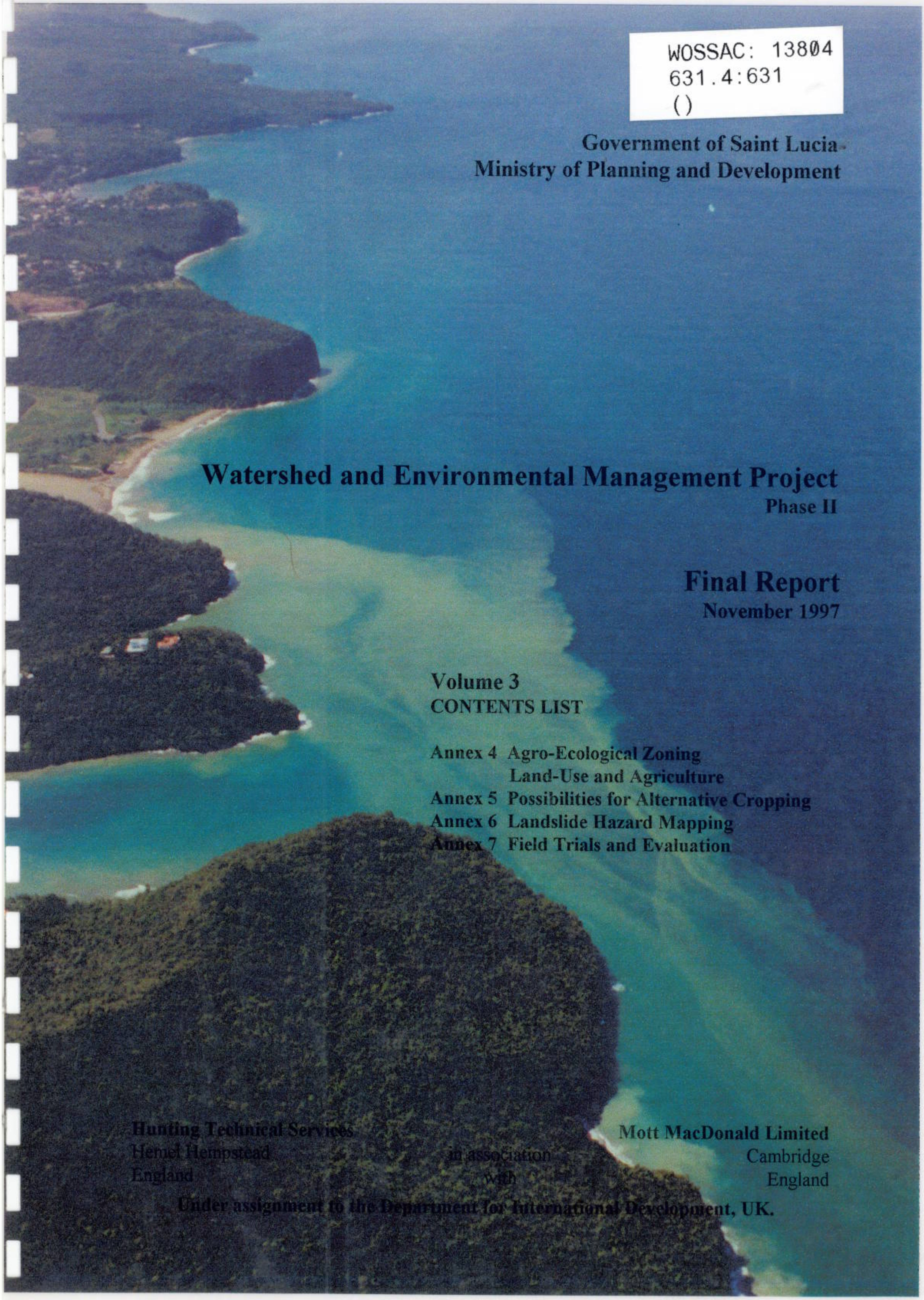


Government of Saint Lucia
Ministry of Planning and Development

Watershed and Environmental Management Project
Phase II

Final Report
November 1997

Volume 3
CONTENTS LIST

Hunting Technical Services
Hemel Hempstead
England

in association with

Mott MacDonald Limited
Cambridge
England

Under assignment to the Department for International Development, UK.

8809

WATERSHED AND ENVIRONMENTAL MANAGEMENT PROJECT
PHASE 2

VOLUME 3

CONTENTS

ACRONYMS AND ABBREVIATIONS

ACP	African, Caribbean and Pacific
AESD	Agricultural Engineering Services Division (of MAFF&E)
ADCU	Agricultural Diversification Coordinating Unit
API	Aerial Photography Interpretation
BDDC	British Development Division in the Caribbean
CAMMA	Canaries and Anse La Raye Marine Management Area
CANARI	Caribbean Natural Resources Institute
CAP	Chapter of GoSL Legislation
CARDI	Caribbean Agricultural Research and Development Institute
CBO	Community Based Organization
CEHI	Caribbean Environmental Health Institute
CIDA	Canadian International Development Agency
CPP	Community Participation Programme
CRM	Coastal Resource Management
CZM	Coastal Zone Management
CZMU	Coastal Zone Management Unit
DCA	Development Control Authority (of MP&D)
DFID	Department for International Development (UK)
EC$	Eastern Caribbean Dollars
EEZ	Exclusive Economic Zone
EH	Environmental Health
EIA	Environmental Impact Assessment
ENCORE	Environmental and Coastal Resource Project
EU	European Union
FAO	Food and Agricultural Organization (of UN)
GATT	General Agreement on Tariffs and Trade
GIS	Geographical Information System
GoSL	Government of St. Lucia
GTZ	German Technical Mission for Co-operation
HTS	Hunting Technical Services
ICZM	Integrated Coastal Zone Management
IFAD	International Fund for Agricultural Development
IoH	Institute of Hydrology (UK)
ISM	Island System Management
LCB	Land Conservation Board
LCDC	Land Development and Drainage Committee
MAFF&E	Ministry of Agriculture, Forestry, Fisheries and Environment
MCWT&PU	Ministry of Communications, Works, Transport and Public Utilities
MF,P, IS&PS	Ministry of Finance, Planning, Information Services and Public Services
MH,HS,FA&W	Ministry of Health, Human Services, Family Affair and Women
MM	Mott MacDonald
NEAP	National Environmental Action Plan
NEC	National Environmental Commission
NEMO	National Emergency Management Organisation
NGO	Non-Governmental Organisation
NRMU	Natural Resource Management Unit (of OECS)
OAS	Organisation of American States

OCDP	Orchard Crop Diversification Project
OECS	Organisation of Eastern Caribbean States
PM	Prime Minister
PPU	Physical Planning Unit (of MP&D)
PS	Permanent Secretary of GoSL Ministry
SFAD	Small Farmer Development Project
SFAP	Small Format Aerial Photography
SI	Statutory Instrument of GoSL Legislation
SLAA	St. Lucia Agriculturalist Association
SLBGA	St. Lucia Banana Growers Association
SLNT	St. Lucia National Trust
SMMA	Soufriere Marine Management Area
SWM	Solid Waste Management
TDB	Tourist Industry Development Board
TOT	Technical Operations Team
ToR	Terms of Reference
TRoPRo	Tropical Produce Support Project
TSD	Tropical Storm Debbie
USAID	United States Agency for International Development
USDA	United States Development of Agricultural
UWI	University of the West Indies
WASA	Water and Sewerage Authority
WIBDECO	Successor to WINBAN
WINBAN	Winward Island Banana Growers Association
WMO	World Meteorological Organisation
WTO	World Trade Organisation
WWF	World Wildlife Fund

Annex 4

Agro-Ecological Zoning, Land-Use And Agriculture

ANNEX 4

AGRO-ECOLOGICAL ZONING
LAND-USE AND AGRICULTURE

CONTENTS **PAGE**

AGRO-ECOLOGICAL ZONING

1.1. AGRO CLIMATIC ANALYSIS

1.1.1 Introduction:

Agro-ecological zoning is the essential precursor for scientific land evaluation. In this section an agro-ecological zoning map is derived, based on analysis of climatic parameters, lithology, soils, topography and resultant ecological / vegetation zones which can be mapped at a general scale of 1:100,000. These zones can then be related to crop suitability at a general level. However, within each of the zones local factors such as slope and soil depth may play a dominant role and these factors would determine the precise suitability rating for any given crop. These factors are only mappable at a more detailed scale, say 1:10,000 or 1:12,500.

1.1.2 Availability of Data:

Data is available from the AESD of the Ministry of Agriculture, and from the Meteorological Office of the Ministry of Communications & Works. Data is currently being collected from 18 automatic rainfall recorders, and 21 manually read rain-gauges; temperature data is collected from 7 stations, and the full range of agro-climatic data from a total of 4 stations. AESD is currently keeping computerised records on a daily basis, and publishes monthly and annual Agro-Met Bulletins.

Reliability of data is considered very variable (see discussion under meteorology / hydrology), with doubts being expressed on many stations. Non-recording during public holidays and weekends, flooding and damage to the recording equipment, changes in location of recording equipment all being significant problems. However, reliability of data post-1980, and particularly post-1985, would appear to be much better, and the installation of the current automatic gauges will now give a very good coverage of the Island.

1.1.3 Rainfall:

Mean annual rainfall varies from 1450mm at Hewanorra to some 3450mm at Edmund Forest, average monthly and annual figures being shown in **Table 1.1**. In general, rainfall is closely related to elevation, with the areas at sea-level in the extreme North and South of the island receiving the least rainfall (mostly cyclonic, with some convectional rainfall). Adjacent sea areas in the Eastern Caribbean receive a mean annual rainfall of some 900mm, this being cyclonic. The high interior of the island receives the most rainfall, with a high proportion of this being orographic. With the central water-divide being closer to the W than the E coasts, and this distance being only 8-9km, rainfall on the West coast tends to be higher than that on the East coast. (For larger islands - e.g. Martinique - with a higher water divide and longer leeward slope, a very marked rain shadow effect is seen, but this does not apply to St. Lucia and the smaller islands).

For all stations rainfall is consistently higher for the latter 6 months of the year, with maximum rainfalls being experienced in September to November. Mean monthly maxima vary from 190mm to 430 mm between the different stations. Conversely February to May are the driest months, with mean monthly minima varying between 45 and 170mm.

1.1.4 Potential Evapotranspiration:

Potential evapotranspiration (ETo) has been calculated by AESD from measurements on temperature, sunshine, windspeed, and relative humidity, and application of the Penman formula. ETo refers to the evapo-transpiration which would result from a short grass vegetation, with soil well supplied with water (i.e. near field capacity). Measurements on actual (Class A) evaporation have been made for five stations, and comparison can be made with Penman (ETo) values: generally Class A pan evaporation figures are some 15-30% above the ETo calculations.

ST LUCIA: AGRO-ECOLOGICAL ZONES

FIGURE 1.1

SCALE 1:100,000

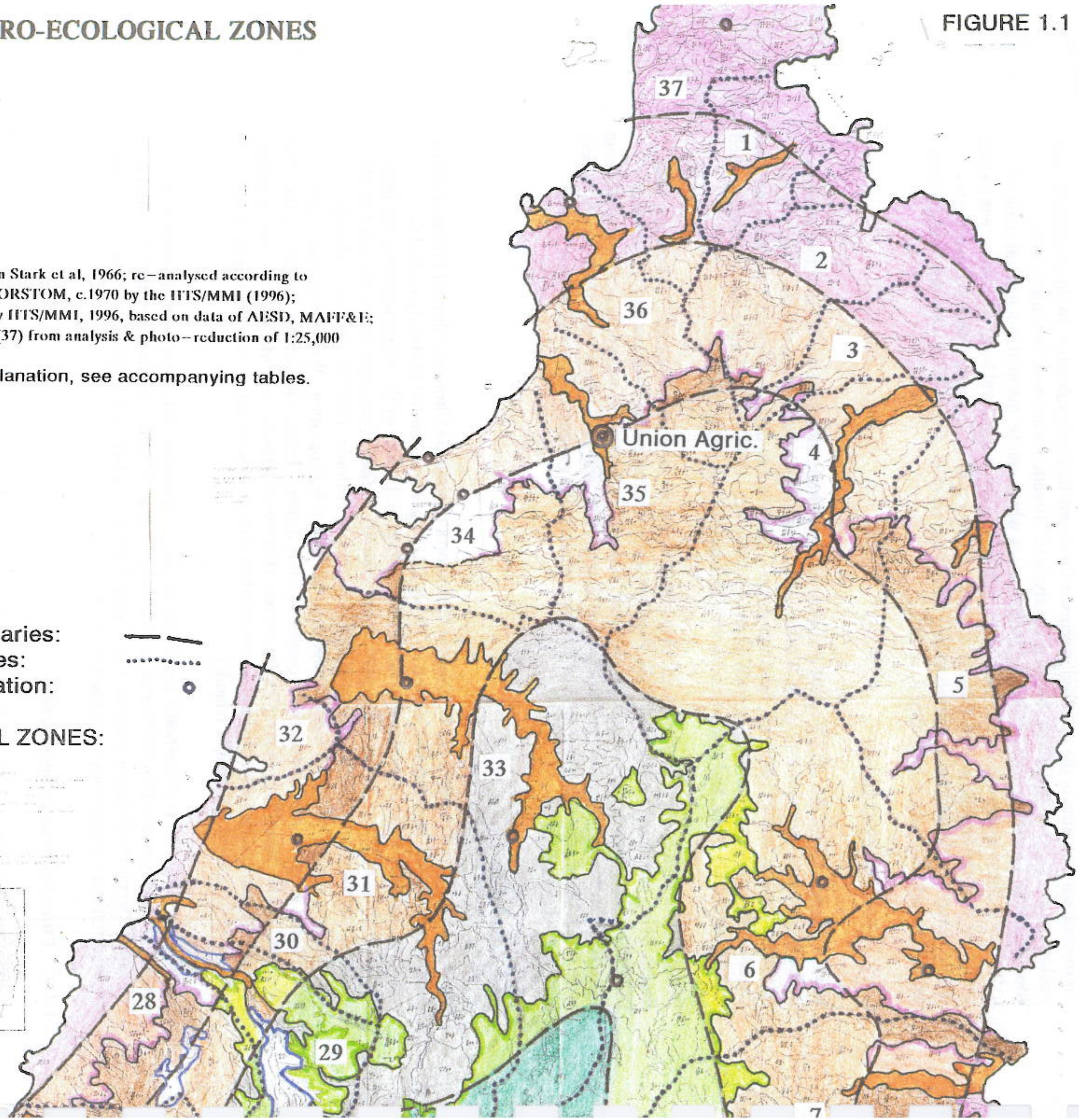
Compilation Note:
i)Soils boundaries based on Stark et al, 1966; re–analysed according to mineralogical divisions of ORSTOM, c.1970 by the HTS/MMI (1996);
ii)Agro–climatic zoning by HTS/MMI, 1996, based on data of AESD, MAFF&E;
iii)Watershed boundaries (37) from analysis & photo–reduction of 1:25,000 map by HTS/MMI.
For full legend & explanation, see accompanying tables.

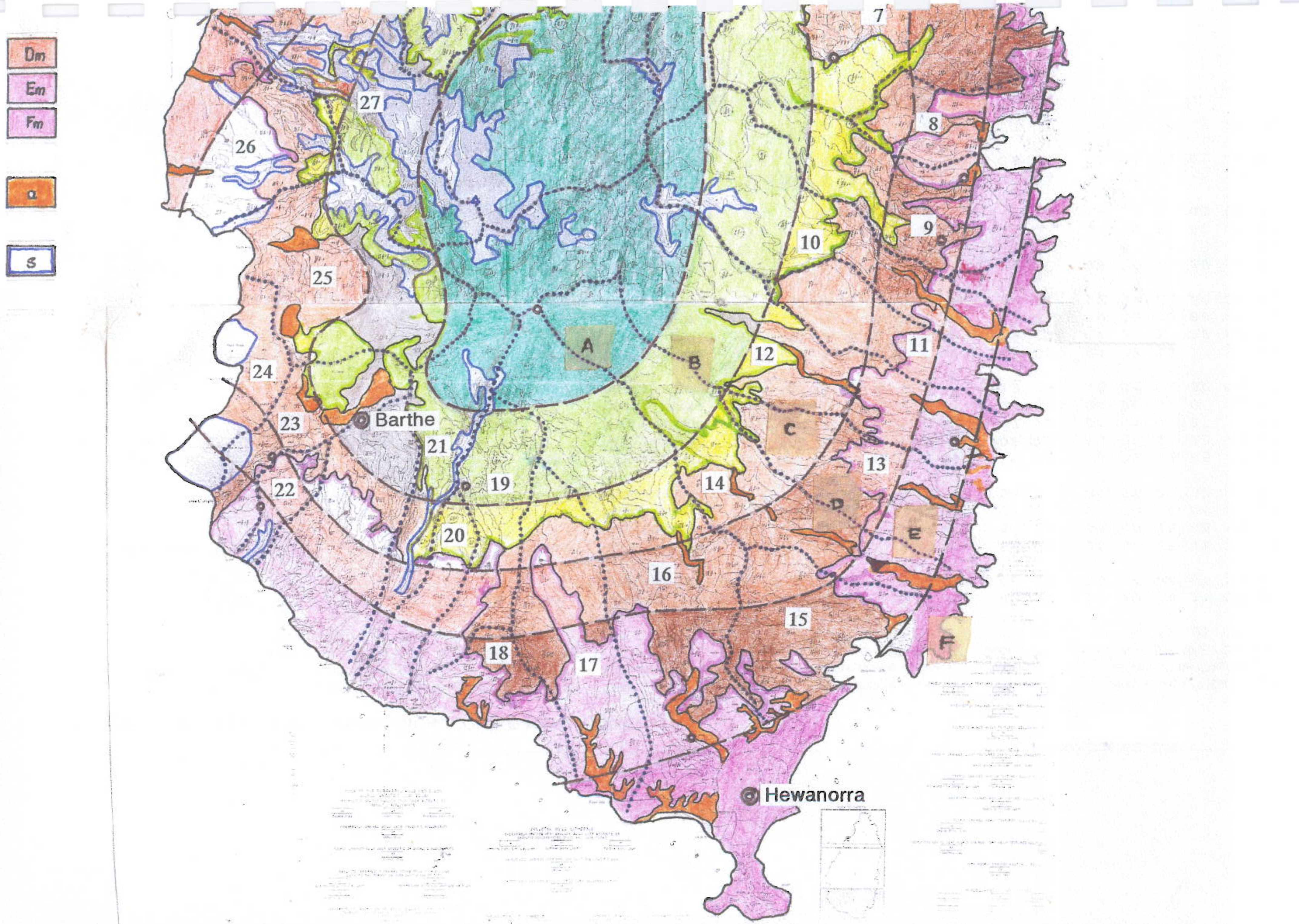
Climatic Zone boundaries:
Watershed boundaries:
Rainfall recording station:

AGRO–ECOLOGICAL ZONES:

Ah
Bh
Ch

Bk
Ck
Dk
Ek





Dm
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Fm
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26
27
A
B
C
D
E
F
Barthe
Hewanorra

FIGURE 1.1: ST LUCIA: AGRO-ECOLOGICAL ZONING MAP LEGEND

UNIT	Rainfall Range (mm)	Rainfall Range (ins)	Annl.Accum SoilMoisture Deficit (mm) (Rain-ETo)	Months with Rainfall <0.5 ETo	Months with Rainfall 0.5-0.99 ETo	Months with Rainfall 1.0-1.99 ETo	Months with Rainfall >2.0 ETo	Severity of Dry Season	Clay Mineralogy	Modal Elevation Range (feet)	Percentage of Unit Within Slope Classes 0-2	2-5	5-10	10-20	20-30	>30	Area (approx) '000ha	Area %	Percentage of Island Within Slope Classes 0-2	2-5	5-10	10-20	20-30	>30
																	61.6	100						
Ah	>3000	>120	0	0	0	4	8	None	Allophane	1000 - 3000	0	0	5	15	35	45	4.3	7.0	0.0	0.0	0.4	1.1	2.5	3.2
Ar									Rock & Debris	1000 - 3000	0	0	0	5	30	65	0.6	1.0	0.0	0.0	0.0	0.1	0.3	0.7
Bh	2500 -3000	100 -120	0	0	2	4	6	V.Weak	Allph-Kaol-Hall	700 - 1800	0	5	5	15	45	30	5.9	9.6	0.0	0.5	0.5	1.4	4.3	2.9
Bk									Kaol-Halloysite	300 - 900	0	5	5	15	35	40	3.4	5.5	0.0	0.3	0.3	0.8	1.9	2.2
Br									Rock & Debris	400 - 1800	0	0	0	10	30	60	0.7	1.1	0.0	0.0	0.0	0.1	0.3	0.7
Ba									Alluvium(mixed)	35 - 150	65	30	5	0	0	0	0.6	1.0	0.7	0.3	0.1	0.0	0.0	0.0
Ch	2000 -2500	80 -100	0-200	0	4	4	4	Weak	Halloysite(hydrd)	500 - 1000	5	5	10	20	40	20	2.6	4.2	0.2	0.2	0.4	0.8	1.7	0.8
Ck									Kaol-Halloysite	200 - 600	5	5	5	15	45	25	10.8	17.5	0.9	0.9	0.9	2.6	7.9	4.4
Cm									Mont-Kaol(shlw)	200 - 400	5	5	15	25	40	10	1.7	2.8	0.1	0.1	0.4	0.7	1.1	0.3
Cr									Rock & Debris	100 - 500	0	0	0	10	30	60	0.4	0.6	0.0	0.0	0.0	0.1	0.2	0.4
Ca									Alluvium(mixed)	15 - 50	70	30	0	0	0	0	1.2	1.9	1.3	0.6	0.0	0.0	0.0	0.0
Dk	1750 -2000	70 - 80	200-400	2	4	4	2	Moderate	Kaol-Halloysite	50 - 400	5	2	15	30	38	10	5.5	8.9	0.4	0.2	1.3	2.7	3.4	0.9
Dm									Mont-Kaol(shlw)	50 - 400	5	5	15	25	40	10	7.9	12.9	0.6	0.6	1.9	3.2	5.2	1.3
Dr									Rock & Debris	50 - 400	0	0	0	10	30	60	0.2	0.4	0.0	0.0	0.0	0.0	0.1	0.2
Da									Alluvium(mixed)	3 - 40	85	15	0	0	0	0	1.6	2.6	2.2	0.4	0.0	0.0	0.0	0.0
Em	1500 -1750	60 - 70	400-600	4	4	4	0	Severe	Mont-Kaol(shlw)	20 - 300	5	5	15	40	30	5	7.9	12.9	0.6	0.6	1.9	5.2	3.9	0.6
Ek									Kaol-Halloysite	20 - 300	5	5	15	40	35	0	2.0	3.2	0.2	0.2	0.5	1.3	1.1	0.0
Er									Rock & Debris	20 - 300	0	0	0	5	30	65	0.2	0.3	0.0	0.0	0.0	0.0	0.1	0.2
Ea									Alluvium(mixed)	3 - 40	85	15	0	0	0	0	1.0	1.6	1.4	0.2	0.0	0.0	0.0	0.0
Fm	<1500	<60	>600	6	2	4	0	V.Severe	Montm(shallow)	10 - 200	5	5	30	35	20	5	2.7	4.4	0.2	0.2	1.3	1.5	0.9	0.2
Fa									Alluvium(mixed)	3 - 20	85	15	0	0	0	0	0.2	0.4	0.3	0.1	0.0	0.0	0.0	0.0
																			9	5	10	22	35	19

FIG.1.1(CONT): ST LUCIA: AGRO–ECOLOGICAL ZONING MAP: LAND SUITABILITY RATINGS FOR MAJOR LAND UTILISATION TYPES

UNIT	SUITABILITY RATINGS FOR BEST 35% OF UNIT FOR MAJOR LAND UTILIZATION TYPES										OPTIMUM LAND USE
	Banana	Coconut	Cocoa	Minor Tree–crops	Cashew	Natural Vegetation (Forest)	Comm–ercial Forestry	Grazing	Annual Crops	Cons–truction	
Ah	N2cst	N2cst	N2cst	S3cst	N2cst	S1	S3ct	N2ct	N2cst	N2st	Natural vegetation (forest) only: watershed protection–wildlife habitat.
Ar	N2cst	N2cst	N2cst	N2cst	N2cst	S3st	N2cst	N2ct	N2cst	N2st	Natural vegetation (forest) only: watershed protection–wildlife habitat.
Bh	S3cst	S3cst	S3cst	S2ct	N2cst	S1	S2ct	S3ct	N2cst	N2st	Minor Treecrops: bananas on slopes < 25deg
Bk	S3cst	S3cst	S3cst	S2ct	N2cst	S1	S2ct	S3ct	N2cst	N2st	Minor Treecrops: bananas on slopes < 25deg
Br	N2cst	N2cst	N2cst	N2cst	N2cst	S3st	N2cst	N2cst	N2cst	N2st	Natural vegetation (forest) only: watershed protection–wildlife habitat.
Ba	S2c:	S3csf	S3cdf	S2cf	N2cst	S1	S2ct	S2cf	S2f	N2sf	Bananas; some annual crops.
Ch	S2t	S2t	S2t	S2ct	S3ct	S1	S1	S2cst	S3cst	S3st	Bananas on slopes <25deg; minor treecrops on slopes over 25 deg.
Ck	S2st	S2st	S2st	S2ct	S3ct	S1	S1	S2cst	S3cst	S3st	Bananas on slopes <25deg; minor treecrops on slopes over 25 deg.
Cm	S2st	S2st	S3st	S2ct	S3ct	S1	S1	S2cst	S3cst	S3st	Bananas on slopes <25deg; minor treecrops on slopes over 25 deg.
Cr	N2cst	N2cst	N2cst	N2cst	N2cst	S3st	N2cst	N2cst	N2cst	N2st	Natural vegetation (forest) only: watershed protection–wildlife habitat.
Ca	S2f	S2csf	S2cdf	S2cf	S3ct	S1	S1	S2cf	S2cf	N2sf	Bananas; some annual crops.
Dk	S2ct	S2cst	S2ct	S2ct	S2c	S1	S1	S1	S3cst	S2st	Bananas on slopes <25deg; minor treecrops on slopes over 25 deg.
Dm	S3cst	S2cst	S3cst	S3cst	S2c	S1	S2c	S2cs	S3cst	S2st	Bananas on slopes <25deg; minor treecrops on slopes over 25 deg.
Dr	N2cst	N2cst	N2cst	N2cst	N2cst	S3st	N2cst	N2cst	N2cst	N2st	Natural vegetation (forest) only: watershed protection–wildlife habitat.
Da	S2cf	S2sf	S3cdf	S2cf	S2c	S1	S1	S2cf	S2cf	N2sf	Bananas; some annual crops.
Em	N2cs	S3cst	N2cs	N2cs	S2c	S1	S2c	S2cs	S3st	S1	Cashew; Landscaped construction
Ek	S3cs	S2cst	S3cs	S3cs	S2c	S1	S2c	S3cs	S3st	S1	Cashew; Landscaped construction
Er	N2cst	N2cst	N2cst	N2cst	N2cst	S3st	N2cst	N2cst	N2cst	N2st	Natural vegetation (forest) only: watershed protection–wildlife habitat.
Ea	S3cf	S3sf	N2cdf	S3csf	S2c	S1	S2c	S2cf	S3cf	N2sf	Bananas; some annual crops (irrigated).
Fm	N2cs	N2cs	N2cs	N2cs	S3c	S1	S3cs	S3cs	S3st	S1	Landscaped construction
Fa	N2cf	S3csf	N2cf	S3csf	S2c	S1	S2c	S3cf	S3cf	N2sf	Some annual crops (irrigated).

S1, S2, S3, N2: Highly, moderately, marginally suitable, permanently not suitable respectively. Subclass limitations: c,s,t,f: climate, soil, topography, flooding.

TABLE 1.1: MEAN MONTHLY RAINFALL TO 1995 (mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	PERIOD	Years
La Caye	91	59	86	80	119	121	158	198	230	239	253	118	1752	75 – 95	21
Cardi	128	86	118	95	177	118	169	254	310	241	297	112	2105	86 – 95	10
Errand	137	85	122	87	180	148	184	243	368	295	327	136	2312	87 – 95	9
Mamiku	96	54	87	86	93	110	131	192	263	223	225	108	1669	85 – 95	11
Patience	107	72	77	88	116	136	172	221	251	271	283	140	1933	75 – 95	21
Troumasse'	74	48	73	52	83	105	148	168	231	192	230	77	1482	83 – 95	13
Mahaut	169	110	150	101	155	180	237	263	357	317	329	170	2537	84 – 95	12
Edmund Forest	229	188	190	173	223	273	337	347	431	406	424	220	3439	79 – 95	17
Hewanorra	86	53	69	52	82	96	164	155	239	176	196	86	1452	82 – 95	14
Beausejour	87	47	60	61	85	110	167	177	207	194	188	103	1485	75 – 95	21
Saltibus	177	116	149	108	130	201	248	281	391	312	390	170	2673	85 – 95	11
Delcer	95	53	63	47	84	140	172	168	246	210	228	84	1591	83 – 95	13
Union Vale	110	65	80	64	81	165	183	240	314	240	257	104	1903	85 – 95	11
Barthe Nursery	159	123	116	101	136	203	262	299	317	321	337	174	2547	75 – 95	21
Winban	131	75	94	79	102	154	227	266	295	241	270	147	2080	75 – 95	21
Soucis	136	73	88	88	115	163	215	288	299	282	268	148	2164	75 – 95	21
Bexon	164	115	151	89	130	187	235	325	426	286	362	162	2630	86 – 95	10
Barre de L'isle	145	102	133	117	180	158	233	284	310	325	347	169	2504	75 – 95	21
Gov't. House	104	72	86	85	132	165	224	263	283	231	240	108	1992	75 – 95	21
George V Park	117	69	86	76	122	145	179	249	296	237	280	118	1973	85 – 95	11
Vigie	110	68	73	68	109	141	188	251	257	243	234	134	1876	75 – 95	21
Union Agr. St.	125	82	92	91	123	150	200	259	269	266	285	138	2080	75 – 95	21
Trouya	91	58	65	76	113	136	180	208	225	206	240	101	1698	75 – 95	21
Cap Estate	63	46	50	52	97	95	121	168	179	182	191	89	1333	75 – 95	21
MEAN,ALL STNS	122	80	98	84	124	150	197	240	291	256	278	130	2050		

TABLE 1.2: MEAN MONTHLY DEFICIT / SURPLUS OF RAINFALL minus POTENTIAL EVAPOTRANSPIRATION (mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX. ACCUM. DEFICIT
La Caye	−28	−68	−62	−77	−48	−31	−5	54	102	115	144	11	−319
Cardi	12	−35	−24	−56	14	−33	12	114	185	114	183	8	−135
Errand	22	−28	−10	−53	28	7	38	113	253	177	221	40	−91
Mamiku	−23	−73	−60	−71	−74	−42	−31	47	135	100	116	1	−374
Patience	−12	−55	−71	−69	−51	−17	10	76	123	147	174	33	−275
Troumasse'	−65	−94	−95	−126	−108	−102	59	18	109	54	97	−34	−624
Mahaut	86	13	28	−18	11	61	109	150	237	215	241	92	−18
Edmund Forest	146	91	68	54	79	154	209	234	312	304	336	142	
Hewanorra	−59	−97	−108	−135	−119	−123	−33	−3	110	31	56	−31	−707
Beausejour	−47	−91	−102	−111	−100	−91	−14	32	89	60	60	−5	−562
Saltibus	94	19	27	−11	−14	82	121	168	272	210	302	92	−25
Delcer	−30	−76	−89	−114	−88	−48	3	33	136	85	108	−16	−461
Union Vale	9	−54	−70	−82	−95	18	27	101	167	115	149	8	−301
Barthe Nursery	76	26	−6	−18	−8	84	134	186	198	219	249	96	−32
Winban	13	−49	−50	−79	−71	5	63	122	168	119	163	42	−250
Soucis	18	−51	−56	−70	−58	14	51	145	172	160	161	43	−234
Bexon	88	26	39	−20	−3	77	118	221	316	193	281	90	−23
Barre de L'isle	62	5	11	−2	36	39	105	171	191	223	259	91	−2
Gov't. House	−7	−48	−53	−63	−25	22	71	127	163	115	138	7	−196
George V Park	6	−51	−53	−71	−35	1	26	113	176	121	177	18	−210
Vigie	−9	−59	−75	−89	−58	−12	25	107	129	119	125	27	−301
Union Agr. St.	6	−45	−56	−66	−44	−2	38	114	141	143	176	31	−213
Trouya	−41	−80	−98	−97	−71	−50	1	57	96	71	115	−11	−448
Cap Estate	−82	−104	−126	−136	−104	−123	−76	11	50	37	51	−27	−779

Source: Analysis by HTS based on primary data from AESD, Ministry of Agriculture.

File:AAMETGEN.wk3

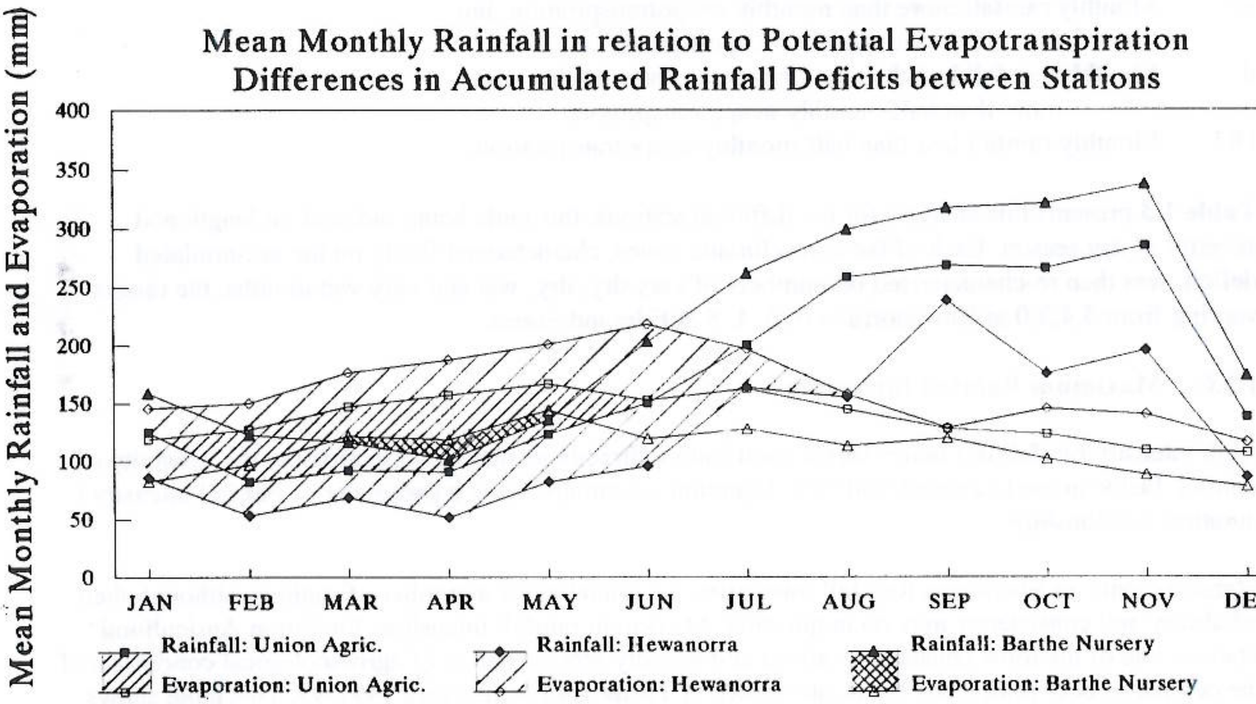
Total annual potential evapotranspiration (ETo) values vary from 1310mm in the central mountains to over 1960mm at Hewanorra. Monthly maximum ETo values are seen during the latter part of the drier season (May), with values varying from 133 to 201mm/month. Monthly minimum values are seen in January, with a range of 83 to 146mm respectively.

1.1.5 Deficits or Surpluses of Rainfall minus Potential Evapo-transpiration

Monthly deficits or surpluses of rainfall minus evapotranspiration are shown in **Table 1.2** for the above stations. Mean monthly accumulated deficits over consecutive months are summed and are shown in the last column in that table.

Results show that accumulated deficits vary from zero (central mountainous part of island) to more than 700 mm (coastal regions in extreme north and south). Accumulated deficits represent perhaps the most important parameter for agro-climatic zonation, and thus iso-lines at 0, 200, 400, 600 and 700 mm deficits are plotted on the island map separating Zones A and B, C, D, E and F respectively (see **Figure 1.1**).

Figure 1.2



Note: deficits of rainfall – evapotranspiration are shaded for respective stations

Figure 1.2 plots these accumulated deficits for three stations:

- Hewanorra, representative of the driest part of the island (Zone F),
- Barthe Nursery, one of the wetter stations (Zone B), and
- Union Agricultural Station, representative of the intermediate zone (between Zones C and D).

The mean deficit for Hewanorra is far in excess of the available water holding capacity (AWC) of even a very high-AWC soil, and thus the soil profile would be at wilting point for several months in an average dry season. The surplus of rainfall over evapotranspiration in the wet season also will only just return the profile to field capacity before the next dry season begins. Net leaching of plant nutrients will thus be relatively small, for an average year. With irrigation, this land would show high capability ratings for many crops. However, for rainfed cropping the land would be Not Suitable for most perennial crops, but probably suitable for short-season seasonal crops.

The mean deficit for Barthe Nursery, by contrast, is very mild, and there would be no retardation of crop or forest growth in an average season. However, the vast surplus of rainfall over evapotranspiration in the wet season would lead to massive leaching of plant nutrients, to surface wash and mass movements, and to problems associated with excessive humidity and low sunshine. The suitability rating for many crops is thus low for this zone.

The mean deficit for Union Agricultural Station is intermediate between the above two stations, with a large soil moisture deficit developing in most seasons (c200mm), and drying out both A and B-horizons in an average soil profile. Crop growth would be retarded significantly during 1-2 months in an average year. During the wet season the soil would be brought to field capacity within the first half of the season, and net leaching would result in the second half. Analysis of data for this station is covered in much greater detail in Section 1.2.4 below.

An analysis of wet and dry months for the different stations was then undertaken, with months being put into four classes:

WW: Monthly rainfall more than twice monthly evapotranspiration;
w: Monthly rainfall more than monthly evapotranspiration, but less than twice monthly evapotranspiration.
d: Monthly rainfall less than monthly evapotranspiration, but more than half monthly evapotranspiration.
DD: Monthly rainfall less than half monthly evapotranspiration;

Table 1.3 presents this analysis for the different stations, this table being indexed on length and severity of dry season. Each of the agro-climatic zones, characterised firstly on the accumulated deficit, was then re-characterised on numbers of very dry, dry, wet and very wet months, the ranges varying from 5,4,3,0 at Hewanorra to 0, 0, 4, 8 at Edmund Forest.

1.1.6 Maximum Rainfall Intensities

High intensity rainfall is a major factor contributing directly to surface wash erosion, the 'erosivity of rainfall' factor in the Universal Soil Loss Equation essentially being a parameter of rainfall intensity / duration relationships.

Measurements on Maximum Rainfall Intensities are available for a number of stations, although their reliability and consistency may be in question. Maximum rainfall intensities for Union Agricultural Station, one of the most consistent stations and broadly representative of agro-ecological conditions of the centres of both pilot watersheds, are shown in **Table 1.4** for the years 1991-95. This table shows maximum rainfalls (mm) and maximum rainfall intensities (mm/hour and mm/min) for different durations over the range 5 minutes to 12 hours. The last sections of this table show three sets of measurements: the mean monthly maximum intensity for the 12 months of 1995; the maximum intensity for the years 91-95 excluding the TSD event; and finally the maximum intensity applying to the TSD event itself. The large differences between these measurements should be noted.

Rainfall intensities at Union Agricultural Station for 15-mminute increments are shown in **Fig.1.3.** These can then be compared with infiltration rates measured in the field under different regimes of banana trash management (see Section 1.2.3 in this Annex, and detailed notes in Annex 7).

To cope with the erosivity factor of rainfall the soil surface should show infiltration rates in excess of 50mm in 1 hour (>0.8mm/min), 70mm in 2 hours ((0.6mm/min) and 120mm in 3 hours (0.4mm/min). Rainfall Intensity Rates over short periods (5minutes) can reach 2.3 mm/minute. These intensities are the maximum that can be expected in most years (i.e. outside hurricane and tropical storm events).

TABLE 1.3: ANALYSIS OF WET AND DRY MONTHS BASED ON MONTHLY AVERAGES OVER 10–20 YEAR PERIOD

STATION:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	No.of Months in Classes: DD	d	w	WW	Agro–Climate Zone
Edmund Forest	WW	w	w	w	w	WW	WW	WW	WW	WW	WW	WW	0	0	4	8	A
Bexon	WW	w	w	d	d	w	WW	WW	WW	WW	WW	WW	0	2	3	7	B
Mahaut	WW	w	w	d	w	w	w	WW	WW	WW	WW	WW	0	1	5	6	B
Saltibus	WW	w	w	d	d	w	w	WW	WW	WW	WW	WW	0	2	4	6	B
Barthe Nursery	w	w	d	d	d	w	WW	WW	WW	WW	WW	WW	0	3	3	6	B
Barre de L'isle	w	w	w	d	w	w	w	WW	WW	WW	WW	WW	0	1	6	5	B
Soucis	w	d	d	d	d	w	w	WW	WW	WW	WW	w	0	4	4	4	C
Errand	w	d	d	d	w	w	w	w	WW	WW	WW	w	0	3	6	3	C
George V Park	w	d	d	d	d	w	w	w	WW	WW	WW	w	0	4	5	3	C
Cardi	w	d	d	d	w	d	w	w	WW	w	WW	w	0	4	6	2	C
Gov't. House	d	d	d	d	d	w	w	w	WW	w	WW	w	0	5	5	2	C–D
Union Agr. St.	w	d	d	d	d	d	w	w	WW	WW	WW	w	0	5	4	3	C–D
Union Vale	w	d	d	DD	DD	w	w	w	WW	w	WW	w	2	2	6	2	D
Winban	w	d	d	DD	d	w	w	w	WW	w	WW	w	1	3	6	2	D
Patience	d	d	d	d	d	d	w	w	w	WW	WW	w	0	6	4	2	D
Vigie	d	d	DD	DD	d	d	w	w	WW	w	WW	w	2	4	4	2	D
Mamiku	d	DD	d	d	d	d	d	w	WW	w	WW	w	1	6	3	2	D
La Caye	d	DD	d	d	d	d	d	w	w	w	WW	w	1	6	4	1	D
Delcer	d	DD	DD	DD	DD	d	w	w	WW	w	w	d	4	3	4	1	E
Troumasse'	d	DD	DD	DD	DD	d	w	w	w	w	w	d	4	3	5	0	E
Trouya	d	DD	DD	DD	d	d	w	w	w	w	w	d	3	4	5	0	E
Beausejour	d	DD	DD	DD	DD	d	d	w	w	w	w	d	4	4	4	0	E
Cap Estate	DD	DD	DD	DD	DD	DD	d	w	w	w	w	d	6	2	4	0	F
Hewanorra	d	DD	DD	DD	DD	DD	d	d	w	w	w	d	5	4	3	0	F

KEY:

Rainfall>2* ETo		Very Wet	WW
Rainfall>ETo	Rainfall<2* ETo	Wet	w
Rainfall>0.5* ETo	Rainfall<ETo	Dry	d
Rainfall<0.5* ETo		Very Dry	DD

Source: Analysis by Hunting Technical Services, Nov.1996, based on primary data from AESD, Ministry of Agriculture.

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TABLE 1.4: MAXIMUM RAINFALL INTENSITIES FOR UNION AGRIC.STATION

File:RNINTUNI.wk3

Year/Event	Maximum Rainfall Depths (mm) for durations of:								
	5	10	15	30	1	2	3	6	12
	mins				hours				
1991	7.5	14.6	17.0	28.3	37.5	38.3	41.3	50.0	85.1
1992	12.0	15.0	25.0	30.0	30.0	66.7	69.8	91.2	110.0
1993	8.0	12.0	17.5	30.0	46.0	52.0	53.5	62.5	77.0
1994	7.6	11.7	13.8	21.5	24.0	37.2		46.4	46.5
1995	9.5	11.7	21.5	27.3	34.3	44.8		66.2	71.2
Debbie	13.8	15.0	24.4	48.0	90.0	160.8		260.6	269.5

Year/Event	Maximum Rainfall Intensity (mm/hour) for durations of:								
	5	10	15	30	1	2	3	6	12
	mins				hours				
1991	90.0	87.6	68.0	56.6	37.5	19.2	13.8	8.3	7.1
1992	144.0	90.0	100.0	60.0	30.0	33.4	23.3	15.2	9.2
1993	96.0	72.0	70.0	60.0	46.0	26.0	17.8	10.4	6.4
1994	91.2	70.2	55.2	43.0	24.0	18.6		7.7	3.9
1995	114.0	70.2	86.0	54.6	34.3	22.4		11.0	5.9
Debbie	165.6	90.0	97.6	96.0	90.0	80.4		43.4	22.5

MAXIMUM RAINFALL INTENSITIES FOR DIFFERENT MONTHS OF 1995:

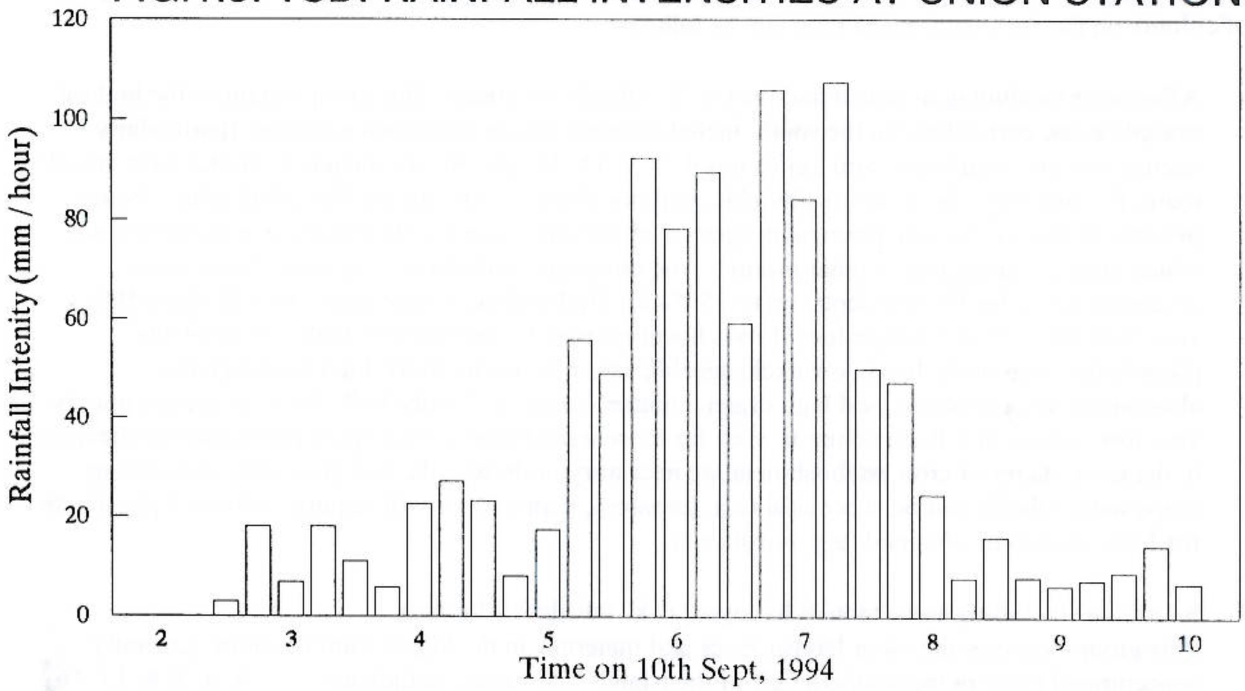
Month	Maximum Rainfall Depths (mm) for durations of:								
	5	10	15	30	1	2	3	6	12
	mins				hours				
JAN	7.4	9.4	11.4	24.3	28.8	36.6		36.8	36.9
FEB	2.9	2.9	2.9	4.5	5.5	5.9		6.7	7.6
MAR	6.2	8.7	9.7	14.8	22.6	26.6		32.2	37.2
APR	9.5	9.9	12.0	19.3	30.8	31.9		49.2	60.9
MAY	7.0	8.0	10.4	18.1	19.0	23.2		53.5	64.5
JUN	6.3	10.5	20.0	26.6	29.6	30.9		42.1	54.4
JUL	5.0	7.0	8.2	10.2	10.7	12.9		14.4	24.2
AUG	6.5	9.5	21.5	27.3	34.3	44.8		66.2	71.2
SEP	5.5	8.7	12.9	13.1	19.1	34.2		37.4	38.2
OCT	5.4	7.5	12.9	16.2	20.7	30.7		43.4	49.1
NOV	7.4	11.7	15.9	23.3	27.9	30.2		30.2	30.8
DEC	7.4	9.5	13.5	13.5	13.5	13.5		14.0	16.0
MEAN (95)	6.4	8.6	12.6	17.6	21.9	26.8		35.5	40.9
MAX (95)	9.5	11.7	21.5	27.3	34.3	44.8		66.2	71.2
Time(mins)	5	10	15	30	60	120	180	360	720
MeanMo.Max. Intensity (95) (mm/min)	1.3	0.9	0.8	0.6	0.4	0.2		0.1	0.1
Max.Intensity (mm/min)(91–95)	2.4	1.5	1.7	1.0	0.8	0.6	0.4	0.3	0.2
Debbie Ints. (mm/min)	2.8	1.5	1.6	1.6	1.5	1.3		0.7	0.4
MeanMo.Max. Intensity (95) (mm)	6	9	13	18	22	27		36	41
Max.Intensity (mm)(91–95)	12	15	25	30	46	67	70	91	110
Debbie Ints. (mm)	14	15	24	48	90	161		261	270

Source: Annual Agromet Bulletin, 1995. AESD, Min. of Agric, St Lucia

Note: Figures for'94 exclude intensities of TSD,recorded here separately.

During TSD rainfall intensities reached almost 3mm/minute (i.e. 180mm / hour) for very short periods (5 minutes), falling to 1.5mm/minute (90mm/hour) for longer periods extending up to 1 hour.

FIG.1.3: TSD: RAINFALL INTENSITIES AT UNION STATION



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1.2. SOIL CONDITIONS

1.2.1. Availability of Data:

Soils in the island were studied in the early 60s by Stark et al.
Mapping was undertaken at 1:25,000 scale, most of the mapping units being complexes of two Soil Series, commonly of highly contrasting characteristics. Some 52 Soil Series, and 9 Miscellaneous Land Types were defined. Mapping units reflected also Slope Categories (with divisions at 0-2, 2-5, 5-10, 10-20, 20-30, and >30degrees); Erosion Categories (zero erosion to Grade 5 [severe erosion]), and stoniness (6 classes). Soil Series were described and discussed. Analysis of some 45 profiles were presented, covering all significant soil series. Analysis covered pH, CEC, TEB, exchangeable cations, C, N, P2O5. Soil Units were placed within a 7-class Land Capability System (Steele et al, 1954, this system being broadly similar to the 8-class USDA system).

