulpomag	Miracle Grow
Picloram	Copper Ammonium	Carbaryl	Urea	Microplex
Alachlor	Complex	Monocrotophos	Ammonium Sulphate	Basic Copper Sulphate
Hexazinone	Dichlofluanid	Ethion	Ammonium Nitrate	Tecmangan (Mm)
Quizalofop-Ethyl	Captan	Chloropyrifos	Diammonium Phosphate	Solubor (B)
Pendimethalin	Chlorathalonil	Perchlordecone	Potassium Nitrate	Zinc Sulphate
Atrazine	Matalaxyl	Bifenthrin	Osmocote	Zinc Chelate
Glyphosate	Propineb	Oxydemeton-Methyl	General Mixtures	Magnesium Sulphate
Ametryne	Copper Oxychloride	Parathion-Methyl	Citrus Mixtures	Iron Chelate
Simazine	Kasqamycin	Omethoate	Banana Mixtures	Manganese Chelate
Bentazone	Basic Copper	Propoxur	Special Formulae	Sulfur
Propanil	Flusilazol	Methamidophos		Manganoese Oxide
Thiobencarb	Tridemorph	Phoxim		Zinc Oxy Sulphate
Trifluralin		Fenbutatin Oxide		Iron Sulphate
Metulfuron-Methyl		Phenamiphos		Boron
Molinate		Disulfoton		Trace Element Mixes
		Cyfluthrin		
		Oxamyl		
		Streptomycin		
		Deltamethrin		
		Profenfos		
		Cypermetrin		
		Butylfos		
		Terbufos		

ANNEX 3

WATER QUALITY DATA COLLECTED FOR SELECTED RIVERS BY NATIONAL HYDROLOGICAL SERVICE, 1982-87

Belize Environmental Water Quality Monitoring Program

Catchment: Belize River

Station: Macal River at Rio On

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3^-	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
20-4-83	5	0	10	6		5	2	3	0.30	1.0	12	33	28.2	7			0.34
13-7-83	2	0	21	1		22	20	20	0.05	1.5		70	29.0	8.6			
24-2-84	0	0	10	0		4	2	2	0.05	10.0	12		22.7	7.1			0.62
17-3-84	5	0	7	0					0.10	0.0	4	30	24	6.6	2	0.74	0.48
11-11-87			14	5	36	22	6	16	0.00		1.25	50	25	7.6	0		
n	4	4	5	5		4	4	4	5	4	4	4	5	5	2	1	3
mean	3		12.4	2.4		13.2	7.5	5.7	0.10	3.1	7.31	45.7	25.8	7.4	1.0		0.48
median	2		10.0	1.0		5.0	2.0	2.0	0.05	1.0	4.0	33.0	25.0	7.1			0.34

Belize Environmental Water Quality Monitoring Program

Catchment: Belize River

Station: Benque Viejo

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
12-5-83	23	0	203	5		216	144	72	0.05	8	2	400	34	8			.
14-7-83	21	0	195	5		184	153	31	0	9	2	400		7.8			0.45
10-8-83	20	0	175	0		184	141	43	0.02	0	20	340	27	8			0.61
27-1-87		0	110	25		330	300	30	0.33	100			24	7.8			
12-11-87			179	5	114	199	151	48	0		0.6	400	25	8.1	0.03		
n	3	4	5	5	1	5	5	5	5	4	4	4	4	5	1	0	2
mean	21.3	0.0	172.4	8.0		222.6	177.8	44.8	0.08	29.2	6.15	385	27.5	7.94			0.53
median	20.0	0.0	179.0	5.0		199.0	151.0	43.0	0.03	8.0	2.0	400	25.0	8.00			

Belize Environmental Water Quality Monitoring Program

Catchment: Belize River

Station: Macal River at Cristo Rey

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	μmhos/cm	°C	units	mg/l	mg/l	m
20-4-83	17	0	85	9		101	17	84	0.05	17	0	210	27.5	8.1			1.2
8-9-83	6	0	33	0		36	28	8	0.05	6	65	92	25	7.4			2.23
17-7-84	13	0	161	0					0.05	25	4	97	24	6	2.1	0.6	1.79
10-11-87			81	7	46	89	70	19	0		0.95	220	25	7.7	0		
n	3	3	4	4	1	3	3	3	4	3	4	4	4	4	2	1	3
mean	12	0	90	4		75.3	37.0	37.0	0.04	16.0	17.5	154.7	25.4	7.3	1.05		1.74
median	13	0	83	3.5		62.5	22.5	13.5	0.05	11.5	2.5	153.5	25.0	7.5			1.50