Subsequent studies have been on:

- soil correlation and classification (Guy Smith, 1981), following very thorough work done on pedology and soil mineralogy in similar environments in the two French Islands (Colmet-Daage, Gautheyrou J and M, Cahier ORSTOM Ser.Pedologie 1968-75),
- soil run-off in relation to rainfall (Norville, 1988-90);
- soil stability (Ahmad & Sheng, 1988) followed by application by Polius, 1989;
- short term studies by WINBAN on such topics as the value of banana trash, soil acidification.

2.2.2 Soil Characteristics

Table 1.5 summarises characteristics of the 52 soil types as described by Stark et al. To this table the consultants have added the USDA classification, the probable mineralogy class (following correlation with similar soils in the French Islands) and a re-working of the analytical data, to present data for topsoil samples of the respective units. Mineralogical groupings, shown by small letters and groupings of colours on the Agro-ecological map, are as follows:

- **Allophane** (including hydrated halloysite): 'h': (shades of green). This group occupies the highest rainfall areas, particularly in the south, including areas where recent ash additions (particularly dacitic ash) are significant. Soil Series nos 4, 5, 9, 11, 14, 26, 36, are included, and textures are silt loam, through silty clay loam to silty clay, with the characteristic greasy feal of allophane being present. However, the true physical properties of allophane are poorly represented by these soils, which appear transitional to other groups. True allophane soils show very high 15-bar water contents (100% for Dystrandepts; up to 350% for Hydrandepts); very high CECs (160me/100g); very high anion fixation capacities (total phosphate may be moderate to high, but available phosphate is extremely low); low exchangeable cation concentrations; high exchangeable aluminium concentrations, and high organic matter contents. Air-dry bulk densities are commonly very low: values of 1.0 are common even for these transitional soils. Higher phosphate fertilization in the early stages of crop establishment are necessary in these soils, and phosphate demanding crops will probably not be successful (e.g. tomatoes, peppers), or will require additional phosphate for full yields to be obtained (e.g. breadfruit).

- **Kaolinite** (including some tabular halloysite): 'k': (shades of brown).
  This group occupies the older landsurfaces and materials in the higher rainfall zones, generally concentrated more in the northern half of the island. Soil Series include nos 1, 2, 3, 6, 7, 8, 13, 16, 20, 21, 22, 23, 24, 25, 48, and textures are most commonly clay, but also include some silty clays and clay loams. Many soils, particularly at lower elevations and with a more appreciable dry season, show significant clay differentiation between A and B-horizons, caused most probably by clay translocation between the two. Soils fall into three USDA Orders: Inceptisols (little clay differentiation, generally more primary minerals remaining); Alfisols (enrichment of clay in B-horizon, higher base status, generally in areas having an appreciable dry season); and Ultisols (clay enrichment, but a more acidic soil, with a much lower base status at depth).

  Generally these kaolinitic soils are somewhat more erodible than the allophanic soils, with alfisols being more erodible, and ultisols less erodible than the inceptisols. Organic matter contents are generally much lower than the allophanoid soils, while CEC values are lower and base status and pH somewhat higher.

- **Montmorillonite:** 'm': (shades of red)
  This group represents the drier and some intermediate areas. Soils are clayey in texture, some showing appreciable stone or boulder contents, and clays show large cracks during the dry season, being characteristic of the montmorin group. CEC values and exchangeable cations are high: often Mg/Ca ratios are high, and sometimes inverted. In drier areas, particularly on the Windward coast, Na concentrations in the subsoil are high. Soils are often shallow, and overlie silica duripans which severely restrict root and water movement. Natural vegetation is dry forest and scrub woodland. Soils are commonly more erodible than the other groups: however, more commonly the soils are not cultivated, and the presence of natural vegetation and the lower rainfall intensities experienced by these soils means that actual erosion is less than for inland areas.

  Although chemical fertility of these soils is higher than for the other upland groups, their shallow depth and occurrence in drier areas means that they are of much lower value agriculturally. In many areas they should be zoned for building: however, the montmorin clay materials should be removed, and foundations made on hard underlying materials as these clays are subject to considerable heave movements, particularly where profiles are deeper and tree roots are present.

Table 1.5: CHARACTERISATION OF THE SOIL SERIES MAPPED AT 1:25,000 SCALE (1966)

Map No.	Soil Series	Topsoil Texture	Slope Range _(deg)_		Internal Drainage	Annual Rain -fall Range ___(mm)___		Available Water Holding Capacity	USDA Order	Area (Acres)	Stab--ility	Parent Material	Mineralogy	Analysis of Topsoil (0-20cm) pH	CEC	TEB	Ca	Mg	K	Na	BS	C	N	P2O5
															___mequiv/100g ODsoil					___	%	%	%	ppm
42	Annus	C	5	25	Slow	1524	3048	Good	Vertisol	3300	F	Andes.Aglm	Montm	5.6	55	48	27	20	0.2	2.1	85	2.0	0.2	30
17	Anse	C	10	30	Slow	1778	3810	Good	Vertisol	6400	F	Andes.Aglm	Kaol/Montm	5.2	43	33	20	18	0.2	0.8	77	1.2	0.2	11
25	Assor	C	10	20	Slow	1778	2540	Good	Ultisol	2700	mS	Dac/Latosol	Kaol	5.2	35	18	10	9	0.3	1.2	50	2.5	0.2	16
38	Balembouche	gtyCL	2	8	Slow in subsoil	1524	2286	Fair	Mollisol	1000	S	Si pan/Dac	Montm	6.1	7	6	5	1	0.1	0.3	79	1.2	0.1	8
39	Balembouche	gtyCL(s)	2	8	Slow in subsoil	1524	2286	Poor				Si pan/Dac	Montm											
21	Belfond	CL	10	30	Moderate to rapid	2413	3048	Good	Alfisol	930	mS	Dac.ash/agl	Halloysite	5.7	11	9	6	1	0.4	0.6	77	1.6	0.1	8
12	Becune	L	15	30	Rapid	1270	1524	Fair to Poor	Mollisol	350	S	Calc.tuff	Shallow	6.7	55	57	38	19	0.2	1.2	100	2.0	0.2	53
20	Bocage	stC	25	35	Rapid	1778	3048	Good	Mollisol	2600	S	Colluv	Halloysite	5.7	36	30	21	11	0.1	0.5	83	2.6	0.3	10
9	Calfourc	SiL	10	20	Rapid	2540	4064	Fair to Poor	Inceptisol/Andisol	600	S	Dacitic ash	Allophane	6.1	27	28	18	6	0.5	1.5	100	8.0	0.5	30
24	Canelles	C	5	25	Moderate	1778	3048	Good	Inceptisol	10200	S	Dac/Latosol	Halloy/Kaol	6.5	30	14	10	4	0.5	0.3	46	4.8	0.6	24
10	Casteau	grboSiL	5	25	Rapid	2413	2667	Good				Colluv	Halloysite											
26	Cochon	SiCL	10	35	Rapid	2032	3810	Fair to poor	Inceptisol/Andisol	4100	S	Dac/Latosol	Alloph/Kaol	5.0	14	4	2	2	0.2	0.7	30	1.5	0.2	0
28	Deglos	SiL	0	1	Extremely Slow	1778	2159	Good				Alluvium	Mixed	5.7	29	26	21	5	0.1	0.7	90	1.7	0.4	50
43	Delomel	C	5	25	Slow to very slow	1524	1905	Fair	Vertisol	3200	F	And/Bst Ag	Montm	5.6	59	52	31	21	1.1	1.0	87	3.5	0.3	13
16	Dennery	C	10	20	Slow to very slow	1270	2032	Fair	Inceptisol	540	mS	Andes.Aglm	Halloysite	5.8	27	23	11	9	0.7	1.0	84	4.0	0.4	22
44	Dugard	C	5	15	Moderate to slow	1270	1651	Fair	Vertisol	1700	F	And/Bst Ag	Montm/shlw	6.7	47	44	32	11	0.6	1.6	93	5.0	0.3	25
48	Esperance	C	10	30	Slow to very slow	2032	2540	Good	Inceptisol	280	S	Dac.ash/agl	Halloysite	6.0	15	13	8	4	0.4	0.3	80	2.4	0.2	20
32	Falaise	stL	15	35	Rapid	1270	2794	Poor to Fair	Mollisol	8000	mS	And/Bas lav	Hall/Montm	6.5	52	47	33	12	0.7	1.8	89	1.9	0.2	9
46	Franciou	stC	5	25	Rapid	1270	1778	Poor	Inceptisol	10600	mS	And/Bst Ag	Montm/shlw	6.5	99	97	73	26	.1.6	4.5	97	2.2	0.2	105
1	Garrand	CL	5	25	Rapid	1905	2540	Good to Poor	Inceptisol	3100	S	And/Bst Cn	Halloysite	6.0	28	25	15	11	1.1	1.4	90	5.0	0.5	20
31	Gommier	stL	5	25	Extremely Rapid	1270	2032	Poor to v. poor	Mollisol	1500	mS	And/Bas lav	Montm	5.9	68	65	35	31	0.4	1.4	96	1.8	0.1	55
45	Hardy	C	5	25	Moderate to slow	1270	1778	Good	Vertisol	10100	F	And/Bst Ag	Montm/shlw	6.6	37	37	26	12	1.0	2.0	100	5.0	0.4	15
13	Haut	CL	10	25	Rapid	2032	2540	Fair	Inceptisol	340	S	Dac.ash/agl	Halloysite	6.4	11	12	10	2	0.2	0.3	100	1.5	0.1	143
19	Ivrogne	stC	20	35	Rapid	1778	3048	Good	Inceptisol	4800	mS	Colluv	Halloysite	6.1	18	17	15	5	0.1	0.7	99	1.6	0.2	81
30	Jalousie	C	2	6	Slow to very slow	2286	2540	Good to Fair				Alluv	Mixed											
15	Jambette	stSiCL	5	25	Rapid	1524	2286	Poor to fair	Inceptisol	860	S	And/Bas lav	Montm	6.2	15	12	9	3	0.4	0.6	83	1.9	0.2	1
5	Jean Baptiste	SiCL	15	35	Rapid to moderate	2032	3810	Fair to Good	inceptisol/Andisol	4700	S	Andes.ash	Allophane	4.6	47	10	5	4	0.2	0.3	20	2.0	0.2	5
49	Latille	CL	0	2	Moderate	1524	2032	Good				Alluv	Mixed	5.6	57	51	43	13	0.1	0.7	90	1.3	0.2	16
6	Mabouya	SiC	18	25	Slow to very slow	2286	3048	Good	Inceptisol	1100	mS	Colluv	Halloysite	5.9	25	21	11	11	0.2	0.7	86	3.0	0.2	14
11	Mahaut	SiCL	5	25	Rapid to moderate	1905	2540	Fair to Good	Inceptisol/Andisol	1000	S	Dacitic ash	Allophane	5.7	21	10	7	2	0.4	0.3	50	2.0	0.2	0
2	Marquis	C	15	25	Rapid to moderate	1905	2540	Fair to Good	Inceptisol	2800	S	And/Bst Cn	Halloysite	5.5	10	5	3	2	0.1	0.7	60	2.3	0.2	7
41	Michel	gtyC	1	5	Slow to very slow	1524	2032	Fair to Good	Alfisol	720	mS	Si pan/Dac	Montm	5.8	11	9	6	3	0.1	0.4	77	1.5	0.1	6
47	Micoud	gtyC	5	25	Slow	1524	2286	Poor to v. poor	Mollisol	4700	mS	Si pan/Dac	Montm	5.7	17	12	7	4	0.1	1.6	80	1.6	0.2	1
3	Moreau	C	15	25	Rapid to moderate	2032	3048	Fair to Good	Ultisol	3200	mS	And/Bst Cn	Kaolinite	5.2	16	9	6	4	0.1	0.6	60	3.0	0.3	15
7	Parasol	C	30	40	Rapid to moderate	2032	2540	Good	Inceptisol	10	S	And/Bst Cn	Halloysite	5.6	24	19	14	5	0.6	0.6	80	2.8	0.2	6
14	Panache	SiC	25	40	Moderate to rapid	2032	2540	Good	Inceptisol/Andisol	7400	S	Andes.ash	Allophane	5.0	20	4	3	1	0.3	0.7	20	2.4	0.2	8
51	Paiye	SiC	0	2	Very slow	1524	1778	Fair				Alluvium	Mixed	6.0	31	30	21	10	0.1	1.2	95	2.2	0.2	13
29	Quilesse	SiC	5	15	Slow to very slow	3048	4064	Good	Inceptisol	1300	F	Colluv	?Alloph/Hal											
22	Rabot	C	15	25	Rapid	2286	3048	Good	Alfisol	1800	S	Dac.ash/agl	Halloysite	6.0	16	15	11	4	0.1	0.6	93	1.5	0.2	6
50	Raveneau	C	0	1	Slow to very slow	1270	2032	Good to Fair				Alluvium	Mixed	5.8	60	55	42	12	0.1	0.9	92	1.8	0.2	20
8	Regnier	stC	20	35	Rapid	2032	2286	Good	Inceptisol	700	S	Colluv	Halloysite	6.1	18	16	12	3	0.6	0.9	86	2.3	0.2	3
18	Richeford	fSCL	0	1	Moderate to rapid	1778	2286	Good				Alluvium	Mixed	4.8	24	18	15	4	0.1	0.3	74	1.3	0.1	29
40	Rozette	gtyC	2	15	Slow to Moderate	1397	2032	Fair	Alfisol	1700	S	Si pan/Dac	Montm	5.7	19	16	9	7	0.1	0.8	94	1.3	0.1	10
27	Soucis	SiCL	0	2	Slow to very slow	1778	3048	Good				Alluvium	Mixed	4.7	26	17	15	3	0.1	0.3	70	2.8	0.2	60
37	Troumasse	L	0	2	Rapid	1524	2286	Good to Fair				Alluvium	Mixed	5.4	28	26	17	9	0.2	0.6	86	2.1	0.2	18
52	Vanard	Peat	0	2	Water-logged	2032	2286	Good to Fair				Peat/Alluv	Peat/Mixed	6.5	99	99	99	9	0.4	3.5	94	17.0	1.1	30
36	Venus	L	20	35	Rapid	2032	3048	Fair to Poor	Inceptisol/Andisol	2700	S	Dac.ash	Alloph (v.s)	5.6	16	9	7	3	0.2	0.7	55	4.0	0.3	10
4	Warwick	C	20	35	Moderate	2286	3810	Good	Inceptisol/Andisol	12100	S	And/Bst Cn	Allophane	4.7	33	11	6	5	0.4	0.4	30	4.0	0.4	2
23	Zenon	grboLS	2	8	Rapid	2286	2540	Fair	Mollisol	400	mS	Alluvium	Halloysite											

Sources: Stark et al, 1966; Smith G.,1981; HTS,1996 based on Colmet-Daage et al, 1973 & Hardy, 1971.

File:SOILS.wk3

1.2.3 Soil Infiltration Rates

Surface soil infiltration rates represent the critical soil parameter determining how much rainwater will enter the soil, and how much will run off for the event of each rain shower.

Measurements on surface infiltration rates for upland soils appear not to have been undertaken in St. Lucia, and thus a programme for measurement by sprinkler infiltrometer was adopted for this project. This was subsequently used in the field trials programme as a key characteristic of the soils under different banana trash management regimes. The sprinkler infiltrometer, rather than the double ring infiltrometer, was chosen in that it simulates rainfall more closely: water is applied by means of a sprinkler rose. For the double ring infiltrometer, which more closely simulates flood irrigation, damage to the soil surface by driving in the ring and by flooding creates very artificial conditions. The measured rates are thus quite different from those observed from the sprinkler infiltrometer or those measured from lysimeters and run-off plots.

In the experiments representative 0.75x1 metre rectangular areas were selected, and corners of the rectangle marked with small sticks or thin pegs. On the downward side of the slope soil was cut away from the lower edge for a depth of 10cm, the face being angled into the slope, and a collector tray placed so that it can collect any run-off from the plot (see Figure 1.3). Three catch cans were placed within the rectangle in order to record depths of water applied. Water was then syphoned from 5 gallon drums through a hose connected to the sprinkler rose, the flow rate of which has been adjusted to deliver a maximum of 3mm/minute over the 0.75 sq m area. The rose was passed over the rectangle, evenly delivering water which wetted the surface and entered the cans as it passed. Water application was continued until run-off commenced, after which a break of 4 minutes was taken for the surface to drain. The times of start and finish of each wetting period (hours: minutes: seconds) were carefully recorded, and the levels of water in the 3 catch cans were then measured. The process was repeated several times for a duration of 1 hour, water levels in the cans being recorded each time. Water running into the collector tray was measured with a measuring cylinder at the end of the experiment. Data was recorded onto field sheets and entered into a Lotus123 spreadsheet for calculation (see Table 1.6, bottom). (Fields marked with an asterisk are those where primary data is input: other fields are set up on formulae to recalculate the input data.)

At the end of the experiment a 'post mortem' was undertaken on the rectangular plot to record the depth and evenness of wetting, and the presence of root channels, cavities, worms and other fauna. Distance from banana mats, features of microtopography, large stones and rock outcrop etc were all recorded. The time and date of the experiment was noted, and compared with rainfall data from nearby gauges.

Results of the infiltration tests showed that there was a large variability of infiltration rates over short distances, but a strong correlation between high infiltration rates and presence of trash cover, earthworm presence and worm channel density. Comparing trash-covered with bare soil surfaces, initial infiltration rates (first 15 minutes) were increased from an average of 48 to 100 mm/hour; terminal rates were increased from an average of 17 to 42 mm/hour. The average amount of water infiltrated over the 90 minute trial period (60+30 minutes) was 40 and 88 mm respectively. [See **Table 1.6**(top) for actual results over 32 tests on the 4 trial sites.]

Extrapolating these average infiltration rates to the TSD event (using the Union Agric.Station rainfall intensity figures), the immediate surface run-off would have been 160 and 72mm respectively for bare and trash covered surfaces, out of a total rainfall figure of 270 mm measured over the 8-hour period. The balance of 88 mm would have been temporarily held in the macro-pores in the soil, and released over the following hours and days as lateral sub-surface water flow through the soil profile.

TABLE 1.6 : SUMMARY OF RESULTS OF INFILTRATION EXPERIMENTS: SOIL CONSERVATION & RUNOFF CONTROL TRIALS File:V31NFSUM.wk3

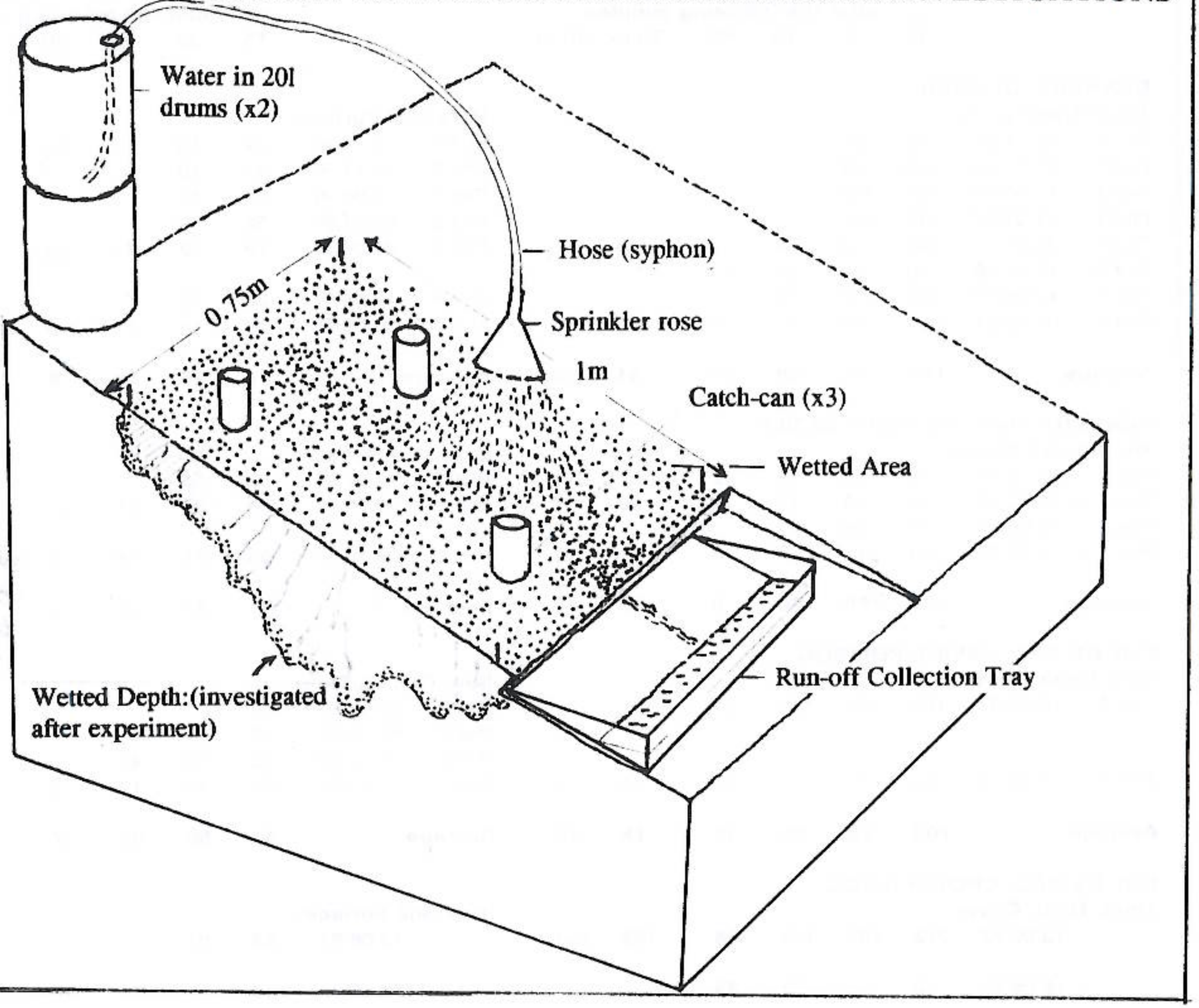
Plot	Date	Infiltration rate (mm/hr) after the following minutes: 15	30	45	60	75+x	90+x	Plot	Date	Infiltration rate (mm/hr) after the following minutes: 15	30	45	60	75+x	90+x
DENNERY: GLAVIER															
Thick Trash Cover:								**Bare Soil Surface:**							
Plot 1	12.11.96	193	67					Plot 2	15.11.96	24	15	11	14		
Plot 1	15.11.96	(48)	59					Plot 2	15.11.96	33	10				
Plot 1	12.06.97	186	162					Plot 2	12.06.97	23	17	8			
Plot 1	01.07.97	138	108					Plot 2	01.07.97	52	49				
Plot 1	30.09.97	144	83	54	67	84	50	Plot 2	30.09.97	79	52	41	33	29	34
Plot 3 –	15.11.96	30	30	24	11										
Plot 3	19.06.97	243	131	90				Plot 4	19.06.97	24	20				
Plot 3	02.10.97	(34)	(29)	(32)	42	53	37	Plot 4	30.09.97	27	18	11	8	12	10
Average		**133**	**91**	**56**	**39**	**84**	**50**	**Average**		**37**	**26**	**18**	**18**	**21**	**22**
DENNERY: PAYS PERDUE / BAZILE															
Thick Trash Cover:								**Bare Soil Surface:**							
Plot 1 =	02.10.97	20	14	13	12	20	16	Plot 2	12.06.97	52	56				
Plot 1 =	04.10.97	29	23	17	12	20	17	Plot 2	02.10.97	34	34	21	15	17	18
Plot 3	12.06.97	72	65	43											
Plot 3 =	04.10.97	19	11	7	3	11	12	Plot 4	04.10.97	30	21	14	9	13	16
Average		**35**	**28**	**20**	**9**	**17**	**15**	**Average**		**39**	**37**	**18**	**12**	**15**	**17**
CUL DE SAC: RAVINE POISSON															
Thin Trash Cover:								**Bare Soil Surface:**							
Plot 3	16.06.97	182	131	120	63			Plot 2	13.06.97	63	71				
								Plot 2	16.06.97	99	64	48			
								Plot 2	16.06.97	70	53	45			
Plot 3	07.10.97	24	21	17	13	15	10	Plot 2	07.10.97	24	12	12	7	18	6
Average		**103**	**76**	**69**	**38**	**15**	**10**	**Average**		**64**	**50**	**35**	**7**	**18**	**6**
CUL DE SAC: CHOPIN RIDGE															
Thick Trash Cover:								**Bare Soil Surface:**							
	13.06.97	272	131	160	158	163	153		13.06.97	23	31				
–	16.06.97	40	28	38	39				13.06.97	103	36	30	31		
Average		**156**	**80**	**99**	**99**	**163**	**153**	**Average**		**63**	**34**	**30**	**31**		
Overall Average		**100**	**67**	**49**	**42**	**52**	**42**	**Overall Average**		**48**	**35**	**24**	**17**	**18**	**17**

Note: Thin trash cover denoted –; Moderate trash cover denoted =.

TABLE 1.6 INFILTRATION EXPERIMENTS: SOIL CONSERVATION & RUN-OFF CONTROL TRIALS: DENNERY File:INFXPDG.wk3

Time Start ***********	Time Stop ***********	Mins	Depth Measurements(mm) Rep1 ****	Rep2 ****	Rep3 ****	Mean (mm)	Sprinkler Intensity (avg over expermnt) (mm/min)	(mm/hr)	Surface Run-off (ml/sq m) ****	(mm) (accumulatd)		Net Infiltration depth (mm)	(avg/expt) (mm/ /min)	(mm/ /hr)	(current rate) (mm/ /min)	(mm/ /hr)
DENNERY: GLAVIER																
30-Sep-97			thick trash cover					Plot 1	New sprinkler:reduced flow rate							
10:58:35 AM	11:13:35 AM	15.00	30	34	20	36.0	2.4	144	0	0	0.0	36.0	2.4	144	2.4	144
11:20:20 AM	11:32:40 AM	34.08	49	60	39	57.3	1.7	101	20	20	0.0	57.3	1.7	101	1.1	67
11:41:30 AM	11:46:12 AM	47.62	58	67	43	64.0	1.3	81	26	46	0.1	63.9	1.3	81	0.9	51
11:51:00 AM	11:55:50 AM	57.25	72	80	59	78.3	1.4	82	48	94	0.2	78.1	1.4	82	0.9	54
11:59:05 AM	12:02:47 PM	64.20	79	88	74	88.3	1.4	83	14	108	0.2	88.1	1.4	82	1.5	88
01:42:30 PM	01:48:30 PM	6.00	11	11	9	18.3	3.1	183	70	70	0.2	18.2	3.0	182	3.0	182
01:57:00 PM	01:59:54 PM	17.40	23	24	18	29.7	1.7	102	126	196	0.4	29.2	1.7	101	1.0	58
02:07:05 PM	02:09:27 PM	26.95	32	32	23	37.0	1.4	82	38	234	0.5	36.5	1.4	81	0.9	52
02:13:35 PM	02:15:30 PM	33.00	38	36	28	42.0	1.3	76	57	291	0.6	41.4	1.3	75	0.8	47

FIGURE 1.3: SPRINKLER INFILTROMETER INVESTIGATIONS



In further comparison with the banana trash experiments, well-established secondary forest at Barre D'Isle, with a deep litter and humus layer, showed an average infiltration rate of some 100mm over 40 minutes.

Limits for required soil infiltration rates for sloping upland soils under cultivation have been tentatively placed at >50, 49-35, 34-20 mm/hour for 1 hour for classes S1, S2 and S3 respectively. Corresponding short-term infiltration rates are >2.5, 2.4-1.5, and 1.4-1.0 mm/minute for a duration of 5 minutes respectively. Soils not meeting these criteria should not be under cultivation to seasonal crops, nor to bananas, but should be planted to permanent treecrops or to forestry plantations.

1.2.4 Soil / Crop Water Balances

Soil / crop water balances were studied in detail by the Consultants for Union Agricultural Station, which had long-term and relatively reliable daily rainfall figures, and, at a mean annual accumulated deficit of rainfall minus potential evapotranspiration of 213mm, was broadly typical of the average 'banana zone area' within the Cul de Sac Catchment. A daily water balance spreadsheet (DLYSLWB9.wk3) was used to run this simulation, taking typical data for a deep clay loam to clay soil profile under firstly banana and secondly natural forest vegetation. The DLYSLWB9 spreadsheet had been developed by the Consultants in their work in fairly similar conditions to St. Lucia in Sri Lanka, and details of the model are presented in Appendix 1.

The model was run using daily rainfall data over the period 1980-95 inclusive, and the following parameters were recorded:

- soil water balances for A, B, and C horizons;
- actual crop evapotranspiration (ETa) in relation to potential evapo-transpiration (ETc): this will --- closely relate to crop growth and yield;
- surface run-off, responsible for peak flows of rivers;
- sub-surface run-off, (mostly peak-flow, but partly base-flow water);
- deep leaching, contributing almost entirely to base-flow of rivers.

For the banana vegetation (ratoon crops) a maximum rooting depth of 120cm was assumed: for natural forest, possessing deep tap roots, a depth of 250cm was taken. Available water holding capacity (AWC) figures for soil A, B, C-horizons were taken as 18%, 15% and 10% respectively. Infiltration rates, in terms of mm/day (or rain event), were taken as 34 and 20mm/day respectively for A and B-horizons for the banana land, and a conservative estimate of 40 and 25 mm / day for the natural forest land. Crop coefficients were taken as 0.95 and 1.20 for bananas and natural forest respectively.

Results from the model are presented in **Table 1.7** which gives a comparison in the water balances between the two vegetative types, presenting total figures for each year, and mean figures for the 16-year period. Actual evapotranspiration is much higher for forest than for bananas (1660 cf 1380mm); conversely surface run-off, sub-surface run-off and deep leaching are much higher for bananas than for forest (180, 100 and 420mm, as compared to 130, 70 and 220 mm respectively). Results show that natural forest reduces considerably the surface and subsurface runoff in comparison to banana cultivation, but that deep leaching, contributing to base flows of rivers, are also heavily reduced.

It is interesting to note that over the Cul de Sac Watershed annual deep leaching of 420mm is equivalent to an average baseflow spread over the entire year of 540 litres/sec: 220mm is equivalent to 280 l/sec. This compares to a minimum flow for the Cul de Sac River of 200 litres/sec.

1.2.5 Correlation of Daily Soil Water balance Spreadsheet (DLYSLWB9.wk3) with measured run-off from experimental plots:

Data collected by Mr Peter Norville on experimental run-off plots connected with soil conservation experiments during the period June-December 1988 gave useful correlation with daily rainfall data input into the DLYSLWB9 model. A print-out of this spreadsheet for this period is presented in **Table 1.8**, and the results are summarised as follows:

Rainfall (15 June- 31 Dec)	2062mm	
ETo	870	
ETa	821	
Surface RunOff	360	
Subsurface Runoff	129	
TOTAL LATERAL RUNOFF		489
C-horizon leaching	665	

MEASURED LATERAL SURFACE & SUPERFICIAL SUBSURFACE RUNOFF FROM CONTROL PLOT 507

The data of the experiment thus correlate very closely with the figures predicted by the DLYSLWB9 spreadsheet.

1.2.6 Dry Period Analysis:

The daily soil water balance spreadsheet (DLYSLWB9.wk3) was also used to obtain ratios of actual to potential evapotranspiration for each pentade (i.e. 5-day period) during the year: this parameter relates very closely to banana yield. Actual ETa values varied over the 16 years from 1250mm in 1987 (with an extremely long dry season) to 1560mm in 1981: this compared to a potential crop evapotranspiration (ETc) figure of 1590mm. Minimum ETa/ETc ratios reached during each dry season

TABLE 1.7: UNION AGR.: COMPARISON IN RAINFALL / RUNOFF / SOIL WATER BALANCES UNDER BANANAS AND FOREST FOR THE PERIOD 1980–95 (ANALYSIS BY DAILY SOIL WATER BALANCE MODEL)

YEAR	ANNL RAIN–FALL	BANANAS (RATOONS) ETc BANANA	ETa BANANA	Minimum ETa/ETc	SOIL WBAL	SURF RNOF	SSRF RNOF	C–hr LECH	Max.Surf Run–Off	PRIMARY FOREST ETc FOREST	ETa FOREST	SOIL WBAL	SURF RNOF	SSRF RNOF	C–hr LECH	Max.Surf Run–Off
1980	1830	1588	1305	0.23	–28	101	89	366	50	2006	1567	–41	52	58	183	43
1981	2506	1588	1558	0.57	–4	372	139	438	121	2006	1986	–2	270	71	135	114
1982	2031	1588	1346	0.35	5	105	86	492	74	2006	1646	3	58	49	275	51
1983	1990	1588	1358	0.19	–2	70	103	460	23	2006	1702	–19	27	73	197	16
1984	1872	1588	1331	0.32	–45	134	88	367	52	2006	1597	–68	96	62	175	41
1985	1777	1588	1304	0.21	48	51	58	320	44	2006	1503	72	32	24	133	32
1986	2085	1588	1382	0.35	–29	209	127	391	97	2006	1625	–33	162	92	226	89
1987	2496	1588	1248	0.13	–25	401	184	691	99	2006	1586	–24	321	112	500	92
1988	2233	1588	1324	0.23	12	296	137	462	183	2006	1562	0	242	96	317	175
1989	2152	1588	1466	0.37	43	120	85	436	67	2006	1703	78	89	47	224	64
1990	2210	1588	1505	0.67	–1	84	95	528	25	2006	1792	–33	34	67	340	17
1991	1891	1588	1339	0.21	–16	108	88	372	48	2006	1538	–15	74	70	212	41
1992	2372	1588	1406	0.38	16	356	153	444	101	2006	1704	32	262	105	261	93
1993	1854	1588	1433	0.39	–50	81	63	331	29	2006	1717	–71	38	45	124	19
1994	1903	1588	1310	0.31	28	243	51	268	238	2006	1520	32	230	16	95	230
1995	2075	1588	1484	0.40	–10	154	86	362	57	2006	1745	–2	107	57	162	50
Means	2080	1588	1381		–4	180	102	420		2006	1656	–6	131	65	222	

Above based on following values:

Soil Tapped by Roots:

	Bananas Thickness(cm)	AWC %	AvailWater(mm)	Forest Thickness(cm)	AWC %	AvailWater(mm)
A–horizon	25	18	45	25	18	45
B–horizon	65	15	98	65	15	98
C–horizon	30	10	30	160	10	160

Infiltration (mm/rainevent):

	Bananas	Forest
Surface	34	40
Subsurface	20	25

Crop Cooeficient (Kc) 0.95 — 1.20

File:\123r3\rain\UNISLWB.wk3

were respectively 0.13 and 0.57 for the two years, although the year 1990 had a higher ratio (0.67) but a lower annual ETa (1505), implying a longer, but less concentrated, dry season. **Table 1.9** shows ETa/ETc ratios for each pentade over the 16 years: lower ratios being shaded more intensely in order to reflect graphically the severity of the dry season. This table shows the large variation from year to year, which is clearly reflected in the yield of rainfed crops.

1.2.7 Characterisation of Watersheds

For the purposes of the study, the map of the 37-watersheds as delineated by the UN Water Resources Exploration & Assessment Project, 1986, was used as a basemap, and statistics for these watersheds are given in **Table 1.10.** The Consultants have added to this table a characterisation of each of the watersheds according to the agro-ecological zones defined. As can be seen, only 10 watersheds show significant areas within the highest rainfall zone (A), while a further 6 watersheds show significant areas in Zone B. Many of the smaller watersheds have their head-waters in drier agro-ecological Zones, and such is the case for the five northern watersheds (1,2,3,36,& 37), and watersheds 8,13,18,20,26, and 32. These drier watersheds often show no flows during the peaks of the dry season.

As can be seen from the table, the two watersheds selected for the pilot study (Cul de Sac and Dennery) both cover a very wide range of agro-ecological zones. Land Use Characterisation of the watersheds are discussed in Chapter 2, while Hydrological Characterisation is fully discussed in the Hydrological Section.

TABLE 1.8: CROP/SOIL WATER BALANCE FOR ROSEAU,ST LUCIA, UNDER RAINFED BANANAS, AND DEEP SILTY CLAY SOIL

Day	RAIN mm/dy	ETo/ mnth	ETo/ day	Kc Max	ETc B'NAN	ETa	R-ETa	A-hr BALN	Attl TEMP	Avrl LECH	Surf RnOf	B-hr BALN	Bttl TEMP	Bvrl LECH	SubS RnOf	C-hr BALN	C-hr LECH	AcSf RnOf	AcSS RnOf	Acum Lech
14-Jun	4.2	153	5.1	0.95	4.8	3.1	1.1	40	0	0	0	0	0	0	0	16	0	0	0	0
15-Jun	1.6	153	5.1	0.95	4.8	3.2	-1.6	38	0	0	0	0	0	0	0	16	0	0	0	0
16-Jun	10.0	158	5.3	0.95	5.0	3.2	6.8	45	0	0	0	0	0	0	0	16	0	0	0	0
17-Jun	1.4	158	5.3	0.95	5.0	3.6	-2.2	43	0	0	0	0	0	0	0	16	0	0	0	0
18-Jun	65.3	158	5.3	0.95	5.0	3.5	61.8	45	59	34	25	34	0	0	0	16	0	25	0	0
19-Jun	6.2	158	5.3	0.95	5.0	5.0	1.2	45	1	1	0	35	0	0	0	16	0	25	0	0
20-Jun	6.2	158	5.3	0.95	5.0	5.0	1.2	45	1	1	0	36	0	0	0	16	0	25	0	0
21-Jun	0.4	158	5.3	0.95	5.0	5.0	-4.6	40	0	0	0	36	0	0	0	16	0	25	0	0
22-Jun	0.0	158	5.3	0.95	5.0	5.0	-5.0	35	0	0	0	36	0	0	0	16	0	25	0	0
23-Jun	7.4	158	5.3	0.95	5.0	5.0	2.4	38	0	0	0	36	0	0	0	16	0	25	0	0
24-Jun	5.8	158	5.3	0.95	5.0	5.0	0.8	39	0	0	0	36	0	0	0	16	0	25	0	0
25-Jun	4.9	158	5.3	0.95	5.0	5.0	-0.1	38	0	0	0	36	0	0	0	16	0	25	0	0
26-Jun	2.1	158	5.3	0.95	5.0	5.0	-2.9	36	0	0	0	36	0	0	0	16	0	25	0	0
27-Jun	0.5	158	5.3	0.95	5.0	5.0	-4.5	31	0	0	0	36	0	0	0	16	0	25	0	0
28-Jun	25.0	158	5.3	0.95	5.0	5.0	20.0	45	6	6	0	42	0	0	0	16	0	25	0	0
29-Jun	14.2	158	5.3	0.95	5.0	5.0	9.2	45	9	9	0	52	0	0	0	16	0	25	0	0
30-Jun	5.1	158	5.3	0.95	5.0	5.0	0.1	45	0	0	0	52	0	0	0	16	0	25	0	0
01-Jul	9.2	158	5.3	0.95	5.0	5.0	4.2	45	4	4	0	56	0	0	0	16	0	25	0	0
02-Jul	1.0	163	5.4	0.95	5.2	5.2	-4.2	41	0	0	0	56	0	0	0	16	0	25	0	0
03-Jul	7.4	163	5.4	0.95	5.2	5.2	2.2	43	0	0	0	56	0	0	0	16	0	25	0	0
04-Jul	0.8	163	5.4	0.95	5.2	5.2	-4.4	39	0	0	0	56	0	0	0	16	0	25	0	0
05-Jul	0.0	163	5.4	0.95	5.2	5.2	-5.2	34	0	0	0	56	0	0	0	16	0	25	0	0
06-Jul	3.8	163	5.4	0.95	5.2	5.2	-1.4	32	0	0	0	56	0	0	0	16	0	25	0	0
07-Jul	1.6	163	5.4	0.95	5.2	5.2	-3.6	29	0	0	0	56	0	0	0	16	0	25	0	0
08-Jul	1.4	163	5.4	0.95	5.2	5.2	-3.8	25	0	0	0	56	0	0	0	16	0	25	0	0
09-Jul	21.8	163	5.4	0.95	5.2	5.2	16.6	42	0	0	0	56	0	0	0	16	0	25	0	0
10-Jul	13.2	163	5.4	0.95	5.2	5.2	8.0	45	5	5	0	61	0	0	0	16	0	25	0	0
11-Jul	6.0	163	5.4	0.95	5.2	5.2	0.8	45	1	1	0	61	0	0	0	16	0	25	0	0
12-Jul	17.4	163	5.4	0.95	5.2	5.2	12.2	45	12	12	0	74	0	0	0	16	0	25	0	0
13-Jul	1.9	163	5.4	0.95	5.2	5.2	-3.3	42	0	0	0	74	0	0	0	16	0	25	0	0
14-Jul	5.2	163	5.4	0.95	5.2	5.2	0.0	42	0	0	0	74	0	0	0	16	0	25	0	0
15-Jul	2.4	163	5.4	0.95	5.2	5.2	-2.8	39	0	0	0	74	0	0	0	16	0	25	0	0
16-Jul	4.0	163	5.4	0.95	5.2	5.2	-1.2	38	0	0	0	74	0	0	0	16	0	25	0	0
17-Jul	3.8	155	5.2	0.95	4.9	4.9	-1.1	37	0	0	0	74	0	0	0	16	0	25	0	0
18-Jul	3.9	155	5.2	0.95	4.9	4.9	-1.0	36	0	0	0	74	0	0	0	16	0	25	0	0
19-Jul	1.1	155	5.2	0.95	4.9	4.9	-3.8	32	0	0	0	74	0	0	0	16	0	25	0	0
20-Jul	11.1	155	5.2	0.95	4.9	4.9	6.2	38	0	0	0	74	0	0	0	16	0	25	0	0
21-Jul	0.4	155	5.2	0.95	4.9	4.9	-4.5	34	0	0	0	74	0	0	0	16	0	25	0	0
22-Jul		155	5.2	0.95	4.9	4.9	-4.9	29	0	0	0	74	0	0	0	16	0	25	0	0
23-Jul	24.0	155	5.2	0.95	4.9	4.9	19.1	45	3	3	0	78	0	0	0	16	0	25	0	0
24-Jul	0.3	155	5.2	0.95	4.9	4.9	-4.6	40	0	0	0	78	0	0	0	16	0	25	0	0
25-Jul	48.6	155	5.2	0.95	4.9	4.9	43.7	45	39	34	5	98	13	13	0	24	4	30	0	4
26-Jul	10.2	155	5.2	0.95	4.9	4.9	5.3	45	5	5	0	98	5	5	0	24	5	30	0	10
27-Jul	9.6	155	5.2	0.95	4.9	4.9	4.7	45	5	5	0	98	5	5	0	24	5	30	0	14
28-Jul	0.3	155	5.2	0.95	4.9	4.9	-4.6	40	0	0	0	98	0	0	0	24	0	30	0	14
29-Jul	5.9	155	5.2	0.95	4.9	4.9	1.0	41	0	0	0	98	0	0	0	24	0	30	0	14
30-Jul	4.7	155	5.2	0.95	4.9	4.9	-0.2	41	0	0	0	98	0	0	0	24	0	30	0	14
31-Jul	34.6	155	5.2	0.95	4.9	4.9	29.7	45	26	26	0	98	26	20	6	24	20	30	6	34
01-Aug	1.1	155	5.2	0.95	4.9	4.9	-3.8	41	0	0	0	98	0	0	0	24	0	30	6	34
02-Aug	6.2	145	4.8	0.95	4.6	4.6	1.6	43	0	0	0	98	0	0	0	24	0	30	6	34
03-Aug	0.3	145	4.8	0.95	4.6	4.6	-4.3	39	0	0	0	98	0	0	0	24	0	30	6	34
04-Aug	14.4	145	4.8	0.95	4.6	4.6	9.8	45	3	3	0	98	3	3	0	24	3	30	6	38
05-Aug	13.3	145	4.8	0.95	4.6	4.6	8.7	45	9	9	0	98	9	9	0	24	9	30	6	46
06-Aug	0.6	145	4.8	0.95	4.6	4.6	-4.0	41	0	0	0	98	0	0	0	24	0	30	6	46
07-Aug	26.5	145	4.8	0.95	4.6	4.6	21.9	45	18	18	0	98	18	18	0	24	18	30	6	64
08-Aug	16.2	145	4.8	0.95	4.6	4.6	11.6	45	12	12	0	98	12	12	0	24	12	30	6	76
09-Aug	11.6	145	4.8	0.95	4.6	4.6	7.0	45	7	7	0	98	7	7	0	24	7	30	6	83
10-Aug	2.6	145	4.8	0.95	4.6	4.6	-2.0	43	0	0	0	98	0	0	0	24	0	30	6	83
11-Aug	0.2	145	4.8	0.95	4.6	4.6	-4.4	39	0	0	0	98	0	0	0	24	0	30	6	83
12-Aug	0.3	145	4.8	0.95	4.6	4.6	-4.3	34	0	0	0	98	0	0	0	24	0	30	6	83
13-Aug	12.2	145	4.8	0.95	4.6	4.6	7.6	42	0	0	0	98	0	0	0	24	0	30	6	83
14-Aug	54.4	145	4.8	0.95	4.6	4.6	49.8	45	47	34	13	98	34	20	14	24	20	43	20	103
15-Aug	27.4	145	4.8	0.95	4.6	4.6	22.8	45	23	23	0	98	23	20	3	24	20	43	23	123
16-Aug	8.4	145	4.8	0.95	4.6	4.6	3.8	45	4	4	0	98	4	4	0	24	4	43	23	127
17-Aug	6.2	145	4.8	0.95	4.6	4.6	1.6	45	2	2	0	98	2	2	0	24	2	43	23	128
18-Aug	0.2	145	4.8	0.95	4.6	4.6	-4.4	41	0	0	0	98	0	0	0	24	0	43	23	128
19-Aug	2.1	137	4.6	0.95	4.3	4.3	-2.2	38	0	0	0	98	0	0	0	24	0	43	23	128
20-Aug	21.1	137	4.6	0.95	4.3	4.3	16.8	45	10	10	0	98	10	10	0	24	10	43	23	139
21-Aug	23.2	137	4.6	0.95	4.3	4.3	18.9	45	19	19	0	98	19	19	0	24	19	43	23	157
22-Aug	0.8	137	4.6	0.95	4.3	4.3	-3.5	41	0	0	0	98	0	0	0	24	0	43	23	157
23-Aug	0.0	137	4.6	0.95	4.3	4.3	-4.3	37	0	0	0	98	0	0	0	24	0	43	23	157
24-Aug	15.6	137	4.6	0.95	4.3	4.3	11.3	45	3	3	0	98	3	3	0	24	3	43	23	161
25-Aug	0.2	137	4.6	0.95	4.3	4.3	-4.1	41	0	0	0	98	0	0	0	24	0	43	23	161
26-Aug	7.0	137	4.6	0.95	4.3	4.3	2.7	44	0	0	0	98	0	0	0	24	0	43	23	161
27-Aug	1.2	137	4.6	0.95	4.3	4.3	-3.1	40	0	0	0	98	0	0	0	24	0	43	23	161
28-Aug	9.2	137	4.6	0.95	4.3	4.3	4.9	45	0	0	0	98	0	0	0	24	0	43	23	161
29-Aug	0.1	137	4.6	0.95	4.3	4.3	-4.2	41	0	0	0	98	0	0	0	24	0	43	23	161
30-Aug	0.9	137	4.6	0.95	4.3	4.3	-3.4	37	0	0	0	98	0	0	0	24	0	43	23	161
31-Aug	3.9	137	4.6	0.95	4.3	4.3	-0.4	37	0	0	0	98	0	0	0	24	0	43	23	161
01-Sep	0.6	137	4.6	0.95	4.3	4.3	-3.7	33	0	0	0	98	0	0	0	24	0	43	23	161
02-Sep	2.7	128	4.3	0.95	4.1	4.1	-1.4	32	0	0	0	98	0	0	0	24	0	43	23	161
03-Sep	0.2	128	4.3	0.95	4.1	4.1	-3.9	28	0	0	0	98	0	0	0	24	0	43	23	161
04-Sep	34.0	128	4.3	0.95	4.1	4.1	29.9	45	13	13	0	98	13	13	0	24	13	43	23	174
05-Sep	11.2	128	4.3	0.95	4.1	4.1	7.1	45	7	7	0	98	7	7	0	24	7	43	23	181
06-Sep	36.3	128	4.3	0.95	4.1	4.1	32.2	45	32	32	0	98	32	20	12	24	20	43	35	201
07-Sep	6.2	128	4.3	0.95	4.1	4.1	2.1	45	2	2	0	98	2	2	0	24	2	43	35	203
08-Sep	13.4	128	4.3	0.95	4.1	4.1	9.3	45	9	9	0	98	9	9	0	24	9	43	35	213
09-Sep	211.2	128	4.3	0.95	4.1	4.1	207.1	45	207	34	173	98	34	20	14	24	20	216	49	233
10-Sep	14.7	128	4.3	0.95	4.1	4.1	10.6	45	11	11	0	98	11	11	0	24	11	216	49	243
11-Sep	2.0	128	4.3	0.95	4.1	4.1	-2.1	43	0	0	0	98	0	0	0	24	0	216	49	243
12-Sep	24.8	128	4.3	0.95	4.1	4.1	20.7	45	19	19	0	98	19	19	0	24	19	216	49	262
13-Sep	13.0	128	4.3	0.95	4.1	4.1	8.9	45	9	9	0	98	9	9	0	24	9	216	49	271
14-Sep	6.0	128	4.3	0.95	4.1	4.1	1.9	45	2	2	0	98	2	2	0	24	2	216	49	273
15-Sep	4.8	128	4.3	0.95	4.1	4.1	0.7	45	1	1	0	98	1	1	0	24	1	216	49	274
16-Sep	7.8	126	4.2	0.95	4.0	4.0	3.8	45	4	4	0	98	4	4	0	24	4	216	49	277
17-Sep	9.2	126	4.2	0.95	4.0	4.0	5.2	45	5	5	0	98	5	5	0	24	5	216	49	283
18-Sep	3.0	126	4.2	0.95	4.0	4.0	-1.0	44	0	0	0	98	0	0	0	24	0	216	49	283
19-Sep	6.6	126	4.2	0.95	4.0	4.0	2.6	45	2	2	0	98	2	2	0	24	2	216	49	284
20-Sep	8.7	126	4.2	0.95	4.0	4.0	4.7	45	5	5	0	98	5	5	0	24	5	216	49	289
21-Sep	14.0	126	4.2	0.95	4.0	4.0	10.0	45	10	10	0	98	10	10	0	24	10	216	49	299

22-Sep	1.2	126	4.2	0.95	4.0	4.0	-2.8	42	0	0	0	98	0	0	0	24	0	216	49	299
23-Sep	0.4	126	4.2	0.95	4.0	4.0	-3.6	39	0	0	0	98	0	0	0	24	0	216	49	299
24-Sep	0.1	126	4.2	0.95	4.0	4.0	-3.9	35	0	0	0	98	0	0	0	24	0	216	49	299
25-Sep	0.0	126	4.2	0.95	4.0	4.0	-4.0	31	0	0	0	98	0	0	0	24	0	216	49	299
26-Sep	0.0	126	4.2	0.95	4.0	4.0	-4.0	27	0	0	0	98	0	0	0	24	0	216	49	299
27-Sep	2.3	126	4.2	0.95	4.0	4.0	-1.7	25	0	0	0	98	0	0	0	24	0	216	49	299
28-Sep	2.6	126	4.2	0.95	4.0	4.0	-1.4	24	0	0	0	98	0	0	0	24	0	216	49	299
29-Sep	1.2	126	4.2	0.95	4.0	4.0	-2.8	21	0	0	0	98	0	0	0	24	0	216	49	299
30-Sep	12.8	126	4.2	0.95	4.0	4.0	8.8	30	0	0	0	98	0	0	0	24	0	216	49	299
01-Oct	19.8	126	4.2	0.95	4.0	4.0	15.8	45	1	1	0	98	1	1	0	24	1	216	49	299
02-Oct	15.8	126	4.2	0.95	4.0	4.0	11.8	45	12	12	0	98	12	12	0	24	12	216	49	311
03-Oct	7.0	126	4.2	0.95	4.0	4.0	3.0	45	3	3	0	98	3	3	0	24	3	216	49	314
04-Oct	36.2	124	4.1	0.95	3.9	3.9	32.3	45	32	32	0	98	32	20	12	24	20	216	61	334
05-Oct	37.4	124	4.1	0.95	3.9	3.9	33.5	45	33	33	0	98	33	20	13	24	20	216	75	354
06-Oct	119.4	124	4.1	0.95	3.9	3.9	115.5	45	115	34	81	98	34	20	14	24	20	298	89	374
07-Oct	4.6	124	4.1	0.95	3.9	3.9	0.7	45	1	1	0	98	1	1	0	24	1	298	89	375
08-Oct	1.2	124	4.1	0.95	3.9	3.9	-2.7	42	0	0	0	98	0	0	0	24	0	298	89	375
09-Oct	18.0	124	4.1	0.95	3.9	3.9	14.1	45	11	11	0	98	11	11	0	24	11	298	89	386
10-Oct	12.0	124	4.1	0.95	3.9	3.9	8.1	45	8	8	0	98	8	8	0	24	8	298	89	394
11-Oct	25.4	124	4.1	0.95	3.9	3.9	21.5	45	21	21	0	98	21	20	1	24	20	298	90	414
12-Oct	6.2	124	4.1	0.95	3.9	3.9	2.3	45	2	2	0	98	2	2	0	24	2	298	90	417
13-Oct	24.2	124	4.1	0.95	3.9	3.9	20.3	45	20	20	0	98	20	20	0	24	20	298	90	437
14-Oct	22.0	124	4.1	0.95	3.9	3.9	18.1	45	18	18	0	98	18	18	0	24	18	298	90	455
15-Oct	23.8	124	4.1	0.95	3.9	3.9	19.9	45	20	20	0	98	20	20	0	24	20	298	90	475
16-Oct	10.8	124	4.1	0.95	3.9	3.9	6.9	45	7	7	0	98	7	7	0	24	7	298	90	481
17-Oct	1.4	124	4.1	0.95	3.9	3.9	-2.5	42	0	0	0	98	0	0	0	24	0	298	90	481
18-Oct	10.2	124	4.1	0.95	3.9	3.9	6.3	45	4	4	0	98	4	4	0	24	4	298	90	485
19-Oct	12.5	124	4.1	0.95	3.9	3.9	6.6	45	9	9	0	98	9	9	0	24	9	298	90	494
20-Oct	5.2	116	3.9	0.95	3.7	3.7	1.5	45	2	2	0	98	2	2	0	24	2	298	90	495
21-Oct	4.4	116	3.9	0.95	3.7	3.7	0.7	45	1	1	0	98	1	1	0	24	1	298	90	496
22-Oct	23.6	116	3.9	0.95	3.7	3.7	19.9	45	20	20	0	98	20	20	0	24	20	298	90	516
23-Oct	0.2	116	3.9	0.95	3.7	3.7	-3.5	42	0	0	0	98	0	0	0	24	0	298	90	516
24-Oct	0.8	116	3.9	0.95	3.7	3.7	-2.9	39	0	0	0	98	0	0	0	24	0	298	90	516
25-Oct	1.0	116	3.9	0.95	3.7	3.7	-2.7	36	0	0	0	98	0	0	0	24	0	298	90	516
26-Oct	3.4	116	3.9	0.95	3.7	3.7	-0.3	36	0	0	0	98	0	0	0	24	0	298	90	516
27-Oct	13.0	116	3.9	0.95	3.7	3.7	9.3	45	0	0	0	98	0	0	0	24	0	298	90	516
28-Oct	2.2	116	3.9	0.95	3.7	3.7	-1.5	44	0	0	0	98	0	0	0	24	0	298	90	516
29-Oct	0.8	116	3.9	0.95	3.7	3.7	-2.9	41	0	0	0	98	0	0	0	24	0	298	90	516
30-Oct	0.7	116	3.9	0.95	3.7	3.7	-3.0	38	0	0	0	98	0	0	0	24	0	298	90	516
31-Oct	0.0	116	3.9	0.95	3.7	3.7	-3.7	34	0	0	0	98	0	0	0	24	0	298	90	516
01-Nov	5.6	116	3.9	0.95	3.7	3.7	1.9	36	0	0	0	98	0	0	0	24	0	298	90	516
02-Nov	1.6	116	3.9	0.95	3.7	3.7	-2.1	34	0	0	0	98	0	0	0	24	0	298	90	516
03-Nov	8.2	116	3.9	0.95	3.7	3.7	4.5	38	0	0	0	98	0	0	0	24	0	298	90	516
04-Nov	23.6	109	3.6	0.95	3.5	3.5	20.1	45	14	14	0	98	14	14	0	24	14	298	90	529
05-Nov	11.0	109	3.6	0.95	3.5	3.5	7.5	45	8	8	0	98	8	8	0	24	8	298	90	537
06-Nov	5.8	109	3.6	0.95	3.5	3.5	2.3	45	2	2	0	98	2	2	0	24	2	298	90	539
07-Nov	0.2	109	3.6	0.95	3.5	3.5	-3.3	42	0	0	0	98	0	0	0	24	0	298	90	539
08-Nov	15.5	109	3.6	0.95	3.5	3.5	12.0	45	9	9	0	98	9	9	0	24	9	298	90	548
09-Nov	0.2	109	3.6	0.95	3.5	3.5	-3.3	42	0	0	0	98	0	0	0	24	0	298	90	548
10-Nov	2.0	109	3.6	0.95	3.5	3.5	-1.5	40	0	0	0	98	0	0	0	24	0	298	90	548
11-Nov	1.0	109	3.6	0.95	3.5	3.5	-2.5	38	0	0	0	98	0	0	0	24	0	298	90	548
12-Nov	6.6	109	3.6	0.95	3.5	3.5	3.1	41	0	0	0	98	0	0	0	24	0	298	90	548
13-Nov	14.8	109	3.6	0.95	3.5	3.5	11.3	45	7	7	0	98	7	7	0	24	7	298	90	556
14-Nov	14.4	109	3.6	0.95	3.5	3.5	10.9	45	11	11	0	98	11	11	0	24	11	298	90	566
15-Nov	29.9	109	3.6	0.95	3.5	3.5	26.4	45	26	26	0	98	26	20	6	24	20	298	97	586
16-Nov	94.6	109	3.6	0.95	3.5	3.5	91.1	45	91	34	57	98	34	20	14	24	20	355	111	606
17-Nov	5.3	109	3.6	0.95	3.5	3.5	1.8	45	2	2	0	98	2	2	0	24	2	355	111	608
18-Nov	0.1	109	3.6	0.95	3.5	3.5	-3.4	42	0	0	0	98	0	0	0	24	0	355	111	608
19-Nov	46.0	109	3.6	0.95	3.5	3.5	42.5	45	39	34	5	98	34	20	14	24	20	360	125	628
20-Nov	16.3	109	3.6	0.95	3.5	3.5	12.8	45	13	13	0	98	13	13	0	24	13	360	125	641
21-Nov	7.5	108	3.6	0.95	3.4	3.4	4.1	45	4	4	0	98	4	4	0	24	4	360	125	645
22-Nov	0.2	108	3.6	0.95	3.4	3.4	-3.2	42	0	0	0	98	0	0	0	24	0	360	125	645
23-Nov	30.8	108	3.6	0.95	3.4	3.4	27.4	45	24	24	0	98	24	20	4	24	20	360	129	665
24-Nov	2.0	108	3.6	0.95	3.4	3.4	-1.4	44	0	0	0	98	0	0	0	24	0	360	129	665
25-Nov	3.2	108	3.6	0.95	3.4	3.4	-0.2	43	0	0	0	98	0	0	0	24	0	360	129	665
26-Nov	0.0	108	3.6	0.95	3.4	3.4	-3.4	40	0	0	0	98	0	0	0	24	0	360	129	665
27-Nov	0.0	108	3.6	0.95	3.4	3.4	-3.4	37	0	0	0	98	0	0	0	24	0	360	129	665
28-Nov	8.3	108	3.6	0.95	3.4	3.4	4.9	41	0	0	0	98	0	0	0	24	0	360	129	665
29-Nov	0.8	108	3.6	0.95	3.4	3.4	-2.6	39	0	0	0	98	0	0	0	24	0	360	129	665
30-Nov	0.0	108	3.6	0.95	3.4	3.4	-3.4	35	0	0	0	98	0	0	0	24	0	360	129	665
01-Dec	0.0	108	3.6	0.95	3.4	3.4	-3.4	32	0	0	0	98	0	0	0	24	0	360	129	665
02-Dec	0.8	107	3.6	0.95	3.4	3.4	-2.6	29	0	0	0	98	0	0	0	24	0	360	129	665
03-Dec	1.8	107	3.6	0.95	3.4	3.4	-1.8	28	0	0	0	98	0	0	0	24	0	360	129	665
04-Dec	2.0	107	3.6	0.95	3.4	3.4	-1.4	26	0	0	0	98	0	0	0	24	0	360	129	665
05-Dec	0.4	107	3.6	0.95	3.4	3.4	-3.0	23	0	0	0	98	0	0	0	24	0	360	129	665
06-Dec	1.4	107	3.6	0.95	3.4	3.4	-2.0	21	0	0	0	98	0	0	0	24	0	360	129	665
07-Dec	0.0	107	3.6	0.95	3.4	3.4	-3.4	18	0	0	0	98	0	0	0	24	0	360	129	665
08-Dec	11.1	107	3.6	0.95	3.4	3.4	7.7	26	0	0	0	98	0	0	0	24	0	360	129	665
09-Dec	10.6	107	3.6	0.95	3.4	3.4	7.2	33	0	0	0	98	0	0	0	24	0	360	129	665
10-Dec		107	3.6	0.95	3.4	3.4	-3.4	29	0	0	0	98	0	0	0	24	0	360	129	665
11-Dec	4.2	107	3.6	0.95	3.4	3.4	0.8	30	0	0	0	98	0	0	0	24	0	360	129	665
12-Dec	0.0	107	3.6	0.95	3.4	3.4	-3.4	27	0	0	0	98	0	0	0	24	0	360	129	665
13-Dec	0.0	107	3.6	0.95	3.4	3.4	-3.4	23	0	0	0	98	0	0	0	24	0	360	129	665
14-Dec	0.2	107	3.6	0.95	3.4	3.4	-3.2	20	0	0	0	98	0	0	0	24	0	360	129	665
15-Dec	0.2	107	3.6	0.95	3.4	3.4	-3.2	17	0	0	0	98	0	0	0	24	0	360	129	665
16-Dec	4.9	107	3.6	0.95	3.4	3.4	1.5	19	0	0	0	98	0	0	0	24	0	360	129	665
17-Dec	1.0	113	3.8	0.95	3.6	3.6	-2.6	16	0	0	0	98	0	0	0	24	0	360	129	665
18-Dec	2.0	113	3.8	0.95	3.6	3.6	-1.6	14	0	0	0	98	0	0	0	24	0	360	129	665
19-Dec	12.5	113	3.8	0.95	3.6	3.6	8.9	23	0	0	0	98	0	0	0	24	0	360	129	665
20-Dec	12.8	113	3.8	0.95	3.6	3.6	9.2	33	0	0	0	98	0	0	0	24	0	360	129	665
21-Dec	5.8	113	3.8	0.95	3.6	3.6	2.2	35	0	0	0	98	0	0	0	24	0	360	129	665
22-Dec	3.0	113	3.8	0.95	3.6	3.6	-0.6	34	0	0	0	98	0	0	0	24	0	360	129	665
23-Dec		113	3.8	0.95	3.6	3.6	-3.6	31	0	0	0	98	0	0	0	24	0	360	129	665
24-Dec	5.0	113	3.8	0.95	3.6	3.6	1.4	32	0	0	0	98	0	0	0	24	0	360	129	665
25-Dec	2.0	113	3.8	0.95	3.6	3.6	-1.6	30	0	0	0	98	0	0	0	24	0	360	129	665
26-Dec	0.0	113	3.8	0.95	3.6	3.6	-3.6	27	0	0	0	98	0	0	0	24	0	360	129	665
27-Dec	0.0	113	3.8	0.95	3.6	3.6	-3.6	23	0	0	0	98	0	0	0	24	0	360	129	665
28-Dec	7.3	113	3.8	0.95	3.6	3.6	3.7	27	0	0	0	98	0	0	0	24	0	360	129	665
29-Dec	1.4	113	3.8	0.95	3.6	3.6	-2.2	25	0	0	0	98	0	0	0	24	0	360	129	665
30-Dec	2.2	113	3.8	0.95	3.6	3.6	-1.4	23	0	0	0	98	0	0	0	24	0	360	129	665
31-Dec	0.3	113	3.8	0.95	3.6	3.6	-3.3	20	0	0	0	98	0	0	0	24	0	360	129	665
	0.1																			
	2062	870			827	821					173				14		20			

ANNL RAIN	ETc B'NAN	ETa B'NAN	MnETa /ETo	SOIL WBAL	SURF RNOF	SSRF RNOF	C-hr LECH	Max Daily SURF
1988	2062	827	821	0.21	31	360	129	665	173

UNION AGR.: BANANA CULTIV.: RATIO OF ETa:ETc FOR EACH PENTADE FOR THE YEARS 1980-95 **TABLE 1.9**

Pentade	Pnt.No	RATIO OF ACTUAL TO POTENTIAL EVAPOTRANSPIRATION FOR EACH PENTADE															
		80	81	82	93	84	85	86	87	88	89	90	91	92	93	94	95
05-Jan	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10-Jan	2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
15-Jan	3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20-Jan	4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25-Jan	5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
30-Jan	6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
04-Feb	7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
09-Feb	8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
14-Feb	9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
19-Feb	10	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
24-Feb	11	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6
01-Mar	12	0.9	1.0	1.0	0.8	1.0	1.0	1.0	0.4	1.0	1.0	1.0	1.0	0.9	0.9	1.0	0.6
06-Mar	13	0.8	1.0	1.0	0.7	0.9	1.0	0.9	0.4	1.0	1.0	1.0	1.0	0.9	1.0	1.0	0.5
11-Mar	14	0.8	1.0	1.0	0.7	0.9	0.9	0.8	0.3	0.9	1.0	1.0	1.0	0.7	1.0	1.0	0.4
16-Mar	15	0.7	1.0	1.0	0.5	0.8	0.7	0.7	0.2	0.8	0.8	1.0	0.8	0.7	1.0	0.9	0.9
21-Mar	16	0.6	1.0	1.0	0.5	0.8	0.7	0.6	0.2	0.6	1.0	1.0	0.6	0.6	1.0	0.7	0.7
26-Mar	17	0.6	1.0	0.9	0.4	0.7	0.6	0.6	0.1	0.5	1.0	0.9	0.7	0.5	1.0	0.6	0.9
31-Mar	18	0.5	0.8	0.7	0.4	0.8	0.7	0.9	0.3	0.4	1.0	0.9	1.0	0.5	1.0	0.7	1.0
05-Apr	19	0.3	0.8	0.5	0.3	0.6	0.7	0.9	0.2	0.8	1.0	0.7	0.9	0.4	0.8	0.7	0.9
10-Apr	20	0.3	0.6	0.4	0.3	0.6	0.5	0.7	0.2	0.7	1.0	0.9	0.9	0.4	0.7	0.5	0.9
15-Apr	21	0.2	0.6	0.5	0.2	0.5	0.5	0.5	0.2	0.5	1.0	0.8	0.9	0.5	0.5	0.4	1.0
20-Apr	22	0.4	1.0	0.7	0.2	0.4	0.5	0.4	0.2	0.4	1.0	0.7	0.7	0.6	0.4	0.6	1.0
25-Apr	23	0.3	1.0	0.6	0.3	0.5	0.4	0.4	0.2	0.3	1.0	1.0	0.6	0.7	0.4	0.5	1.0
30-Apr	24	0.4	1.0	0.5	0.2	0.5	0.8	0.6	0.2	0.2	1.0	0.9	0.5	0.5	0.8	0.4	1.0
05-May	25	0.4	1.0	0.4	0.3	0.5	0.6	0.5	0.2	0.4	1.0	0.7	0.4	0.6	0.8	0.8	1.0
10-May	26	0.3	1.0	1.0	0.3	0.7	0.5	1.0	0.2	0.4	1.0	0.7	0.3	0.6	0.9	0.6	0.9
15-May	27	0.2	1.0	0.8	0.7	0.5	0.8	1.0	0.4	0.3	1.0	0.7	0.2	0.9	0.7	0.5	0.8
20-May	28	0.3	1.0	0.7	0.6	0.5	0.6	1.0	0.8	0.3	0.8	1.0	0.6	0.8	0.6	0.4	0.6
25-May	29	0.4	1.0	0.6	1.0	0.4	0.7	0.9	1.0	0.3	0.7	0.8	0.5	0.7	0.5	0.3	0.6
30-May	30	0.7	1.0	0.7	1.0	0.3	0.5	0.8	1.0	0.4	0.6	0.8	0.7	0.6	0.8	0.4	1.0
04-Jun	31	0.6	1.0	0.6	1.0	0.5	0.4	0.7	1.0	0.4	0.5	0.9	0.5	1.0	0.6	0.7	1.0
09-Jun	32	0.8	1.0	0.6	1.0	0.4	0.3	0.9	1.0	0.4	0.4	0.8	0.5	1.0	0.5	0.9	1.0
14-Jun	33	0.7	1.0	0.6	1.0	0.5	0.3	0.9	1.0	0.6	0.4	1.0	0.7	1.0	0.5	0.7	1.0
19-Jun	34	0.9	1.0	0.7	1.0	0.4	0.2	0.8	1.0	0.6	0.6	1.0	0.5	1.0	1.0	0.8	1.0
24-Jun	35	1.0	1.0	0.7	1.0	0.3	0.3	0.7	1.0	1.0	0.4	1.0	0.4	1.0	1.0	0.6	1.0
29-Jun	36	1.0	1.0	0.5	1.0	0.7	0.3	0.9	1.0	0.9	0.5	1.0	0.9	1.0	1.0	0.5	1.0
04-Jul	37	1.0	1.0	0.4	1.0	1.0	0.7	0.7	1.0	1.0	0.5	0.9	1.0	1.0	0.9	0.8	1.0
09-Jul	38	0.9	1.0	0.7	1.0	1.0	0.5	0.6	1.0	0.9	1.0	1.0	1.0	1.0	0.9	0.6	1.0
14-Jul	39	0.9	1.0	0.6	1.0	1.0	0.7	0.7	1.0	1.0	1.0	1.0	0.9	1.0	0.9	0.5	1.0
19-Jul	40	1.0	1.0	0.6	1.0	1.0	0.9	0.8	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.5	0.9
24-Jul	41	1.0	1.0	0.7	1.0	1.0	1.0	0.6	1.0	1.0	1.0	1.0	0.9	1.0	1.0	0.7	0.9
29-Jul	42	1.0	1.0	0.8	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	0.9	1.0	1.0	0.7	1.0
03-Aug	43	1.0	1.0	0.9	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	0.8	1.0	1.0	0.7	1.0
08-Aug	44	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0
13-Aug	45	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0
18-Aug	46	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0
23-Aug	47	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0
28-Aug	48	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
02-Sep	49	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
07-Sep	50	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
12-Sep	51	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
17-Sep	52	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
22-Sep	53	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
27-Sep	54	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
02-Oct	55	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
07-Oct	56	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
12-Oct	57	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
17-Oct	58	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
22-Oct	59	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
27-Oct	60	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
01-Nov	61	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
06-Nov	62	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
11-Nov	63	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
16-Nov	64	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
21-Nov	65	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
26-Nov	66	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
01-Dec	67	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
06-Dec	68	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
11-Dec	69	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
16-Dec	70	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
21-Dec	71	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
26-Dec	72	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
31-Dec	73	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 1.10 : ST LUCIA: WATERSHED STATISTICS AND CHARACTERISATION WITH RESPECT TO AGRO-ECOLOGICAL ZONES (INDIVIDUAL AREAS IN HECTARES)

Nr Watershed Name	Area (km2)	Rainfall Volume b cu m	Rainfall Depth (mm)	Ah	Ar	Bh	Bk	Br	Ba	Ch	Ck	Cm	Cr	Ca	Dh	Dk	Dm	Dr	Da	Em	Ek	Er	Ea	Fm	Fa
Agro-Ecological Zone and Approximate Rainfall Range(mm)				>3000		3000-2500				2500-2000					2000-1750					1750-1500				<1500	
1 Salle/Lapins	6.7	10.3	1530	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	335	0	0	34	302	0
2 Esperance	9.7	16.5	1700	0	0	0	0	0	0	0	10	0	0	0	0	19	504	0	0	437	0	0	0	0	0
3 Trou Grauval / Dauphin	10.0	16.3	1630	0	0	0	0	0	0	0	40	20	0	0	0	20	450	0	0	470	0	0	0	0	0
4 Marquis	31.0	67.3	2170	0	0	0	0	0	0	0	1860	248	0	62	0	93	496	0	217	93	0	0	31	0	0
5 Grande Anse / Louvet	29.2	52.9	1810	0	0	0	0	0	0	0	613	0	0	0	0	701	701	0	29	788	58	0	29	0	0
6 Fond d'Or	41.0	98.4	2400	328	41	738	41	0	0	287	1271	123	0	287	0	123	451	0	246	82	82	0	0	0	0
7 Dennery <<<<	21.4	44.7	2090	0	0	385	0	0	0	278	428	21	0	21	43	428	107	0	107	150	107	0	43	21	0
8 Riviere Galet / Trois Islet	11.0	19.4	1760	0	0	0	0	0	0	77	165	11	0	0	0	176	319	0	11	286	22	0	11	22	0
9 Mamiku / Patience	16.0	29.4	1840	0	0	144	0	0	0	304	160	0	0	0	48	288	272	0	16	288	16	0	0	64	0
10 Fond	18.1	45.1	2490	181	54	543	0	54	0	199	199	0	0	0	0	199	91	0	36	145	0	0	54	54	0
11 Volet	8.6	16.9	1970	0	0	9	0	0	0	9	301	0	0	0	0	129	112	0	0	224	0	0	0	77	0
12 Troumassee	31.7	91.0	2870	951	159	507	63	0	0	127	380	0	0	32	0	95	254	0	32	285	0	0	95	127	63
13 Micoud / Ravine Bethel	13.1	24.9	1900	0	0	0	0	0	0	26	223	0	0	0	0	223	197	0	0	328	0	0	52	249	13
14 Canelles	17.3	43.1	2490	329	0	329	0	0	0	173	242	0	0	17	0	277	35	0	35	156	0	0	69	35	35
15 Roarne/Rugeigne/Palmiste/St Urban	22.8	36.5	1600	0	0	0	0	0	0	0	0	0	0	0	0	410	0	0	0	319	1049	0	46	433	23
16 Vieux Fort	28.8	63.9	2220	346	0	432	0	0	0	259	202	0	0	0	0	374	0	0	29	288	317	0	58	490	86
17 Black Bay	15.2	26.9	1770	0	0	122	0	0	0	137	198	30	0	0	0	198	122	0	0	395	167	0	61	46	46
18 Laborie	5.5	8.9	1620	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	352	121	0	33	17	0
19 Piaye	9.6	22.3	2320	19	0	336	0	0	0	144	58	58	0	0	0	125	125	0	0	96	0	0	0	0	0
20 Balembouche	5.2	10.1	1950	0	0	16	0	0	0	125	0	31	0	0	0	0	161	0	0	187	0	0	0	0	0
21 Doree	11.1	29.4	2650	289	33	278	22	33	0	56	89	22	22	0	0	0	133	22	0	111	0	0	0	0	0
22 Choiseaul / Trou Barbet / Trou Marc	18.1	36.2	2000	0	0	0	380	0	0	0	217	217	0	0	0	0	434	0	0	561	0	0	0	0	0
23 L'Ivrogne	6.5	14.7	2260	0	0	104	46	0	46	7	130	0	0	26	0	91	7	33	0	91	52	20	0	0	0
24 Pitons	7.1	13.5	1910	0	0	0	0	0	0	0	284	0	71	0	0	92	0	85	0	0	7	170	0	0	0
25 Soufriere	17.2	42.1	2450	86	0	344	344	172	0	86	550	52	0	86	0	0	0	0	0	0	0	0	0	0	0
26 Mamin / Mahaut	13.7	26.2	1910	0	0	14	0	14	0	69	301	343	69	14	0	69	425	27	27	0	0	0	0	0	0
27 Canaries	14.6	37.2	2550	102	88	307	102	277	0	88	146	0	146	0	0	73	58	58	15	0	0	0	0	0	0
28 Anses la Verdure / Cochon / Galet	13.1	27.6	2110	0	0	52	52	26	0	39	249	0	39	0	0	288	275	13	0	275	0	0	0	0	0
29 Grande Riviere de Anse-la-Raye	8.9	23.8	2670	0	0	329	71	107	0	116	80	0	9	9	27	18	27	27	27	27	0	9	9	0	0
30 Petite Riviere de Anse-la-Raye	5.7	12.6	2210	0	0	74	74	0	0	6	154	0	0	0	0	57	148	0	6	29	0	0	23	0	0
31 Roseau	49.1	145.3	2960	1277	246	246	982	0	147	0	589	49	0	295	0	196	246	0	442	147	0	0	49	0	0
32 Mt. Bellevue	4.8	9.0	1870	0	0	0	0	0	0	0	0	0	0	0	0	24	384	0	0	72	0	0	0	0	0
33 Cul de Sac <<<<	40.9	112.9	2760	409	0	614	1227	0	409	0	368	0	0	327	0	409	41	0	245	41	0	0	0	0	0
34 Castries	14.3	29.6	2070	0	0	0	0	0	0	0	386	315	0	0	0	29	629	0	0	72	0	0	0	0	0
35 Choc	12.7	28.6	2250	0	0	0	13	0	0	0	724	191	0	13	0	13	254	0	64	0	0	0	0	0	0
36 Bois d'Orange	11.3	21.0	1860	0	0	0	0	0	0	0	170	0	0	0	0	79	396	0	34	283	0	0	170	0	0
37 Cap	15.4	23.7	1540	0	0	0	0	0	0	0	0	0	0	0	0	0	123	0	0	539	0	0	108	770	0
TOTALS (Areas in sq km)	616.4	1378.2	2240.0	43.2	6.2	59.2	34.2	6.8	6.0	26.1	107.9	17.3	3.6	11.9	1.2	53.4	79.7	2.7	16.2	79.5	20.0	2.0	9.7	27.1	2.7
(% of Total Area)	100.0 %			7.0	1.0	9.6	5.5	1.1	1.0	4.2	17.5	2.8	0.6	1.9	0.2	8.7	12.9	0.4	2.6	12.9	3.2	0.3	1.6	4.4	0.4

Sources: St Lucia Water resources: Preliminary Assessment, April,1986. (UN Water Resources Exploration & Assessment); Agro-ecological Zones by HTS/MMI, 1996-97.

Notes: Full characterisation of Agro-Ecological Zones is given in Fig.1.1.
h=halloysite/allophane zone; k=kaolinite zone; m=montmorillonite zone; a=alluvial zone; r=steepland and rock outcrop.

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2. LAND USE AND AGRICULTURE

2.1. Existing Land Use Mapping

2.1.1 Availability of Data:

Mapping and materials relating to current land use includes the following:

a) Panchromatic Stereoscopic Air Photography of Jan-April, 1992, at a nominal scale of 1:10,000. (On inspection, the mean scale proved to be 1:14,900, with a range of 1:13,000-1:16,000). Only the coastal 50-60% of the island is covered, including approximately 55% of the Cul de Sac, but only 20% of the Dennery watersheds. The most important upper watersheds in both cases were not covered.

Quality of the photography is very variable, most coastal areas being very clear and with good contrast. Most inland areas, however, are much less clear, and contrast is commonly poor. However, open banana areas are clearly recognisable in nearly all cases.

b) Mapping undertaken by Roche Itee, Group Conseil, in 1992, as part of the CIDA-funded Forest Management Plan, 1992-2002. Mapping is largely based on SPOT Imagery of 10th October, 1989, with original coloured hardcopy at 1:50,000 scale being enlarged to 1:25,000. Some field checking and correlation was undertaken, and existing topo maps and 1977 air photos were also used to differentiate some classes.

c) Mapping undertaken by Hunting Technical Services in 1984 based on 1:12,500 scale aerial photography flown in 1977 and 1981. Comparisons with 1966 photography were also made , with respect to contraction of forest at the expense of smallholder agricultural land.

2.1.2 Purposes of the Study

The Consultants undertook a review of the above data, in order to achieve the following objectives:
a) To check degree of detail and reliability of the Roche Itee (1992) land use mapping, which has been undertaken systematically over the entire island.
b) To obtain changes of land use since the 1977 Air Photo Interpretation (API) land use study which was undertaken by Hunting Technical Services in 1984. This work also included a study of land use changes over the period 1966-77, particularly with respect to deforestation.
b) To develop a methodology for undertaking a definitive land use map at a detailed scale (say 1:10,000) which can be used to predict and quantify soil erosion and run-off at subcatchment level, and can serve as a tool for subcatchment-level land use planning.

2.1.3 Land Use Mapping Legends used by Former Studies:

Map legends used in the former studies were investigated and compared. Legends include the following:

a) Roche Itee, Group Conseil, 1992 Legend:

1 Natural Tropical Moist / Wet and Rain Forest (Undifferentiated development stages)
2 Mangrove
3 Plantation Forest
4 Scrub Forest
6 Mixed Farming (between Natural Forest and / or Scrub Forest, and Intensive farming)
7 Intensive Farming (can include up to 25% of Forest)
8 Farming Densely Vegetated (Cocoa, Coconut, Fruit trees intercropping
9 Flatland Intensive farming
10 Eroded Agricultural Land
11 Rural Settlement (Rural housing surrounded by gardens)

12 Urban Settlement (includes all human made Infrastructures)
13 Rock and Exposed Soils
14 Water

Scale of Mapping: 1:25,000

Coverage of Mapping: Island-wide. Maps produced both as large-sheet layout, and divided into individual watershed areas. Areas (in acres) of Land Use Units in individual watersheds are given in **Table 2.1.** An example of this mapping for the Cul de Sac test sample area, enlarged to 1:12,500, is given in **Figure 2.1.**

b) Hunting Technical Services, 1984. Legend:

1a Rain Forest (broad leaved)
1b Montane Thicket
1c Mangrove
1d Elfin Woodland
P Plantation Forest Species
2 Secondary Forest (includes some shifting cultivation)
3 Scrub Forest
4 Open woodland (scattered trees in woodland)
5 Grassland
6 Commercial Agricultural Lands (e.g. estates)
7 Intensive small farming (>70% under organised smallholding agric)
8 Mixed Small Farming (25-70% under scattered individual smallholdings)
9 Rural Settlement (houses schools etc.)
10 Urban & Industrial

Subheadings for Agricultural Development included: cc coconuts, ba bananas, t tobacco, g grassland. (Where complexes of two units occur, the dominant one is listed first). In the map the shaded areas denote land which was forest in the 1977 photography, but are currently under non-forest land uses.

Scale of Mapping: 1:12,500

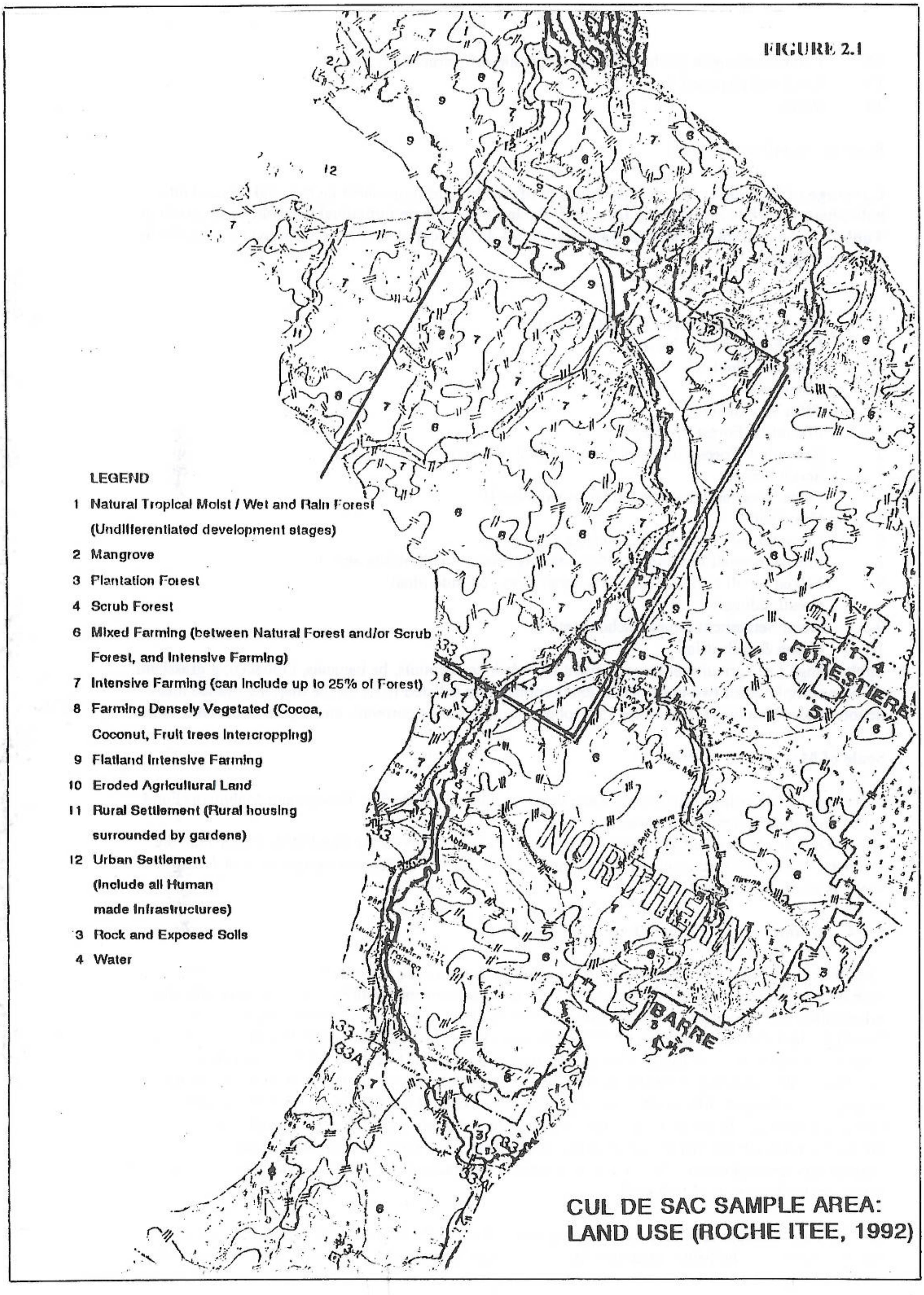
Coverage of Mapping: Three large watersheds, including Cul de Sac, Roseau and Mabouya (Fond D'Or), one sheet covering each watershed.
(Note: Dennery Watershed as referred to in this study in fact covers the Fond D'Or, rather than the Dennery Watershed.) An example of this mapping for the Cul de Sac test sample area, at 1:12,500 scale, is given in **Figure 2.2.**

2.1.4 Comments on Former Land Use Mapping:

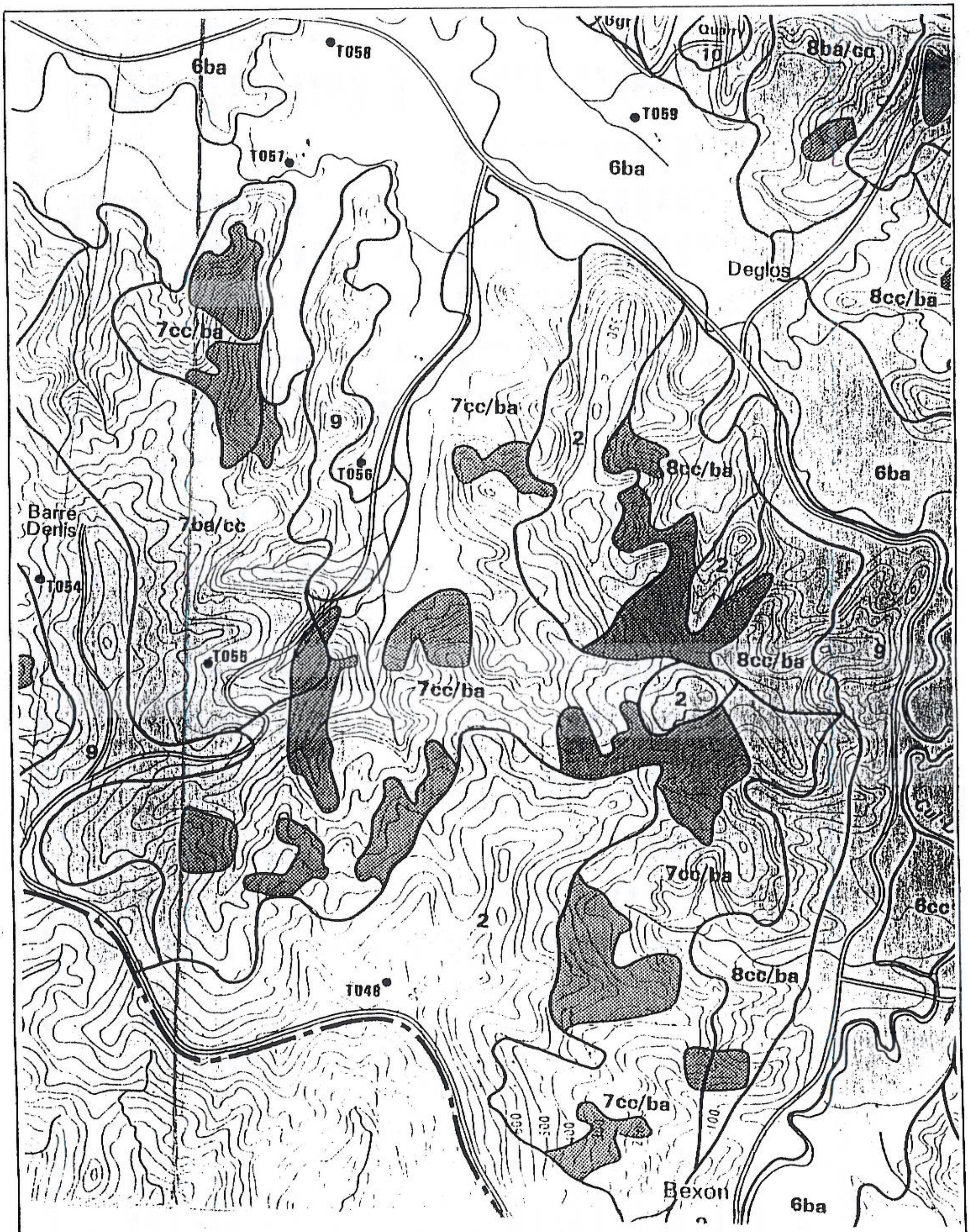
The Roche Itee Land Use Mapping is very generalised, both categorically and cartographically. Although moderately useful at a National Level, it is far from sufficiently detailed to give land use information at a Watershed level, let alone a Sub-Catchment Level. For example, the Intensive Farming Class (7) can include up to 25% of forest, while the Mixed Farming Class (6) can contain even much larger areas of forest. Thus delineation of pockets of forest, say of 25 ha in extent, is not possible on this mapping. A further problem is that types of cultivation are not differentiated: for example pure banana cultivation is not separated from coconut cultivation, or well-covered mixed treecrop holdings. The problem with the mapping stems largely from the use of Satellite imagery as the source material: the lack of detail of the information (i.e. pixels of 20m) and the lack of stereoscopic coverage make this medium unsuitable for land use mapping in so complex an area as St. Lucia, particularly at 1:25,000 scale.

The HTS 1984 mapping is very much more precise than the Roche Itee mapping, with pockets of forest as small as 2 ha being separated. Most of the agricultural land in the study area falls under two

FIGURE 2.1



CUL DE SAC SAMPLE AREA:
LAND USE (ROCHE ITEE, 1992)



For Legend see Section 2.1.3

FIGURE 2.2

CUL DE SAC SAMPLE AREA: 1:12,500
LAND USE (HTS, 1984)

TABLE 2.1: AREAS OF LANDUSES (ACRES) WITHIN EACH WATERSHED

Land Use Category	WATERSHED NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
							Dennery													
Naural Forest (1)	0	319	104	1809	1567	2454	971	264	348	2160	52	2770	0	704	0	927	91	84	156	0
Mangrove	27	12	0	12	20	27	0	12	27	40	178	156	25	12	245	0	7	7	0	0
Plantation Forest	0	0	0	82	54	208	0	27	0	10	0	336	0	210	0	74	0	0	0	0
Scrub Forest	1006	998	1161	507	2701	482	284	198	741	136	274	301	877	558	1762	418	504	324	0	0
Grass and Open Woodlands	222	0	166	0	109	20	119	20	131	0	12	27	378	126	514	376	339	106	195	0
Mixed Farming	232	521	351	1488	1562	2486	2481	603	852	862	568	1055	469	941	746	1960	1337	549	0	0
Intensive Farming	15	388	541	3109	798	3121	1102	1280	1352	937	531	2854	1171	1488	835	2891	927	111	870	193
Farming Densely Vegetated	0	0	0	15	0	0	0	0	183	250	450	173	52	0	0	119	91	32	1011	719
Flatland Intensive Farming	0	25	0	185	0	801	0	0	0	0	0	0	0	0	44	188	0	0	74	324
Eroded Agricultural Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rural Settlement	52	158	35	519	0	450	0	20	284	47	0	89	363	294	12	166	138	0	0	0
Urban settlement	67	0	0	0	0	170	277	52	0	54	27	0	0	0	1011	245	336	0	104	25
Rock and Exposed Soils	35	7	32	15	329	12	0	0	20	7	44	20	15	0	185	0	0	111	7	0
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL (Acres)	1656	2428	2390	7741	7140	10231	5234	2476	3938	4503	2136	7781	3350	4333	5354	7364	3770	1324	2417	1261

Land Use Category	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	TOTAL	%
													Cul de Sac						
Natural Forest (1)	321	0	91	472	731	951	1762	1352	1144	526	5041	133	1490	54	381	536	91	29856	19.6
Mangrove	0	0	0	0	0	0	0	12	12	0	7	7	7	0	0	7	7	866	0.6
Plantation Forest	25	0	0	0	0	0	0	0	0	0	27	0	138	0	5	0	0	1196	0.8
Scrub Forest	0	91	91	274	0	796	72	677	12	106	59	351	20	262	321	450	1562	18571	12.2
Grass and Open Woodlands	0	0	0	25	84	0	0	27	0	0	0	0	0	72	0	86	257	3216	2.1
Mixed Farming	1302	1191	235	170	1522	944	1374	1080	739	529	2071	35	2179	408	768	551	558	35782	23.5
Intensive Farming	709	2110	766	101	919	217	188	44	292	133	3496	52	3852	467	1132	423	64	40146	26.4
Farming Densely Vegetated	348	84	336	343	652	304	163	12	27	0	5	0	193	0	0	12	0	4242	2.8
Flatland Intensive Farming	0	0	0	0	0	0	0	0	0	0	1023	0	929	0	72	0	0	3267	2.1
Eroded Agricultural Land	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0.0
Rural Settlement	114	573	86	35	193	86	25	20	0	101	351	91	551	119	373	264	84	5822	3.8
Urban Settlement	25	432	0	101	178	12	35	20	0	22	106	324	657	2098	124	499	1016	8006	5.3
Rock and Exposed Soils	0	0	27	250	32	7	0	0	0	0	0	0	0	7	0	0	52	1096	0.7
Water	0	0	0	0	0	0	0	0	0	0	69	0	79	0	0	0	86	234	0.2
TOTAL (Acres)	2844	4481	1637	1771	4311	3317	3619	3244	2226	1417	12255	993	10095	3487	3176	2828	3777	152305	100.0

Source: Roche Itee, 1993. Note 'Mixed Farming' Class may include significant areas of non-cultivated land.

File:WTRSHDLU.wk3

classes: commercial agricultural lands (6) and intensive small farming (>70% under organised smallholding agriculture) (7). Areas of mixed small farming (25-70% under scattered individual smallholdings) (8) are less common, and areas of high forest within them have been separated out. Presence of predominant crops within a unit are also indicated, e.g. Unit 7ba/cc means that firstly bananas and secondly coconuts are found within the particular Unit 7 area.

2.1.5 Land Use Changes over the period 1966-77-92.

Inspection and analysis of the 1992 aerial photographs shows that forest cover has further contracted very considerably over the period 1977-92, with only small areas of forest remaining within the test area. Some of the forest areas are secondary, with agricultural treecrops (mangoes, breadfruit and coconut) intermixed with larger proportions of wild species. However, the net effect is that these areas would behave exactly as secondary forest in terms of runoff and surface wash erosion.

Areas of construction and associated homegardens can be delineated much more exactly on the 1992 1:10,000 (1:15,000) air photos, but the overall area under this land use would appear not to have increased significantly over the 1977-92 period. However, the generality of the 1984 (1977) mapping may be an important factor here.

2.1.6 Land Use delineation used for the current photo-interpretation (1992 photography)

For consistency and simplicity, it was decided to retain the format of the HTS 1984 Land Use Legend, but to define in greater detail the cropping proportions within each of the classes. Mapping has been completed for a trial area of some 900ha (2220acres) in the centre of the Cul de Sac watershed, this being an area of relatively high rural population pressure and consequent inappropriate land use. Modifications to the legend are thus as follows:

6b	V.intensive banana cultivation (>90% of gross area under bananas, and commonly >95% of area). (Most of this land was estate land, but currently most is divided into smaller holdings).
7b	Intensive smallholder banana cultivation (70-90% under bananas)
7cm	Coconuts forming >35% cover, overlying mixed cropping in which bananas predominate.
7c	Coconuts forming >65% cover, sometimes overlying grassland or scrubland, or sometimes mixed cropping (some bananas, with cocoa, citrus).
7t	Mixed permanent treecrops forming >65% cover, including breadfruit, mangoes, golden apple (ambrella), citrus, avocado, sometimes intermixed with small pockets of banana cultivation.
7tm	Mixed permanent treecrops forming 35-65% cover, including breadfruit, mangoes, golden apple (ambrella), citrus, avocado; but intermixed with small pockets of banana and possibly seasonal crop cultivation which are difficult to differentiate and map, even at 1:12,500 scale.
7m	Mixed smallholder cropping, including 20-35% permanent treecrops, but also larger areas of mixed bananas, seasonal cropping, fallow and rough grazing.
1/2	Forest Land, but with no clear indication as to being either primary or secondary forest.
7t2	Mixed permanent treecrops but including regeneration of natural forest species, making up >65% of permanent tree cover.

Within the Land Use Units, the percentage of banana cropping, in comparison to perennial treecrops, is a critical parameter. Percentages for the different units are as follows:

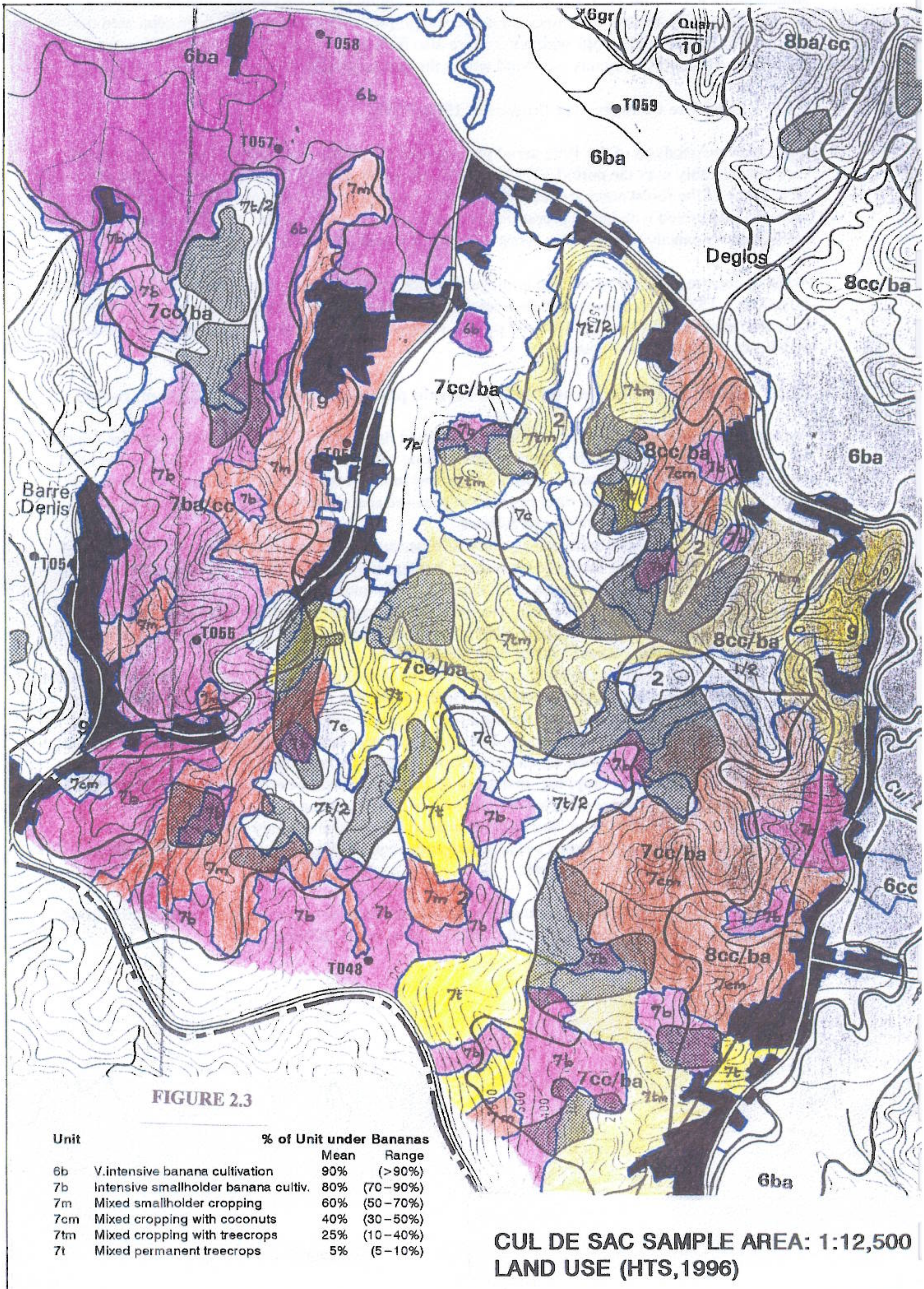


FIGURE 2.3

Unit		% of Unit under Bananas Mean	Range
6b	V.intensive banana cultivation	90%	(>90%)
7b	Intensive smallholder banana cultiv.	80%	(70–90%)
7m	Mixed smallholder cropping	60%	(50–70%)
7cm	Mixed cropping with coconuts	40%	(30–50%)
7tm	Mixed cropping with treecrops	25%	(10–40%)
7t	Mixed permanent treecrops	5%	(5–10%)

CUL DE SAC SAMPLE AREA: 1:12,500
LAND USE (HTS,1996)

Unit	Description	Percentage of Unit under Bananas %	(Range)
6b	V.intensive banana cultiv	90	>90
7b	Intensive smallholder banana cultiv	80	70-90
7m	Mixed Smallholder cropping	60	50-70
7cm	Mixed cropping with coconuts	40	30-50
7tm	Mixed cropping with treecrops	25	10-40
7t	Mixed permanent treecrops	5	0-10 -

These units are shown in the map of the test sample area in the Cul de Sac Watershed (**Figure 2.3**).