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Belize Environmental Water Quality Monitoring Program

Catchment: Belize River

Station: Big Falls Ranch

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
14-4-83	27	0	173	8		458	358	100	0.1	250	10	750	29.5	8			
11-8-83	20	0	120	0		220	180	40	0	75	35	410	27.5	8		0.4	1.17
7-5-86		0	160	50		470	405	65	0.3	140			30	7.8			2.78
n	2	3	3	3		3	3	3	3	3	2	2	3	3		1	2
mean	23.5	0	151	19.3		382.7	314	68	0.1	155	22.5	580	29	7.93			1.98
median		0	160	8		458	358	65	0.1	140			29.5	8			

Belize Environmental Water Quality Monitoring Program

Catchment: Belize River

Station: Double Run

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
2-4-82		0	125	265		450	400	50	0.05	190	0.56	490	25	7.8			0.4
12-4-83	58	0		50		405	379	26	0.07	285	4	910	29	8			0.74
12-4-83		0	100	75		460	390	70			0.56	670	26	706			
9-5-83	28	0	166	39		544	425	119	0	315	0	1000	31	8			0.57
2-7-83	14	0	93	24		220	30	190	0.04	85	15	480	28	7.4			2.22
27-10-83	15	0	135	17		200	190	10	0	61	7	430	28	7.5			2.76
2-11-83	13	0	121	6		150	90	60	0.04	12	22	275	25	7.8			4.1
13-1-84	17	0	166	12		280	220	60	0.01	100	5	550		7.6			1.39
13-1-84	17	0	161	17		260	200	60	0.01	100	2	560		8			
3-11-84		0	148	22	56	301	248	53			2.2	640	26	8.2			
19-5-86			165	62		475	415	60	0.33				30	7.8			
n	7	10	10	11	1	11	11	11	9	8	10	10	9	11			7
mean	23.1	0	138	53.5		340.4	271.5	68.9	0.06	143.5	5.8	600.5	27.5	7.8			1.7
median	14	0	135	24		301	248	60	0.01	85	2.1	550	26	7.8			0.57

Belize Environmental Water Quality Monitoring Program

Catchment: Sibun River

Station: Freetown

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
5-5-83	15	0	120	241		226	141	85	0.02	48	4	1050	27	7.7			1.06
2-8-83	12	0	95	22		116	84	32	0.03	10	5	260	27.5	7.6			1.67
30-4-86		0	65	45		250	200	50	0.33	85			30	7.6			
4-11-87		0	92	54	62	149	110	39			12	450	26	7.42			
n	2	4	4	4	1	4	4	4	3	3	3	3	4	4			2
mean	13.5	0	93.0	90.5		185.2	133.7	51.5	0.13	47.7	7	586.7	27.6	7.58			1.37
median		0	93.5	49.5		187.5	125.5	44.5	0.03	48	5	450	27.2	7.6			

Belize Environmental Water Quality Monitoring Program

Catchment: North Stann Creek

Station: Middlesex

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
29-7-82		0	40	10		40	25	15				440	26.2	8			
28-9-82		0	40	15		25	15	10			0.89	60	27	8.2			
26-4-83	6	0	14	8		8	4	4	0.03	0	2	49	26.5	7.2			0.69
20-7-83	6	0	10	3		9	6	3	0.05	0.5	5	45	26	6.7			1.12
13-5-86		0	20	15		30	25	5	0.33	33.3			30	7.4			
22-10-87		0	13	3		14	12	2			0.65	62	24	8.6			
n	2	6	6	6		6	6	6	3	3	4	5	6	6			2
mean	6	0	22.8	9		21	14.5	6.5	0.14	11.28	2.14	131.2	26.6	7.7			0.91
median		0	17	9		19.5	13.5	4.5	0.03	0.5	1.44	60	26.3	7.7			

Belize Environmental Water Quality Monitoring Program

Catchment: Sittee River

Station: Kendall

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
28-4-83	8	0	30	7		27	19	8	0	0	4	81	29	71			0.76
n	1	1	1	1		1	1	1	1	1	1	1	1	1			1
mean																	
median																	0

Belize Environmental Water Quality Monitoring Program

Catchment: Moho River

Station: Station 15 (Blue Creek)

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
26-8-86		0	150	35		330	270	60	0.33	120			30	7.6			
n		1	1	1		1	1	1	1	1			1	1			
mean																	
median																	