2.1.7 Small Format Aerial Photography and associated Land Use Mapping

The Consultants eventually were able to undertake Small Format Aerial Photography for the two pilot watersheds, and able to use this for some detailed land use mapping. This is described in detail in Chapter 3.

2.2 Slope Analysis

2.2.1 General

Slope data has been derived in all cases from the topographical maps, published at 1:25,000 scale, but also available as film positives at the field scale (1:10,000). These maps show contours at 25 feet for the interval 0-250 feet, and at 50 feet above the 250 ft contour.

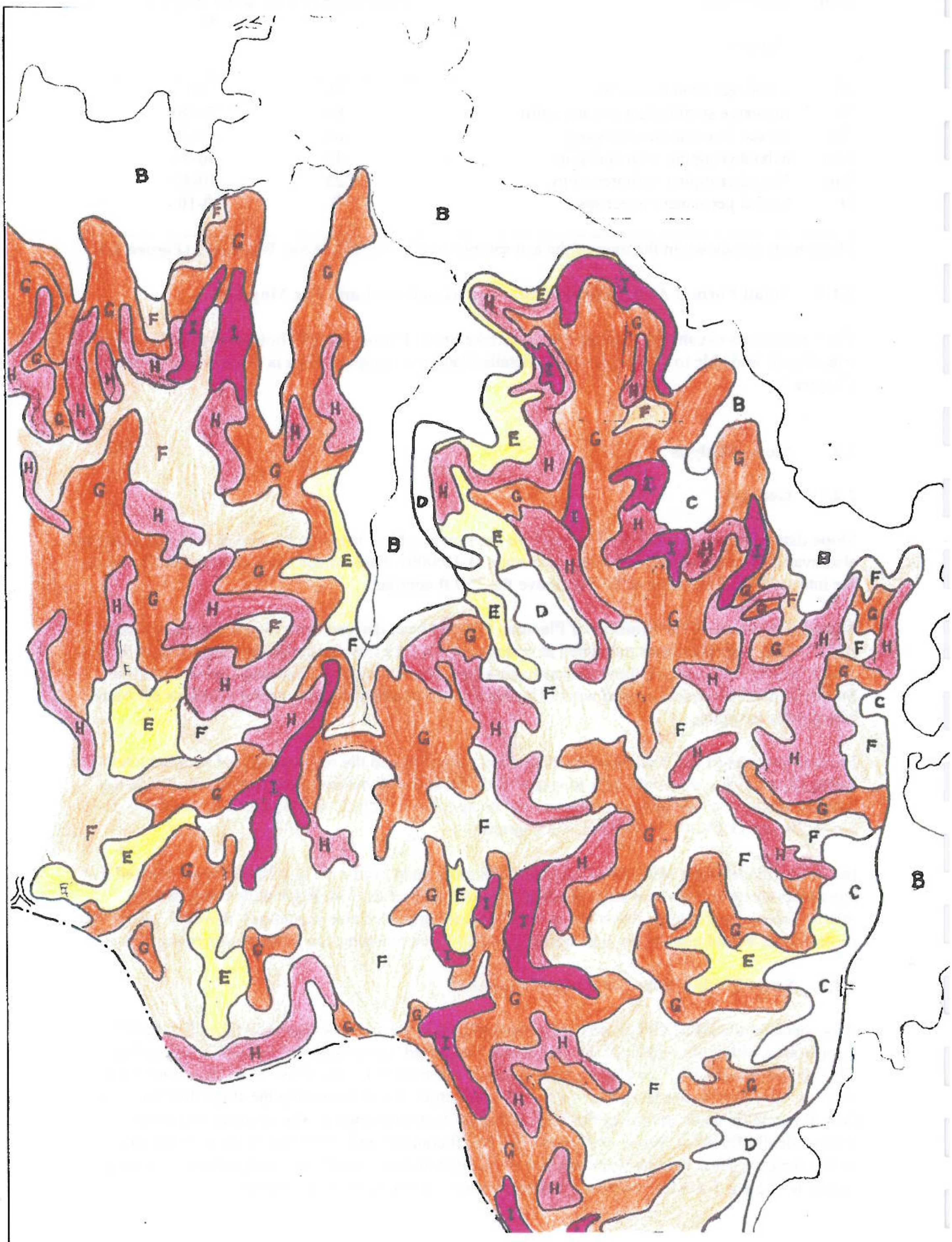
Slope information on the Ministry of Planning GIS has been derived from digital elevation model (DEM) data, with print-outs published at scales of up to 1:25,000 for the slope classes 0-2; 2-5, 5-10, 10-20; 20-30; >30 degrees, these classes having been used in the 1966 Soil and Land Suitability Survey and in subsequent related work. The consultants consider these as useful divisions for basic island-wide mapping.

For the purposes of the Watershed-level detailed mapping, and the requirements of detailed land suitability analysis, we would seek to retain all of the above divisions but to further sub-divide the three latter classes. Our revised classes would be as follows: A:0-2; B:2-5; C:5-10; D:10-15; E:15-20; F:20-25; G:25-30; H:30-35: I:>35 degrees.

Inspection made of the Ministry of Planning GIS slope map print-outs at 1:10,000 scale showed that there were many areas where slope shading appeared erroneous, with slope units being heavily oriented along the contour. Areas along the ridge lines appeared also suspicious. It would appear that further work would need to be done before this GIS slope mapping can be used on a routine basis.

2.2.2 Slope Study within Cul de Sac Watershed

As a check on the DEM GIS slope data a conventional slope analysis was undertaken for the 900-ha sample area within the middle of the Cul de Sac watershed, (agro-ecological zone Ck, but including alluvial floodplain Ca). Two slope templates were constructed for the above slope divisions, for the two contour intervals above and below the 250 ft contour. Lines separating the slope divisions were then drawn in on an overlay over the 1:12,500 scale contour mapping. The exercise was done independently for areas above, and below, the 250 ft contour, and at the end of the exercise any areas of discrepancy along the line were further investigated and then rectified. The resulting slope map is shown in **Figure 2.4**. Measurements on slope classes on this map are as follows:



For Legend see Section 2.2.2

FIGURE 2.4

CUL DE SAC SAMPLE AREA: 1:12,500
SLOPE ANALYSIS (HTS, 1996)

CLASS	B	C	D	E	F	G	H	I	TOTAL
SLOPE (DEG)	<5	5-10	-15	-20	-25	-30	-35	>35	
Percent Area	25.0	3.3	1.3	6.3	23.3	19.1	16.7	5.0	100.0

Results show a high percentage of the total area over 30 degrees slope (21.7%), with 5.0 % over 35 degrees slope. This land should not be in banana cultivation, and land over 35% should be planted to deep-rooting permanent trees as a matter of urgency. A very high percentage of the land is of slopes of 20-30 degrees (42%), the vast majority of this being under banana cultivation. This use can continue, but soil conservation measures (trash cover and trash lines) should be installed as a high-priority measure. Some 25% of the land is of < 5 degrees slope, representing the valley bottom land, most of which has a high flood risk, but otherwise would be highly suitable for bananas. Surprisingly only 10.8% of the land is in the gently sloping categories, (5-20 degrees slope), which would show a low flood risk and a high suitability rating for banana cultivation.

2.3. Land Suitability

2.3.1 Ecologically Suitable Crops

With a huge variation in agro-ecological zones, practically the full range of tropical crops could be grown successfully somewhere in the island. For the perennial crops, these could include (in decreasing order of rainfall requirement): tea, rubber, oilpalm, cocoa, banana, coffee, cinnamon, clove, pepper, coconut, sugarcane, cotton, cashew, plus a wide range of tropical fruits including avocado, breadfruit, citrus, mango, papaya, passion fruit and pineapple. On flatter land a wide range of seasonal crops could be grown, including taro, yams, sweet potatoes, arrowroot, maize, grain legumes, peppers, and many vegetables.

Because of limitations of slope, clayey soils, and for many alluvial areas increasingly flooding, seasonal crops are less well suited to St. Lucian conditions. Thus the tropical rootcrops, ideally suited to the more sandy and loamy soils in neighbouring St. Vincent, are not so suited to St. Lucia. The requirement thus is for perennial crops giving good ground cover, and good litter cover or tolerant of a low-level weed cover.

Of the perennial crops, tea, rubber and oilpalm, which are ecologically very well suited to the sloping lands of St. Lucia would be unsuitable because of requirement for concentrations of suitable land around central processing factories, and a heavy investment requirement for these factories. Labour costs are also a critical factor, and a high labour cost in St. Lucia (US$15/day, cf $5/day for competing countries) would make tea and rubber uneconomic under conditions here. Oilpalm would likewise not be suited because of a requirement of at least 6,000ha of land in close proximity to a factory, with the land ideally of under 15 degrees slope.

For the drier lands sugarcane would be fairly well suited, although slope again would have been a major constraint, as well as competing demands for land (construction) and high labour costs.

Alternative crops are discussed in detail in Annex 5 'Possibilities for Alternative Cropping'.

2.3.2 Land Utilization Types (LUTs) for St. Lucia

Potential land uses for St. Lucian conditions have thus been reduced to seven main agricultural land utilisation types: bananas, coconut, cocoa, minor treecrops (mainly fruits), cashew, grazing, and annual crops. Construction (residential, tourism, commercial), and two forestry land utilization types need also to be considered: Natural Forest, and Commercial Forest Plantations.

Land requirements for these LUTs can be summarised as follows:

a) Bananas: even rainfall distribution, with an average of no more than one 'very dry' month (200mm accumulated rainfall deficit) per year. Not exposed to high wind; cloud cover and humidity not too intense; elevation < 1200 feet; soils deep, well drained, low resistance to root penetration, high AWC and CEC, high fertility status (may be applied artificially); slopes ideally not more than 25 degrees; close proximity to roads;

b) Coconuts: as above, but a greater tolerance to dry periods (3 very dry months and 400mm accumulated rainfall deficit); preference for deep, lighter textured soils; slopes up to 35degrees.

c) Cocoa: as for bananas, but requirement for not excessive rainfall and humidity in wet season (<5 very wet months/year); soils of higher pH (5.7-6.5), high natural fertility status and high AWC and CEC; slopes not above 30 degrees.

d) Minor treecrops (fruits): as for bananas, but some show greater tolerance to wetter conditions and a much wider range of soil types; slopes up to 35 degrees; proximity to farmer's house (to reduce praedial larceny);

e) Cashew: requirement for appreciable dry season 2-5 'very dry' months; very tolerant of poor soil conditions, particularly in moister areas; slopes up to 30 degrees;

f) Grazing: as for bananas, but more tolerant of poorer soil conditions, although less clay and higher infiltration rate is important; slopes up to 25 degrees;

g) Annual crops: as for bananas, but strict requirement for land of gentle slopes (<10 degrees);

h) Commercial Forest Plantations: wide range of species enable plantations to be established over a wide range of agro-ecological zones; reasonably tolerant of poor soil types; slopes up to 40 degrees;

i) Construction: not suited to flood hazard areas, or areas with appreciable landslide hazards (thus most of Zones A and B).

2.3.3 Suitability Ratings for the 10 LUTs

Suitability ratings for the 10 LUTs have been assigned to the best 35% of the land represented by each of the 20 agro-ecological zones. These ratings are shown in the table accompanying **Figure 1.1.**

2.4 Potential Land Use Options and Implications for Land and Water Management: Consideration of Land with 30 deg slope and deep soil profile (>250cm rootable material)

Potential Land Use Options and their implications for steeply sloping land with deep soils, typical of the upper parts of most watershed areas, are shown in **Table 2.2.** Here various parameters of land sustainability are assessed for each land use, and the effect these have on the two main processes of erosion: mass movements (i.e. landslides, debris flows, slumping etc.) and surface wash erosion (i.e. sheet erosion, rilling, etc.).

2.4.1 Mass movements

Mass movements (slumping, debris flow, debris avalanche, solifluction etc.) effect generally small areas at any one time - possibly 1/10 to 2 hectares in extent - but involve great depths of material - commonly 2 to 8 metres in one event. They are promoted by heavy rainfall on saturated soil, on land with very steep slopes (usually over 30 degrees), usually in situations where the unconsolidated soil is deep (more than 2 to 2.5 metres) and often in areas where vegetation with deep tap roots (e.g. large trees) has been removed, or partially cleared, within the last 5-7 years. Shallow -rooting crops (e.g. seasonal crops or bananas) have relatively little or no stabilising effect on the land with respect to mass movements. Events like Tropical Storm Debbie in October, 1994, and the heavy rain of 26 October 1996, have caused hundreds of mass movement events over the island, but the total area slipped or buried in each occasion may only total only 100-200 hectares, possibly involving some 1000-2000 slips. Although mass movements may be catastrophic locally, damaging or threatening infrastructure, destroying dwellings and killing their occupants, they are of lesser significance agriculturally than surface wash erosion.

In **Table 2.2**, the third column shows the perceived risk of landslides, expressed as percent probability for mass movements occurring at any one site over the next 50 years, and the average soil loss that this would represent in terms of tonnes of soil / ha / year. The latter parameter is a product of three factors: percent probability (per year) of mass movements occurring, the volume of material represented by one hectare of soil of 250cm depth, and the percentage of the mass movement material being finally removed from the locality (approximately 25%). In the table we have estimated the risk of a landslide occuring in forested land of 30% slope to be 1% for the 50 year period, while for banana land this is increased to 10-20%, and for seasonally cultivated land it would be as high as 50%. The soil loss that these figures would represent per year would average out at 2, 20-40, and 100 tonnes/ha/year respectively.

2.4.2 Surface wash movements

Surface wash movements, by contrast, affect all cultivated land in the country to a greater or lesser extent, but remove only the surface few millimetres of soil in each event. The amount of surface wash erosion is determined by erodibility of soil, erosivity of rainfall, slope gradient, slope length, and exposure of the soil to rain drop impact. The latter factor is largely determined by soil management. Crops giving very good groundcover, and producing litter or trash giving good ground cover, are the best crops for conserving the soil and should be promoted in areas where surface wash erosion is a problem (e.g. on 80% of the cultivated areas in St. Lucia). Surface wash erosion is much more important agriculturally than mass movements, as it removes the most fertile upper part of the topsoil and any fertilizer recently added to the soil. It is likely that up to 1/3 of all fertilizer used in St. Lucia is lost due to surface wash removals.

In **Table 2.2**, the fifth column shows the perceived risk of surface wash erosion under the eight different groups of land uses, and the associated average soil losses in terms of tonnes of soil per hectare per year. For Natural Forest on 30 degree slopes the probable soil loss is in the region of 5 t/ha/year, increasing to 20-100 for banana cultivation and 500 for seasonal crops. As the rate of soil formation under St. Lucian conditions would be 1-2mm/year for most geological materials, and as 1mm of soil over an area of 1 hectare weighs 10-15 tonnes, losses of up to about 20 t/ha/year would be sustainable. However, removals of any topsoil would mean that the farmer has to compensate for plant nutrient losses by increased applications of fertilizers.

2.4.3 Conclusions on Land Use Options on Steep (>30deg) Land:

From the above analysis, and the data presented in **Table 2.2**, the following conclusions can be made:

a) Natural Forest is by far the best land use for land of 30 degrees slope and above, retaining soil and water better than any competing land use. Thus any further deforestation of this land needs to be resisted with great vigour.

b) Forest Plantation, Permanent Treecrops, (and VP tea) all are excellent crops for soil conservation on steep land, if under good management. Young stands of trees, however, will not anchor unconsolidated soil into the bedrock, and hence landslide risk in these areas continues to be high until the trees are well established. Similarly, although tea is good for reducing surface wash erosion, its relatively shallow roots do not provide much protection from mass movements. (Tea although ecologically very well suited to upper catchment areas of St. Lucia is not recommended here because of its high labour demand, requirement for a central factory for processing, and requirement for good marketing links.)

TABLE 2.2: LAND USE OPTIONS AND IMPLICATIONS: (LAND OF 30 DEG SLOPE AND DEEP SOIL PROFILE)

LAND USE OPTION	ABUNDANCE OF DEEP TAP ROOTS (ANCHORING SOIL TO BEDROCK)	RISK OF LANDSLIDES [Probability of slides over next 50 Years] (Avg soil–loss:t/ha/yr)	INFILTRATION RATE (mm/day)	RISK OF SURFACE WASH EROSION (Average Soil Loss: tonnes/ha/year)	EVAPO–TRANS–PIRATION Crop Coef(Kc)	IMPLICATIONS FOR LAND MANAGEMENT	IMPLICATIONS FOR WATER MANAGEMENT
1.Natural Forest	Abundant	F.low [1%] (2t/ha/yr)	High 40mm	V.low (5t/ha/yr)	High (1.20)	Land Use sustainable, but little immediate financial returns/ha.	F.clean surface run–off High base flow/surface runoff ratio.
2.VP Tea (mature)	F.common (shade trees)	High [10%] (20t/ha/yr)	F.high 34mm	F.low (20t/ha/yr)	Mod.high (0.95)	Land Use sustainable, but requirement for v. good management.	Reasonable surface run –off; high base flow.
3.Forest Plantation or Perennial Treecrops (mature)	Common	Moderate [5%] (10t/ha/yr)	High 40mm	Low (10t/ha/yr)	High (1.15)	Land Use sustainable, but requirement for vg trash management.	Reasonable surface run –off; high base flow.
4.Forest Plantation or Perennial Treecrops (young: first 10 yrs)	Rare (only begin–ing to be re–established)	High [10%] (20t/ha/yr)	F.high–High 37mm	Low (10t/ha/yr)	High (1.00)	Land Use sustainable, but requirement for vg trash management.	Reasonable surface run –off; high base flow.
5.Bananas:good trash management + tied contour drains	Absent	High–v.high [20%] (40t/ha/yr)	High 40mm	F.low (20t/ha/yr)	Mod.high (0.95)	Land Use on limit of sustainability:requrmt for v.good managmnt	Reasonable surface run –off, mod.silt & nutrient content;high base–flow
6.Bananas:good trash management + surface drains	Absent	High [10%] (20t/ha/yr)	Moderate 34mm	Moderate (50t/ha/yr)	Mod.high (0.95)	Land Use probably not sustainable	Surface run–off with high silt and nutrient content
7.Bananas:poor trash management + surface drains	Absent	High [10%] (20t/ha/yr)	F.low 25mm	High (100t/ha/yr)	Moderate (0.90)	Land Use definitely not sustainable	Surface run–off with v. high silt and nutrient content
8.Seasonal Crops: eg.Taro	Absent	V.high [50%] (100t/ha/yr)	Variable:gen–erally F.low. 25mm	V.high (500t/ha/yr)	Low (0.70)	Land Use definitely not sustainable	Surface run–off with extremely high silt and nutrient content

File:LUOPTION.wk3

c) Bananas under average (i.e. poor trash) management are clearly not a sustainable land use on 30deg slopes. Good trash management (covering the ground surface with an even coverage of trash, or installing closely-spaced trash lines) will cut down soil losses through surface wash considerably. However, tied contour drains with the above good trash management will be required to reduce the problem to a sustainable level. For landslide-risk areas, however, the latter practice would not be advocated, as retaining water on the contour during the latter part of the wet season would further promote mass movements. For this reason the Consultants would advocate planting of such land to perennial treecrops with deep taproots.

iv) Seasonal cultivation (taro, yams, sweet potato, peppers) are clearly not suited to steep land. With the decline in banana prices, there is a grave danger that banana land would be converted to these crops which would exacerbate the erosion problem.

2.5 Forestry

Forestry must play a key role in any watershed management programme, with areas of activity in many countries falling under three headings: conservation forestry, commercial forestry (both natural forests and forest plantations), amenity forestry (roadside plantings, parks etc.) and agro-forestry.

The main forestry role in St. Lucia is filled by the Forestry Department under the MAFF&E, although a number of NGOs are currently engaged in forestry activities. (For example CANARI have been engaged in Community Forestry Projects since the 1980s). In this case the NGOs will rely on the Forest Department for technical advice and seedlings as no NGOs are currently employing trained foresters.

The Forestry Dept. is currently following the 10-year Management Plan which was drawn up with Canadian (CIDA) assistance. Currently about 40 acres per year are being re-afforested, including activities in Dennery (areas occupied by former squatters), Millet (Roseau Watershed), and activities now scheduled for the Northern Dry Scrub Forests (Watersheds 1-4, and 35-37).

In the past planting has been dominated by three main species: Blue Mahoe, Mahogany and Caribbean Pine. Teak has been planted in some drier areas, and leguminous species have also been planted particularly for rapid groundcover establishment and for fuelwood plantings. Although an excellent species, Blue Mahoe (Hibiscus elatus) is currently not favoured because of its susceptibility to the Hibiscus Pink Mealybug, which has devastated plantings in the island of Grenada. Mahogany, also an excellent timber species, has a requirement for shade in its early growth stages. It is currently underplanted to coconuts/bananas and other treecrops on agricultural holdings, as in enrichment plantings in natural forests.

Current activities have been increasingly focussed on planting 'wildings' -i.e. wild seedlings, collected from Natural Forest, and particularly those species that attract wildlife, for example, the St. Lucia Parrot. There does not appear to be much interest in trying new exotic species. Some exotics which have been very successful elsewhere, - e.g. Lucaena - have not been successful locally, possibly because of soil acidity and inoculation problems. Caribbean Pine is the most successful species for establishment on degraded, acid soils in St. Lucia as in many other humid tropical areas.

Education in the conservation role of forestry, and in eco-tourism activities (including forest trails and walks) is obtaining much more interest. Current projects are for eco-tourism development and for community development, the Roseau Sub-Watershed area being essentially an extension forestry / community forestry project. Smallholder interest is very heavily on fruit trees, particularly mangoes, rather than timber trees, and the Forest Department is attempting to meet this demand from its nursery. Roadside planting (planned by Min of Communication and Works) and riverbank planting are other areas of activities. The local Forest Officer has been active on the Dennery WMAF, and the Consultants view the role of the Forestry Officers as crucial for the success of Watershed Management in the country.

TABLE 2.3 : PROVISIONAL YIELD TABLES: TROPICAL FOREST PLANTATIONS

Age Years	Remaining Crop: No. trees /ha	Remaining Crop: Mean DBH (cm)	Remaining Crop: Mean H (m)	Remaining Crop: BA m2/ha	Remaining Crop: Mean Vol/tree (m3s.ob.)	Remaining Crop: Vol /ha (m3s.ob.)	Removals: No. trees /ha	Removals: Mean DBH (cm)	Removals: Mean H (m)	Removals: BA m2/ha	Removals: Mean Vol/tree (m3s.o.b.)	Removals: Vol /ha (m3s.o.b.)	Accum.Prodn.: BA m2/ha	Accum.Prodn.: Vol /ha m3sob	Accum.Prodn.: M.A.I. m3sob	Girth (m)	Price (EC$ /dm3)	Value Harvested (EC$ /tree)	Value Harvested (000EC$ /Ha)	Accum. Value (000EC /Ha)	Accum. NetValue (000EC /Ha)	Discount Rate 1 %: Accum. NPV (000EC /Ha)	Discount Rate 1 %: Accum. NPV/Yr (EC$ /Ha/Yr)	Discount Rate 6 %: Accum. NPV (000EC /Ha)	Discount Rate 6 %: Accum. NPV/Yr (EC$ /Ha/Yr)
TEAK, Height Class I (Agro-ecological Zones D, E, F)																									
6	750	13	11.0	10.0	0.069	52	400	10	9.0	3.1	0.035	14	13.1	66	11.0	0.31	0.31	11	4.4	4.4	2.9	2.7	448	2.0	335
13	500	20	15.0	15.7	0.200	100	250	15	13.0	4.4	0.104	26	23.2	140	10.8	0.47	0.38	39	9.9	14.2	10.0	8.8	676	4.7	361
20	320	26	17.5	17.0	0.371	119	180	19	15.0	5.1	0.183	33	29.6	192	9.6	0.60	0.52	96	17.2	31.5	23.2	19.0	952	7.2	362
30	200	34	19.0	18.2	0.675	135	120	26	16.0	6.3	0.341	41	37.1	249	8.3	0.82	0.69	236	28.4	59.8	45.3	33.6	1120	7.9	263
40							200	40	20.5	25.1	0.935	187	44.0	301	7.5	1.26	1.06	995	199.1	258.9	203.4	136.6	3415	19.8	494
PINUS CARIBAEA, Height Class I (Agro-ecological Zones A, B, C)																									
6	800	12.5	10.0	9.8	0.058	47	400	9	9.0	2.5	0.026	10.5	12.3	58	9.6	0.28	0.12	3	1.2	1.2	0.4	0.4	69	0.3	51
11	500	22	19.0	17.5	0.311	155	300	16	17.0	6.0	0.164	49	26.0	215	19.5	0.50	0.12	19	5.8	7.0	3.5	3.2	289	1.9	170
16	350	28	21.5	21.5	0.600	210	150	22.5	20.0	6.0	0.372	56	36.0	326	20.3	0.71	0.12	44	6.6	13.7	7.8	6.6	413	3.1	191
21	250	36	23.0	25.5	1.046	261	100	28	21.0	6.1	0.592	59	46.1	436	20.7	0.88	0.12	70	7.0	20.6	12.3	9.9	474	3.6	172
30							250	43	25.0	36.3	1.569	392	56.9	567	18.9	1.35	0.12	196	49.0	69.6	50.0	37.1	1237	8.7	290
ALBIZZIA FALCATA (Agro-ecological Zones A-D)																									
4	500	17	9.5	11.0	0.123	62	500	13	8.0	6.5	0.067	33.5	17.5	96	23.9	0.41	0.12	8	4.0	4.0	2.2	2.2	538	1.8	443
10	250	27.5	20.0	15.0	0.623	156	250	16	17.0	7.5	0.287	72	29.0	262	26.2	0.50	0.12	34	8.5	12.5	7.4	6.7	673	4.1	415
15							250	35	23.5	24.0	1.175	293	38.0	399	26.6	1.10	0.12	139	34.7	47.1	33.7	29.0	1937	14.1	938
EUCALYPTUS SP, All Classes (Agro-ecological Zones A-D)																									
7	550	16	10.0	11.0	0.090	50	650	10	7.0	5.0	0.023	15	16.0	65	9.3	0.31	0.21	5	3.1	3.1	1.9	1.8	251	1.3	179
13	340	27	15.0	19.5	0.367	125	210	17	12.0	5.0	0.119	25	29.5	165	12.7	0.53	0.21	25	5.2	8.4	5.1	4.5	345	2.4	184
18	200	35	20.0	19.5	0.822	165	140	24	16.0	6.5	0.320	45	36.0	250	13.9	0.75	0.21	67	9.4	17.8	11.8	9.9	548	4.1	230
25							200	40	25.0	25.0	1.300	260	41.5	345	13.8	1.26	0.22	284	56.9	74.7	56.2	43.8	1753	13.1	524
NATURAL REGENERATED MAHOGANY/JAK PLANTATIONS (Agro-ecological Zones A-D)																									
10	1300																								
20	600	20	17.0	19.0	0.210	125	700	11	11.0	6.5	0.048	35	25.5	160	8.0	0.35	0.16	8	5.5	5.5	2.9	2.4	118	0.9	45
30	270	32	23.0	22.0	0.730	200	330	20	18.0	9.0	0.200	65	37.5	300	10.0	0.63	0.21	42	13.8	19.3	12.5	9.3	310	2.2	73
40	100	41	25.0	13.5	1.300	130	170	35	24.0	16.0	0.900	155	45.0	385	9.6	1.10	0.42	380	65.4	84.7	63.8	42.8	1071	6.2	155
45							100	45	26.0	16.0	1.640	165	47.5	420	9.3	1.41	0.81	1321	132.9	217.6	169.4	108.2	2405	12.3	273

Source: Tables presented in Forestry Master Plan for Sri Lanka, 1986, based on FRDP compilation.
Prices based on Sri Lanka State Timber Corp Mar 97 figures. Accumulated Net Value figures include a reduction of 15.5% for taxes, EC$0.27/cuft for loading charges, and 10% for additional charges.
DBH-diameter at breast height; BA-basal area; H-height; MAI-mean annual increment.

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The Forest Department currently provides seedlings free of charge. Nursery capacity at the time of the CIDA project was at a maximum of some 100,000 seedlings per year: currently it has declined to some 80-90,000, including Christmas tree seedlings.

Commercial felling is undertaken only after permits have been obtained, and only selective felling is undertaken - all clear felling has been stopped. Current timber production is only a tiny fraction of consumption, although much of the local timber is of higher value. Illegal felling apparently is now very much less of a problem than previously, and new encroachment onto forest reserves is now not significant. Part of the reason may be decline of banana prices: another part would be the more efficient policing actions of the Forest Department. Promotion of planting on private land is less active than in many countries, although support with advice and seedlings is readily forthcoming. In the long-term the government could create tax incentives for forestry activities - e.g. exempt forestry land from the forthcoming land tax, if the forestry holding is properly managed; grant income tax relief for money from private sources sunk into forestry activities.

It is unlikely that returns from forestry activities would compete with those from treecrops - let alone bananas - if only financial benefits from timber sales are counted. High costs of labour, and very high costs involved with managing very steep and inaccessible land, would be further disincentives for commercial forestry in St. Lucia. Timber, being a essentially a long-term crop, is highly sensitive to discount rate applicable to a country or project. As an illustration for tropical timbers in Sri Lanka, covering environments very similar to those in St. Lucia, **Table 2.3** shows income flows and the effects of different discount rates on Net Present Values for different timber species. The short-term Albizia becomes very much more attractive relative to the higher value, but longer-term species, as discount rates increase.

In terms of economic value to St. Lucia, one would also have to assess the environmental benefits of having steepland under forestry rather than say bananas. This would have to include an assessment of the value of lower flood peaks (less flooding of agricultural land and infrastructure in the floodplains), the value of soil being retained on the slopes rather than washed into riverbeds and thence the sea, the value of increased baseflow during dry seasons, particularly if the water is being used for domestic purposes, and the value of a more attractive landscape for tourists and residents. In international terms, one should also assess the value of carbon sequestration represented by the forests. However, this is beyond the scope of the present assignment.

3. SMALL FORMAT AIR PHOTOGRAPHY AND ITS USE IN LAND USE MAPPING

3.1 Introduction

The TOR call for detailed mapping of the two pilot watersheds, and Existing Land Use Mapping is an essential component of this. However, a major problem is that there is a lack of recent stereoscopic aerial photography on which this mapping and associated assessments can be based. The only photography giving reasonable coverage is that of 1977: the more recent photography (1992) covers only 50% of the Cul de Sac and less than 20% of the Dennery Pilot Watersheds, with the most crucial upper areas not covered in either watershed. Conventional air photography is severely limited for high rainfall / high elevation areas in the humid tropics due to cloud cover for the vast majority of the time, and even the best photography shows an appreciable proportion of cloud in the high elevation areas: this was clearly the case in the 1992 photography.

To overcome these problems the Consultants proposed to use Small Format Air Photography (SFAP), chartering a local helicopter as a platform for the photography. It was hoped to fly the area during a fine day in the dry season, picking a time at short notice, and covering the two watersheds at an elevation of 4500 feet. With a conventional (28mm) wide-angle lens on a 35mm camera, the scale of the photography would be about 1:10,000 at 6x4inch format, and some 90 prints would be sufficient to give stereoscopic coverage over the entire area.

The Consultants' firm, Hunting Technical Services, had used SFAP previously in Palawan, the Philippines, which has the same cloud problems as St. Lucia. In that case the larger size of the project justified purchase and construction of more sophisticated equipment, including the construction of a special camera mount which kept the lens facing in a vertical direction. This mount replaced the under-cargo door in a twin-engined Cessna aircraft which was used as the platform for the photography. A special 250-exposure camera body was also purchased for that project.

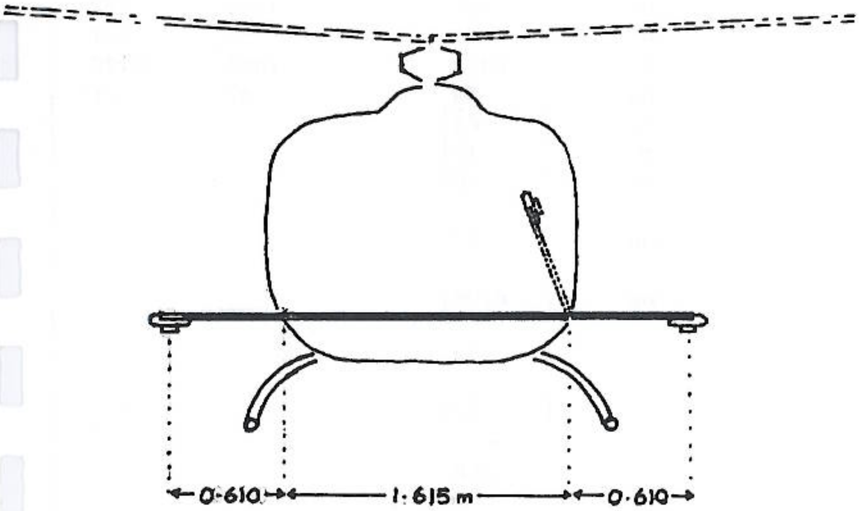
The Consultants proposed the SFAP as an additional relatively small item (c.EC$4000) to BDDC in mid-November 1996, and this was immediately approved.

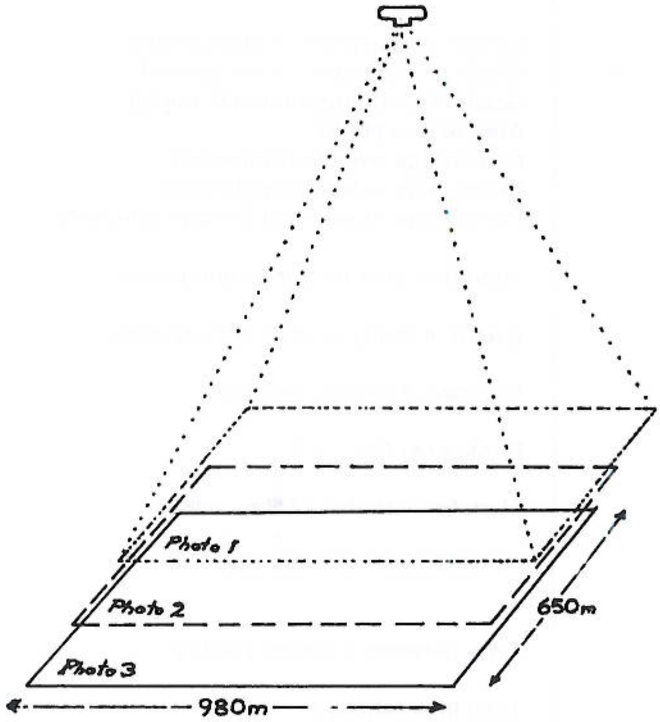
Unfortunately significant periods of fine weather did not occur during the 1997 Dry Season while the Consultants were in St. Lucia, and by July it seemed unlikely that any photography would be obtainable, particularly from an elevation of 4500 feet. However, photography at a lower elevation (2500 feet) could avoid most of the cloud problems for much of the time, but would involve 4 times the number of photos and require much more time to compile a land use map. Problems of distortions in the high-gradient, high elevation areas of the Project Area would also be much greater. The Consultants discussed these problems during their meeting on 21/7/97, but resolved to proceed with the SFAP if at all possible. It was considered that this would act as a useful pilot project for up-to date land use compilations, and, if successful, could be used in other watersheds in due course.

3.2 Planning and Logistics

The Consultants discussed logistics of the SFAP with the helicopter pilot of St. Lucia Helicopters Limited and made several inspections of the helicopter in order to design and build a simple device to mount the cameras outside the machine (see **Figure 3.1**).

Figure 3.1: Mounting device for 35mm cameras in Aerospatial Helicopter





Flight lines were devised to give economic coverage of the two watersheds and to produce satisfactory overlap with a 28mm lens (see **Figure 3.2**). An interactive spreadsheet was designed to calculate number of photos, distances, scales, and timing required given focal length of lens, elevation and speed of the helicopter (see **Table 3.1**). A speed of 45 knots (83kmph) was considered by the pilot to be the minimum which could be maintained fairly constantly without problems of directional accuracy. This gave an interval of 10 secs between photos. With the doors of the helicopter removed, faster speeds would have caused wind problems for the photographers and possibly wind buffeting problems for the mounting apparatus. The elevation of 2500 feet was considered to be the maximum to avoid major cloud problems. (Cloud shadow, however, would still be a problem at these lower elevations.)

As cost of film was a small proportion of the total cost of the SFAP, it was decided to use two cameras simultaneously in case of any problem. A very short trial flight was undertaken in order to check if the photography was satisfactory, prior to the main flight. The trial flight did indeed show that one of the cameras was not working properly, perhaps because of the SLR mirror mechanism jamming due to vibrations. A third camera was thus obtained for the main flight (Nikon SLR with a Vivitar 24mm [v.wide angle] lens, kindly loaned by the MAFF&E Publicity and Information Office). UTM coordinates were worked out for start and finish of each of the 13 flight lines as it was hoped to use the helicopter GPS to position the machine for the start of each flight line. Unfortunately the GPS was not working, and thus navigation had to be undertaken using the 1:25 000 topographical map. The Project Hydrologist / Water Engineer kindly agreed to serve as navigator.

3.3 Results of the Flying

The photography was undertaken on Thursday 16th October, between 9am and 11am. The position of the lines flown, in relation to the lines planned, is shown in **Fig 3.2.** In coastal areas, and in inhabited areas no navigational problems were encountered, but over forested areas navigation proved difficult and explains why some runs were somewhat off course. Flying along compass bearings apparently was not sensible, due to cross winds having a relatively severe effect when the helicopter's air speed was as

TABLE 3.1: SMALL FORMAT AIR PHOTOGRAPHY OF CUL DE SAC & DENNERY: KEY MEASUREMENTS

		Planned	Actual 1	Actual 2
Length of negative:	mm	36	36	36
Focal length of lens:	mm	28	24	35
Height of helicopter above ground:	ft	2500	2500	2500
	m	760	760	760
Length of one photo on the ground:	m	977	1140	782
Width of one photo on the ground:	m	651	760	521
Scale of photo (assuming 6" prints):	1:	6412	7480	5129
Area of one photo:	ha	64	87	41
Percentage overlap (widthwise)	%	65		
Percentage sidelap (lengthwise):	%	15		
Percentage of area lost through tortuosity:	%	10		
Therefore area unique to one photo:	ha	17		
Extent of Study Area (2 Watersheds)	ha	6206		
Number of photos needed:		364		
Photos per film – roll:		37		
Therefore number of film – rolls:		9.8		
Groundspeed of helicopter:	Km/hr	83.4		
	m/sec	23.2		
Time between adjacent photos:	secs	9.8		
Total time required:	mins	79.7		

Run Order	Run No.	Distance(km) RunDistnce	Distance(km) Betw'nRuns	Coordinates StartingPoint		Coordinates FinishingPoint		Bearing Deg	Bearing Dir	No. of Photos
			2.63							
1	C1	10.60		508.83	1547.10	511.68	1536.95	165	SSE	48
			1.60							
2	D1	5.00		513.25	1537.01	517.88	1538.88	68	ENE	23
			1.63							
3	D2	7.25		519.48	1538.65	512.75	1535.93	248	WSW	33
			0.88							
4	D3	8.43		512.90	1535.10	520.73	1538.25	68	ENE	38
			1.25							
5	D4	6.38		520.20	1537.17	514.28	1534.78	248	WSW	29
			3.20							
6	C2	10.33		512.43	1537.35	509.63	1547.25	345	NNW	46
			0.98							
7	C3	8.23		510.55	1547.00	512.80	1539.12	165	SSE	37
			1.43							
8	C4	6.73		513.26	1540.48	511.43	1546.90	345	NNW	30
			0.98							
9	C5	5.50		512.38	1546.62	513.90	1541.35	165	SSE	25
			4.55							
10	C6	3.75		509.61	1542.93	506.35	1544.77	300	NW	17
			0.85							
11	C7	3.50		506.56	1545.58	509.62	1543.88	60	SE	16
			1.15							
12	C8	3.50		509.28	1544.98	506.18	1546.71	300	NW	16
			1.23							
13	C9	1.80		507.41	1547.00	508.96	1546.13	60	SE	9
			3.63							
TOTAL		80.98	25.95							367

File: AIRPHOTO.wk3

low as 45 knots. In retrospect drawing a cross section of the central water-divide of the country and positioning of ends of runs with respect to this cross section would have led to better results.

The 35mm Automatic exposure / automatic rewind camera performed well on most runs although 2 of the 8 rolls of film failed to wind on in the camera. The high wind in the open helicopter made loading and unloading of the cameras difficult, and may explain this. The quality of the photography was fairly good, with camera-shake being only a slight problem in a small proportion of the photographs. With the lens being vertical, and not being very wide angle, distortions as seen between overlapping photos of flat or gently sloping land were relatively small, making map compilation from a photo laydown relatively easy. However, the effect of variable elevation of the ground surface, and somewhat variable elevation of the helicopter, made scales of adjacent photos rather different for most areas. Scales of each photo were thus calculated, and the appropriate reduction factor on the photo-reducing photocopier was calculated for each acetate overlay on which the air photo interpretation (API) was undertaken. Along the runs good coverage was obtained, and on average some 5-10% overlap was seen between adjacent photos (the flight lines being essentially planned to give stereo coverage with the 28mm lens).

Unfortunately the 28mm camera again had problems of jamming when mounted on the apparatus. Thus the 24mm camera was used as a back-up but was hand held, necessitating oblique (near vertical) photography. Exposures were in the range 1/1000 sec at f/4-5.6 with more highly reflecting vegetation in bright sunshine to 1/500 sec at f2.8 in forested areas under light cloud shadow. Some full-oblique stereoscopic photography was also taken with the 24mm camera and this proved particularly useful in showing mass movement scars in the high gradient, high elevation areas, and in the high landslide-risk areas in the Bexon-Ravine Poisson area (see colour plate). With the much wider angle lens, some 55-70% overlap was seen with adjacent photos. The quality of the lens was also noticeably better than with the non-SLR 35mm camera, and this was reflected in prints being less grainy. The non-vertical nature of the photography and the very wide angle lens meant that use of this photography directly for mapping was very difficult. However comparison with the 35mm lens photography gave a great deal of added information, although it made API and subsequent mapping a much more time consuming activity.

3.4 Results from Air Photo Interpretation:

The photography was excellent in giving up-to-date land use on both agriculture and construction.

Routine Mapping at a scale of 1:10 000 was planned, but this has been shown to be highly intricate in most areas due to the very complicated pattern of land use. It was thus considered that land use mapping at 1:7,500 would be more appropriate, particularly in areas of habitation and smallholder land use. In addition, fitting the API to the controlled basemap proved to be extremely time-consuming to give accurate results for the steeply sloping areas. Comprehensive mapping of the entire watersheds was thus not possible within the 5 weeks remaining of the project period, especially as the Land Use/Environment specialist had other duties to complete in his assignment. Within the short time remaining the Consultants were able to present mapping of two key sample areas within the Cul de Sac Watershed. These include the Ravine Poisson area (**Fig.3.3**) which is an area of steep slopes, and showing both building and agricultural practises in inappropriate areas. The second area covers the lowermost parts of the Cul de Sac Valley (**Figure 3.4**), again showing inappropriate land use, but due to large scale construction, and insufficient attention being focussed on need for flood buffers in floodplain areas, and problems of alluvial materials for building foundations.

To complete interpretation and mapping on a controlled basemap at 1:7500 scale, the consultants estimate that a further 5-6 staff weeks would be required for the two watersheds. About half of this time is required for the interpretation, the balance for adjusting the interpreted boundaries to fit the controlled basemap, which is difficult in the steeply sloping areas.

The land use legend used in the HTS 1984 study, and modified for the December, 1996 Interim Report, was further ammended and redefined and is presented here as **Table 3.2**. This seeks to tackle the problems of multiple cropping, and of culivation on a very small scale. With the legend are presented figures on percentage cover of bananas, and estimated current soil loss, in tonnes/ha/year for the different subunits, at various slope limits.

Much construction activity has occurred since the previous topo map and the HTS land use map were compiled, and this includes domestic houses, industrial and commercial buildings, and roads and agricultural service tracks. The Cul de Sac watershed is much more affected than Dennery, where activity has been predominantly in the Dennery town area. The higher, more Easterly parts of the Cul de Sac watershed have shown the greatest changes, and much of this has been on unsuitably steep land or land threatened by future landslides. Both domestic house construction and banana growing have been notable there. The SFAP was excellent in be able to give an updated picture on land use.

The lower parts of the Cul de Sac valley have shown major river straightening and road projects (both the Morne Diversion Road and roads to service houseplot areas), and large areas are demarcated for industrial/commercial activities, in spite of major physical problems (flood risk, unsuitable materials for foundations). This is a major area of concern, and needs more careful considerations from the Planning Authorities.

Base maps are readily updateable for the more gently-sloping areas (see **Fig 3.4** for showing the extent of activities in the lower Cul de Sac valley area.) Major environmental problems are evident in these areas (see Annex 8, and illustrations in the colour plate, **Figure 3.5**). Land Use Planning proposals for lower Cul de Sac (and preliminary proposals for the lower Roseau) give cause for concern for both environmental and economic reasons.

Mass movement (landslide) scars are still much in evidence (ex TSD, with some active in Oct 96), and these can clearly be located, especially in the critical Ravine Poisson Area. **Fig 3.3** shows these scars in relation to land use for that area. Stereoscopic photos (24mm set) were very useful in interpreting landform and thence recognising areas of very high landslide risk. **Fig 3.6** shows a block diagram showing such very high risk areas. It is alarming that clearly uplanned / unapproved building is still rapidly occuring in these areas.

Extent of banana cultivation is clearly visible for most areas, facilitated by the darker green tones common with fertilised bananas, and the speckled appearance on the 1:5000 photos. Some difficulties with interpretation, however, occur in the following situations:

- where bananas are an understorey to a relatively dense canopy of trees (ie bananas being exposed in <40% of total areas);
- where bananas are in intense hill shadow or cloud shadow (reprinting with a greater exposure would partly overcome this problem; also shadow was less of a problem on the later runs -after 10am- than those at the start of the photogrpahy -9am)
- where low, plant-crop bananas are under-fertilised and are in very weedy fields. (In this case separation from grassland / scrubland may be difficult).

Much evidence was obtained that land is going out of bananas, particularly on the more marginal land where bananas have been cultivated for a longer period (eg Choppin Ridge). The extent of grassland / scrubland was very much greater than expected, and much of this had clearly been bananas previously. The danger is that this will be used in the future for annual crops. Areas in the extreme East, above Marc Marc, still show recent banana plantings on steep slopes, and clearly very recent encroachment onto Crown Land, and this is of major concern.

Individual trees can clearly be distinguished and in some cases the species recognised (eg flowering with teak, darker foliage with breadfruit, lighter and pinker tinges with the new flush on mangos). Sharper prints with a higher quality lens would be more useful here.

Combinations of different crops were clearly recognised (see land use legend), with bananas, coconuts and other treecrops being mixed in many areas. Following a standard convention for crop combinations (see **Table 3.2**) the equivalent acreage of bananas can readily be calculated.

Much forest land appeared to be mature secondary forest in which many introduced treecrop and other perennial species predominate. For soil and water conservation purposes this forest will behave similarly to primary forest, although biodiversity will be far less. Areas of plantation forestry (and possibly enrichment plantings in degraded natural forest?) were clearly interpretable in the photos (extreme E of the Cul de Sac).

Individual species in the high-elevation primary forest have characteristic signatures which are highly visible in the photos. Due to elevation of the land, scale of photos is more detailed than for the lower areas (c 1:2500-3000 cf 1:5000). Correlation of species with photo signature at this scale would be possible future activity. Large areas of primary forest remain (perhaps due to extreme difficulties of access). Many mass movement scars, including deposits of mudflow materials, can still be seen, although most of these are now covered with short, dense, secondary vegetation.

3.5 Cost of SFAP:

The cost of the SFAP, is shown as follows:

Item	Originally envisaged (4500feet-100 photos)	Revised Calculation (2500ft-370 photosx2)	Final Outurn 2500ft-550ph
Helicopter	1 hr (US$900)	10 mins trial 80 mins (US$1350)	20 min trial 110 mins (US$1950)
CameraHire	(US$167)	None	None
Films&Procsng	(US$111)	(US$400)	(U$300)
Apparatus	None	(US$80)	(US$80)
TOTAL	US$1178	US$1830	US$2330

The cost as originally envisaged was based on photography at 4500 feet, taking only 100 photos. The revised calculation was based on flying at 2500 feet, with some 370 photos taken in duplicate, with 80 mins for the definitive flight and only a 10 min trial run. The final outurn involved 550 photos, but with a 20 minute trial and 110 mins of final flight time. Some extra time was taken in investigating problems above the Roseau Dam (see photo in Annex 8), and due to problems of navigation. With experience some 80 minutes of main-flight and 5 minutes of trial flight should be sufficient for a 6200ha area, which would put the cost of the photography at $1655, or 27 cents per ha, 11 cents (say 7 pence) per acre.

3.6 Recommendations for future SFAP and Land Use API:

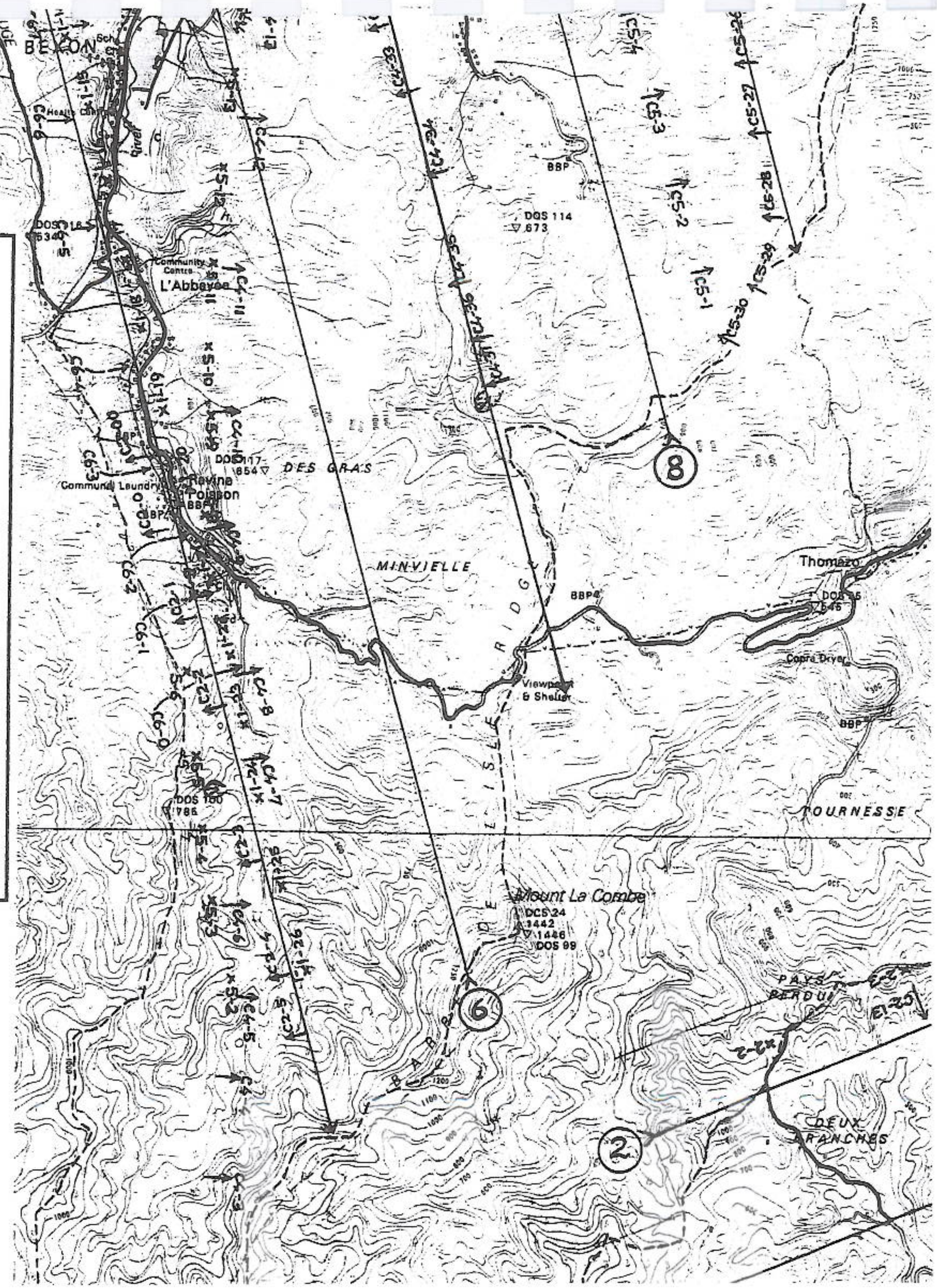
1. A more thorough navigation briefing of both pilot and navigator would have been useful. Position of ends of runs in relation to a cross section of the peaks along the central mountain spine of the island would probably have improved navigation accuracy.

2. Vibrations from the helicopter appear too severe for SLR mirror mechanisms when these cameras are connected to our floor-mounted apparatus. Construction of a knee-mounted apparatus would

BABONNEAU
Cabiche
RESINARD
TALVERN
Girard
Bocage
LA FITTE
Ti Rocher
FOND CACAO
CANNIE
Guesneau
Mount du Chazeau
Health Centre
Four Roads Junction
Gros Morne
Trois Pitons
Dubrassay
Deglos
Forestiere
En Pois Doux
COMBAT
Water Pipeline
Piton Flore
FLOISSAC
Crown Lands Gap
Marc Marc
BEXON
Dryers
TICOLON
Morne St Joseph
La Croix Maingot
Barre Duchaussée
Fond Manger
Mount Terr Fallee
MARIGOT
Coolietown
Pereu
La Perle
Ciceron
Mount Ciceron
Couparil Estate
Tennis Courts
Golf Course
REDOUIT
PORT CHARLOTTE
BAGATELLE
GOODLANDS
ANSE FERE
GRANDE CUL DE SAC BAY
Banana Plantation
Distillery
Refinery Under Construction
Cul De Sac River
BARRE DENIS
ODSAN
MORNE BRIDGE
BISHOPS GAP
DERRIERE FORT
RAVINE CHABOT
ENTREPOT
13
11
12
7
9
10

SMALL FORMAT AIR PHOTOGRPAHY (SFAP): CUL DE SAC & DENNERY

FLIGHT DIAGRAM TIME OF PHOTOGRAPHY: 16 OCT 97, 9–11am.



LEGEND

c.1:5,000 vertical photography (35mm lens): photo centres — x 1–23
(Taken from port side of helicopter)
[1–23 indicates film no. and print no.]

Position of selected frames: ▭

c.1:7,500 near–vertical photography (24mm lens): — ↑ C1–23
(Taken from starbord side of helicopter)
(arrow indicates direction of view & nearest point to helicopter)
[C1–23 indicates film no. and print no.]

Position of planned flight lines, & line no.(1 to 13): ←⑦

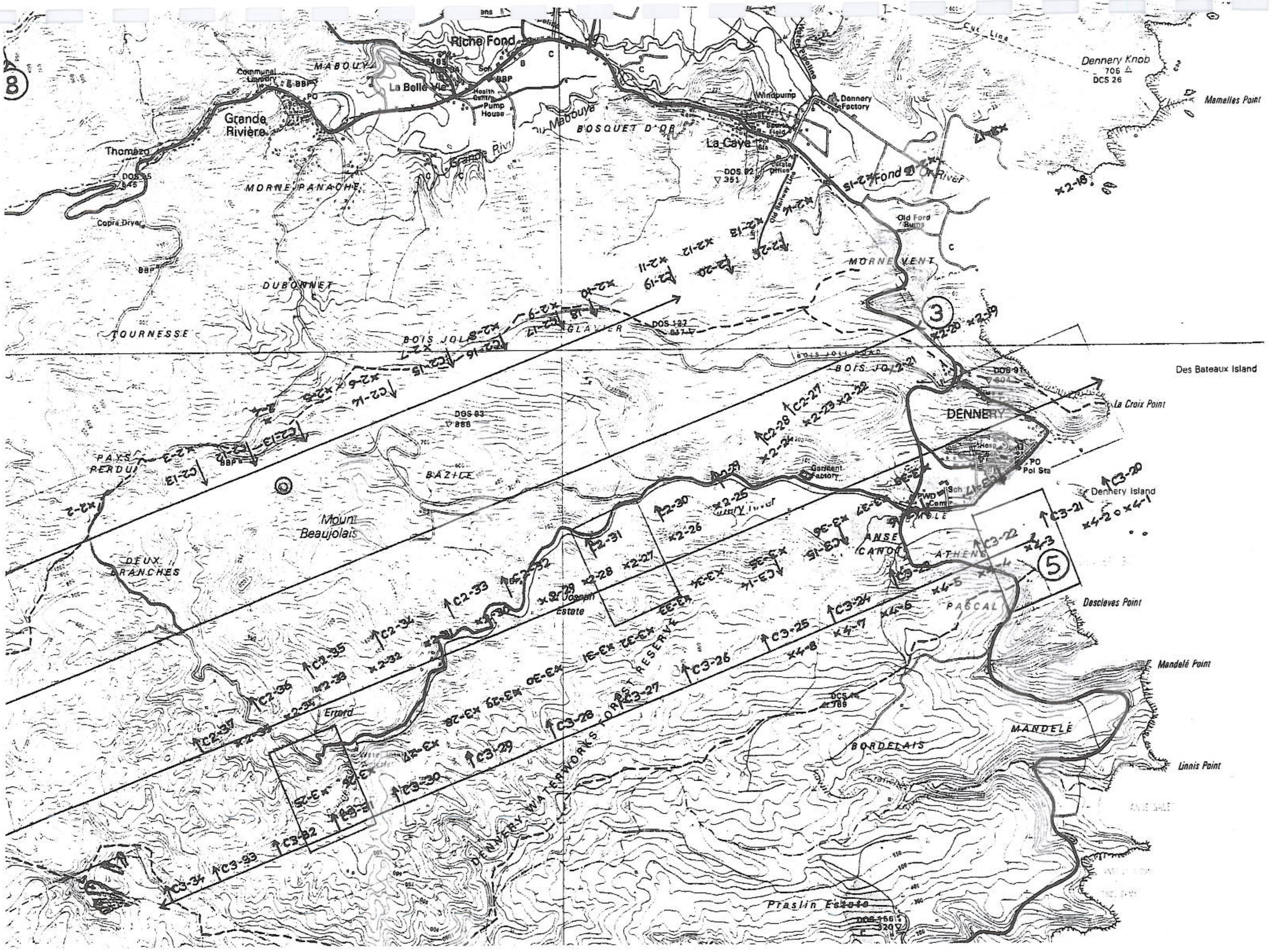
Watershed boundaries:

Major Landslide Scars:

Agricultural Trials Sites: ○

Engineering (slope meter) trials sites: ▲

File: V3SFAP.wk3


Riche Fond
La Belle Vie
Grande Rivière
Thomazo
MABOUYA
MORNE PANACHE
BOSQUET D'OR
La Caye
Dennery Factory
Windpump
Dennery Knob
706
DCS 26
Mamelles Point
Fond D'Or River
Old Ford Bums
MORNE VENT
DUBONNET
TOURNESSE
BOIS JOLI
GLAVIER
Des Bateaux Island
La Croix Point
DENNERY
PO
Pol Sta
Dennery Island
ANSE
CANOT
ATHENS
PASCAL
Descleves Point
Mandelé Point
MANDELÉ
Linnis Point
BORDELAIS
Praslin Estate
St Joseph Estate
Errard
Mount Beaujolais
BAZILE
PAYS PERDU
DEUX BRANCHES
DENNERY WATERWORKS FOREST RESERVE
Copra Dryer
Health Centre
Pump House
Garment Factory
3
5
8

possibly have overcome this. The non-SLR camera performed well, although it was limited by the quality of the lens.

3. Very short (5mins) trial flights are needed to verify that everything is working. For logistics reasons, this would have to be undertaken at the end of another (i.e. tourist) flight and would thus mean the apparatus would have to be installed in the helicopter with the engine still running.

4. Limitations on logistics of use of the helicopter are severe. The 2nd helicopter of the company was being used in Montserrat, and the third was under repair. Cruise charter work had first priority, and this is particularly busy in the afternoons. For short flights start-ups with a static helicopter are rare, making installation of any apparatus difficult. Simplicity and flexibility are thus required in any equipment design and final photography. Finally weather is a major limiting factor, even for photography at 2500 feet.

5. 4 cameras and 3 photographers (navigator taking oblique photos) are essential: cost of helicopter hire is 7 times that for even triplicate photography. With noise, air buffeting etc. possibility for things going wrong are increased.

6. The following camera features are ideally required: automatic re-wind, cable release, automatic exposure with fixed speed (1/1000 sec) and variable aperture. A 250-exposure camera back would be ideal, but it appears cost is some US$3000 and a special film type and film processing lab has to be used. Developing of such a film in the US or UK would probably be necessary.

7. Standardisation on a 28mm lens format would have been useful: the 35mm lens does not cover a sufficiently wide area (more flight lines would have been required) while the 24mm lens increases distortions.

8. More frequent photos (more overlap) would have been useful: 65% is ideal.

9. ISO 200 film would have been more useful. Under cloud shadow exposure used was 1/500sec at f/2.8 with ISO 100 film. Some camera shake was apparent at 1/500sec and particularly at 1/250 sec, and the faster film speed would have helped to overcome this.

10. Within the open helicopter, everything has to be tied down, including any paper, maps, film containers etc. (An empty computer bag was used in the trip, tied in with the seat belt, and this proved useful.)

11. With stereo coverage with good overlap (60-65%) API using the enclosed legend is a relatively straightforward exercise, although rather time consuming (up to 1 hour for 40ha of typical smallholder land at 1:5,000-1:7,500). Problems were encountered where overlap was insufficient, particularly where relative elevations, flight directions and attitudes between adjacent photos were different.

12. For flat or gently sloping areas, adjustment of photo-overlay scale and fitting to a controlled basemap proved a simple and straightforward exercise, using a variable reducing / enlarging photocopier. Some 15 mins was required for a 40ha area. For steeply sloping areas the exercise proved both difficult and time-consuming, taking 1 hour per 40ha area.

13. Detail of land cover units for smallholder areas require an ideal scale for draft mapping at 1:7,500. This would probably stand reduction to 1:10,000 scale for a final printed map.

14. Some further 5-6 weeks of land use interpretation and cartographic work would be necessary to complete a 1:7,500 map of the two watersheds based on a controlled basemap. The Consultants would plan to retain the photographs and negatives for the immediate future pending a decision on this work. In the long-term it will be necessary to store both the photos and the negatives in a controlled-humidity environment (i.e. a room with 24-hour air conditioning).

FIGURE 3.5: PROBLEMS OF LAND USE IN THE PILOT WATERSHEDS

T left Cul de Sac: Ravine Poisson area between Chopin Ridge Road (right) and main highway (bottom left). Typical land uses under smallholder management include 9:Rural settlement (houses, yards and immediate houseplots); 10i:Industrial/ Institutional; 7b:Intensive smallholder banana cultivation; 7bt:bananas with tree-crops forming 15–50% cover; 7bf:banana fallow land, or v.young plant crop; 7m mixed smallholder cropping; 5:grassland/scrubland; 2/7t:secondary forest/ smallholder treecrops; 7c/5:coconuts withgrassland/scubland.
(See full Land Cover/Land Use Legend, discussed in this Annex)
Note banana cultivation on steep slopes, threatening downslope construction. (SFAP photo 5–7, scale c.1:4,500). Note photo on right gives oblique view of this area, and adjacent land in Bexon–Chopin ridge.

T right Cul de Sac upper valley looking W across Ravine Poisson and Chopin Ridge,with Lower Roseau valley in background.Note Ribbon development in areas of moderate to severe landslide risk, and steep–slope cultivation and landslide scars in foreground. Area of photo (Top Left) is located in centre–left of this photo. The area of Chopin Ridge has 4 of the Project's 5 landslide–monitoring trials. This area has had a history of bad landslides: some 100 people were killed here in 1938 by landslides and associated mudflows. (SFAP oblique photo C5 32)

B left Near Dennery Town. Homestead Plots spreading W onto scrub forest to N of River. Diversified high–value annual crops (with irrigation) in floodplain to the S of river. Diversification/annual cropping is to be welcomed on such land, which is almost flat, but has a 1–in–10 year flooding risk (Sept–Nov). Note upper end of Dennery Town flood protection bund (bottom, left), installed as part of Phase 1 works. Homegardens in upland areas could benefit from spoil materials cleared from river, as soils are v.shallow. (SFAP photo 3 37, scale 1:4,500).

B right Cul de Sac.Bexon area. Note area of river straightening in top centre of photo. Note lack of perennial tree protection along many river banks. Unconsolidated alluvial material is hence v.susceptible to river scouring. Note patchy nature of banana crops which have still not fully recovered from 26Oct96 flooding. Note agric.feeder track going into steepland at bottom left of photo serving banana areas which have expanded at the expense of forest cover.(SFAP photo C4 31)

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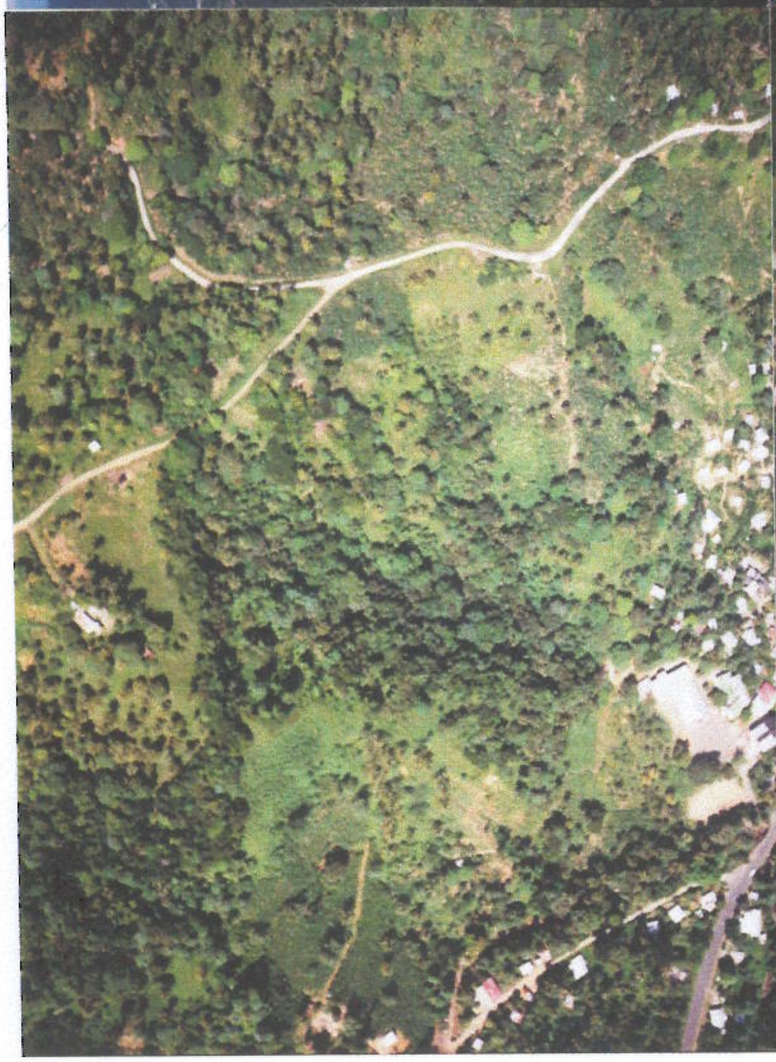


TABLE 3.2: LAND COVER / LAND USE LEGEND: SMALL FORMAT AIR PHOTOGRAPHY (SFAP) SCALE 1:5,000−1:7,500

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Unit	Subunit Mapped	Description	% bananas	Estimated soil loss, t/ha/yr, for slopes of: 2deg	15deg	25deg	35deg	Remarks on current rates of erosion: (Applies to land under average levels of management)
1a	1a	Rain Forest (broad leaved)		0.1	1	3	5	Most of erosion through Mass Movements.
1b		Montane Thicket						
1c		Mangrove						
1d		Elfin Woodland						
P		Plantation Forest Species		0.2	2	6	10	Assumes long−cycle plantatns; selctv felling, good mnmnt.
2	2	Secondary Forest / Logged +−enriched Primary Forest		0.2	2	4	7	Most of erosion through Mass Movements.
3		Scrub Forest		0.2	2	6	10	Soils more highly erodible for these areas
4		Open Woodland						
5	5	Grassland / Scrubland		2	20	60	100	Assumes some seasonal cultivation (c 20% of area / yr)
6		Commercial Agricultural Lands (eg Estates)						(Assumes higher % of good land,& better level of mnmnt)
	6b	V.intensive banana cultivation	90	7	14	40	60	Deep drains in alluv.land show appreciable erosion
	6bf	− " −, v.young plant crop, or currently fallow	(0)	14	25	60	100	Ground cover commonly poor.
	6bc	− " −, interplanted with coconuts forming 15−50% cover	65	4	8	25	50	Some protn.from surface wash, little from mass movmts
	6cb	− " −, interplanted with coconuts forming 55−80% cover	35	2	4	14	30	Some protn.from surface wash, little from mass movmts
	6g	Grassland (generally hydromorphic)		1	4			Permanent dense cover usual
7		Intensive Small Farming						
	7b	Intensive smallholder banana cultivation	80	10	20	60	100	Deep drains in alluv.land show appreciable erosion
	7bf	− " −, v.young plant crop, or currently fallow	(0)	20	40	90	150	Ground cover commonly v.poor.
	7bc	− " −, interplanted with coconuts forming 15−50% cover	60	6	12	40	90	Some protn.from surface wash, little from mass movmts
	7cb	− " −, interplanted with coconuts forming 55−80% cover	30	3	6	20	45	Some protn.from surface wash, little from mass movmts
	7bt	− " −, interplanted with treecrops forming 15−50% cover	60	6	12	35	60	Treecrops give better protcn from mass movements
	7tb	− " −, interplanted with treecrops forming 55−80% cover	30	3	6	17	30	Treecrops giving good protcn from mass movements
	7m	Mixed smallholder cropping	50	5	10	20	75	Fair coverage by treecrops/perennials
	7tm	Mixed smallholder cropping dom.by treecrops	20	3	5	15	25	Treecrops giving good protcn from mass movements
	7t	Smallholder treecrops	0	2	4	12	20	Well established trees / complete ground cover
	7r	Seasonally culivated and/or bare soil surface	0	40	90	200	500	Massive erosion, especially on steeper slopes.
8		Mixed Small Farming						
9	9	Rural Settlement (houses, yards, and immediate houseplots)		6	12	40	90	Combines area of mixed cultivatn, plus high runoff area
10		Urban, Periurban/Residential, Commercial, Institutional, Industrial						
	10i	Industrial/Institutional		6	12	40		Combines area of mixed cultivatn, plus high runoff area
	10h	Residential / Homegardens		6	12	40	90	Combines area of mixed cultivatn, plus high runoff area

Complex Units include:
2/1; 2/7t; 5/7m; 5/7t; 7c/5; 7t/2; 7t/5.

Note: First unit in complex assumed to occupy 60% of area of the complex, second unit 40%.

Note: estimates on erosion include both surface wash and mass movements, averaged on yearly basis. Erosion estimates are of the Consultants, largely based on comparisons with:
Hunting Technical Services Limited, June 1984. The Roseau, Dennery, and Cul de Sac Drainage and Conseervation Project.
LTS, RDC, HTS, March 97. Sri Lanka: Upper Watershed management Study (ADB PPTA). Land Resources, Land Use Planning, and Watershed Management Aspects.

Note: Above legend is an enlargement, with small modifications, of the Hunting Technical Services 1984 legend.

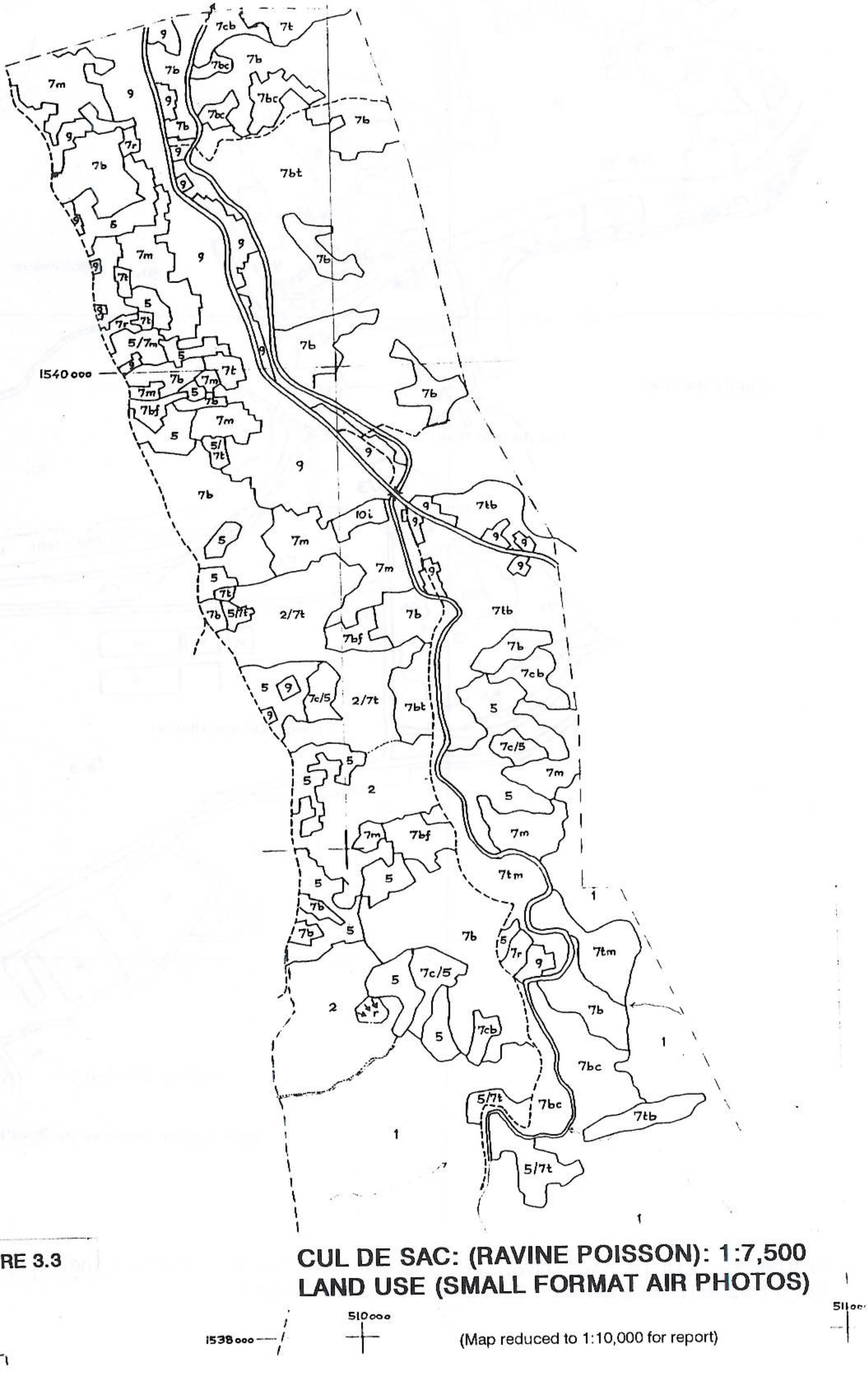


FIGURE 3.3

CUL DE SAC: (RAVINE POISSON): 1:7,500
LAND USE (SMALL FORMAT AIR PHOTOS)

(Map reduced to 1:10,000 for report)

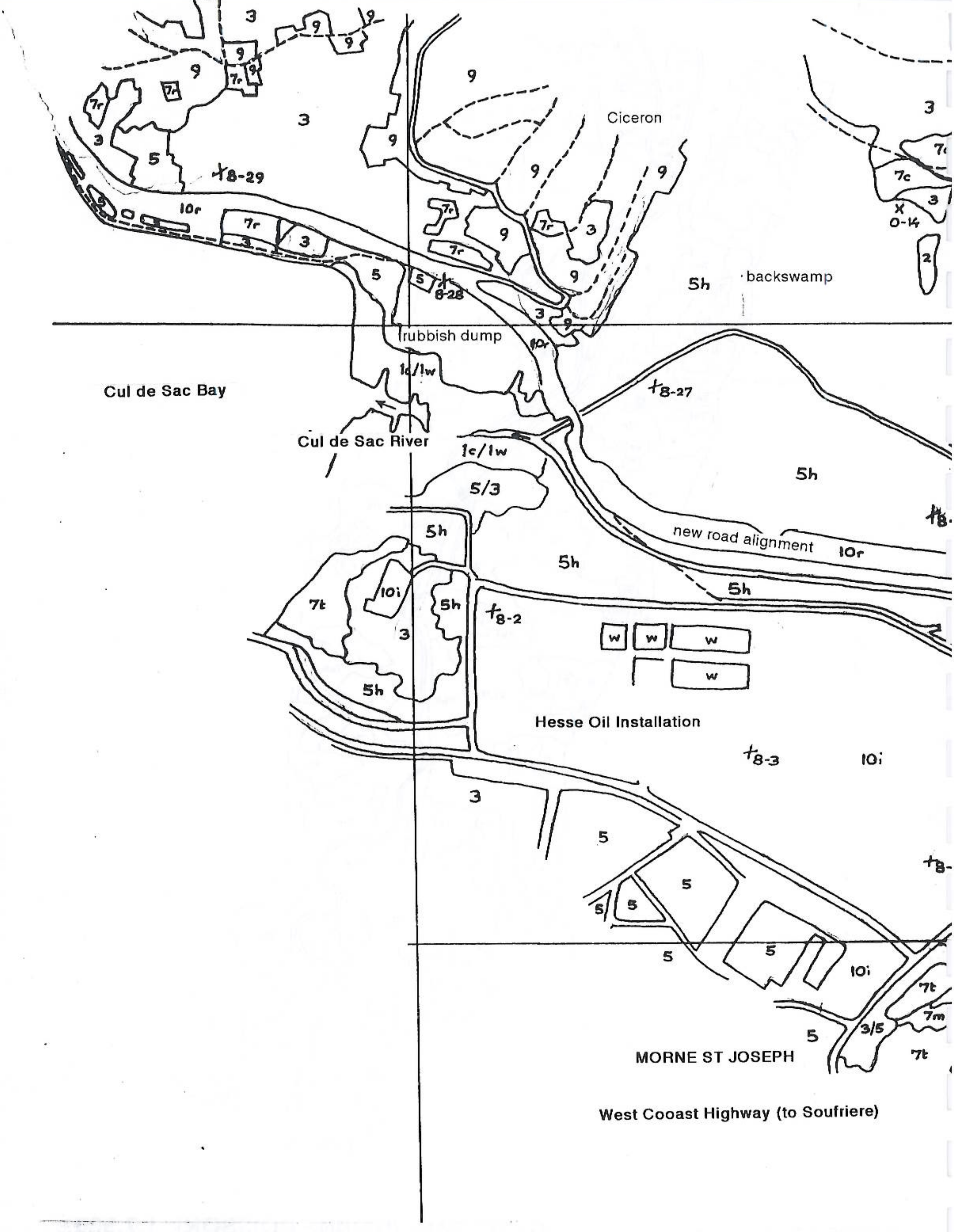


FIGURE 3.4: CUL DE SAC: LOWER FLOODPLAIN & ADJACENT AREAS: 1:7,500
LAND USE INTERPRETATION (SMALL FORMAT AIR PHOTOS)

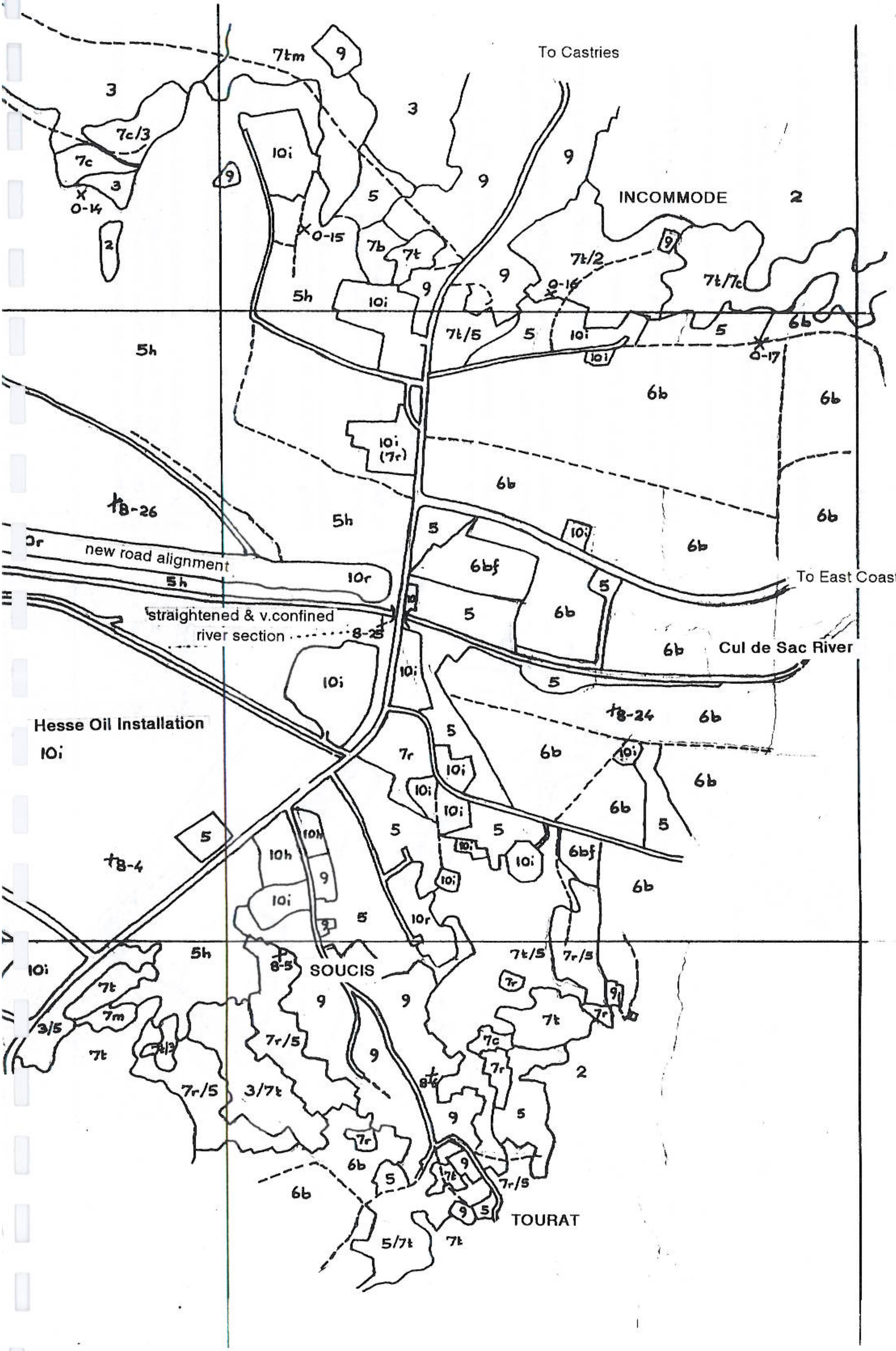
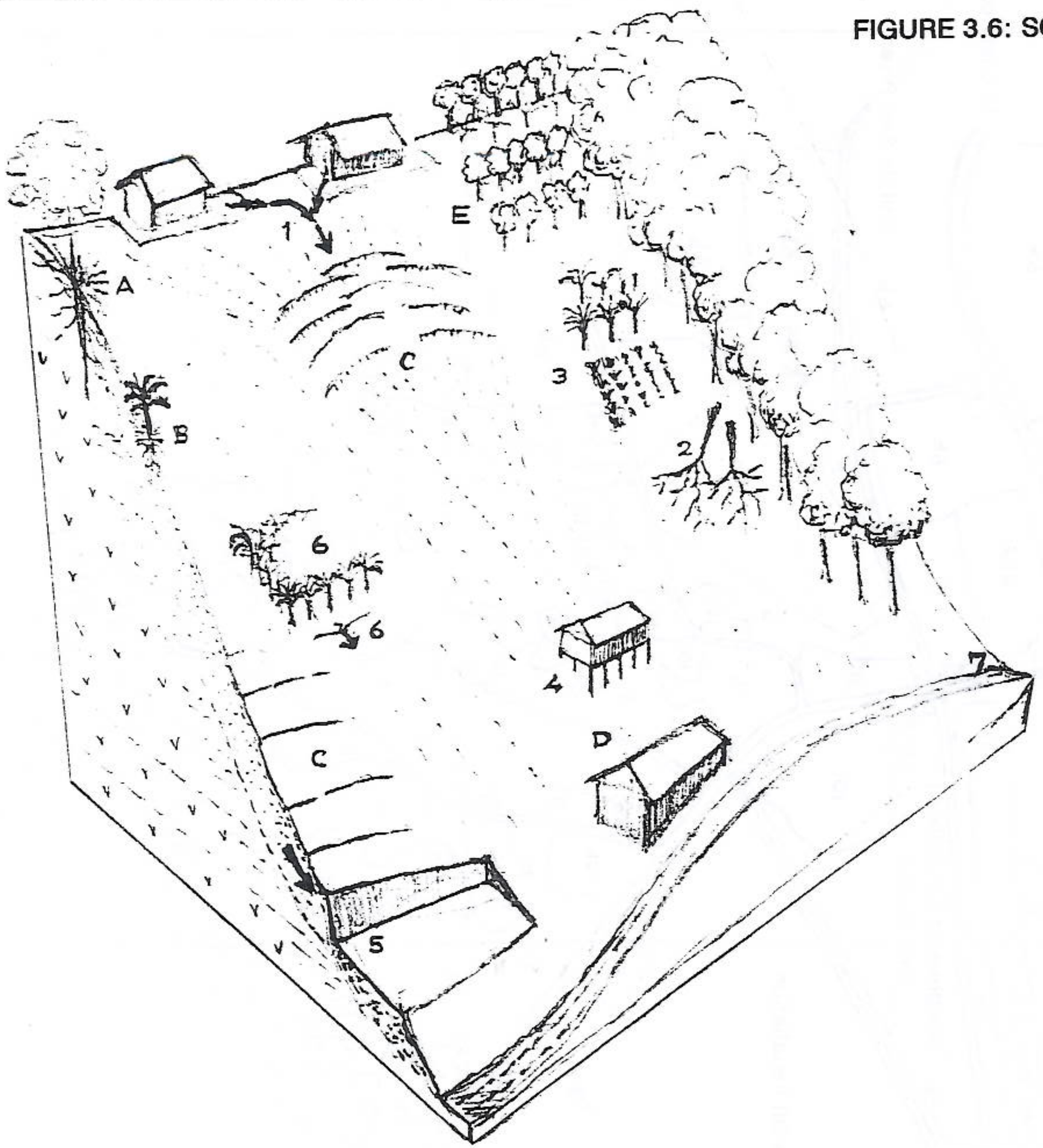

To Castries
INCOMMODE
To East Coast
new road alignment
straightened & v.confined
river section
Cul de Sac River
Hesse Oil Installation
SOUCIS
TOURAT
0-14
0-15
0-16
0-17
8-26
8-25
8-24
8-4
8-5

FIGURE 3.6: SCHEMATIC BLOCK DIAGRAM: RAVINE POISSON AREA



Factors increasing risk of Mass Movements (Landslides):(1 to 7):

1.Building along ridge–line (adjacent steep slopes):producing concentration of drainage water from roads and houseplots

2.Removal of forest vegetation which was anchoring soil to bedrock

3. Cultivation of seasonal crops–ground provisions– and bananas (cultivation and paths wrongly run up–and–down slope)

4.Siting of buildings on steep slopes

5.Base of slope further de–stabilised by cuttings for roads & houselots

6. Banana cultivation: poor trash management: extra run–off of water, subsequently infiltrating in areas of incipient cracks on steep slopes

7. Feeder road construction opening up new steep areas to encroachment, deforestation and inappropriate agricultural use

Other features to note:

A. Well–established tree: deep taproot and dense,strong network of surface roots anchoring soil to firm bedrock

B. Banana rooting: network of surface roots, but less strong, and complete lack of deep taproots

C. Cracks and terracettes formed by incipient mass movements: major landslide quite probable here during next TSD–type rainfall

D. Buildings under threat from burial by landslide materials

E. Better land use practice: underplanting of bananas on sloping land (20–30deg) with fruit–trees: close spacing on contour (eg 12ft) – wider spacing between contours (eg 24–30ft). Bananas to continue as nurse crop for 3–4years.

File:V3AN4f36

Appendix A

APPENDIX 1

DAILY SOIL WATER BALANCE MODEL (DLYSLWB9.WK3)

The Daily Soil Water Balance Model is shown diagrammatically in the appended Figure, with the big letters in the diagram corresponding to column letters in the worksheet. The individual components represented by these letters are explained in the accompanying Table 1. A print-out for the main ('Maha') rainy season for the rainfall station at Batalagoda (late August to December, 1986) is shown in Table 2. The data that needs to be entered into the spreadsheet, and the output data for this spreadsheet, are shown in Figure 2. Finally the water balance for the A, B, and C-horizons of the soil are shown in Figure 3 for this season.

In the model certain data are constant for the site, with only agro-climatic data, (notably rainfall, but also potential evapotranspiration of the crop or natural vegetation) being variable over time. The constants for the site are as follows:
Soil Type: Reddish Brown Earth (Typic/Rhodic Tropustalf), Ulhitiya Series, deep phase.
Soil Depth: 20, 80 and 120 cm thicknesses for A, B, and C-hors respectively.
Soil Available Water-holding Capacities (AWCs): 10, 12, and 5.5% V/V respectively.
Infiltration Rates: 32mm/day or rainstorm for surface, 13mm for subsurface, applying to soil horizons at field capacity
Vegetation: natural dryland forest; rooting depth to depth of bedrock (thus potential water uptake from entire A, B and C-horizons); crop coefficient constant at 1.18.

The variable figures are for rainfall (daily figures from the Batalagoda Research Station), and for potential evapotranspiration, varying from 6.4mm/day down to 3.6mm/day.

The figures given for this maha rainy season follow a long drought, so available soil water in all three horizons starts off at zero. Note that the soil's A-horizon will wet first, with the 20mm reservoir of available water being exceeded on 17th September. Rain on 18th September (36.1mm) then mostly percolates into the B-horizon, although a little (3mm) will run-off laterally as the final infiltration rate of 32mm / rainstorm is exceeded.

The B-horizon reservoir then fills up. By 15th October the B-horizon reservoir is filled, so water then flows into the C-horizon reservoir. However, the final infiltration rate for the clayey B-horizon is very low (only 13mm/rainstorm) so 4mm of the 17mm runs off laterally at the top of the B-horizon.

The C-horizon reservoir then begins to fill on subsequent rainstorms on 5 and 6 November, but only reaches 39mm out of the maximum 66mm before the dry weather sets in.

Note how the soil then dries out: the A-horizon first, then the B, then finally the C. The amount of run-off for the season is very small - only 20mm - of which 4mm is surface run-off and 16mm is subsurface.

Table 1

SRI LANKA RBE SOILS: DAILY SOIL WATER BALANCE MODEL: LEGEND

COL	CODE	EXPLANATION	REMARKS
A	Day	Date	Every 5th day in month given.
B	RAIN HAK88	Daily rainfall (mm)(for Station Code & Year)	Figures from Met Dept, Colombo
C	ETo/ mnth	Potential evapotranspiration (mm / month)	Figures from nearest agro-met statn (with curve smoothing)
D	ETo/ day	Potential evapotranspiration (mm / day)	C/30
E	Kc	Crop coefficient	Figures from HTS Handbook
F	ETc	Crop evapotranspiration	calculated from D and E
G	ETa	Actual crop evapotranspiration	Equals ETc for up to 33% depletion of AWC. Thereafter decreases proportionately.
H	R-EV	Daily rainfall minus Actual Crop evapotranspiratn	calculated from B and G
I	A-hr BALN	Balance of available water in A-horizon(mm)	Max 20mm within 20cm horzn(10%AWC) calculated from H and previous day's Ivalue
J	Attl TEMP	Temporary store of water in & on A-horizon	Amount of surplus daily water over the 20mm storable in A-horizon
K	Avrt LECH	Vertical movement of water from A to B-horizon	Max 32mm/day(rainstorm), therafter water moves laterally
L	Surf RnOf	Lateral surface run-off	If K hits 32mm ceiling surface run-off recorded in L
M	B-hr BALN	Balance of available water in B-horizon	Max 96mm within 80cm horzn(12%AWC) calculated from K and previous day's Mvalue, but if I hits zero, M will be reduced by value of H.
N	Bttl TEMP	Temporary store of water in B-horizon	Amount of surplus daily water over the 96mm storable in the B-horizon
O	Bvrt LECH	Vertical leaching of water from B to DPR-horizons	Max 10mm/day(rainstorm), therafter water moves laterally
P	SubS RnOf	Lateral subsurface run-off in & on B-horizon	If O hits 10mm ceiling sub-surface run-off recorded in P
Q	C-hr BALN	Balance of available water in C-horizon	Max 66mm within 120cm hor(5.5%AWC) calculated from O and previous day's Q value, but if M hits zero Q will be reduced by value of H.
R	C-hr LECH	Vertical leaching of water out of C (DPR)-horizon	Surplus of water after AWC of C-hor (ie 66mm in Q) is saturated
S	AcSf RnOf	Accumulated surface run-off (mm)	Accumulated totals of column L
T	AcSS RnOf	Accumulated sub-surface run-off (mm)	Accumulated totals of column P
U	Acum Lech	Accum.vert.leaching of water below B-horizon	Accumulated totals of column R

SOIL WATER BALANCE: BATALAGODA, MAHA 1986: DEEP WELL-DRAINED RBE SOIL: FOREST VEGETATION

A Day	B RAIN mm/dy BAT86	C ETo/ mnth pt49	D ETo/ day	E Kc Max	F ETc	G ETa	H R-ETa	I A-hr BALN	J Attl TEMP	K Avrt LECH	L Surf RnOf	M B-hr BALN	N Bttl TEMP	O Bvrt LECH	P SubS RnOf	Q C-hr BALN	R C-hr LECH	S AcSf RnOf	T AcSS RnOf	U Acum Lech
					0.0			0				O				O				
Au29	0.0	192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0	192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep1	0.0	192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
		192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
		192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
		192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
		192	6.4	1.18	7.6	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.4	191	6.4	1.18	7.5	0.0	1.4	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
		191	6.4	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
15		190	6.3	1.18	7.5	0.1	-0.1	1	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	190	6.3	1.18	7.5	0.1	3.4	4	0	0	0	0	0	0	0	0	0	0	0	0
	17.3	189	6.3	1.18	7.4	0.3	17.0	20	1	1	0	1	0	0	0	0	0	0	0	0
	36.1	189	6.3	1.18	7.4	1.3	34.8	20	35	32	3	33	0	0	0	0	0	3	0	0
	10.5	188	6.3	1.18	7.4	3.2	7.3	20	7	7	0	41	0	0	0	0	0	3	0	0
	1.3	187	6.2	1.18	7.4	3.7	-2.4	18	0	0	0	41	0	0	0	0	0	3	0	0
		187	6.2	1.18	7.4	3.5	-3.5	14	0	0	0	41	0	0	0	0	0	3	0	0
	1.3	186	6.2	1.18	7.3	3.3	-2.0	12	0	0	0	41	0	0	0	0	0	3	0	0
	2.3	186	6.2	1.18	7.3	3.2	-0.9	11	0	0	0	41	0	0	0	0	0	3	0	0
	1.0	185	6.2	1.18	7.3	3.1	-2.1	9	0	0	0	41	0	0	0	0	0	3	0	0
	7.3	184	6.1	1.18	7.2	3.0	4.3	13	0	0	0	41	0	0	0	0	0	3	0	0
	0.5	183	6.1	1.18	7.2	3.2	-2.7	11	0	0	0	41	0	0	0	0	0	3	0	0
		183	6.1	1.18	7.2	3.0	-3.0	8	0	0	0	41	0	0	0	0	0	3	0	0
	0.0	182	6.1	1.18	7.2	2.8	-2.8	5	0	0	0	41	0	0	0	0	0	3	0	0
	0.0	181	6.0	1.18	7.1	2.7	-2.7	2	0	0	0	41	0	0	0	0	0	3	0	0
	12.2	180	6.0	1.18	7.1	2.5	9.7	12	0	0	0	41	0	0	0	0	0	3	0	0
Oct1	35.3	179	6.0	1.18	7.0	3.0	32.3	20	24	24	0	65	0	0	0	0	0	3	0	0
	3.4	177	5.9	1.18	7.0	4.9	-1.5	19	0	0	0	65	0	0	0	0	0	3	0	0
		176	5.9	1.18	6.9	4.8	-4.8	14	0	0	0	65	0	0	0	0	0	3	0	0
		175	5.8	1.18	6.9	4.5	-4.5	9	0	0	0	65	0	0	0	0	0	3	0	0
		173	5.8	1.18	6.8	4.2	-4.2	5	0	0	0	65	0	0	0	0	0	3	0	0
	5.8	172	5.7	1.18	6.8	3.9	1.9	7	0	0	0	65	0	0	0	0	0	3	0	0
	2.2	170	5.7	1.18	6.7	4.0	-1.8	5	0	0	0	65	0	0	0	0	0	3	0	0
	12.6	169	5.6	1.18	6.6	3.8	8.8	14	0	0	0	65	0	0	0	0	0	3	0	0
	0.6	166	5.5	1.18	6.5	4.2	-3.6	10	0	0	0	65	0	0	0	0	0	3	0	0
		163	5.4	1.18	6.4	4.0	-4.0	6	0	0	0	65	0	0	0	0	0	3	0	0
	3.7	160	5.3	1.18	6.3	3.7	0.0	6	0	0	0	65	0	0	0	0	0	3	0	0
	15.7	157	5.2	1.18	6.2	3.6	12.1	19	0	0	0	65	0	0	0	0	0	3	0	0
	22.2	154	5.1	1.18	6.1	4.2	18.0	20	17	17	0	81	0	0	0	0	0	3	0	0
	4.9	151	5.0	1.18	5.9	5.0	-0.1	20	0	0	0	81	0	0	0	0	0	3	0	0
15	38.2	148	4.9	1.18	5.8	4.9	33.3	20	33	32	1	96	17	13	4	13	0	4	4	0
	1.9	146	4.9	1.18	5.7	5.7	-3.8	16	0	0	0	96	0	0	0	13	0	4	4	0
	2.8	144	4.8	1.18	5.7	5.7	-2.9	13	0	0	0	96	0	0	0	13	0	4	4	0
	0.5	142	4.7	1.18	5.6	5.6	-5.1	8	0	0	0	96	0	0	0	13	0	4	4	0
	11.9	139	4.6	1.18	5.5	5.3	6.6	15	0	0	0	96	0	0	0	13	0	4	4	0
	1.6	136	4.5	1.18	5.3	5.3	-3.7	11	0	0	0	96	0	0	0	13	0	4	4	0
	1.0	134	4.5	1.18	5.3	5.2	-4.2	7	0	0	0	96	0	0	0	13	0	4	4	0
	4.0	132	4.4	1.18	5.2	5.0	-1.0	6	0	0	0	96	0	0	0	13	0	4	4	0
		131	4.4	1.18	5.2	4.9	-4.9	1	0	0	0	96	0	0	0	13	0	4	4	0
		129	4.3	1.18	5.1	4.6	-4.6	0	0	0	0	92	0	0	0	13	0	4	4	0
	8.8	127	4.2	1.18	5.0	4.3	4.5	4	0	0	0	92	0	0	0	13	0	4	4	0
	8.8	125	4.2	1.18	4.9	4.5	4.3	9	0	0	0	92	0	0	0	13	0	4	4	0
	1.2	124	4.1	1.18	4.9	4.6	-3.4	5	0	0	0	92	0	0	0	13	0	4	4	0
	13.0	122	4.1	1.18	4.8	4.4	8.6	14	0	0	0	92	0	0	0	13	0	4	4	0
	9.1	120	4.0	1.18	4.7	4.6	4.5	18	0	0	0	92	0	0	0	13	0	4	4	0
	1.4	118	3.9	1.18	4.6	4.6	-3.2	15	0	0	0	92	0	0	0	13	0	4	4	0
	2.2	116	3.9	1.18	4.6	4.6	-2.4	13	0	0	0	92	0	0	0	13	0	4	4	0
Nov1	8.5	115	3.8	1.18	4.5	4.4	4.1	17	0	0	0	92	0	0	0	13	0	4	4	0
	5.0	114	3.8	1.18	4.5	4.5	0.5	17	0	0	0	92	0	0	0	13	0	4	4	0
	1.3	113	3.8	1.18	4.4	4.4	-3.1	14	0	0	0	92	0	0	0	13	0	4	4	0
	2.0	113	3.8	1.18	4.4	4.4	-2.4	12	0	0	0	92	0	0	0	13	0	4	4	0
	34.9	112	3.7	1.18	4.4	4.3	30.6	20	23	23	0	96	19	13	6	26	0	4	10	0
	23.5	111	3.7	1.18	4.4	4.4	19.1	20	19	19	0	96	19	13	6	39	0	4	16	0
	4.6	110	3.7	1.18	4.3	4.3	0.3	20	0	0	0	96	0	0	0	39	0	4	16	0
		110	3.7	1.18	4.3	4.3	-4.3	16	0	0	0	96	0	0	0	39	0	4	16	0
		110	3.7	1.18	4.3	4.3	-4.3	11	0	0	0	96	0	0	0					
		109	3.6	1.18	4.3	4.3	-4.3	7	0	0	0	96	0	0	0					
		109	3.6	1.18	4.3	4.3	-4.3	3	0	0	0	96	0	0	0					
	3.0	109	3.6	1.18	4.3	4.3	-1.3	1	0	0	0	96	0	0	0					
	2.4	109	3.6	1.18	4.3	4.3	-1.9	0	0	0	0	96	0	0	0					
		109	3.6	1.18	4.3	4.3	-4.3	0	0	0	0	91	0	0	0					
15		109	3.6	1.18	4.3	4.3	-4.3	0	0	0	0	87	0	0	0					
		109	3.6	1.18	4.3	4.3	-4.3	0	0	0	0	83	0	0	0					
		109	3.6	1.18	4.3	4.3	-4.3	0	0	0	0	78	0	0	0					
		109	3.6	1.18	4.3	4.2	-4.2	0	0	0	0	74	0	0	0					
		109	3.6	1.18	4.3	4.0	-4.0	0	0	0	0	70	0	0	0					
		110	3.7	1.18	4.3	3.9	-3.9	0	0	0	0	66	0	0	0					
	0.9	110	3.7	1.18	4.3	3.8	-2.9	0	0	0	0	64	0	0	0					
		110	3.7	1.18	4.3	3.7	-3.7	0	0	0	0	60	0	0	0					
		110	3.7	1.18	4.3	3.5	-3.5	0	0	0	0	56	0	0	0					
		110	3.7	1.18	4.3	3.4	-3.4	0	0	0	0	53	0	0	0					
		111	3.7	1.18	4.4	3.3	-3.3	0	0	0	0	50	0	0	0					
		111	3.7	1.18	4.4	3.2	-3.2	0	0	0	0	46	0	0	0					
		111	3.7	1.18	4.4	3.1	-3.1	0	0	0	0	43	0	0	0					
	0.0	111	3.7	1.18	4.4	3.0	-3.0	0	0	0	0	40	0	0	0					
	0.0	111	3.7	1.18	4.4	2.9	-2.9	0	0	0	0	37	0	0	0					
	0.0	112	3.7	1.18	4.4	2.8	-2.8	0	0	0	0	35	0	0	0					
Dec1	2.0	112	3.7	1.18	4.4	2.7	-0.7	0	0	0	0	34	0	0	0					
	7.6	112	3.7	1.18	4.4	2.7	4.9	5	0	0	0	34	0	0	0					
	4.6	112	3.7	1.18	4.4	2.8	1.8	7	0	0	0	34	0	0	0					
	1.1	113	3.8	1.18	4.4	2.9	-1.8	5	0	0	0	34	0	0	0					
	4.0	113	3.8	1.18	4.4	2.9	1.1	6	0	0	0	34	0	0	0					
	0.2	114	3.8	1.18	4.5	2.9	-2.7	3	0	0	0	34	0	0	0	39	0	4	16	0
		114	3.8	1.18	4.5	2.8	-2.8	0	0	0	0	34	0	0	0	39	0	4	16	0
		114	3.8	1.18	4.5	2.7	-2.7	0	0	0	0	32	0	0	0	39	0	4	16	0
		114	3.8	1.18	4.5	2.6	-2.6	0	0	0	0	29	0	0	0	39	0	4	16	0
	1.3	115	3.8	1.18	4.5	2.5	-1.2	0	0	0	0	28	0	0	0	39	0	4	16	0
		115	3.8	1.18	4.5	2.5	-2.5	0	0	0	0	25	0	0	0	39	0	4	16	0
		115	3.8	1.18	4.5	2.4	-2.4	0	0	0	0	23	0	0	0	39	0	4	16	0
		115	3.8	1.18	4.5	2.3	-2.3	0	0	0	0	21	0	0	0	39	0	4	16	0
		115	3.8	1.18	4.5	2.2	-2.2	0	0	0	0	18	0	0	0	39	0	4	16	0
15		115	3.8	1.18	4.5	2.1	-2.1	0	0	0	0	16	0	0	0	39	0	4	16	0
		115	3.8	1.18	4.5	2.1	-2.1	0	0	0	0	14	0	0	0	39	0	4	16	0
	0.2	115	3.8	1.18	4.5	2.0	-1.8	0	0	0	0	12	0	0	0	39	0	4	16	0
	0.3	115	3.8	1.18	4.5	1.9	-1.6	0	0	0	0	11	0	0	0	39	0	4	16	0
		115	3.8	1.18	4.5	1.9	-1.9	0	0	0	0	9	0	0	0	39	0	4	16	0
	4.3	116	3.9	1.18	4.6	1.8	2.5	2	0	0	0	9	0	0	0	39	0	4	16	0
	0.1	116	3.9	1.18	4.6	1.9	-1.8	1	0	0	0	9	0	0	0	39	0	4	16	0
	6.1	116	3.9	1.18	4.6	1.8	4.3	5	0	0	0	9	0	0	0	39	0	4	16	0
		116	3.9	1.18	4.6	2.0	-2.0	3	0	0	0	9	0	0	0	39	0	4	16	0
		116	3.9	1.18	4.6	1.9	-1.9	1	0	0	0	9	0	0	0	39	0	4	16	0
		117	3.9	1.18	4.6	1.9	-1.9	0	0	0	0	8	0	0	0	39	0	4	16	0
		117	3.9	1.18	4.6	1.8	-1.8	0	0	0	0									