Belize Environmental Water Quality Monitoring Program

Catchment: Moho River

Station: Station 17 (Jordan)

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
26-8-86		0	155	35		350	300	50	0.33	135			30	7.7			
n		1	1	1		1	1	1	1	1			1	1			
mean																	
median																	

Belize Environmental Water Quality Monitoring Program

Catchment: Rio Grande

Station: Big Fall

Date	Acidity	Alkalinity		Chloride	$CO_{2(aq)}$	Hardness			Iron	SO_4^{2-}	Turbidity	EC	Temp	pH	NO_3	PO_4^{3-}	Stage
Units	mg/l	P mg/l	T mg/l	mg/l	mg/l	total mg/l	Ca mg/l	Mg mg/l	mg/l	mg/l	FTU	µmhos/cm	°C	units	mg/l	mg/l	m
27-2-84	11	0	185	0		180	60	120	0.02	20	0			8.2			0.94
22-8-86		0	60	15		190	150	40	0.33	60			30	7.2			
n	1	2	2	2		2	2	2	2	2	1		1	2			1
mean		0	122.5	7.5		185	105	80	0.18	40				7.7			
median																	

ANNEX 4

LIST OF PEOPLE CONSULTED DURING THE COURSE OF THE PROJECT

Mr. Ismael Fabro
Chief Environmental Office
DOE

Mr. Martin Alegria
Environmental Officer
DOE

Mr. Albert Roches Jr.
Environmental Assistant
DOE

Gilbert Lenares
Chief Public Health Inspector
Public Health Bureau

Anthony Flowers
Chief Laboratory Technician
Water Quality Control Laboratory
Public Health Bureau

Stephanie Flowers
Laboratory Technician
Water Quality Control Laboratory
Public Health Bureau

Mr. John Link
Acting Chief Agricultural Officer
Ministry of Agriculture

Mr. Noel Jacobs
Aquaculture and Research Officer
Department of Fisheries

Mr. Denroy McCord
Chief Engineer
Belize WASA

Dr. Ram
Geology & Petroleum

Dr. Franklin
Brodies Chemicals

Ms. Barbara Tillet
Department of Housing and Planning

Mr. Albert Roches Sr.
Senior Public Health Inspector
Public Health Bureau

Mr. Will Heyman
Researcher
PACA Project

Mr. Arend van de Kerk
Country Engineer
PAHO

Mr. Eldridge Castillo
Technician
CZMU

Ms. Ineke van de Kerk
Volunteer
CZMU

Ms. Janet Gibson
Programme Coordinator
CZMU

Mr. Earl Green
Chief Forestry Officer
Department of Forestry

Dr. Ed Pulver
Agronomist
NARMAP

Dr. Lalit
Agronomist
NARMAP

Mr. Mark Nolan
Chief of Party
NARMAP

Dr. Bruce King
ODA

Mr. David Gray
LIC

Mr. Evan Cayetano
Belize Center for Environmental Studies

Ms. Lou Nicolait
Belize Center for Environmental Studies

Mr. Frank Panton
Chief Hydrologist
National Hydrological Service

Mr. Mario Fernandez
Pesticides Control Board

Mr. Rudolf Williams
Technician
National Hydrological Service

Mr. Kirk Johnson
Technician
National Hydrological Service

Mr. Carlos Fuller
Chief Meteorologist
National Meteorological Service

Mr. Raymond Harrison
Severn Trent International
FAO Consultant

Mr. Kenneth A. Gillett
Commissioner of Lands and Surveys

Mr. Carlos Santos
Director
I.D.E.A.S.

Ms. Noreen Fairweather
Head Technician
LIC

Ms. Jennifer Harrison
GIS Specialist
LIC

Dr. Vladimir Rathauser
Representative
PAHO

Mr. Carlos Guerra
Sanitary Engineer
Public Health Bureau

Mr. Mark Menzies
Laboratory Technician
WASA

Ms. Beverly Clare
Laboratory Technician
WASA

Mr. Lloyd Parriot
Chief Technician
Fisheries Laboratory
Department of Fisheries

Dr. Vic Gonzalez
Permanent Secretary
DOE

Mr. Richard Belisle
Forestry Department
Ministry of Natural Resources

Mr. Wilford Pascascio
Technician
Veterinary Laboratory
Ministry of Agriculture

Mr. Carlos Guerra
Environmental Technician
DOE

Mr. Agripino Cawich
Chief Administrator
NARMAP

Mr. Joseph McGann
Project Manager
USAID NARMAP

Correspondence with:

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Ing. Humberto Romero Alvarez
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Sr. Jorge Cabrera
Executive Secretary
Central American Commission for Environment and Development

Ing. Julio Burbano
Ingeniero del País
Oficina Sanitaria Panamericana
México

Ing. Mauricio Pardon
Ingeniero del País
Oficina Sanitaria Panamericana
Guatemala

Sr. Jacobo Finkelman
Representante
Oficina Sanitaria Panamericana
Guatemala

Dr. Filiberto Pérez Duarte
Director General de Salud Ambiental
Secretaría de Salud
México

ANNEX 5

ANNEX 5.1 LIST OF REVIEWERS OF DRAFT ENVIRONMENTAL WATER QUALITY MONITORING PROGRAM DOCUMENT AND DOE WRITTEN COMMENTS

The following persons took part in a briefing session in Belmopan on 26/1/1995 in which the consultants presented their draft report (DRAFT WQMPver3.2) and monitoring protocol to an assembled peer review group, receiving oral comments and suggestions on the previously distributed documents:

Anthony Flowers	Public Health Bureau	Water Analyst
Stephanie Gillet	Public Health Bureau	Water Analyst
Osmond Engleton	University College Belize	Consultant
Carlos R. Guerra	Public Health Bureau	Sanitary Engineer
Arend van de Kerk	PAHO/WHO	Country Engineer
Anthony Nicasio	HECOPAB	Director
Evan Caitano	Belize Centre for Env. Studies	Coordinator
Carlos Guerra	Department of Environment	Env. Technician
William Neal	Ministry of Natural Resources	Chief Ag. Off.
Mark Nolan	NARMAP	Chief of Party
Elridge Castillo	Fisheries Department	Research Asst.
Ismael Fabro	Department of Environment	Chief Env. Off.
Mario Fernandez	Pesticides Control Board	Secretary
Joseph McGann	USAID	Project Manager
E.D. Green	Ministry of Natural Resources	Chief For. Off.
W.F. Panton	National Hydrological Service	Chief Hydrologist

Note that a copy was also sent to Mr. Sylburn Arthurs at the Public Health Bureau.

Written comments were subsequently received from the DOE staff and Messrs. Caitano, Fernandez, Arthurs, van de Kerk and Castillo. The majority of these comments have been included in the finalized version of the report, including all of the requested modifications suggested by DOE as detailed to the consultants in their letter dated April 11, 1995.

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Ministry of Tourism and The Environment
Belmopan
Belize C.A.

11th April, 1995

Mr. Michael Lee
Department of Natural Resources
Escuela Agricola Panamericana
P. O. Box 93
Tegucigalpa, Honduras, C.A.

Dear Dr. Lee

Kindly accept my apologies for the delay in submitting our final comments to the draft document regarding the National Water Quality Monitoring Program for Belize.

Below please find the comments of the DOE in regards to its revision of this document. The comments are divided into two main sections:

Section A. General Comments

1. In general the DOE was very much satisfied with the draft report; both in format and content..

2. However, the DOE feels that the document could be improved on if high resolution/quality maps were included. A copy of the map used during the presentation could be provided in a side-pocket as an annex to the document.

3. The presentation was very effective in communicating to the participants the salient points and in obtaining from them their input and active participation during the review of the document.

4. In addition, based on comments of the participants at the review session, the DOE also gathered that most people felt that a thorough review of the existing situation had been carried out. They also felt comfortable and were in agreement with most of the recommendations included in the document.

Section B. Specific Comments

1. While the document contents was acceptable, we ask that you carefully review the document for accuracy, Mr. Evan Cayetano's and Mr. S. Arthurs submissions would be most helpful in this respect.

2. In addition, the DOE would have to agree with Mr. S. Arthurs of the Public Health Bureau on his recommendations for corrections.

3. Central Laboratory Issue: Personally I would prefer to see recommendations for the establishment of a national accredited Pollution Control Laboratory, either as a statutory board or as a privately-owned and operated laboratory that would meet the analytical needs of both the public and private sector ,in regards to soil, water and air quality analysis.

   Unlike Mr. S. Arthurs' position, I still maintain that there exists within various GOB agencies equipment which could form part of the equipment requirements of the National Laboratory; however I do support that these agencies need to have specific analytical equipment, in regards to their day to day monitoring activities.

4. Despite the various recommendations regarding the establishment of a Central Laboratory, we would appreciate receiving from you, your unbiased and professional recommendation on the direction and measures that Belize needs to take in order to fulfill its present and future analytical needs.