DAILY SOIL WATER BALANCE WORKSHEET
INPUT DATA REQUIRED

SOIL HORIZON DEPTHS & AWCs

	Depth(cm)	AWC%	AW(mm)
A-hor	20	10.0	20
B-hor	80	12.0	96
C-hor	120	5.5	66

INFILTRATION RATES(mm/rainstorm)
Surface 32
Subsurface 13

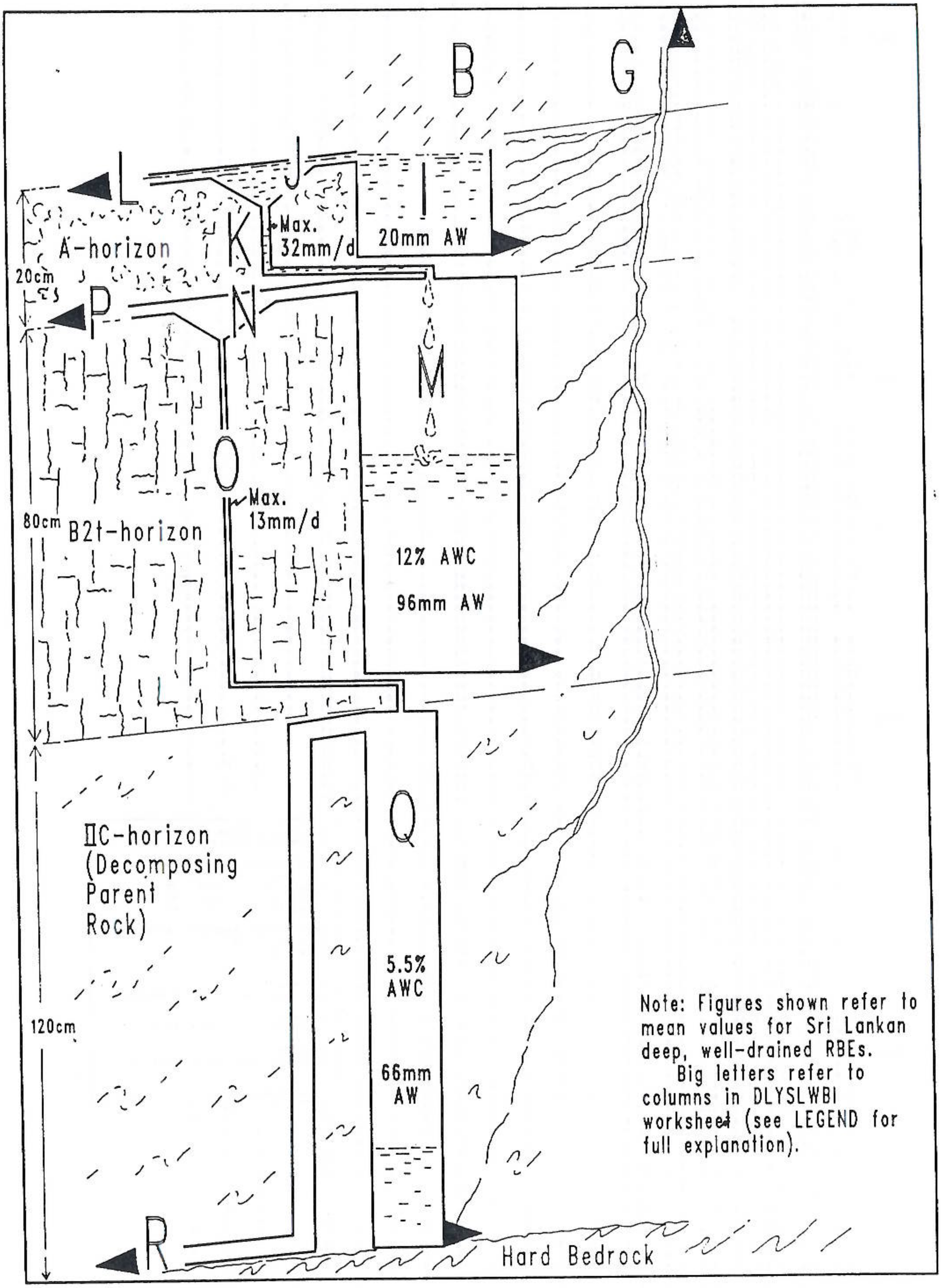
```
macro:e
{goto}c6~/rec6..c130~/fcce{?}~

macro:d
{goto}a6~/rea6..a130~/fcce{?}~

macro:s
{goto}b6~/reb6..b130~/fcce{?}~
```

File: DSWBINSP.WK1

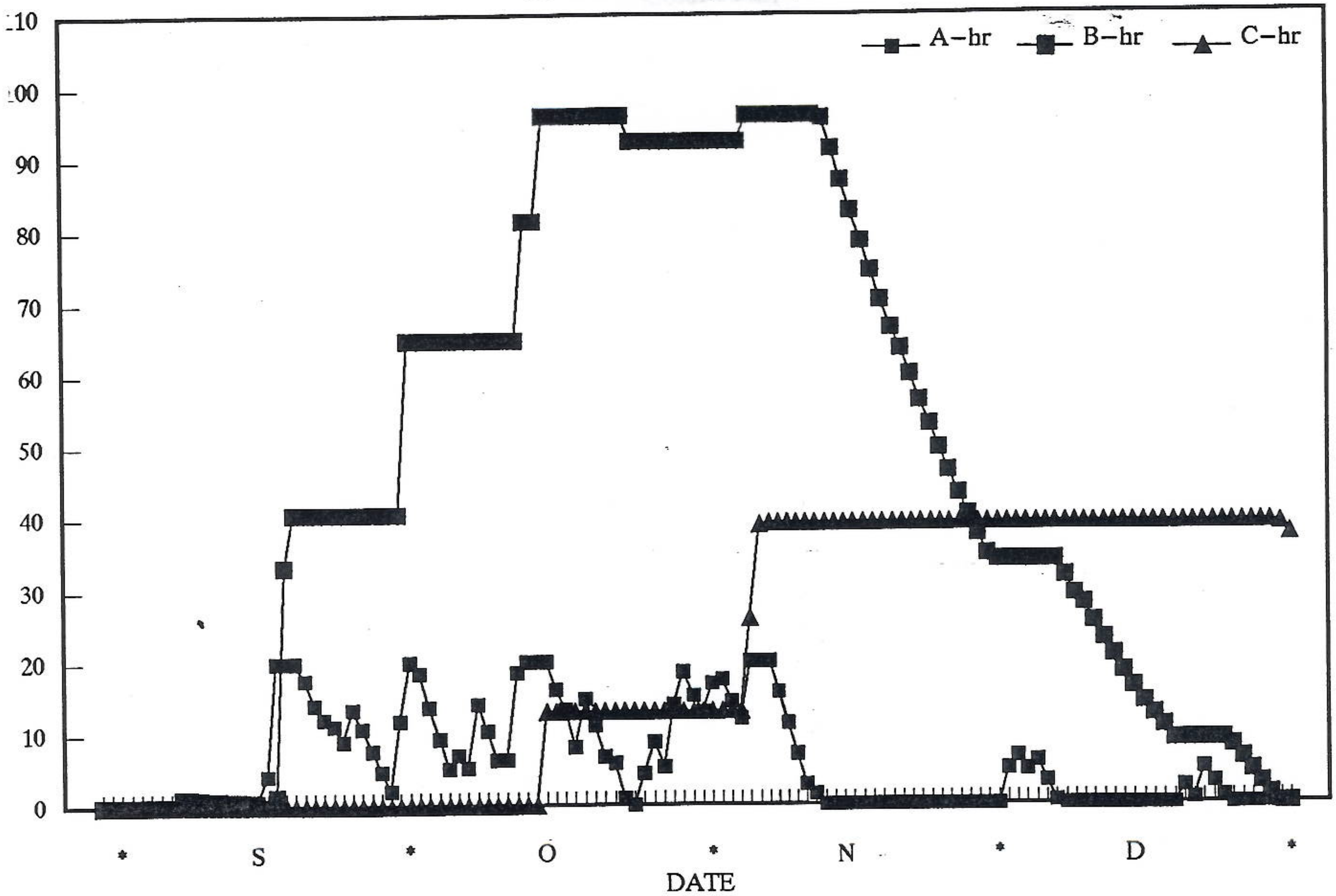
DAILY SOIL WATER BALANCE MODEL : SCHEMATIC REPRESENTATION



Note: Figures shown refer to mean values for Sri Lankan deep, well-drained RBEs.
Big letters refer to columns in DLYSLWBI worksheet (see LEGEND for full explanation).

SOIL WATER BALANCE: RBE(d), NTL.FOREST

BATALAGODA, MAHA, 1986



Annex 5

Possibilities for Alternative Cropping

St. Lucia: Watershed and Environmental Management Project

Final Report
Annex 5

Possibilities for Alternative Cropping

Chapter 1

Introduction

The early sixties saw the demise of the sugar industry and the first commercial banana plantings on St. Lucia. From a modest 5500 acres, planting had increased to 13200 acres by 1986 and to an estimated 19000 acres by 1996. Much of this increase in acreage, driven by high prices in the mid eighties, was on steep hillsides and in many cases existing tree crops were felled to make way for bananas. In response to demands from farmers, feeder roads were constructed giving access to these new lands with little thought to conservation or environmental issues.

By the late 70's, some more astute observers began to feel uneasy with the increasing dependance on a single crop, and 1979 saw the first serious attempt to promote diversification, but again, concern over the deterioration of the environment was not the major concern.

The need for diversification, particularly into tree crops, has become progressively more evident over the years, but the various initiatives met with little success in terms of farmer acceptance.

It took the impact of Tropical Storm Debbie to bring home the urgent need for better conservation of the steep upper catchment areas and concurrent with this, falling banana prices and low profitability has put the marginal hillside farmers under pressure.

In his report, Main Socio-Economic Issues in Watershed and Environmental Management Planning, (Technical Annex 9) the Socio-Economist sets out a strong case for diversification, and it is the purpose of this Technical Annex to analyse and present the facts in support of this.

The term "diversification" covers a multitude of crops, both annual and perennial and including flowers, but this Annex deals primarily with tree crops, having a potential to conserve the steep slopes, while at the same time providing an income for the farmer.

In their search for literature, the Consultants experienced many problems. Valuable reports and data have been misplaced or forgotten, personnel have moved on and diversification issues seem to have lost their earlier sense of urgency and purpose. It has however been possible to assemble a reasonable overview, to assess progress, highlight problems, and to propose a course of action to remedy defficiencies.

This work goes well beyond the Consultant's Terms of Reference, but in view of the potentially serious situation in the upper catchments to ignore diversification would, in the Consultant view, have been irresponsible. However, based on the information available to the Consultants, few packages can be proposed with confidence, and any programme of demonstration plots is, at this stage, limited.

Chapter 2

A Brief Historical Perspective

The first serious attempt at increasing plantings of tree crops, was the Orchard Crop Diversification Project, funded by BDDC. The project ran from 1979 to around 1985. The programme included support to enlarge and improve the plant propagation facility at Union, and set out to establish:

Mango-vars.	Julie & Graham	250 acres
Avocado-vars.	Lula & Fuerto	130 acres
Grapefruit-vars.	Ruby Red & Marsh seedless	80 acres
Orange-vars.	Washington naval Valencia Ortanique	25 acres
Lime	Local WI vars	10 acres
Cocoa		35 acres
Other crops		20 acres
TOTAL		**550 acres**

Subsidies were given for land clearing, drainage, lining out/planting, maintenance, fertiliser, herbicides and pesticides, and seedlings were also provided at subsidised rates.

An evaluation done in 1987, showed that acreage targets achieved 80% success, but most planting was not done on an orchard basis as planned.

Problems relating to marketing, price of produce, and future input supplies were evident.

Project timing coincided with booming banana prices.

The trees established under this project are now in full bearing.

In 1987, IICA funded a study, The Fruit Sub-Sector in the Windward Islands - Diagnosis - Strategy - Actions. In St. Lucia, the main focus was on mango, avocado, grapefruit, breadfruit and plantain. The report contained a wealth of agronomic data, varietal characteristics and summarised problem areas as:

- agronomy and management
- the lack of supporting institutions at farm level
- transport
- low production and variable fruit quality

The Heads of OECS Governments met in St. Lucia in March 1988 specially to discuss diversification in its broadest terms, and to look for a way forward. As a direct result of this, the Agricultural Diversification Coordination Unit (ADCU) was established in December 1989 under the auspices of OECS, with its head quarters in Dominica, supported initially by member governments, Geest and BDDC.

ADCU's brief was:
- to examine and develop market potential
- to develop a database of UK markets and prices, initially using the Natural Resources Institute in the UK.
- to circulate information on market prospects
- to protect private exporters from exploitation by dubious operators and importers.

In 1990, major funding became available with the advent of the TROPRO Project (USAID) 1990-1996. Support to the value of US$10 million was provided and implementation was through ADCU. Project objectives were:
- to increase marketable production. This included the employment of Israeli Technicians and Agronomists who working with CARDI, concentrated on disease control, pruning, increasing production, irrigation and water management, orchard management, flower induction, harvesting etc. (AREP Programme).

- to establish a GIS-based crop agro-ecological zoning mapping exercise, on a catchment basis, in order to determine crop suitability.

- to improve the market intelligence data base with COLEACP assistance (ex NRI).

- market development through post harvest improvements, establishment of grading standards, packaging and training. 217 trial shipments of produce were organised and containerisation, palletisation etc. were evaluated. A cooling unit was established at Hewanorra.

- to examine transport options, both by sea and air, to negotiate rates and organise schedules.

Much of this work is still ongoing, and regular market intelligence reports are circulated.

Sadly, much of the information and data gathered during the TROPRO project has been misplaced and was not available to the Consultants, including much needed data, collected on farms by CARDI on cost and production. Currently CARDI, which is not in receipt of any major donor funding can only be described as run down.

Other related work of which the Consultants are aware are:
- Competitiveness of the Non-Traditional Agricultural Sector in OECS - a Diagnostic Analysis ADCU/IICA 1993
- Economic Incentives and the Agri-Food Sector of OECS Countries - a Quantative Assessment ADCU/IICA 1996
- Transformation of Tropical Fruits for the Caribbean CARIRI/IICA 1995

All these studies contribute to the pool of essential knowledge, but do not examine the main issues head-on.

The Consultants are aware of another project, Small Farmer Agricultural Development, believed to have been funded by IFAD, but not reviewed due to lack of reports and opportunity.

The final initiatives worthy of mention are:
- the University of the West Indies - Outreach Programme. The Programme, with assistance from USAID, is mainly concerned with the institutional development of extension services. Within the overall programme there is an 18 month project, Improved Hillside Tree Crop Project with a main objective of determining sustainable farming systems for steep hillside land. Land has been allocated and on farm sites selected, but to date there are no designs or plantings.

- The Cocoa Project - this falls within the remit of the MAFF&E and is jointly funded by the St. Lucia Agriculturalist Association (SLAA), the country's sole buyer/exporter. It is estimated that some 500 acres of cocoa exists, but much of this is not harvested or marketed. From an annual production of 129 tonnes in 1970, SLAA purchases fell to an all time low in 1996, when only 30 tonnes was produced. In the banana boom years, a lot of good cocoa plantings were cleared to make way for the banana. Project targets for 1997/98 included new plantings of 50 acres, rehabilitation of a further 150 acres and production of 80-100 tonnes. Other supporting elements included one new and one upgraded fermentary, solar driers and farmer training.

Despite all efforts, production statistics show a decline for most tree crops over the period 1992-1995. Figures are presented in **Table 2.1**. The reasons for this could be many but probably the most significant is a combination of high labour requirements for bananas on a regular basis and poorly developed marketing channels for many of the alternative crops.

Table 2.1 Estimated Crop (Tonnes) Production 1992-1996

PRODUCE	1992	1993	1994	1995	1996
Banana	143,139.7	140,057.2	96,591.5	119,117.6	112,132.8
Coconut	n.a.	n.a.	n.a.	n.a.	n.a.
Copra	4,098.0	5,039.5	3,583.8	2,622.5	2,389.9
Cocoa	67.8	50.0	64.4	47.1	33.2
Sweet Potato	259.0	333.4	281.6	506.8	557.8
Yams	294.9	347.1	454.0	442.0	595.6
Tannia	35.4	75.7	48.7	42.7	102.4
Tomato	153.4	116.5	182.8	147.7	152.6
Cabbage	124.8	199.8	238.3	231.7	255.5
Cucumber	209.6	208.6	245.0	223.7	260.5
Carrot	44.8	17.5	24.4	8.8	23.8
Sweet Pepper	32.7	35.6	53.0	44.8	65.0
Okra	23.4	45.2	52.4	72.0	65.8
Melon	117.7	79.8	153.2	100.8	102.9
Pumpkin	167.6	135.4	167.5	165.5	172.9
Ginger	3.6	7.2	5.5	6.0	19.8
Lime	134.6	125.5	174.0	172.8	184.6
Sweet Orange	619.0	574.2	698.0	660.4	673.8
Grapefruit	931.1	814.0	898.8	1182.4	887.6
Avocado	205.6	238.1	234.6	250.3	488.9
Dasheen	294.2	395.8	371.3	417.0	647.4
Plantain	777.4	704.0	411.6	531.0	1172.2
Lettuce	79.4	80.4	104.0	90.0	86.0
Breadfruit	2644.0	2318.4	2045.3	1968.8	1999.47
Sour Sop	183.7	251.8	164.7	158.0	109.8
Hot Pepper	173.3	97.7	224.8	304.6	224.5
Mango	2541.6	2197.1	3245.2	1846.0	1959.4
Pineapple	275.7	389.9	347.0	250.9	121.4

Source: Planning and Statistical Unit, Ministry of Agriculture

It is also noted that production of most annual/seasonal crops is rising. However, these crops are not recommended on sloping land, and their introduction is most ex-banana land, if over 5 degrees slope, would considerably worsen the erosion problem.

Chapter 3

The Current Situation

3.1 Introduction

While there are some encouraging trends, the current situation leaves little room for complacency. Even a casual observer cannot fail to notice an abundance of unharvested fruit, and fruit left rotting on the ground. This is indicative of many problems, which from interviews with farmers, government staff and exporters, remain largely the same as those originally diagnosed. The results of the Socio-Economist reconnaissance survey also support this view (Annex 9).

3.2 Production and Receipts from Alternative Crops

Alternative crops are mostly grown as mixed stands, commonly with bananas and commonly with a large number of species in homestead plots. Figures available from the 1996 census of Agriculture (as reported in Paul, 1996) list some 6420 'acre-equivalents' of alternative crops, (16% of cultivated area) comprising mango, 2350; breadfruit 1350; plantain 700; avocado 590; sweet orange 580; grapefruit 450; limes 160; tangerine 100; pineapple 90; lemon 50. It is likely that large errors are inherent in such figures, which furthermore ignore acreages of other treecrops whose production is recorded, including macambou, soursop, paw paw, golden apple, passion fruit, carambola, sour orange and guava. Also excluded from this list are three traditional tree crops, including coconut, cocoa and coffee.

Statistics on total production of the alternative crops are likewise difficult to obtain, as the majority of production is consumed locally and does not enter formal marketing channels. Of the crops formally marketed, reliable statistics are available on exports, and local sales to supermarkets and hotels. These totaled some 3040 tonnes for 1996, excluding banana sales to local and non-UK export markets, which totaled some 1890 tonnes. Sales to export markets totalled 1810 tonnes; those to local supermarkets were 920 tonnes, while those to local hotels were 310 tonnes. Production statistics for the last 4 years for these three groupings of markets are given in **Table 3.1**. **Figure 3.1** shows sales to the three groups for 1996 in terms of volume and estimated value. **Figure 3.2** shows sales for all groups for the 4 years.

Aggregated figures show large increases in sales over the 4 years to both export markets and local supermarkets, but nearly all of this increase is represented by banana sales. (This increase has probably been promoted by decreases in price in the main, UK, market.) Other crops show mostly stable production, or production fluctuating from year to year: the TSD year (1994) showed decreases in production for many crops. Of the other crops showing increases in production, plantains (supermarkets and export), avocado (export), limes (supermarkets), macambou (supermarkets), paw paw (hotels and supermarkets), sour orange (supermarkets) and guava (hotels) are notable. However, most of these crops involve low total volumes (590 tonnes for plantain, 390 for all the other crops). Two crops showed large decrease in sales: pineapple and soursop, due to collapse of export sales. (St. Lucia is not competitive in the latter two commodities, vis a vis other producers.)

Statistics on value of production to farmers have been based on total sales and estimates of prices per tonne of each commodity (C. Paul, 1997). These vary from only EC$150 for sour orange and soursop, through $400 for green banana, plantain and mango, $500 for breadfruit, passion fruit and carambola, $600 for paw paw to $750 for pineapple. The final column in **Table 3.1** gives the total estimated value for each commodity for 1996, and this is represented graphically in the pie-chart (**Figure 3.3**).

Table 3.1 : Formal Markets of Selected Fruit and Tree Crops (tonnes)

CROPS	Exports				Supermarkets				Hotels				Total Formal Markets				Estimated Price (96) EC$/tonne	Marketed % of Total Productn	Total Est.Value of 1996 Prodn. (000 EC$)
	1993	1994	1995	1996	1993	1994	1995	1996	1993	1994	1995	1996	1993	1994	1995	1996			
Green Banana *	482.2	239.2	1010.4	1534.5	16.8	9.4	27.7	73.2	16.6	17.1	18.4	17.5	515.6	265.7	1056.5	1625.2	400	98.5	660
Breadfruit	907.6	795.4	751.7	769.1	2.7	5.0	18.1	17.4	16.9	17.6	17.6	13.3	927.2	818.0	787.4	799.8	500	60	667
Plantain	141.8	37.3	83.2	254.3	174.3	129.3	148.2	299.8	35.8	39.1	33.8	31.9	351.9	205.7	265.2	586.0	400	50	469
Mango	498.5	696.2	393.3	386.9	26.6	76.7	40.2	69.3	24.0	37.9	27.8	33.6	549.1	810.8	461.3	489.8	400	75	261
Julie					3.1	9.5	8.2	12.5	0.7	1.2	1.1	0.6							
Graham					12.8	37.7	11.3	30.1	4.1	8.1	3.0	4.2							
Other					10.7	29.5	20.7	26.7	19.1	28.6	23.7	28.8							
Ripe banana					39.8	45.1	83.0	89.3	138.9	155.6	198.5	177.7	178.7	200.7	281.5	267.0	250	15	445
Grapefruit	16.8	18.5	22.8	22.3	123.9	133.5	195.8	142.2	62.8	72.8	76.8	57.4	203.5	224.8	295.4	221.9	300	75	89
Hot pepper	81.1	186.2	252.3	190.8	1.8	4.9	6.6						82.9	274.0	258.9	190.8	500	15	636
Avocado	49.5	39.5	52.0	130.3	20.9	27.0	22.4	29.2	12.7	15.3	13.1	11.6	83.1	81.8	87.5	171.1	400	65	105
Sweet orange	0.8	16.9	5.2	4.6	105.8	113.5	120.3	127.2	30.8	36.6	30.4	36.7	137.4	167.0	155.9	168.5	350	75	79
Pineapple	181.5	135.9	73.5	7.6	16.4	13.1	14.3	9.8	74.9	93.9	87.7	67.6	272.8	242.9	175.5	85.0	750	30	213
Limes		2.7	0.9	1.1	37.8	51.2	51.6	60.2	12.3	15.5	16.3	12.5	50.1	69.4	68.8	73.8	250	60	31
Macambou	1.2	0.2	3.0	2.6	14.0	14.1	23.2	57.5	0.3	0.6	1.0	0.6	15.5	14.9	27.2	60.7	300	35	52
Soursop	67.5	35.8	37.8	26.8	2.9	5.1	3.4	6.9	5.0	5.4	6.2	4.7	75.4	49.3	47.4	38.4	150	65	9
Paw paw		0.9	2.0	3.9	3.4	5.8	7.8	12.0	21.4	20.9	20.7	21.6	24.8	27.6	30.5	32.5	600	25	78
Golden apple	12.2	29.2	12.5	7.8	12.3	9.3	14.4	20.1	0.5	1.7	2.1	1.6	25.0	40.2	29.0	29.5	250	40	18
Passion fruit		3.5		0.9	7.7	9.7	9.5	22.9	0.4	1.8	2.2	3.4	8.1	15.0	11.7	27.2	500	40	34
Tangerine			0.2	0.1	20.3	19.2	23.6	15.7	2.3	7.0	4.3	5.0	22.6	26.2	28.1	20.8	250	50	10
Lemon			0.1	0.1	8.1	6.9	9.5	9.3	4.9	5.8	4.9	7.5	13.0	12.7	14.5	16.9	200	50	7
Carambola					0.5	0.6	1.7	7.7	0.3	1.3	1.9	2.6	0.8	1.9	3.6	10.3	500	40	13
Sour orange					5.3	5.5	6.8	9.1	0.6	0.9	1.2	0.4	5.9	6.4	8.0	9.5	150	75	2
Guava							0.1	1.1	0.6	1.2	1.4	2.0	0.6	1.2	1.5	3.1	250	60	1
TOTALS	2441	2237	2701	3344	641	685	828	1080	462	548	566	509	3544	3556	4095	4928			3878
Averages, over 4 years:				2681				809				521				4031			

Source: Paul, 1997, based on GoSL Statistics.

Note: * other than bananas to the UK.

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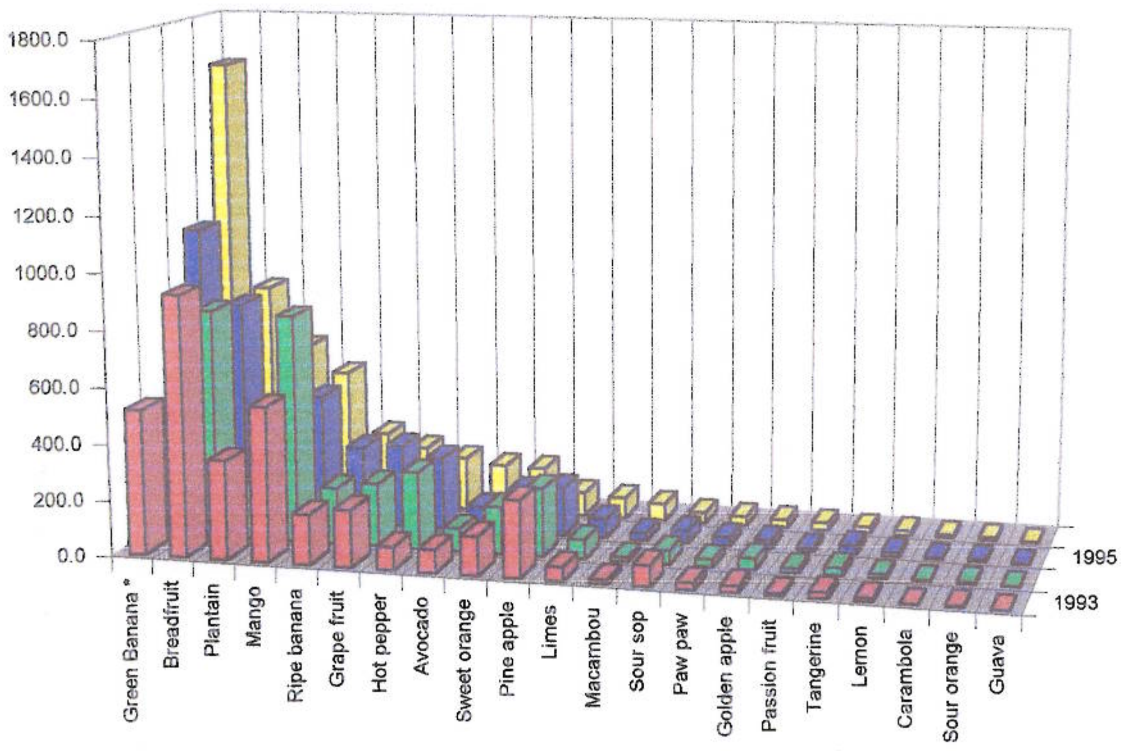
Figure 3.1: St. Lucia: Markets for Major Alternative Fruit & Tree Crops 1993-1996 (tonnes/year)



* Other than WIBEDCO bananas to UK

Fig. 3.2: 1996 Markets for Main Alternative Fruit & Tree Crops

(Formal Markets: Recorded Sales)

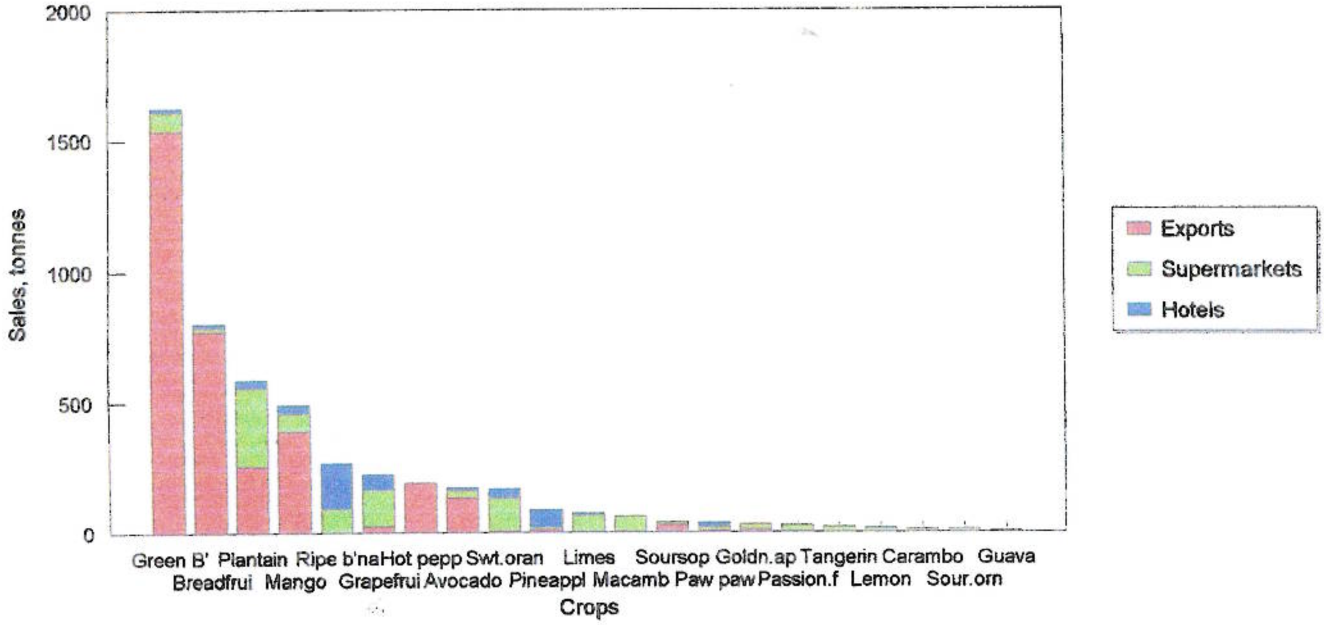
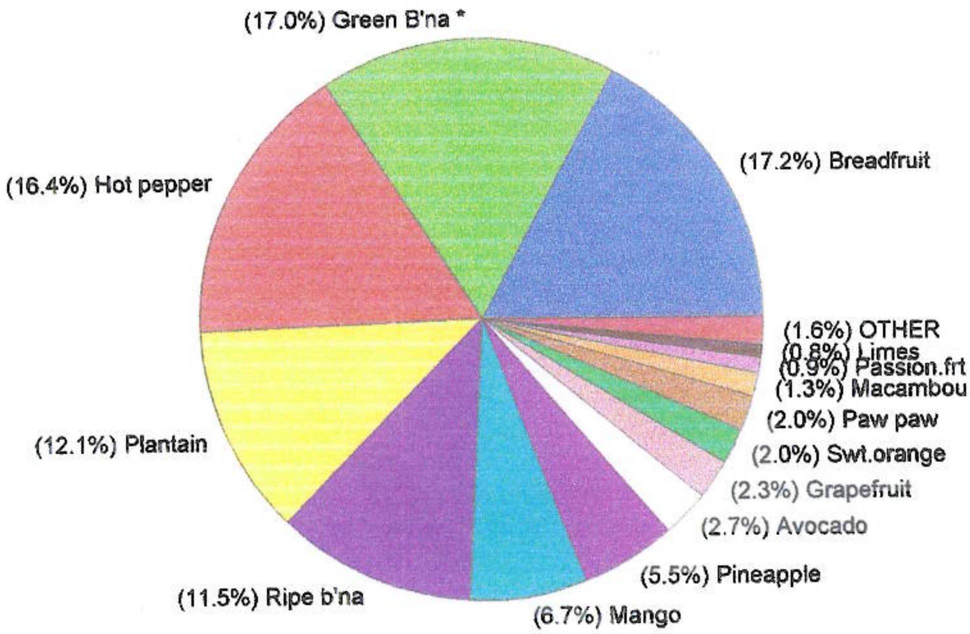


Fig. 3.3: St Lucia: Value of Production for Main Alternative Fruit & Tree Crops

1996 Production, Total EC$3.9 Million



3.3 Institutional Support

ADCU is still actively supporting marketing initiatives. Such aspects as transport, packaging and potential market outlets continue to receive attention and much supportive data is available. Regular market intelligence reports are produced and circulated within OECS member countries including St. Lucia. Currently market potential through U.K. supermarkets is being investigated, and ADCU is in touch with such groups as Waitrose, Safeway, Marks & Spencer and J.C. foods.

ADCU is also currently without a major donor but there is a new initiative under preparation, the Strategic Plan, with possibilities of funding from EU, FAO and CDB. CARDI would also be a beneficiary. Following an analysis of constraints, a future programme is likely to focus on:

- marketing support and market information systems
- policy and planning
- technical support/assistance
- institution building/strengthening
- production coordination
- research

In St. Lucia, institutional support does not enjoy high priority, having only one officer within MAFF&E assigned to alternative crop marketing. While he still receives ADCU Market Intelligence reports, the dissemination of information appears to be less formal than desirable and Extension Staff and Exporters do not feel adequately supported. A monthly journal, Fresh Produce Exporter, is still produced and circulated by ADCU, and this is supplemented by faxed weekly market prices.

3.4 Marketing

Marketing of produce falls into three categories
- Exports
- Local Supermarkets
- Hotels

Exports - Exports from St. Lucia are done by 25 Private Exporters of varying size and the St. Lucia Marketing Board. They are provided with market information but among themselves do not pool this, each tending to have his own suppliers. An Exporters Association has been established but does not function well. This secretive system, which includes SLMB, is not efficient and leads to exporters being short of produce to fill orders and farmers with produce to sell not being able to find buyers. Similar inefficiencies in consolidating consignments for export and shipping/air freight space also exist.

While many farmers claim that they cannot find market for their fruit, ADCU's stand has for some time been, that good marketing opportunities exist. The truth lies somewhere between these positions, if producers can produce in sufficient quantity marketing does not pose a problem, but small quantities and non-consolidated shipping is hard to accommodate. The latter scenario gives exporters access only to the wholesale market in the UK, rather than the more lucrative supermarkets.

Packaging is generally good, using standard boxes designed by ADCU and locally manufactured at Vieux-Fort.

Quality is arbitrary, there being no proper standards followed. The market tends to be demand led, and at times of very high demand, quality is very much a secondary consideration. Any grading done, is by individual exporters, who reject fruit having any obvious damage or other defect. No premium is paid to producers for improved quality and thus there is no incentive.

Problems may be categorised as:

- Produce	-	irregular supply
	-	variable quality
	-	inconsistent varieties
	-	no database of trees
- Farmer	-	scattered/non orchard plantings
	-	low prices
	-	lack of secured outlets
	-	no guidance on varieties or quality
	-	harvesting technique problems
- Exporter	-	poor representation in recipient countries
	-	poor transport arrangements, high cost and non-availability

Local Processing - According to CARIRI/IICA (March 1995) Transformation of Tropical Fruits for the Caribbean, there are nine processors active in St. Lucia. Mostly these are very small "cottage" type operations producing juices, jams and marmalade, wine, ice cream/yoghurt, dried fruit and pickles and spices. Fruits used by processors in St. Lucia reportedly are, banana/plantain, citrus, guava, paw paw, pineapple, soursop, tamarind and golden apple, but only small amounts are involved, and total production in 1993 was around 400,000 kilos. When compared to the import bill (1995) for vegetables and fruit, of EC$26 million, the potential for expansion is enormous. MAFF&E has a food processing laboratory with demonstrations and training facilities, combined with a soil analysis facility. In recent times little or no use has been made of the food processing side.

Nucleus Estate – Many countries, when faced with the marketing problems now facing St. Lucia have used the nucleus estate – smallholder system. Nucleus Estates are established, aimed at producing sufficient quantities of produce to achieve market penetration and justify the establishment of the necessary infrastructure, and smallholders are then encouraged to go into production under the protective wing of the nucleus estates. There would seem to be the beginnings of such a system in St. Lucia. The current situation regarding estate plantings are:

River Doree:	Julie Mango	– 65 acres
	Graham Mango	– 5 acres
	Avocado	– 15 acres (proposed)
Mamiku Estate:	Julie Mango	– 8 acres
	Golden Apple	– 1.25 acres
Fond Estate:	Graham Mango	– 20 acres
	Tommy Atkins Mango	– 10 acres
	Julie Mango	– 2 acres
Sunshine Harvest:	Citrus (various)	– 100 acres (proposed
Mount Coubaril Estate:	Julie Mango	– 5 acres
	Citrus (various)	– 10 acres (proposed)
Union Vale Estate:	Julie Mango	– 5 acres

This aspect warrants further investigations and could be included in the TOR of the Short Term Consultant.

Chapter 4

The Problems in the Watersheds

Over half of the land mass of St. Lucia has slopes in excess of 20^0.

Agro-ecological zones and percentages of different slop ranges in each zone are presented in figure 1.1 of Annex 5. This shows that over half of the land mass in St. Lucia has slopes in excess of 20 degrees. In the most favoured upland zones climatically for smallholder agriculture, i.e. zones Bb, Bk, Ch and Ck, slopes in excess of 20 degrees comprise some 70-75% of the landscape, and slopes in excess of 30 degrees some 25-30% of the landscape. Achieving sustainable farming systems on such sloping land is thus of the highest importance.

As bananas decline in profitability, those farmers having the highest costs and lowest returns will be the first to leave the industry. It is the Consultants considered opinion, that many such farmers will be those cultivating bananas high in the watersheds on steep land, or in other words, the most vulnerable in terms of erosivity and likely to cause major problems in the flat banana lands below.

In response to questions in the reconnaissance survey, many farmers said that in the event of further falls in profitability of bananas, that they would abandon their land and there is physical evidence in support of this. They were not sufficiently confident in the growing of alternative (tree) crops. There is also a danger that with prices and demand for dasheen very strong, farmers may utilise these cleared lands for annual crops. The consequences of this would be total disaster for the watersheds in terms of erosion, soil loss and much damage to the rivers and flood plain, and the more profitable banana plantations.

It is in consideration of this that the Consultants feel it their duty to put forward feasible alternatives, and while on the basis of currently available data, packages for on-farm demonstration are limited, ways can also be suggested for rectifying the lack of data.

Chapter 5

An Analysis of Potentially Suitable Tree Crops

5.1 Problems with Alternative Crops

A number of problems are inherent with any increase in areas of alternative crops:

1. Annual Crops, and particularly Root Crops, would be considerably worse than bananas from a soil conservation point of view. In a Watershed Management and Environmental Project we should be extremely cautious before advocating any increase in annual crop cultivation, even if this made good sense economically in the short term.

2. Many Perennial Crops, where bearing is all-year-round (i.e. seasonality is low) have either problems of low prices/per unit area (as is the case with coconut), or high labour and physical inputs (coffee, cocoa).

3. Most perennial crops which are seasonal have major problems of marketing, and also problems with praedial larceny.

4. Most perennial crops have long delays to bearing and full production. Smallholder farmers dependent on a minimal area of land can not afford a 3-7 year wait for a significant proportion of their land to come into bearing.

5. The high local labour costs, in relation to competing countries producing tropical products, are a major constraint for many crops and markets.

5.2 Advantages in Crop Production and Marketing in St. Lucia

In spite of problems, St. Lucia has some comparative advantages in relation to many competing countries:

1. A wide range of agro-ecological zones, providing almost ideal growing condition for a wide range of tropical produce. Most soils are reasonably fertile, and do not present major problems for nutrient supply and crop management.

2. Availability of reasonable quantities of domestic water in all areas and irrigation water in many areas. (Studies on baseflows of rivers during the dry season, however, are required before any large-scale abstractions are planned. Environmental implications, particularly for aquatic life below the abstraction points, also will need to be studied).

3. Local centres for agricultural research and development. In general, St. Lucia is ahead of the other Commonwealth volcanic islands in this respect, although weaknesses may apply for some specific crops.

4. A sophisticated local urban market for many products. Supermarkets alone have major demand for a wide range of crops.

5. A large and rapidly expanding market for resident tourists, for cruise ship visitors (and potentially cruise ship caterers), and for visiting yachtsmen. This is a high quality, but potentially high price, market.

6. Connections with West Indian (and particularly St. Lucian) expatriates in the UK, USA and Canada. These people represent a large existing market for tropical produce, and also good connections for the supply and marketing of this produce.

7. Short distance of most agricultural areas to ports and airports, and a good road infrastructure connecting most areas.

8. Regular, fast and efficient banana boat export to the UK market. These ships have spare capacity, and could carry alternative produce which could be marketed in a similar way to existing bananas.

9. Frequent wide-body jet services to main distant markets (USA, UK, Continental Europe, Canada, Antigua, Barbados, Trinidad). Although jet services are aimed at the passenger market, particularly for tourism, most wide-bodied jets have spare cargo capacity which could carry perishable produce at an attractive rate for the exporter.

5.3 Alternative perennial Crops Suitable for Cultivation on Sloping Land

A long-list of 27 crops ecologically suited to sloping land under St. Lucian agro-ecological conditions is shown in **Table 5.1**. This comprises the main perennial crops grown in the humid tropics, and their agronomic characteristics. Suitability for St. Lucian agro-ecological zones (see map, Annex 5 and Main Report) and slopes are also presented in the table.

This list was discussed locally and a further 20 crops were suggested, but many of these were considered to be of local interest only. However, carambola, lemon, sour orange, shaddock, tangerine, golden apple, guava and macambou were retained, taking the long-list to 35 ecologically suitable crops **Table 5.2.**

The two above tables also present data on labour requirement, seasonality, time to bearing, and marketing prospects, and based on these parameters the overall future prospects for each crop in St. Lucia are given.

Some 29 of the 35 crops are known in St. Lucia, and their status in terms of current local importance, area occupied and volume recorded is shown in **Figure 5.1**. Main harvest periods for these crops are also shown. Existing marketing outlets for these crops are shown in **Figure 5.2.** and prices paid to the farmer for the main crops during 1995 are shown in **Figure 5.3.**

Crops can be considered under various groupings:

5.3.1 Crops rejected mainly because of labour costs or large required minimum area:

Tea: Ecologically ideally suited, and an excellent crop for soil conservation reasons. Possible niche market for small volumes of green tea, but a factory for black tea would require a minimum of 500ha and labour costs would be uncompetitive.

Rubber: Likewise ecologically ideally suited, including for soil conservation, but labour costs again problematic.

Oil Palm: Ecologically well suited, but both terrain problems and high labour costs, and large minimum area for economic factory conspire to make this unattractive. (Note, however, that land going out of bananas due to labour problems in Costa Rica has now gone into oil palm, but that land is mainly very gently-sloping, aiding mechanised harvesting.)

5.3.2 Crops to be tried experimentally before being advocated on any scale

Jakfruit:	Ecologically well suited, and excellent for soil conservation, but surprisingly not popular in the West Indies. (However, one of the main Exporters, is now growing 40 trees on his estate, aiming to market the fruit with Asian Community in Cananda). Excellent timber, plus fruit, use as vegetable, and use of nuts makes this an ideal multi-purpose tree. New S & SE Asian varieties. Deserves much greater promotion.
Litchi:	High value, both fresh and processed, but may require a cooler, less humid climate for economic yields. Needs testing in different agro-ecological zones.
Mangosteen:	High value, and ideally suited ecologically and for soil conservation reasons, but slow grower. Smallholder homegarden crop.
Rambutan:	Mod. High value, and ideally suited ecologically and for soil conservation reasons. Many new varieties developed in SE Asia.

5.3.3 Traditional crops, but unlikely to expand greatly because of labour and marketing reasons:

Sugarcane:	Ideally suited for drier zones (C,D,E), but terrain and labour costs would make this uneconomic on any large scale. Possible enterprise for distilleries, rum etc.
Pepper:	Useful as understorey crop to coconuts etc., but labour costs and low prices make this less attractive.
Clove:	(as for pepper)
Cinnamon:	Again too labour-intensive for economic production. Soils possibly too heavy-textured for optimum production.

5.3.4 Crops Having Existing Marketing Outlets

A further exercise was undertaken which looked at marketing outlets through local exporters and the status of the various crops in St. Lucia. This data is presented in **Figure 5.2.**

5.3.5 Further considerations in use of perennial crops for soil conservation

- Planting on contour, close together, with wider spaces between rows (i.e. rectangular, rather than square or triangular basis). Pathways to run horizontally.
- Preferably use deep-rooting seedling varieties, rather than grafted dwarf varieties which often have shallower rooting systems.
- Perennial treecrops should ideally be underplanted to existing bananas, with shade and trash management being adjusted to suit the young trees. Young trees should be fertilised independently to the bananas, generally with higher N and higher P mixtures in the early years.
- For land with slopes of over 15 degrees, cultivation of annual crops in the initial 3-4 years between the young trees should be resisted.

TABLE 5.1: ALTERNATIVE PERENNIAL CROPS SUITABLE FOR CULTIVATION ON SLOPING LAND – INITIAL LONG LIST

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Crop	Years to Bearing	Spacing X(m)	Spacing Y(m)	Plants /ha	Rooting Depth	Target Yield t/ha	Input Requirements: Fertilizer	Input Requirements: Pesticide	Land & Climate Requirements: Slopes	AgecZones A	B	C	D	E	Labour Requirement	Seasonality	Marketing Prospects	Remarks	Note	Overall Future Prospects
Avocado	5–6	7	12	119	D	7–8	Moderate	Low	<35deg		●	●	●		Moderate	High	F. Good	Good drainage essential; Marketing via banana boat & air freight	1	Promising
Banana	1	3	3	1111	mS	33–40	V.high	V.high	<25deg		●	●	●		High	Low	V.good	Falling prices, except for premium quality; current certification for quality prodn. hopeful;		OK:depnds.on cost & quality
Breadfruit	3–6	10	12	83	vD	50–80	Moderate	V.low	<35deg		●	●	●		Moderate	Mod–high	Moderate	Good drainage essential; Existing marketing by airfreight to UK	1	Promising
Cashew	3–9	7 7	7 14	204 102	D	nuts: 1 fruits:15	V.low	V.low	<25deg				●	●	Field:moderate Procesng:high	Mod–high	V.good	Nut–processing v.labour–intensive; fruit processing for bottled cordials, etc	3,5	Moderate
Cinnamon	4–6	2	3	1667	D	quills: 0.1–0.2	Moderate	V.low	<35deg		●	●	●		High	Low	Moderate –small vol.	Likes v.acid, poor soils, but severe competition from low–labour cost producers		Poor
Citrus (grapefruit)	4	7	10	143	D	10–15	Mod–high	Mod–high	<25deg		●	●	●		Moderate	High	Mod.–good	Marketing via banana boat; local processing for juices & canned products		Moderate
(lime)	3	5	7	286	D	15–20	Mod–high	Mod–high	<25deg			●	●		Moderate	High–mod.	Mod.–good	Some marketing via banana boat; but mainly local processing for juices & essential oils		Mod–good
(nvl orange)	4	6	8	208	D	7–10	Mod–high	Mod–high	<25deg			●	●		Moderate	High–mod.	Moderate	Local processing for juices & essential oils; some local marketing for fresh fruit		Promising
Clove	6–15	5	10	200	D	Dried: 0.6–1.2	Mod–high	Mod–high	<30deg		●	●	●		High	Mod.–high	Poor	Severe competition from low income prod–ucers; current price v.depressed		V.poor
Coffee(Arbc)	3	2.5	2.5	1600	mD	0.7–1.1	Moderate	Mod–high	<30deg		●				High	Mod.–high	Mod.–good	Competition from lower–cost producers; current price v.good		Promising
Cocoa	4	3	3	1111	mD	1.0–1.8	Moderate	Mod–high	<30deg		●	●			Mod–high	Moderate	Moderate	Traditional local crop; disease problems; req.for pH>5.7 & higher fertility;		F.good
Coconut	5–8	8	8	156	mD	Nuts:9,000 –15,000	Moderate	Moderate	<30deg			●	●	●	Low	Low	Moderate	Prices & profitability low for copra; local 'jelly –nut' prospects good, esp for dwarf varieties		Moderate
Jakfruit	3–8	8	8	156	vD	60–90	Mod–low	V.low	<35deg		●	●	●		Low	High–mod.	Timber:good Fruit:poor	V.valuable, mod–fast growing timber;demand for fruit undeveloped		Mod.–Good
Litchi	4–6	8	8	156	D	15–30	Moderate	Moderate	<30deg		●	●			Moderate–low	High	F.good	Would need trials & promotion: promising as processed, & fresh (local & exported)		Promising
Mango	5–9	8	10	125	vD	12–18	Moderate	Moderate	<30deg		●	●	●		Moderate	High	F.good	Local quality excellent. few pests & diseases cf competing countries	2,4	Promising
Mangosteen	10–15	10	12	83	vD	3–6	Moderate	Moderate	<30deg		●	●			Low	High	Mod–poor	Good for soil consvn; not known locally; would need promotion;mainly local market,&air export		Moderate
Nutmeg	5–8	8	8	156	vD	ntmg:.5–1 mace:.1–.2	Moderate	Low	<30deg		●	●	●		Moderate	Moderate	F.good	Good for soil consvn; labour–sensitive; sold dried or as essential oil (poor fruits)		Moderate
Oil Palm	5	6	6	278	mD	40–80	High	Moderate	<20deg		●	●			Mod–high	Low	Mod–good	Likes acid soils but requires min.2000 ha to justify factory;transport & labour costs importnt		Mod.–Poor
Papaya	1	3	3	1111	mS	30–60	High	Mod–high	<20deg		●	●	●		Mod–high	Low	Moderate	Local demand for quality fruit; prospects for air frt export; good prospects for papain etc.	1	Moderate
PassionFruit	1–2	2	5	1000	S	15–20	V.high	V.high	<25deg		●	●	●		High	Low–mod	Mod–good	Excellent for fruit juices, cordials; some local demand for fresh fruit, prcd fruit for export	3,4	Moderate
Pepper	2–4	2.5	2.5	1600	mS	Dry: 4–5	High	Mod–high	<35deg		●	●	●		High	Mod–high	Poor	Good as intercrop with coconuts & other crops; Difficult to compete with low–cost producers;		Poor
Pineapple	1	0.5	2	10000	S	10–12	High	Moderate	<10deg			●	●		Mod.–high	Low	Mod–good	Local demand for quality fresh fruit; export possibilities via banana boat; erosion problm.	3,4	Moderate
Plantain	1	3	3	1111	mS	33–40	V.high	V.high	<25deg		●	●	●		High	Low	V.good	Local and export markets; reasonable prices; inputs and land requirements as for bananas		Good
Rambutan	5–6	8	8	156	vD	30–60	Moderate	Moderate	<30deg		●	●	●		Moderate	High	Mod–good	Good possibilities for export promotion; possible export via banana boat; needs trials		Good
Rubber	7	5	8	250	D	Dry: 1.2–1.5	Mod–low	Mod–low	<35deg		●	●	●		V.high	Mod–low	Poor	Good for soil conservn & likes v.acid soils; but some processing req. & labour costs expensive		V.poor
Soursop	3–5	5	10	200	mD	20–40	Moderate	Moderate	<30deg		●	●	●		Moderate	High	Mod–good	Good possibilities for export promotion (air) & for processed juices; needs trials	3,4	Good–mod
Tea	3	0.9	1.5	7400	D	Dry: 1.8–2.6	High	Mod–high	<30deg	●	●	●			V.high	Low	Poor	Good for soil conservn & likes v.acid soils; but requires min.200ha & factory for black tea; some prospects for green tea, but labour expv.		V.poor

Sources: Ceylon Fertilizer Corp, Crop Recommendations; & Agricola, 1978 'Handbook for the Ceylon Farmer'; CARDI 'Cost of Production Database',1994; ADCU/IICA Competitiveness Study,1993;Purseglove, 'Tropical Crops', 1974.

Note: As investigated by ADCU/IICA: 1 competitive for St Lucia; 2 marginally non–competitive for StL; 3 non–competitive for St L; 4 competitive for other islands; 5 marginally uncompetitive in other islands

TABLE 5.2: ALTERNATIVE PERENNIAL CROPS SUITABLE FOR CULTIVATION ON SLOPING LAND – FINAL LONG LIST

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Crop	Years to Bearing	Spacing X(m)	Spacing Y(m)	Plants /ha	Rooting Depth	Target Yield t/ha	Input Requirements Fertilizer	Input Requirements Pesticide	Land & Climate Requirements Slopes	Land & Climate Requirements AgecZones A B C D E	Labour Requirement	Seasonality	Marketing Prospects	Remarks	Note	Overall Future Prospects	Recommended Fertiliser Mixture N	P2O5	K2O	MgO
Avocado	5–6	7	12	119	D	7–8	Moderate	Low	<35deg	• • •	Moderate	High	F. Good	Good drainage essential; Marketing via banana boat & air freight	1	Promising	11	23	15	
Banana	1	3	3	1111	mS	33–40	V.high	V.high	<25deg	• • •	High	Low	V.good	Falling prices, except for premium quality; current certification for quality prodn. hopeful;		OK:depnds.on cost & quality	15	8	30	
Breadfruit	3–6	10	12	83	vD	50–80	Moderate	V.low	<35deg	• • •	Moderate	Mod–high	Moderate	Good drainage essential; Existing marketing by airfreight to UK	1	Promising	11	23	15	
Carambola																				
Cashew	3–9	7 7	7 14	204 102	D	nuts: 1 fruits:15	V.low	V.low	<25deg	• •	Field:moderate Procesng:high	Mod–high	V.good	Nut–processing v.labour–intensive; fruit processing for bottled cordials, etc	3,5	Moderate	20	16	13	
Cinnamon	4–6	2	3	1667	D	quills: 0.1–0.2	Moderate	V.low	<35deg	• • •	High	Low	Moderate –small vol.	Likes v.acid, poor soils, but severe competition from low–labour cost producers		Poor	22	12	15	
Citrus																				
(grapefruit)	4	7	10	143	D	10–15	Mod–high	Mod–high	<25deg	• • •	Moderate	High	Mod.–good	Marketing via banana boat; local processing for juices & canned products		Moderate	15	16	20	
(lemon)																				
(lime)	3	5	7	286	D	15–20	Mod–high	Mod–high	<25deg	• •	Moderate	High–mod.	Mod.–good	Some marketing via banana boat; but mainly local processing for juices & essential oils		Mod.–Good				
(nvl orange)	4	6	8	208	D	7–10	Mod–high	Mod–high	<25deg	• •	Moderate	High–mod.	Moderate	Local processing for juices & essential oils; some local marketing for fresh fruit		Promising				
(sour orange)																				
(shaddock)																				
(tangerine)																				
Clove	6–15	5	10	200	D	Dried: 0.6–1.2	Mod–high	Mod–high	<30deg	• • •	High	Mod.–high	Poor	Severe competition from low income prod–ucers; current price v.depressed		V.poor	9	8	16	1
Coffee(Arbc)	3	2.5	2.5	1600	mD	0.7–1.1	Moderate	Mod–high	<30deg	•	High	Mod.–high	Mod.–good	Competition from lower–cost producers; current price v.good		Promising	20	10	18	
Cocoa	4	3	3	1111	mD	1.0–1.8	Moderate	Mod–high	<30deg	• •	Mod–high	Moderate	Moderate	Traditional local crop; disease problems; req.for pH>5.7 & higher fertility;		F.Good	19	8	16	4
Coconut	5–8	8	8	156	mD	Nuts:9,000 –15,000	Moderate	Moderate	<30deg	• • •	Low	Low	Moderate	Prices & profitability low for copra; local 'jelly –nut' prospects good, esp for dwarf varieties		Moderate	10	6	31	
Golden apple																				
Guava																				
Jakfruit	3–8	8	8	156	vD	60–90	Mod–low	V.low	<35deg	• • •	Low	High–mod.	Timber:good Fruit:poor	V.valuable, mod–fast growing timber;demand for fruit undeveloped		Mod.–Good				
Litchi	4–6	8	8	156	D	15–30	Moderate	Moderate	<30deg	• •	Moderate–low	High	F.good	Would need trials & promotion: promising as processed, & fresh (local & exported)		Promising				
Macambou																				
Mango	5–9	8	10	125	vD	12–18	Moderate	Moderate	<30deg	• • •	Moderate	High	F.good	Local quality excellent, few pests & diseases cf competing countries	2,4	Promising	24	12	10	
Mangosteen	10–15	10	12	83	vD	3–6	Moderate	Moderate	<30deg	• •	Low	High	Mod–poor	Good for soil consvn; not known locally; would need promotion;mainly local market&air export		Moderate				
Nutmeg	5–8	8	8	156	vD	ntmg:.5–1 mace:.1–.2	Moderate	Low	<30deg	• • •	Moderate	Moderate	F.good	Good for soil consvn; labour–sensitive; sold dried or as essential oil (poor fruits)		Moderate				
Oil Palm	5	6	6	278	mD	40–80	High	Moderate	<20deg	• •	Mod–high	Low	Mod–good	Likes acid soils but requires min.2000 ha to justify factory;transport & labour costs importnt		Mod.–Poor				
Papaya	1	3	3	1111	mS	30–60	High	Mod–high	<20deg	• • •	Mod–high	Low	Moderate	Local demand for quality fruit; prospects for air frt export; good prospects for papain etc.	1	Moderate	9	19	24	
PassionFruit	1–2	2	5	1000	S	15–20	V.high	V.high	<25deg	• • •	High	Low–mod	Mod–good	Excellent for fruit juices, cordials; some local demand for fresh fruit, prcd fruit for export	3,4	Moderate	11	12	15	5
Pepper	2–4	2.5	2.5	1600	mS	Dry: 4–5	High	Mod–high	<35deg	• • •	High	Mod–high	Poor	Good as intercrop with coconuts & other crops; Difficult to compete with low–cost producers;		Poor	14	11	14	2
Pineapple	1	0.5	2	10000	S	10–12	High	Moderate	<10deg	• •	Mod.–high	Low	Mod–good	Local demand for quality fresh fruit; export possibilities via banana boat; erosion problm.	3,4	Moderate	15	5	33	
Plantain	1	3	3	1111	mS	33–40	V.high	V.high	<25deg	• • •	High	Low	V.good	Local and export markets; reasonable prices; inputs and land requirements as for bananas		Good	15	8	30	
Rambutan	5–6	8	8	156	vD	30–60	Moderate	Moderate	<30deg	• • •	Moderate	High	Mod–good	Good possibilities for export promotion; possible export via banana boat; needs trials		Good				
Rubber	7	5	8	250	D	Dry: 1.2–1.5	Mod–low	Mod–low	<35deg	• • •	V.high	Mod–low	Poor	Good for soil conservn & likes v.acid soils; but some processing req. & labour costs expensive		V.poor				
Soursop	3–5	5	10	200	mD	20–40	Moderate	Moderate	<30deg	• • •	Moderate	High	Mod–good	Good possibilities for export promotion (air) & for processed juices; needs trials	3,4	Good–mod				
Sugarcane	1	0.3	1	33333	mD	100	Moderate	Mod–low	<25deg	• • •	Mod–high	High	Mod–poor	Historic crop but high labour costs, min.2000ha req.for factory,high transport costs,steep terrain		Poor				
Tea	3	0.9	1.5	7400	D	Dry: 1.8–2.6	High	Mod–high	<30deg	• • •	V.high	Low	Poor	Good for soil conservn & likes v.acid soils; but requires min.200ha& factory for black tea; some prospects for green tea, but labour expv.		V.poor				

FIG 5.1: STATUS OF PERENNIAL CROPS SUITABLE FOR CULTIVATION ON SLOPING LAND

Crop	Status in St Lucia	Marketed Production '96 (tonnes)	Area (Acres)	Harvest Period J F M A M J J A S O N D ● ● ● ● ● ● ● ● ● ● ● ●
Avocado	●●●●	169	590	– – – – ● ● ● ● – –
Banana	●●●●●	112000	20500	● ● ● ● ● ● ● ● ● ● ● ●
Breadfruit	●●●●	800	1350	– – – ● ● ● ● ● ● ● – –
Carambola	●●●	10		– – ● ● ● ● ● – –
Cashew	●	?		● ●
Cinnamon	●	?		
Citrus (grapefruit)	●●●●	222	450	– – – – – ● ● ● ● –
(lemon)	●●●	17	50	● ● ● ● ● ● ●
(lime)	●●●	74	160	– ● ● ● ● ● ● –
(nvl orange)	●●●●	169	580	● ● – – ● ● ●
(sour orange)	●●●	10		
(shaddock)	●	?		
(tangerine)	●●	21	100	● ● ● ● ●
Clove	●	?		
Coffee(Arbc)	●	?		
Cocoa	●●●●		780	– ● ● ● – – –
Coconut	●●●●		11900	● ● ● ● ● ● ● ● ● ● ● ●
Golden apple	●●	30		
Guava	●●●	3		● ● ● ● ● ● ● ● ●
Macambou	●●●	61		● ● ● ● ● ● ● ● ● ● ● ●
Mango	●●●●	490	2350	– ● ● ● ● – –
Nutmeg	●	?		
Papaya	●●●	33		● ● ● ● ● ● ● ● ● ● ● ●
PassionFruit	●●●	27		● – – ● ● – – – – – ● ●
Pepper	●	?		
Pineapple	●●	85	90	● ● ● ● ● ● ● ● ● ● ● ●
Plantain	●●●●	586	700	● ● ● ● ● ● ● ● ● ● ● ●
Soursop	●●	38		– – – ● ● – – – – ● ● ●
Sugarcane	●	?		● ● ● ● ● ●

Sources: MALFF, 1996 St Lucia Census of Agriculture, Portrait of Main Findings; C.Paul, pers comm; L.Charles, pers comm. CARDI 'Cost of Production Database',1994; ADCU/IICA Competitiveness Study,1993;Purseglove, "Tropical Crops', 1974.

Note: Status in St Lucia: Predominant crop ●●●●●; v.important economically ●●●●; subsidiary crop (<100t/yr) but increasing ●●●; subsidiary but static or decreasing ●●; minor crop, production not recorded ●.
Harvest Period: Period of peak availability ●; Period of reduced availability –; Possibility for extending season –.

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FIG 5.2:EXISTING MARKETING OUTLETS FOR PERENNIAL CROPS SUITABLE FOR CULTIVATION ON SLOPING LAND

Crop	Status in St Lucia	Marketed Production '96 (tonnes)	Area (Acres)	Agent Number / Watershed Number (see below for listing) 1 / 6	2 / 6	4 / 32	5 / 34	6 / 6	7 / 32	8 / 34	9 / 6	10 / 16	11 / 6	12 / 16	13 / 32	14 / 32	15 / 32	16 / 34	17 / 6	18 / 34	19 / 34	20 / 22	21 / 16	23 / 34	24 / 21	25 / 16
Avocado	●●●●	169	590	●	●		●	●		●			●	●		●	●	●	●				●	●		
Banana	●●●●●	150000	20500			●	●		●			●			●				●		●				●	
Breadfruit	●●●●	800	1350	●	●		●	●		●	●		●	●	●	●	●	●						●	●	●
Carambola	●●●	10																								
Cashew	●	?																								
Cinnamon	●	?																								
Citrus						●	●																			
(grapefruit)	●●●●	222	450																●							
(lemon)	●●●	17	50																							
(lime)	●●●	74	160																							
(nvl orange)	●●●●	169	580																●		●					
(sour orange)	●●●	10																								
(shaddock)	●	?																								
(tangerine)	●●	21	100																							
Clove	●	?																								
Coffee(Arbc)	●	?																								
Cocoa	●●●●		780																							
Coconut	●●●●		11900						●			●						●								
Golden apple	●●	30		●				●						●	●								●	●		
Guava	●●●	3																								
Macambou	●●●	61						●		●					●											
Mango	●●●●	490	2350	●	●	●		●		●	●	●	●		●	●	●	●				●	●	●	●	●
Nutmeg	●	?																								
Papaya	●●●	33																								
PassionFruit	●●●	27																			●					
Pepper	●	?																								
Pineapple	●●	85	90																						●	
Plantain	●●●●	586	700	●	●	●		●	●	●	●	●			●	●		●	●		●			●		
Soursop	●●	38		●	●					●	●			●	●		●							●	●	
Sugarcane	●	?																								

Sources: MALFF, 1997. 'Fresh Produce Exporters of St Lucia – Exporters of Caribbean Fresh Fruits, Vegetaables and Cut Flowers.
Agent Numbers are as follows: 1 Valton Enterprises, Richfond, Dennery; 2 Virginie Enterprises, La Caye, Dennery; 4 Est Caribbean Tropical Produce, Bexon; 5 A & V Co.Ltd, Sunbilt, Castries; 6 James Vallon, Derniere Riviere, Dennery; 7 Brown's Tropical Export, Bexon/Marc; 8 T & J Foods, Ciceron, Castries; 9 Tropical Produce, Derniere Riviere, Dennery; 10 Laymoy Company Ltd, Vieux Fort; 11 South East Produce, Despin / Au Leon, Dennery; 12 Agro/Aqua Producer Exporter Ltd, Vieux–Fort; 13 H.F.Jn Baptiste Ltd, Odsan, Castries; 14 TNT Produce (Import/Export) Ltd, Odsan, Castries; 15 Perineau Exports, Ravine Poisson; 16 St Lucia Marketing Board, Castries; 17 Elias John Export Import Company, Richfond, Dennery; 19 A & L Fresh Produce Export, Entrepot, Castries; 20 Windward Islands Tropicals, La Fargue, Choiseul; 21 R & A Exports, Vieux Fort; 23 Branica Trading, La Pansee, Castries; 24 River Doree Hodings, River Doree, Mt Lezard, Choisuel; 25 Sunshine Exotics, Vieux–Fort;

MALFF, 1996 St Lucia Census of Agriculture; Portrit of Main Findings; C.Paul, pers Comm; L.Charles, Pers comm;

Watershed Numbers are as follows: 1 Trou Sallee; 2 Esperance; 3 Dauphin; 4 Marquis; 5 minor E Coast; 6 Fond d'Or/Mabouya; 7 Dennery; 8; 9 Praslin; 10 Fond; 11 Micoud; 12 Troumassee; 13; 14 Cannelles; 15 Roarne Rugeine; 16 Vieux–Fort; 17 ; 18 ; 19 Piaye; 20 ; 21 Doree; 22 Choiseul; 23 L'Ivrogne/Trou Marc; 24 ; 25 Soufriere; 26 ; 27 Canaries; 28 ; 29 Grande Riviere de L'Anse la Raye; 30 Petite Riviere de L'Anse la Raye; 31 Roseau; 32 Cul de Sac; 33; 34 Castries; 35 Choc; 36 Bois D'Orange; 37 Cap.

Note: Status in St Lucia: Predominant crop ●●●●●; v.important economically ●●●●; subsidiary crop (<100t/yr) but increasing ●●●; subsidiary but static or decreasing ●●; v.minor crop, production not recorded ●.
Harvest Period: Period of peak availabilitPeriod of reduced Possibility for extending season –.

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Chapter 6

Crop Prospects

6.1 Objective

The main objective of the above ananlysis is to ascertain which crops have the best prospects in terms of potential production and marketing. Crops not excluded in the analysis, can be grouped into four categories:

Category 1	Crops with known potential and on which there is sufficient data to make a recommendation
Category 2	Crops with known potential but requiring additional data before they can be recommended
Category 3	More recently introduced crops which show promise
Category 4	Other crops which should be introduced for observation and screening

6.2 Category One

Crops that can be included in this group are discussed below and are:

Avocado
Breadfruit
Grapefruit
Orange
Cocoa
Coconut
Mango
Plantain

6.2.1 Avocado

Exports in 1996, 130.3 tonnes. The most important destination is the UK where the small green ripe types are preferred. A large number of the trees in St. Lucia are derived from seedlings of a wide range of West Indian types, and virtually no plantation or orchard plantings exist. Favoured varieties are Lula, Pollock and Simmonds. Yields under good conditions range from 2 to 5 tonnes per acre or 85 to 200 lbs. per tree - typical prices paid by exporters are EC$0.50 to $0.75 per lb., giving a potential income of EC$ 42.50 to EC$ 100. per tree. Market demand is good.

6.2.2 Breadfruit - Exports in 1996 - 769.1 tonnes

No known varieties and stock of trees very mixed. A dwarft type has been selected. Types are recognised and fruit is a variable size and quality, but can be selected at point of purchase by an experienced buyer. Yields average 12 tonnes per acre and fruit are worth EC$ 1.00 per fruit to exporters giving a potential of EC$ 6000 per acre. Market demand in UK is steady.

6.2.3 Grapefruit and Orange

Exports in 1996 were only 22.3 and 4.6 tonnes respectively, but the fruits are popular with local supermarkets and hotels, where 1996 sales were 199.6 and 163.9 tonnes. Good varieties have been planted, Ruby Red and Marsh seedless grapefruit which supplement a good local varieties and Valencia and Washington Naval orange. Yields of 14 and 19 tonnes per acre are possible and local markets can be further developed. Valencia orange in particular has potential for the fresh juice market.

6.2.4 Cocoa

Previously a popular crop in the upper catchments with a strong demand due to St. Lucia cocoa's unique flavour. Production has seen an upturn from an all time low in 1996. It can be grown with shade, using either forest or fruit trees

6.2.5 Coconut

The 1996 Agricultural Census, put existing plantings at around 700,000 trees or some 9500 acre equivalents, many of the trees being in mixed stands with other crops including bananas. The St. Lucia Coconut Growers Association, is the only purchaser of copra made on farm. The SLCGA operates a factory which expresses, deoderises and purifies coconut oil, for sale in local shops. It also, has a capacity to produce margarine but this enterprise requires a high proportion of imported fish oil. Following bankruptcy mainly due to mismanagement of financial resources, the factory has only recently (September 97) been restarted. After overhauling and repairing the machinery and the buildings, the Association plans to start buying in late November.

The price paid to growers will be 40 cents/lb. for farm produced copra. Using a conversion factor of 4 nuts = 1 lb. copra, a neglected tree would yield 10lbs. copra and a well tended tree 25 lbs. At 40 cents/lb., this translates to EC$ 4.00 and EC$ 10.00 per tree. Assuming half of this would cover the cost of dehusking drying etc., the figures would be EC$ 2.00 and EC$ 5.00 per tree, which at 65 trees per acre would be EC$ 130 and EC$ 325 per acre.

From a processing point of view, using figures based on the Consultants experience, a gross profit of some EC$ 14.6 million could be generated from which running costs, maintenance and repairs, labour and management costs would have to be deducted. Provided the SLCGA stick to their central enterprise of refined oil, which can be marketed in St. Lucia and the Caribbean, the economics look promising, and given good response from farmers in terms of copra deliveries, there would seem to be potential for increasing the price paid to growers.

6.2.6 Mango - Exports 1996 - 386.9 tonnes.

There is more mango in St. Lucia than any other alternative fruit crop, with a reported acre equivalent of 2352. The proportion of known varieties to seedling mangoes is not known. Julie is the most popular, and yields under good conditions around 125 kg per tree or 600 fruits. Typical price paid by exporters is 35 cents per fruit, yielding EC$ 210 per tree or EC$ 10,080. Not all fruit is of marketable quality but on average 60% would be well graded. Yields are however widely variable depending on variety, management, inputs etc. Demand is good, particularly in the UK where St. Lucia enjoys a good marketing window in August – September. Long varieties and Graham also find a market, but the latter, promoted by BDDC in the OCDP project, although of excellent quality and a good traveler, does not enjoy the popularity it deserves.

6.2.7 Plantains

Plantains, which have similar characteristics and requirements as bananas, are popular, both as an export crop (254.3 tonnes 1996) and for local supermarkets and to a lesser extent hotels 9299.8 tonnes in 1996). Some 700 acre equivalents exist in St. Lucia, but demand for export exceeds current production. Yield is in the region of 7 tonnes per acre and at the typical price paid by exporters of 50 cents, is worth $7,700 per acre. Many good varieties are available.

6.3 Category Two - This group comprises:

- Guava
- Macambou (a type of plantain)
- Paw paw
- Passion fruit
- Soursop

Generally this group is of less importance from a conservation view point. Guava, passion fruit and soursop have potential for the local juice market and soursop has some export potential. Macambou and paw paw are relatively minor crops.

6.4 Category Three - This has only two crops:

Golden apple and Carambola, the latter having been recently introduced. Both have potential for the local juice market with some limited demand for export. Neither crop has good conservation potential.

6.5 Category Four

This group is derived from an analysis of **Table 3.1** and contains crops that the Consultants believe should be tried.

They are:

Arabica coffee
Jak fruit
Litchi
Mangosteen
Rambutan

Seed supplies are available, and ADCU is able to provide information on sources. As a primary objective, collections of say 20 of each species should be established at CARDI or Union Farm or both, for observation and evaluation.

Chapter 7

Recommendations

7.1 General

The urgent need for action is not in dispute, but the time which the Consultants were able to devote to Alternative Crops was limited, and with so many institutions involved, establishing why more progress has not been made was not a straight forward as it at first seemed. One clear objective must remain paramount - to provide farmers with technical information, costs of inputs and value of outputs, physical demonstrations on their own farms, and supporting infrastructure covering all aspects from provision of planting material through to harvesting and marketing.

In Annex 9, Main Socio-Economic Issues, the Socio Economist proposed the establishment of a National Action Force to push diversification forward. In sounding out opinions, several professionals strongly supported this proposal. There is, as is apparent from the contents of this annex, currently a lack of readily available data on which to work. However, the formation of an Action Force should be given serious consideration in that it would give focus to the main issues raised, should the recommendations for a short consultancy meet with acceptance.

7.2 The Proposed Programme

In view of the lack of time the Consultants were able to spend on alternative crops, difficulties encountered in locating and obtaining essential reports, and the importance which they attach to getting a programme of diversification started, a short consultancy is proposed. In consultation with ADCU, CARDI, and MAFF&E staff the consultant would:

- collect and collate all existing data on alternative crops and summerise the situation
- identify weakness, constraints and deficiencies and propose solutions to rectify
- recommend a programme of work that would lead to definition of technical packages
- make recommendations for tree crops by agro-ecological zone
- design and cost a programme of on-farm demonstration
- review institutional involvement and recommend changes where necessary
- assess the need for incentives, how they would operate and which institution would be most appropriate

Without wishing to prejudge the outcome, current thinking suggests that the programme is likely to include:

- the inclusion of a Diversification Unit within the overall institutional framework of the LCB.
- the establishment of a one acre on-farm demonstration using a mix of fruit tree crops, one for each WAMF and contracted through the WMAF.
- the establishment of targets for conversion, bananas to fruit trees for each WMAF. Initial targets could be 10% of land over 25^0 slope.
- The deposition of funds to the National Federation of Credit Unions for on-lending to farmers at 6% interest, to alleviate loss of income during a change of cropping.

7.3 The Cropping Models

Based on existing knowledge and data, the following crops can be provisionally recommended for contour plantings within farmers fields, gradually replacing existing bananas:

- Avocado
- Breadfruit

- Grapefruit
- Sweet Orange
- Mango
- Plantain
- Cocoa
- Coconut (dwarf varieties, specifically for drinking).

Cost and output data available to the Consultants was sparse and highly variable. Actual profitability depends on management and inputs, and yields can be increased by 100% in some cases. Nevertheless, the above crops can be promoted, pending the assembly of better data during the Short Term Consultancy.

7.4 Responsibilities of MAFF&E for Alternative Crops

Immediate attention should be given to raising the profile of the division within MAFF&E. Action should include:

- increased staff.
- better dissemination of available information on marketing (radio-tv-through extension staff)
- staff training and orientation
- pivotal and coordinating role within the proposed Action Force on Crop Diversification.

7.5 Research and Development

CARDI was formerly a key institution in supporting alternative crops through research, but currently appears to be lacking in direction and drive. The reason for this must be established and a course of action put in place to regain the former positive involvement. CARDI should be heavily involved in the design and implementation of the on-farm demonstration progamme.

7.6 Transport

Air has become the most favoured means of transporting produce, but a number of problems were reported. Excluding BWI flights which are routed via Trinidad, there are 6 flights per week from St. Lucia to the UK. Assuming an average freight capacity of 24 tonnes, some 7500 tonnes could be transported. In 1996 3344 tonnes were air freighted, and this limits expansion. Trial shipments by sea, using the regular weekly banana boat, have been successful but exporters report that more recent shipments have resulted in much deterioration in fruit and heavy losses. Recommendations for immediate action are:

- better coordination of air freight through ADCU, Exporters Association intervention.

- immediate improvements to the Hewanorra Air Cargo Service facilities. The buildings belong to the Civil Aviation Authority which government and ADCU cut put under pressure.

- a re-examination of shipping where potential exists for utilising space bought by SLBGA.

7.7 Donor Support

For a hillside farmer to change from his monocropping banana require to an alternative crop will seriously affect his income. Assuming that bananas are used as a nurse crop, he will face progressively diminishing returns over a 5 year period, by which time, income from the alternative crop will start to come on stream. With income already low at less than EC$ 7000 per annum (see Annex 9), serious consideration should be given to financial incentives. In order to try and assess the loss in income, the Consultants extracted relevant costs from the Cost of Production Data Base "CARDI 1994", and excluding farm labour, except for harvesting, to provide a common base to the banana costings given in Anenx 9 and a true comparison, produced a table illustrating the effect on income during a change of cropping. Julie Mango was chosen mainly because of data availability. A more detailed analysis covering a wider range of crops could well feature in the Short Term Consultancy. These could take the form of:

INCOME DEFICIT DURING CHANGE FROM BANANA TO MANGO (50 TREES / ACRE – LOW TECH) FOR A TYPICAL 3–ACRE HILLSIDE FARM (EC$ / YEAR)

	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr10	Yr15
Assumed banana revenue	6885	5508	4131	2754	1377	0	0	0	0	0	0
Mango non–harvest costs	0	1122	354	423	708	459	459	459	459	459	459
Mango harvest costs	0	0	0	57	906	1809	2172	2451	2730	3102	4344
Mango revenue	0	0	0	1938	3879	7758	8937	10053	11169	13341	18306
Net Income	6885	4386	3777	4212	3642	5490	6306	7143	7980	9780	13503
Deficit (–) / Additional Income (+)	0	–2499	–3108	–2673	–3243	–1395	–579	258	1095	2895	6618

Internal Rate of Return: 15.3 %

Note: assumes farmer provides his own labour except for harvesting
Total deficit to Yr 6 is EC$13497. Finances for project cosidered over a 20–year period. File:V3BANMNG.wk3

- extending credit lines through the existing self regulating Credit Union system, where interest rates of 6% apply.
- subsidised planting material
- direct grants to farmers paid through the WMAF.

7.8 Observation Plots

Through liaison with ADCU seed sources for new fruit tree introductions should identified, seed procured, and plots established at CARDI and Union Farm, and sub-stations covering wetter and drier agro-ecological zones.

7.9 Crop Processing

Attempts should be made to exploit the potential for local processing. A survey of hotels and restaurants could easily provide an indicator of market requirement and a detailed examination of the government publication "Annual Digest of Statistics" would shed further light on the matter.

7.10 Crop Residues

As a side issue, there would seem to be potential to develop a small feed industry, using crop residues. Currently all animal feed is imported, making pig and poultry enterprises marginal in terms of competing with cheap imports, primarily from the states. At the same time, coconut meal is exported from the Soufriere factory. Such items could be:

- coconut meal
- dried waste banana
- citrus pulp

Annex 6

Landslide Hazard Mapping

ANNEX 6

LANDSLIDE HAZARD MAPPING

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Landslide Hazard Mapping

1 Review of land degradation due to landslides and debris flows

Documented information on land degradation due to landslides in St. Lucia is contained in a few published and unpublished reports, including DeGraff, 1985; DeGraff et al., 1989; and Prior and Ho (1972). Apart from a gap from 1967 to 1994, the historical record of tropical storms and hurricanes which have affected the island from 1938 to the present, suggests that during this period there were at least thirteen major landslide-producing storm events on the island. In addition to these, landslides invariably develop on an annual basis during the rainy season or during high-rainfall periods of non-storm years. The high frequency and widespread distribution of these slope failures are evidence that landsliding is a dominant erosional process on the island. DeGraff (1985) relates the high landslide frequency to the natural process of isostatic adjustment characteristic of elevated volcanic terrain undergoing tectonic uplift (mountain-building). Active downcutting of streams accompanies uplift and promotes steep slopes; landsliding is one of the main erosional processes active in this adjustment.

Several types of landslides have been documented, including debris flows, debris slides, rock falls, rock slides and landslide complexes. Of the several landslide types, debris flows are the most common and are the primary contributor to land degradation. These flows occur in soil or weathered rock, are typically small in size, (tens of metres in width and several metres in depth), and are initiated as shallow failures in the upper regions of the slope. The failed material, saturated with water becomes mobilised, flows downslope at high velocity, and carves deep erosion channels. They typically develop in topographic depressions at the heads of drainage ways, immediately or within metres of ridge crests. They have a distinctive appearance, viz. a spoon-shaped scars in their upper regions with elongated erosion tracks downslope. The erosive potential of these landslides is considerably enhanced by vegetation which becomes incorporated into the mobilised flow. The soil cover may be partially removed, or, as is often the case, the entire soil cover is removed, exposing the bedrock surface.

Although debris flows are relatively small in size, their cumulative effect on land degradation, including loss of fertility and loss of soil cover, is significant. This was most recently demonstrated during TSD, when numerous debris flows were initiated on steep slopes in the upper catchments of watersheds. These flows removed a substantial volume of soil and destroyed large tracts of forest and agricultural crops. Debris flows also eroded the upper slopes of roads and road beds, leading to the collapse of several road foundations. The significant volume of soil and other landslide debris carried by these flows to streams resulted in increase sedimentation of rivers and contributed to flooding downstream. Steep agricultural land under banana cultivation was particularly prone to erosion due to debris flows.

2 Review of landslide and debris flow hazard zoning

Two studies, commissioned by the Organisation of American States (OAS), represent the complete documentation on landslide and debris flow hazard zoning on the island. DeGraff (1985) prepared both a landslide inventory and a landslide hazard map of the island for purposes of regional planning. The landslide inventory, based on mapping of landslides from 1:15000 black and white aerial photographs of 1977 and 1981, complemented by field surveys in selected areas, shows the types and distribution of landslides which were prevalent during this period. Landslides were mapped in every watershed and included debris flows, debris slides, rockfalls and rockslides. Except for the central part of the island, the landslide hazard map classified the island into four categories of landslide hazard viz. low, medium, high and extreme (**Figure 1**). Most of the island was identified as having a medium landslide hazard. The hazard map was developed using a factor correlation method, which correlated landslide occurrence with the distribution of bedrock type and slope gradient. Both bedrock and slope gradient maps were prepared at 1:50000 scale, while the landslide inventory was based on 1:15000 and 1:25000 mapping. The analyses were conducted at 1:50000 scale and transferred to a 1:25000 topographic scale for presentation.

Following TSD in September 1994, the OAS commissioned a second study to generate landslide hazard information, particularly with respect to debris flows. This study was in response to i) the abundance of debris flows which were initiated during the storm and ii) the observation that the high incidence and distribution of these flows was not consistent with the hazard zoning classification of the earlier mapping. It was recognised that, while the hazard map of DeGraff represented the hazard associated with all landslide types, it did not reflect the hazard associated uniquely with debris flows.

The study consisted of a reconnaissance survey of eleven watersheds identified as priority by the Ministry of Planning. The survey was done along the island's primary and secondary roads and accessible waterways, and consisted of i) field mapping, at the reconnaissance level (1:25000 scale) of the locations of TSD-triggered landslides and ii) mapping of the landslides generated from 1986 to 1991, using aerial photographs. The level of investigation varied, from cursory to detailed, from watershed to watershed, depending on accessibility and time.

A second objective of the study was to prepare landslide hazard information using formats which would be easily understood by potential users, such as planners, thus enabling the planning department to incorporate landslide data as a land use and development criteria. The landslide hazard database consists of a suite of three annotated maps, at 1:25000 scale and a companion guidance document. The map database contains an updated landslide inventory map (**Figure 2**), a debris flow hazard map (**Figure 3**) and a map of primary areas of debris flow initiation and existing and potential debris flow runout regions. Each map contains a detailed legend with explanatory text on the appropriate use of the map and map limitations. The guidance document provides recommendations on land use feasibility in zones of varying debris flow stability. Both the maps of DeGraff and Rogers were prepared manually. The maps by Rogers have since been digitised and form part of the national GIS database of the island.

3 Improvement in the accuracy of landslide hazard mapping to scale of 1:10000 in St. Lucia

Landslide hazard mapping typically involves the mapping and analysis of the physical factors which influence landslides. These physical factors include the following:

- geomorphological factors such as slope angle, slope form and slope aspect
- soil or rock type
- rainfall characteristics, such as rainfall intensity and antecedent moisture
- configuration of the underlying bedrock surface
- vegetation cover
- other factors, such as the location of spring lines, wind direction and wind speed.

A main product of such analysis is a landslide hazard map, which classifies a region into zones of varying susceptibility to the hazard. In the case of St. Lucia, and other regions in which debris flows are the predominant landslide type, landslide hazard mapping typically involves an analysis of geomorphology, soil type, and rainfall characteristics. Of these, geomorphology, in particularly the components of topography, viz. slope gradient and slope form, are the most important.

Figure 1: Lanslide hazard map, after DeGraff (1985)

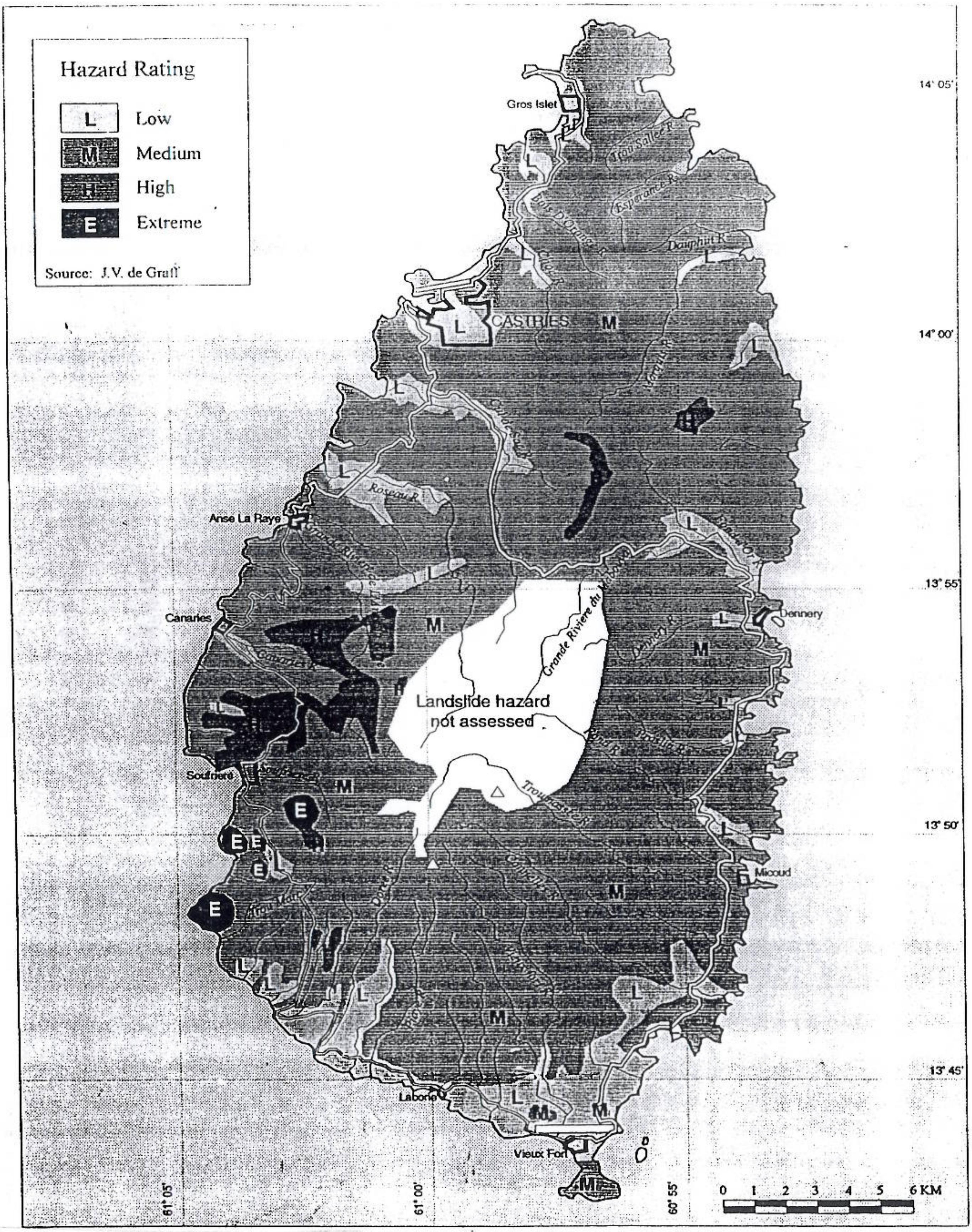
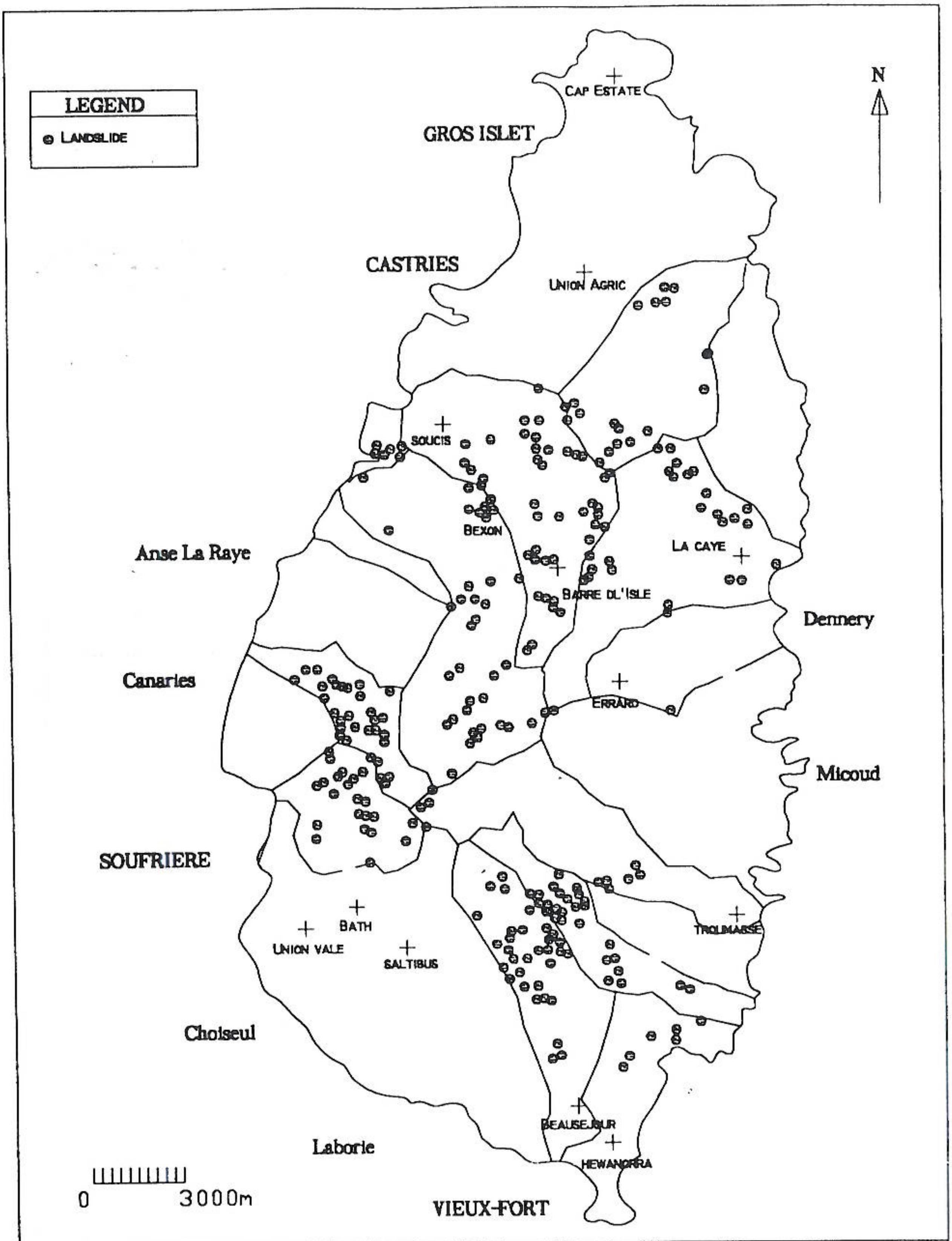
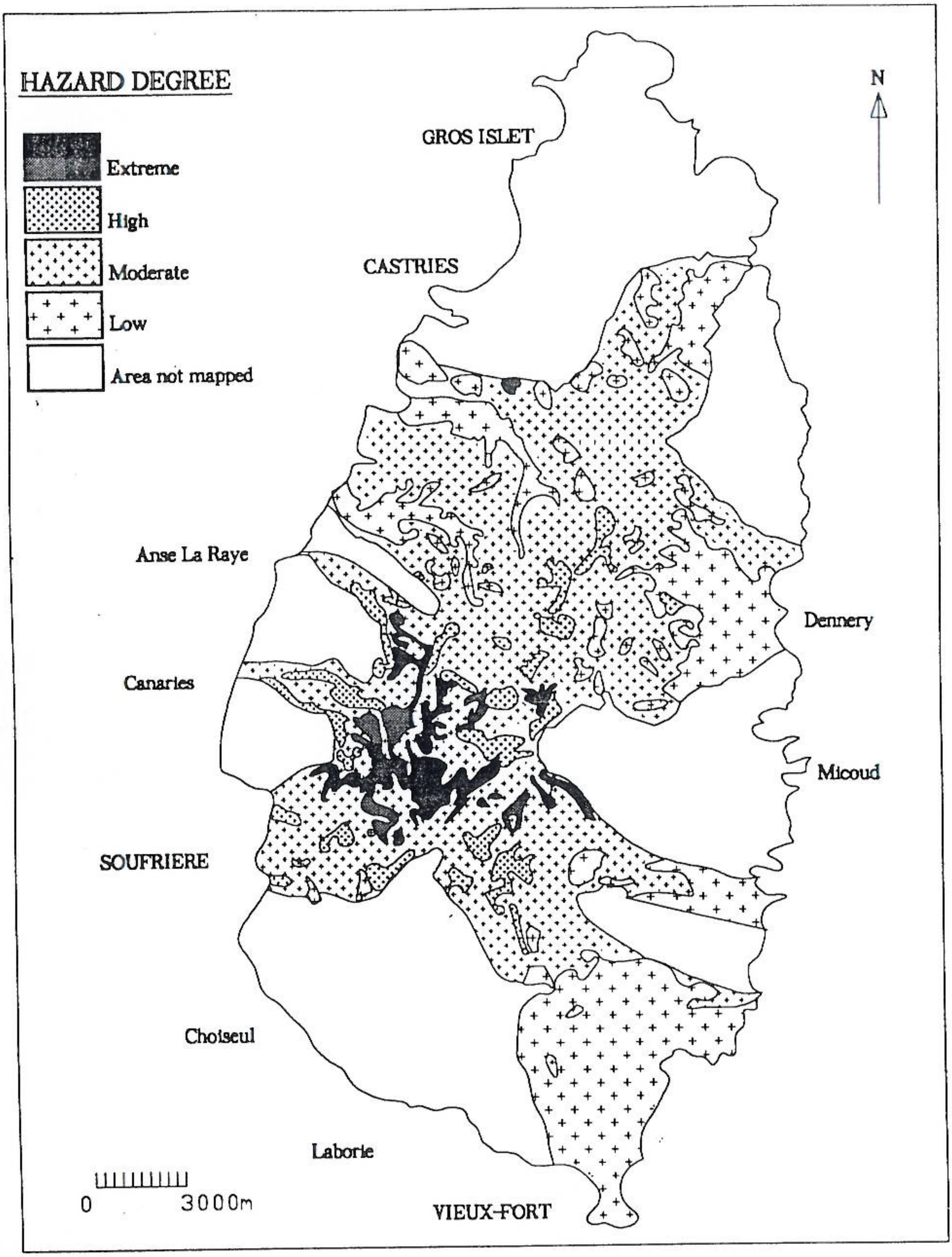


Figure 2: Updated landslide inventory



Landslides generated during Tropical Storm Debby (selected watersheds)

Figure 3: Debris flow hazard map, after Rogers (1995)



The mapping and analysis of landslide hazard are performed at various scales, depending on the level of accuracy desired and the final purpose of the map. Smaller scales reflect less detail and are therefore less accurate. For example, for purposes of regional planning, hazard maps are prepared at a scale of 1:25000 or less. On the other hand, for project –level studies, such as for the investigation for a housing development, larger scaled maps (1:10000 or greater) are required. The larger scale allows for detailed definition of physical parameters and thus a more accurate representation of the hazard degree. Since the mapping unit at 1:25000 scale is relatively large, the values of the landslide-influencing parameters in each unit are averaged over the unit, and thus the hazard associated with each unit is generalised. Therefore, it is possible that a hazard unit defined as moderate may contain pockets of high and low hazard zones. This is acceptable, since the purpose of the map is for interpretation at the regional level. In order to improve the mapping accuracy, the analysis is performed on a larger scale, for example 1:10000.