5. You may note that most of the agencies involved in the management and protection of Belize's water resources are in agreement for the need to improve and coordinate their monitoring objectives.

6. We are in agreement with the recommendations of Mr. S. Arthurs in regards to Data Management and the Water Quality Monitoring Program included in Page 2 of his submission.

We have not yet been able to receive comments from the Hydrology Department and the others. Therefore, we ask that you go ahead and finalize the document; any subsequent changes will be made later on since we will be getting from you copies of the document in diskette format WP 5.1/5.2 or WP 6.0.

Yours respectfully,

ISMAEL FABRO
CHIEF ENVIRONMENTAL OFFICER
DEPARTMENT OF THE ENVIRONMENT

ANNEX 5.2 PARTICIPANTS IN ENVIRONMENTAL WATER QUALITY MONITORING PROGRAM WATER QUALITY MONITORING PROTOCOL TRAINING

During the period June 6 to June 8, 1995 a training workshop was carried out by Dr. Michael D. Lee, Dr. John D. Stednick and assistant, David M. Gilbert in country. Participants of the workshop included 12 Belizean technicians from the Public Health Bureau (2), Central Farms laboratory, the Department of Environment (2), University College Belize (2), WASA, the Coastal Zone Management Unit, the Belize Centre for Environmental Studies and the National Hydrological Service (2) and three external participants; one recent Belizean graduate from a US university Masters program in watershed science and two U.S. volunteers associated with the Monkey Bay water quality project. Participants were selected jointly by the consultants and Mr. Ismael Fabro of DOE based on the likelihood of their future participation in coordinated and systematic water quality monitoring at a national level in Belize.

The training workshop adopted the following format:

Day 1

- Classroom instruction in velocity-area discharge measurement and introduction to standard field equipment
- Field instruction in velocity-area discharge measurement (Roaring Creek)
- Field instruction in gauging station design and installation and stage-discharge relationship determination (Banana Bank)

Day 2

- Classroom instruction in water quality theory and monitoring design
- Classroom instruction in water quality sampling procedures, quality assurance and quality control
- Classroom introduction to standard field equipment

Day 3

- Field instruction in water quality sampling and equipment use including streamside analysis of pH, temperature, electrical conductivity, dissolved oxygen, alkalinity and hardness (Roaring Creek)
- Field instruction in water quality sampling and equipment use including streamside analysis of pH, temperature, electrical conductivity, dissolved oxygen, alkalinity and hardness (Macal River at Cristo Rey)
- Field instruction in sample chain of command and laboratory management procedures (Central Farms laboratory)

During the first day instruction, Mr. Frank Panton, Chief Hydrological Officer at the Belize National Hydrological Service, participated as technical advisor in the classroom and field.

List of Participants

Anthony Flowers	Public Health Bureau	Water Analyst
Stephanie Gillet	Public Health Bureau	Water Analyst
Honorio Duran	University College Belize	Water Analyst
Carlos Guerra	Department of Environment	Env. Technician
Carl McCulloch	Belize Centre for Environmental Studies	Field Technician
Albert Roches Jr.	Department of Environment	Env. Technician
Elridge Castillo	Fisheries Department	Research Asst.
Rudolf Williams	National Hydrological Service	Sen. Hyd. Technician
Kirk Johnson	National Hydrological Service	Sen. Hyd. Technician
Steve Bejos	Central Farms laboratory	Soil Analyst
Mark Menzies	WASA	Water Analyst
Thippi Thiaganajam	University College Belize	Lecturer
Sharret Yearwood	No affiliation	Masters graduate
Betsy Nelson	Monkey Bay Project	Volunteer
Ginny Leikam	Monkey Bay Project	Student

ANNEX 6

MAPS OF RIVER CATCHMENTS AND LAND-USE

The following maps, are enclosed in the back cover of this report.

1. Watershed Boundaries, Roads and Rivers (produced by LIC GIS)

   2 Sheets
   Scale: 1:250,000

2. Topography

   2 Sheets
   Scale: 1:250,000

3. Land Use 1989/92 (produced by LIC GIS)

   2 Sheets (mosaic)
   Scale: 1:200,000

4. Proposed Environmental Water Quality Monitoring Program sampling sites

   1 Sheet
   Scale: approximately 1:1,250,000

5. Full extent of Belize's river catchment boundaries including Mexican and Guatemalan extensions

   1 Sheet
   Scale: approximately 1:1,250,000

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