As indicated above, the landslide hazard maps prepared post TSD were prepared for use at the regional level, and thus were prepared at 1:25000 scale. The maps are based on mapping and analysis, at 1:25000 scale, of five factors, viz. location of landslides, slope gradient, slope form, soil type and average annual rainfall. Thus the locations of landslides were mapped in the field on a 1:25000 topographic base, slope gradient and slope curvature were generated from the 1:25000 topographic sheets and a map of soil type was extracted from 1:25000 land capability map. A map of mean annual rainfall of the island was only available at 1:50000 scale, and as such was used as the basis for generation of rainfall classes.

While the 1:25000 topographic base is appropriate for regional level studies, it is not appropriate for use in the development of hazard maps at 1:10000 scale, since the 1:25000 topography is generalised and does not contain detailed variations in the topography. The significance of the topographic parameter is particularly important at project-level scales, since debris flows are relatively small features (30 metres average size) and also occur on specific locations in the terrain. Thus the topographic base must be sufficiently accurate to pick up these highly localised debris flow prone sites in the terrain.

Our investigations have revealed that, while topographic maps of the island exist at 1:25000, 1:10000 and 1:2500 scale, each of these is based on 1:25000 mapping. This means that for the larger scaled maps; 1:10000 and 1:2500, the level of topographic detail is the same as obtains for the 1:25000 topographic base. In other words, the existing 1:10000 and 1:2500 maps are simply enlarged versions of the 1:25000 topographic base, rather that enhancements in topographic detail. Thus they cannot be used to improve the accuracy of the existing hazard maps.

To overcome this problem, the Consultants explored other sources from which 1:10000 topographic base could be extracted. Satellite imagery of the island was not available, and thus a digital elevation model could not be obtained. Also the available aerial photographs at 1:10000 scale covered the urban regions of the island, regions which are largely outside of the landslide prone zones. In light of the non-availability of the critical topographic base at appropriate scale, a hazard map at 1:10000 scale was not prepared.

The Consultants have however, attempted detailed field mapping of those landslides induced by TSD and the October 26th event. Problems were experienced since secondary forest regrowth cover and agricultural crops have revegetated many of the TSD scars. (Good examples of these re-vegetated scars were seen on the helicopter SFAP survey, and illustrations of these are given in **Fig 1.2 of Anenx 8**). An attempted an at aerial survey of the two watersheds was made, using small format air photography to map the landslides (**Figure 4**). In spite of these limitations and in keeping with the terms of the TOR, **Figure 5** outlines the recommended requirements and procedures for improving landslide hazard map accuracy to a scale of 1:10000.

Figure 4

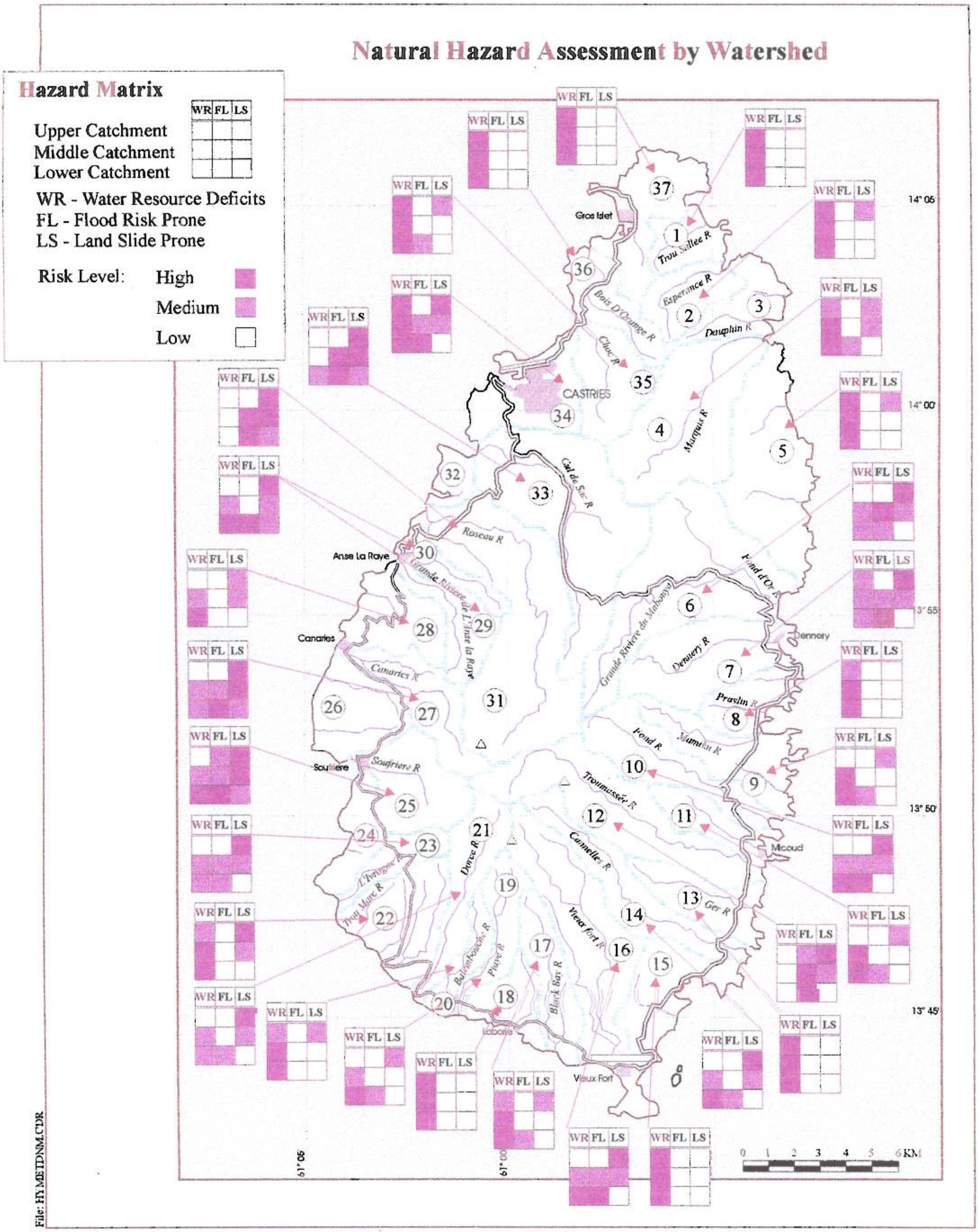

Natural Hazard Assessment by Watershed
Hazard Matrix
WR FL LS
Upper Catchment
Middle Catchment
Lower Catchment
WR - Water Resource Deficits
FL - Flood Risk Prone
LS - Land Slide Prone
Risk Level: High
Medium
Low
Gros Islet
CASTRIES
Anse La Raye
Canaries
Soufriere
Laborie
Vieux Fort
Micoud
Dennery
Trou Sallee R
Esperance R
Dauphin R
Bois D'Orange R
Choc R
Marquis R
Cul de Sac R
Roseau R
Grande Riviere de L'Anse la Raye
Canaries R
Soufriere R
Grande Riviere du Mabouya
Dennery R
Praslin R
Fond R
Mamiku R
Troumassée R
Canelles R
Ger R
Vieux fort R
Black Bay R
Piave R
Doree R
Trou Marc R
14° 05'
14° 00'
13° 55'
13° 50'
13° 45'
61° 05'
61° 00'
0 1 2 3 4 5 6 KM
File: HYMETDNM.CDR

Figure 5: Recommended requirements and Procedures for improving landslide hazard mapping accuracy to a scale of 1:10 000

Procedure for improving landslide hazard mapping accuracy to 1:10000 scale

1. Acquire a digital elevation model (DEM) of the island (maximum grid resolution 10 metres)

2. Use the St. Lucia national geographic information system (GIS) database to generate, from the DEM, topographic maps of the island at 1:10000 scale

3. Using the 1:10000 topographic base developed in (2) above, map the locations of individual landslides developed during and post TSD, including Little TSD, using one or more of the following mediums:
   i) Small format air photography, as described elsewhere in this document, but for the entire island
   ii) 1:10000 or larger aerial photo surveys of the island
   iii) satellite imagery (maximum resolution 10 metres Spot Imagery
   iv) Perform ground surveys to map those landslide not identified by either of these methods and to verify the existence of those landslides indicated in (i) to (iii) above,

4. Use the DEM to generate maps of slope gradient, slope curvature at 1:10000 scale

5. Extract relevant rainfall data (1:50000 mean annual rainfall, rainfall intensity data) from the national GIS

6. Apply the landslide hazard assessment methodology outlined in Rogers (1995)* to generate the landslide hazard maps at 1:10000, using the parameters, slope gradient, slope curvature, soil type, mean annual rainfall or rainfall intensity

Steps 2, 4 and 5 of the hazard mapping procedure should be executed in a GIS environment to ensure efficiency and accuracy.

*Rogers, C. T. (1995). Post Tropical Storm Debbie landslide hazard assessment study of St. Lucia. Organisation of American States, 34pp.

4 Possible correlation between rainfall intensity/duration and landslide incidence

There is abundant evidence in St. Lucia and confirmed elsewhere, that landslides are triggered by heavy rainfall. Most landslides on the island occur during the rainy season and the record of landslide-producing storms shows that damaging landslides follow periods of intense rainfall. Whether a landslide develops is a function of both the pre-storm rainfall and the rainfall intensity during the storm.

Ideally, the most accurate approach to establish a relationship between landslide occurrence and rainfall intensity would be to compare, for an individual storm, landslide incidence with short duration rainfall intensity during the storm. The only documented record of landslides during a single storm, is the post TSD inventory of Rogers (1995). However, the inventory is limited in the sense that it records landslides only for selected watersheds, and in addition, the mapping is skewed along the transportation routes, mainly primary and secondary roads. Nevertheless, this inventory represented the best available information and thus was used in the analysis.

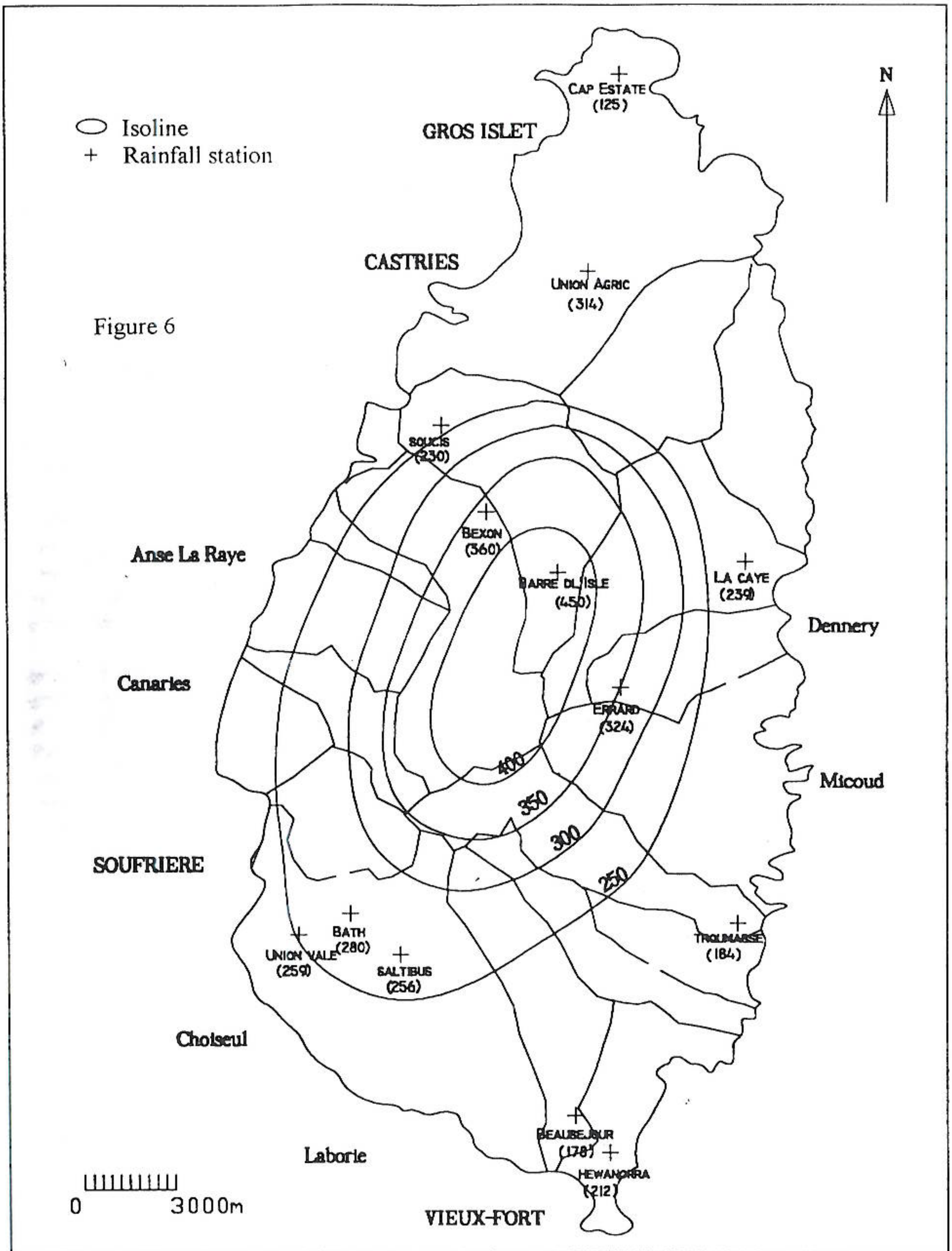
The rainfall intensity data for TSD is also poor. At the time of TSD, data was being collected from 18 automatic rainfall recorders, and 21 manually read rain gauges. Only from five of these stations (Errard, Bexon, Soucis, Saltibus and Delcer) could reliable rainfall intensity data be obtained, and two of these, Saltibus and Delcer were outside the main zone of heaviest rainfall.

In the absence of short duration rainfall intensity values for the storm, other estimates of rainfall intensity were considered. Average annual rainfall has been used elsewhere as an approximation for rainfall intensity. The basis of this is the fact that a station with highest average annual rainfall is also likely to posses a record of maximum monthly and maximum daily rainfall and also short-duration rainfall intensities. Other approaches have used maximum monthly rainfall and maximum daily rainfall. It can be appreciated that the smaller the time step used, the more likely is the correlation between rainfall intensity and landslide incidence.

Given (i) the variability in rainfall regimes in tropical climates and the fact that in such climates a high annual rainfall is not a guarantee of a particularly high maximum monthly or maximum daily rainfall, (ii) the fact that the TSD rainfall data for more than one station has shown little correlation between average annual rainfall and actual short duration intensities, (iii) that 1994 rainfall records show that TSD was the only storm event for the year and that daily rainfall for the period of the storm was the highest for the year and (iv) the availability of rainfall data, it was decided that, for purpose of this study, maximum daily rainfall would provide the best approximation of rainfall intensity.

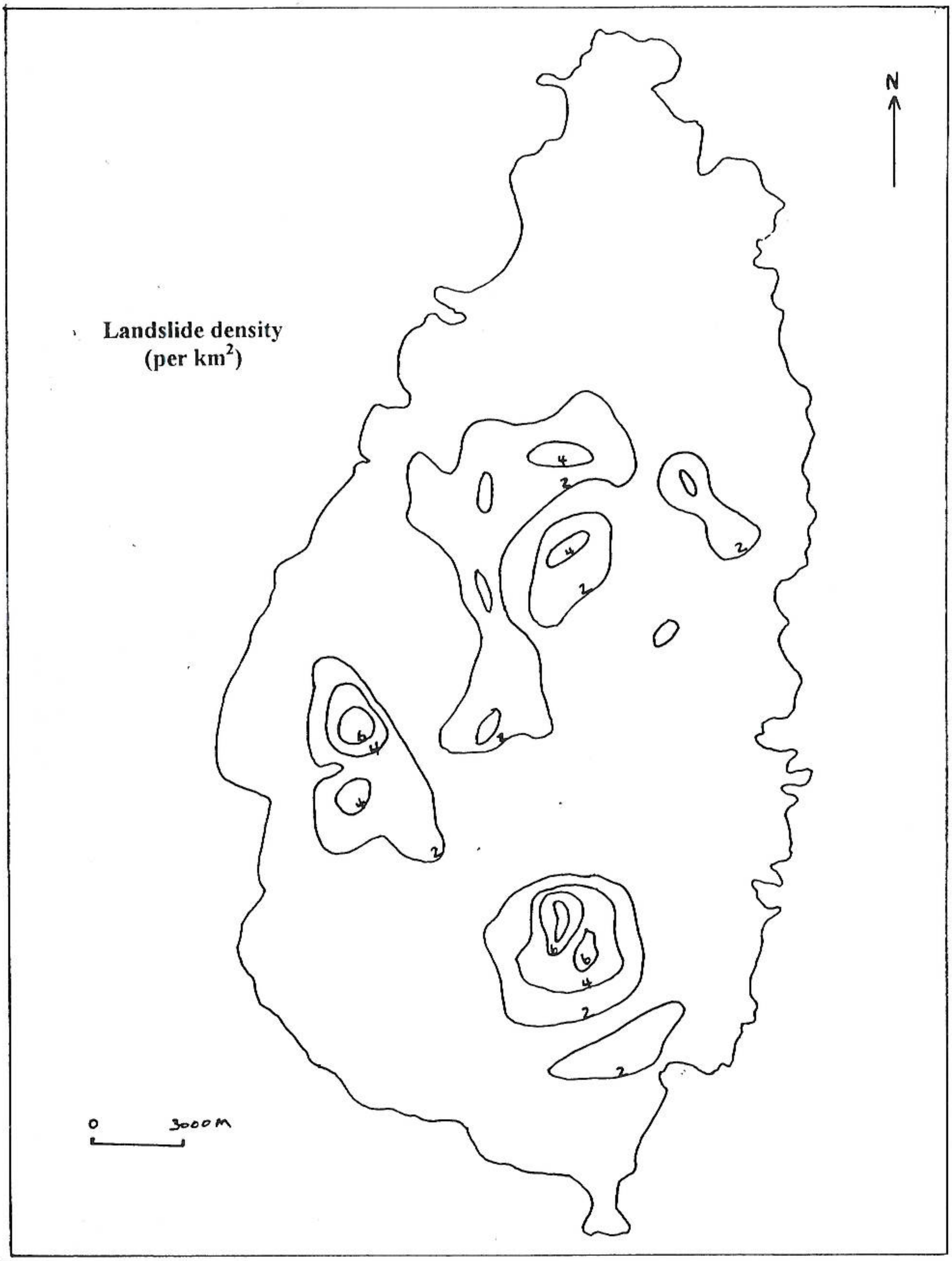
Maximum daily rainfall figures from 1994 were extracted for the records of the Agricultural Engineering Division, Ministry of Agriculture for the 10 stations (**Figure 6**) for which data was available. The maximum daily rainfall values were then contoured to generate estimated rainfall intensity isolines (**Figure 6**). Similarly, utilising the landslide inventory map of TSD to calculate landslide density generated a landslide density map (**Figure 7**). The two maps were then superimposed and compared.

Figure 6



Estimated rainfall intensity isolines (in millimetres), Tropical Storm Debby

Figure 7: Landslide density map



The estimated rainfall intensity isolines indicate that a relationship between topography (elevation) and estimated intensity exists. The highest intensities occur in the region of the Barre de L'Isle Ridge. Estimated intensity values decrease to the east and west. The lowest values are to the southwest of the island. The gradient of the isolines suggests a more rapid increase in estimated intensity with elevation on the eastern side of the island, relative to the south and southwest. This is consistent with the topography of the island.

Some correlation between landslide density and elevation is indicated, however, the relationship is not distinct. Relatively high densities occur in the Barre de L'Isle Ridge region, in the upper catchments of the Roseau, Soufriere and Canaries rivers, and in the middle catchments of the Vieux Fort and Canelles rivers. The highest densities occur in the more southerly watersheds (Soufriere, Canaries, Vieux Fort and Canaries); this is consistent with the path of TSD, which entered the island from the south.

Super imposition of the two maps reveals a relatively poor correlation between landslide density and estimated intensity. This may be attributed to:

1. The fact that the landslide data used in the study consisted of only a subset of the landslides triggered by TSD, that many of the landslides triggered at higher elevations were not mapped due to inaccessibility, and additionally, that the distribution of the mapped landslides is skewed along transportation routes.

2. Limitations in the use of maximum daily rainfall as an estimate of rainfall intensity. Although the estimated rainfall intensity isolines generated from maximum daily rainfall at rainfall stations does show increases in values with elevation, the trends indicated may be generalised due to the small sample size (10 rainfall stations) used to generate the isolines. In particular, the possible variation in rainfall intensity with slope is not likely to be indicated. Alternatively, the poor correlation may be an indication that maximum daily rainfall is not reflective of short duration rainfall intensities during the storm.

5 Recommendations

There is need for the development and execution of a comprehensive landslide management plan for the island. This plan should outline the strategies and techniques which need to be taken to minimise risk and reduce losses prior to, during and post a disaster. The management plan should include the following components:

1. A geographic information system – based landslide hazard management system (LHMS) to organise, and manage landslide hazard data in an efficient manner. The LHMS should contain the basic data for hazard, vulnerability and risk assessment and for production of hazard data for decision making. The basic data should include:
   - Existing and updated landslide inventories of the island
   - Existing landslide hazard map
   - Existing debris flow hazard maps
   - Landslide hazard source data at appropriate scale; 1:25000 to 1:10000
     - A digital elevation model of the island (maximum grid resolution 10 metres)
     - Rainfall characteristics, e.g. mean annual rainfall, pre-storm rainfall, short duration rainfall intensities
     - Socioeconomic data for vulnerability and risk assessments, viz. land use,
     - population, infrastructure, , utilities, location of high risk structures/facilities

2. A decision support system containing the encoded methodologies for hazard, vulnerability and risk assessment, to enable potential users such as planners and engineers to generate relevant hazard data for decision-making The decision support system should be linked to and form an integral part of the LHMS.

3. Greater priority must be given to hazard data collection for effective analysis and decision-making in hazard management. Effective disaster hazard management require a full understanding of the landslide phenomena. Concerted effort must be made to improve the quality of the hazard/disaster data required to perform analysis and to better understand the phenomena for disaster management purposes. This applies to both rainfall intensity data and to documentation of landslides triggered by individual storms. In the first case, improvements in the network of rainfall stations with continuous recorders capable of documenting rainfall intensity measurements have already been put in place; proper maintenance must be carried out so as to ensure that they perform efficiently during landslide-producing storms.

   In the case of the latter, greater priority needs to be given to the mapping of the full inventory of landslides which occur during any given storm. Such mapping must include both reconnaissance surveys by road, use of small format air photography, and/or satellite imagery. Additionally, disaster management plans must incorporate specific funding for post-disaster monitoring so that landslide inventories may be performed in full and at the level of detail required. In this context, landslide personnel should form part of official post-disaster teams and be allowed access to disaster sites immediately after the event.

4. Socio-economic data, such as land use and population data should be added to existing hazard maps to generate vulnerability and risk maps for priority areas of the island. These maps will provide an indication of the communities and resources at risk.

5. Landslide hazard data should be routinely used as essential criteria in land use planning. Such data should also be incorporated into the development and updating of national physical development plans and environmental management plans.

6. Design criteria for capital works projects in landslide–prone zone must be established.

7. Warning systems, such as slope monitoring systems and development of rainfall intensity and duration thresholds for debris flow occurrence should be put in place for pilot regions. Monitoring of rainfall intensity and duration at rainfall stations on the island during an impending storm can serve to warn communities in high risk landslide zones of impending danger from potential debris flows.

8. Education and training programmes must form an integral component of the LHMS. These programmes should designed to upgrade the upgrade the skills of relevant disaster personnel and to make the population more hazard-literate and disaster-ready. Suggested programmes include:
   - training in disaster management techniques
   - training in method of landslide hazard assessment at project level
   - effective use and interpretation of landslide hazard data for planning and engineering use
   - non-engineering and engineering methods of slope stabilisation
   - outreach education programs to farmers etc, on simple techniques to minimise landslide risk
   - postgraduate scholarships in disaster management.

9. WMAFs should play a pivotal role in the above activities. This is already starting in the upper parts of the Cul de Sac Watershed, where high-landslide-risk areas co-incide with areas dense settlement (e.g. Bexon, Poisson, Marc Marc).

Annex 7

Field Trials and Evaluation

ANNEX 7

FIELD TRIALS

CONTENTS **PAGE**

Final Report
Annex 7

Chapter 1

Introduction

One of the core programme elements defined by BDDC and included in the project document stated.

- *identification and field testing of solutions to unsolved problems (e.g. flood hazard planning, landslide/slope stabilisation, sustainable land use, river stabilisation, social impact, conservation of biodiversity and environment), disaster preparedness and management.*

In pursuance of this, the Consultants prepared a draft Trials Programme early in November 1996 as a basic for discussion, and subsequently, an agreed programme was published. This is presented at Appendix A.

The programme included agronomic, community participation, river engineering, bioengineering and geotechnical/landslide trials for implementation during the dry season - March to August - a period when the Consultants were not in St. Lucia.

While the agricultural, community participation and bioengineering trials came under direct project control, the remainder, the engineering trials were for implementation through the Ministry of Works, and their capacity to construct and manage the trials, was in a sense, also being tested.

With few exceptions, lessons to be learned from an evaluation of the trials are not evident during the time span of the Phase 2 project, in the case of the community participation trial, for instance, it may take two to three years before any final conclusion can be reached.

The scope of this Annex is therefore limited to what has been learned to date, and it also highlights the need for continued government involvement in the longer term trials.

Chapter 2

Agronomic Trials

2.1. Introduction and Objectives:

Cultivation of bananas on steep lands was identified by the project as the single most important misuse of land contributing to the erosion problem; both surface wash erosion, and a greater risk of mass movements, (landslides, debris flows etc.) being involved. Much of the steep land now cultivated has been cleared from forest over the last 30 years, with most of this having occurred in the last 15 years in response to the high banana prices during the period 1980-92. The worsening of the erosion and flooding problems can thus be closely correlated with the expansion of bananas on steeply sloping land at the expense of forest cover.

Although extension work on bananas is the responsibility of the SLBGA, extension on field activities has had much less emphasis than on harvesting and quality control activities (Harris, 1993; Reid, 96, pers com). In addition, those field activities promoted have been on fertiliser and pest control, with very little work done on soil conservation. Extension staff of the Ministry of Agriculture have concentrated on crops other than bananas, and again soil conservation activities would appear to have received relatively low priority.

Erosion and Run-off Control Trials were thus started by the Project, with the following initial objectives:

- to obtain measurements on infiltration and run-off on steeply-sloping banana land under different practises of trash cover and trash lines, to verify the hypothesis that trash cover can improve infiltration by a large factor as well as protect the soil surface from raindrop impact;
- to obtain measurements on any yield increases that would result from better soil and water conservation;
- to obtain costs of soil conservation measures in terms of labour and any materials used;
- to assess the relative costs and benefits of the different treatments being considered, i.e. even spread of trash over the soil surface, orientation of trash in trash lines held down by stakes along the contour, and tied contour drains;
- to demonstrate to extension staff and farmers the benefits obtainable and the methods used in these trials.

It was hoped that on the basis of these trials a simple extension leaflet would be produced, which could be circulated to extension staff and farmers.

The subject of banana trash management was selected as it was considered to have immediate impact. Trials with alternative perennial crops were deliberately not chosen under this project period for three reasons:

i) being long-term crops, such trials would have yielded very little useful information within a 10-month period;

ii) considerable work has been done by other projects on precisely this subject, and it was considered that this work needed reviewing before any further implementation was undertaken (see Annex 6 on Alternative Cropping);

iii) support from MAFF&E appeared limited and budget allocation was completely inadequate for any long-term programme.

The role of vetiver on the project was also discussed. Vetiver forms part of the bio-engineering (slope stabilisation) trials, and its role could have been extended to agronomic trials. However, with bananas, vetiver has been shown to have serious problems due to excessive shade with most banana fields after the 5th month of the plant crop. Trash management was thus considered a much more important subject for investigation within the context of the project.

2.2 Design of the Erosion and Run-off Control Trial

Sites selected were under mature banana cultivation (2nd or subsequent years of ratoon cropping) and were under standard control conditions including:

- typical smallholder banana land representative of the banana belt in the two watersheds (Agro-ecological Zones B-D);
- slopes within the range 20-35 degrees;
- smallholder management at typical levels.
- some surface drainage, generally installed several years previously.

This typical banana land usually shows the following problems:

a) the soil surface is not adequately protected against raindrop impact;
b) the unprotected surface quickly suffers soil structure breakdown and a reduction in infiltration rate;
c) surface wash movements then occur over the surface, removing fertiliser and topsoil;
d) existing drains remove excess surface water, but also much nutrient-rich topsoil;
e) poor drain construction (unprotected sides, uneven and excessive slopes) have lead to slumping, gullying, etc.

At each field experiment site the following parameters were intended to be measured:

- composite topsoil analysis: exchangeable cations, CEC, total and available P, organic C and N;
- sprinkler infiltrometer measurements giving measurements on infiltration rate and any subsequent run-off;
- fresh banana root density;
- soil run-off;
- banana fruit yield;
- banana fresh-trash weight;
- Leaf Area Index (LAI).

Details of the Sprinkler Infiltrometer methodology used are given in Annex 5.

At each site the following treatments were investigated:

i) Control Conditions: involving some shallow surface drainage and banana trash left at random in piles;
ii) Even coverage of banana trash: the trash would be placed over the entire surface, pseudostems being cut into strips, and this would be orientated along the contour; the trash would be obtained from production in situ;
iii) Even coverage of banana trash, but at double the density; further trash would be brought in from banana lands in flatter areas;
iv) Banana trash placed in lines on contour, and held by short stakes. Trash obtained from production in situ.
v) as (iv) above, but with installation of tied contour drains (silt traps);

vi) as (v) above, but with banana trash also brought in from flatter areas to give double the standard application rate; half of the trash would be used to cover the ground surface, the other half placed in lines on the contour and held by short stakes.

The positioning and orientation of the tied contour drains (silt traps) as in (v) and (vi) above, required careful consideration as they would not be advocated for the landslide-risk areas, because water retained on the contour could further increase landslide risk. The assessment of benefits of soil conservation (i.e. control of surface wash erosion) against the slightly increased risk of mass movements (landslides, etc.) would have to be considered by the project.

On all sites inputs were applied, including fertiliser at the recommended rate (i.e. 0.5lb / mat / 3months), and also lime at the recommended dosage in order to counteract the acidifying effects of the fertilisers.

The overall design of each of the four sites is shown schematically in **Figure 2.1.**

2.3 Location and Management of the Trials:

After delays due to need for approval for funding etc., the trials were eventually started on four sites, representative of the steep smallholder banana land in the two Pilot Watersheds. Although the Consultants requested one MAFF&E officer to be in charge of the trials, the Government made available the services of three extension officers covering the specific areas in which the trials were located. Although this had the advantage that the officers were familiar with the farmers and land in their respective areas, it had a distinct disadvantage in that the officers were also covering a large number of other activities, and did not view the trials as of the highest priority. The Consultant also had the problem of having to repeat explanations of the activities to three separate individuals. A further big problem was the exceptionally rainy weather experienced during the 3-week period when the trials were being set up, with the officers, labourers and the consultant working soaked for much of the time. The actual setting out of the subplots was thus not done as thoroughly as the Consultant would have liked.

Selection of ideal plots also proved difficult. Criteria for selection included:

- consent of the farmer: in a couple of cases we wasted much time explaining the trials to the farmers, only to learn that they were not keen for us to proceed (problems of family land, consent of the owner being given as the excuse);

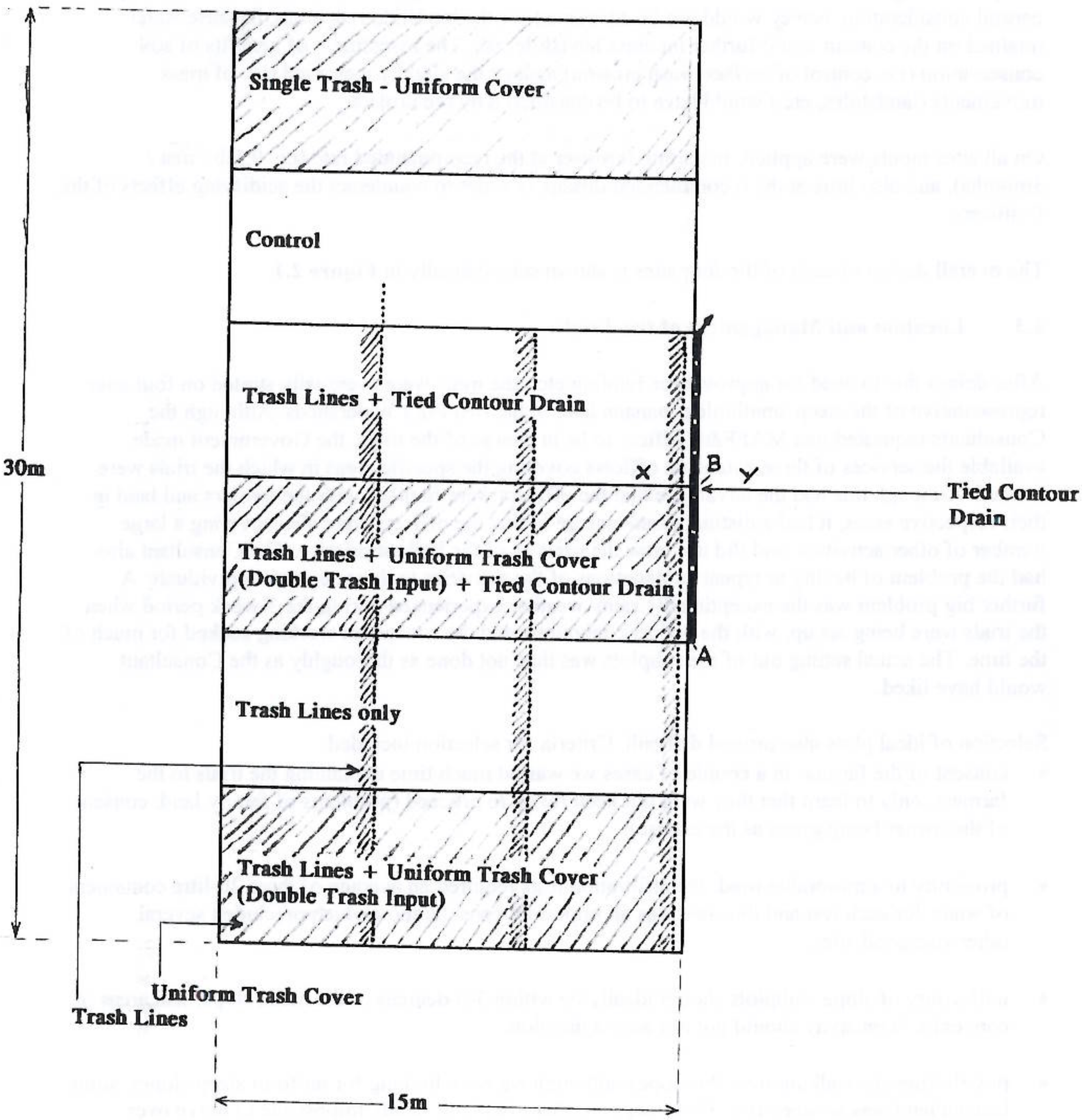
- proximity to a motorable road: the infiltration tests required an average of three 20-litre containers of water for each test and thus this was an important consideration which precluded several otherwise good sites;

- uniformity of slope: subplots should ideally be within 3-5 degrees of the mean slope, and areas of convexity / concavity should not run across the plots;

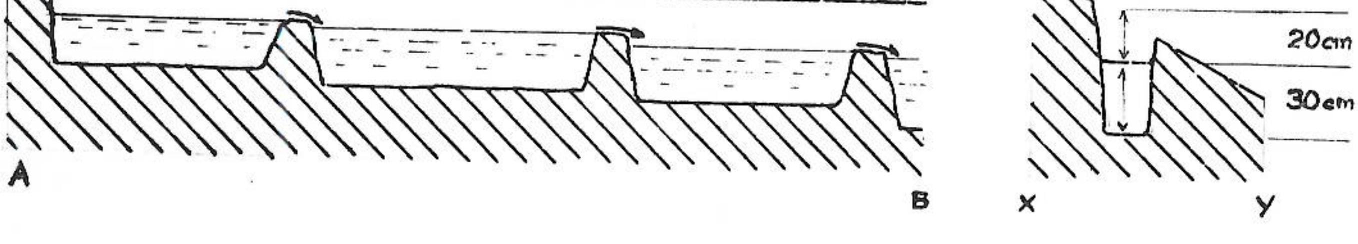
- possibilities for walking over the slopes: although we were looking for uniform steep slopes, some banana land was so steep (i.e. 35-45 degrees) that it was physically impossible to move over without the use of ropes (i.e. belaying). Rain made the problem even worse.

GENERAL PLAN OF SOIL CONSERVATION TRIALS

Figure 2.1:



Cross Section of Tied Contour Drain:



The two Dennery sites were set up under the control of Mr Fermin Faucher of the Dennery Extension Office (Region 3); the two Cul De Sac trials were split between two regions: Region 7 (Roseau) trials under the control of Miss Antoinia Felix, and Region 8 trials, under the control of Mr Aloysius Lesfloris.

Details of the four sites are tabulated as follows:

LOCATION	MEAN AN. RAINFALL (mm)	RAINFALL DEFICIT (mm)	ELV. (ft)	SLOPE (deg)	AGRO ECOL ZONE	SOIL SERIES (Stark et al, 1966)
DENNERY						
Glavier (E)	1900	200	400	25-30	Dk/Ck	24/2 D/E 1 F
Pays Perdu	2400	50	870	25-37	Ck	4/26/3 E/F 1F
CUL DE SAC						
Chopin Ridge	2500	100	700	20-23	Ck	20/5 F 2 F
Ravin Poisson	3170	0	250	25-36	Bk	24/17/3E/D 1/0F

2.4 Erosion and run-off measurements from natural forest, as a comparison to data from banana cultivated areas.

Sprinkler infiltrometer measurements were undertaken as a further control to the experiments on the banana fields. It seemed likely that erosion losses through surface wash would be very low, and that surface infiltration rates would be very much higher than in the case of banana cultivation on similar land. Because of increased infiltration rates, landslide risk for these areas may actually be higher than in the case of banana cultivation, particularly if some of the larger trees, with the strongest anchoring roots, are removed. (This correlates with the observation that recently reafforested land often shows the greatest landslide risk: deep tap roots anchoring the trees into the bedrock are not yet established, but the higher infiltration afforded by the good vegetation and litter cover increases water content of the subsoil and hence risk of mass movements.)

2.5 Progress of Trials

Trials were set up on three of the four sites by the three extension officers working under the supervision of the Land Use Planner / Environmentalist, during early to mid November, 1996. Trials on the 4th site - Pays Perdu- was set up by the Region 3 Officer, Mr Faucher, in early December, 1996. Trash treatments as prescribed were applied to these sites, and preliminary measurements on sprinkler infiltration in bare soil conditions and under trash piles were made. Slope gradient measurements were taken, and detailed sketch maps of the sites drawn up. Two composite topsoil samples from each site were taken: one representing the upper part of each site, the other the lower part. Samples were analysed by the WIBDECO laboratory, and results are presented and discussed below.

Fertiliser and lime at the recommended quantities (WINBAN) were purchased for the trials, with the lime being applied as uniform applications to the land prior to coverage by trash. Fertilizer and lime applications had to be separated by at least one month.

The Project's field vehicle was made available to the extension staff undertaking the trials on a fortnightly basis, so that conditions of the sites could be monitored. All equipment for the trials was kept with the driver in the vehicle. The following was checked:

- trash cover being maintained at the required treatment level;

- trash lines being maintained;
- de-trashing of the banana plants being carried out, and trash being applied according to the prescribed plan;
- fertiliser being applied according to the prescribed amounts and methods;
- tied contour drains being cleared of sediment, the quantity of which would be noted;
- other required field operations being carried out by the farmer, including tieing of banana stems, application of dythene tubing, nematode and leafspot control etc. Dates of these treatments were recorded.

The Consultants' Team Leader, and the Land Use Planner/Environmentalist together maintained a presence in the country for most of the project period, and kept a close watch on the development of the trials. The Land Use Planner was furthermore engaged in field measurements and recordings during three main periods: November, 1996, and June/July, and September/October, 1997. During the remaining periods the Consultants' driver, Mr. Matthew Emmanuel undertook this role and took the initiative of organising with the extension officers dates and times for field visits.

Although the trials were set up during very wet weather, the weather during the remaining period was generally favourable for banana growth, with rather more rain than normal in January/February (but not producing excessive runoff), and a dry period in April/May. Fairly even rainfall was experienced over the period 10 June-early November, this being sufficient for banana production for most areas, but not being excessive so as to cause significant run-off. The expected flow of water into the contour drains has thus not occurred so far this season.

Progress at each of the sites can be summarised as follows:

Dennery: Glavier(E):
Distance to tarmac road: <10m.
Trash maintained as scheduled, although site was worst affected by wind exposure, bright sun and drought in April/May; cracking in this clayey soil evident in June/July visit. Problems of topples were rather bad, but problem was not related to treatments. Farmer (without consultation) suddenly decided to replant in early July: trash from cut-out bananas then spread onto plots as per schedule. Production from coconuts in the same field not collected and coconuts were a serious weed, germinating and blocking drains etc. Replanted bananas have grown well, but plot has been short of new trash for period August-October, 97. Sticks from trash lines had to be collected from some 1000 m away, both for set-up and maintenance periods. Differences between trash plots and non-trash plots has been most marked, with decomposing trash well anchored by banana roots; non-trash sites show degraded surface soil structure.

Dennery: Pays Perdu:
Distance to tarmac road: 500m; distance to motorable track: <10m.
Trash maintained as scheduled, and no problem of supply of sufficient trash was encountered. Drought and exposure problems notably much less severe than at Glavier, and level of farm management notably better, particularly in maintenance of banana cover and in tieing against topples. Trash-covered plots had a big positive effect on weed suppression, most notably in June/July. Differences in infiltration between trash and non-trash plots were surprisingly small in Oct.97, perhaps due to positive effects of weeds in non-trash plots, and less earthworm activity than normal in the trash plots. This matter needs further investigation: pH at this site is lower than others, perhaps due to higher fertiliser applications not being balanced by lime. Again, sticks from trash lines had to be collected from some 1000 m away, both for set-up and maintenance periods.

Cul de Sac: Chopin Ridge:
Distance to tarmac road: 250m (along fairly steep slippery path).

Trash maintained as scheduled, and only a small problem of supply of trash was encountered. Trash covered plots had a positive effect on weed suppression, most notably in June/July. Large differences in infiltration between trash and non-trash sites were seen, and were clearly related to observed macro-porosity. Site is rather exposed, on convex spur, and a fair proportion of topples were observed in Sept 97, although again not related to trash management. Farmer shows more interest than others, although level of management is little above average: complains that credit for fertiliser/pesticides is a major constraint. Sticks from trash lines had to be collected 300m away.

Cul de Sac: Ravine Poisson:
Distance to tarmac road:500m with a deep-ford crossing of the Cul de Sac River, impassable for short periods in v.wet weather; distance to motorable track: 100m across adjacent field.
Trash initially maintained as scheduled, but farmer undertook partial replanting in May 97 and trash supply from site has since been insufficient. Lower part of trials have been maintained in better state than upper part. Farmer is devoting much less attention at this site, his income being derived from other produce largely on other land (breadfruit, citrus, mangoes) and acting as a middle man for export of this produce. Mature grapefruit and sweet orange trees are interplanted with bananas and comprise 10% of cover. Trials site, and surrounding fields, give the impression that chemical inputs used have been much less than at other sites, weed problem also more severe than at other sites. Again weeds are much less of a problem in the trash-covered sites. Sticks for trash lines had to be collected from 350 and 1000m away.

2.6 Results

Table 2.1: SOIL CHEMICAL ANALYSIS: EROSION & RUN-OFF TRIALS

LOCATN.	LAB No	VALUES: pH (H2O)	pH (KCl)	Exch.K (me/100g)	O.M. (%)	P(Truog) (ppm)	INTERPRETATION: pH	Exch.K	O.M.	P(Truog)
DENNERY:Glavier										
Upper	9	4.7	3.8	0.79	4.38	98.4	Low (acid)	High	Medium	V.high
Lower	10	6.2	4.9	2.09	4.62	55.5	Slightly acid	V.high	Medium	V.high
DENNERY: Pays Perdu										
Upper	3	4.6	3.8	0.32	5.58	19.6	Low (acid)	Medium	Medium	Medium
Lower	4	4.7	3.8	0.39	4.33	13.7	Low (acid)	Medium	Medium	Medium
CUL DE SAC: Chopin Ridge										
Upper	5	4.9	3.9	0.45	5.34	10.0	Low (acid)	Medium	Medium	Low
Lower	6	5.0	3.8	1.10	5.62	9.3	Low (acid)	V.high	Medium	Low
CUL DE SAC: Ravine Poisson										
Upper	7	4.8	3.7	0.60	2.39	9.2	Low (acid)	High	Low	Low
Lower	8	4.9	3.8	0.83	4.44	49.6	Low (acid)	High	Medium	V.high

Remarks:
1. Composite topsoil (0-20cm) samples taken representative of upper and lower parts of each trial area.
2. Sampling undertaken during period 15-30 Nov, 1996; analysis by WIBDECO laboratory, January, 1996.
3. Interpretation based on International Citeria for Tropical soils, considering a wide range of tropical crops. Interpretation for specific crops (eg Bananas) may differ from this.

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Thirty-two infiltration tests were carried out by the Consultants during the course of the trials. Five tests were carried out in November, 96; 16 tests during June/July, 97 and 11 tests during September/October, 97. Results of the infiltration experiments are given in detail in Appendix 7.1, and are summarised in **Table 2.2.**

Potential Environmental Issues of the proposed banana trash management, as elucidated by the trials, are summarised in **Table 2.3.**

2.7 Discussion: Soil Chemical Analysis: Interpretation

Composite topsoil samples (0-20cm depth) were taken during the period 15-30 November, 1996 at the start of the trials. The Upper and Lower halves of each of the four sites were sampled, giving eight composite samples.

A complete suite of analyses were requested from the WIBDECO laboratory, to cover the basic fertility parameters, including pH (water and KCl), CEC (pH7 and soil pH), exchangeable acidity and Al, exchangeable Ca, Mg, K, Na, available P2O5, organic C and total N. However, due to problems of equipment only pH (water and KCl), each K, organic matter and available P determinations could be undertaken. However, these produced interesting results, which are presented in **Table 2.1**, and are discussed below.

All but one of the samples showed low to very low pH (H2O) values (4.6-4.9), indicative of a long history of banana growing with insufficient lime being applied. Results of analyses undertaken by Stark et al (1966) showed that similar areas at that time had pH values of around 5.8. Thus pH has fallen by 1 unit (or more) in the intervening 30 years, largely due to fertiliser applications with banana cultivation not being matched by lime applications. (A ratio of 1 kg lime for every 3 kg of fertiliser should be applied).

The sample covering the lower part of the Glavier Area showed a higher pH (6.2), almost certainly due to colluviation downslope, perhaps of both naturally-occurring Ca and Ca in any added lime.

Exchangeable-K levels varied from medium (at Pays Perdu) to very high (lower part of Glavier). Again downslope colluviation may explain the latter result. Lower samples were higher in exchangeable-K than upper samples at all four sites. Responses of bananas to K would be definite at Pays Perdu and probable at the upper locations of the other sites. The importance of prevention of colluvial wash of fertiliser nutrients downslope is emphasised by these results.

Available P levels were even more variable between the different sites, with Chopin Ridge showing low levels, Pays Perdu medium levels, Ravine Poisson very variable levels (low and v.high), and Glavier v. high levels. For ratoon bananas, these P-levels are not likely to be problematic, but for plant crops some response to extra P (as TSP) is likely to be seen. For many crops other than bananas significant responses to P are likely to be seen.

Organic matter levels are moderate for all samples apart from the upper location at Ravine Poisson, where they are low.

Overall conclusions on this analytical data are:

i) soil conservation is important for retention of fertiliser nutrients as well as for other reasons, and significant downslope wash was seen at three of the four sites for K, P, organic matter, and bases (influencing pH);

Table 2.2 SUMMARY OF RESULTS OF INFILTRATION EXPERIMENTS:
SOIL CONSERVATION & RUNOFF CONTROL TRIALS

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Plot	Date	Infiltration rate (mm/hr) after the following minutes: 15	30	45	60	75+x	90+x
DENNERY: GLAVIER							
Thick Trash Cover:							
Plot 1	12.11.96	193	67				
Plot 1	15.11.96	(48)	59				
Plot 1	12.06.97	186	162				
Plot 1	01.07.97	138	108				
Plot 1	30.09.97	144	83	54	67	84	50
Plot 3 –	15.11.96	30	30	24	11		
Plot 3	19.06.97	243	131	90			
Plot 3	02.10.97	(34)	(29)	(32)	42	53	37
Average		133	91	56	39	84	50
DENNERY: PAYS PERDUE / BAZILE							
Thick Trash Cover:							
Plot 1 =	02.10.97	20	14	13	12	20	16
Plot 1 =	04.10.97	29	23	17	12	20	17
Plot 3	12.06.97	72	65	43			
Plot 3 =	04.10.97	19	11	7	3	11	12
Average		35	28	20	9	17	15
CUL DE SAC: RAVINE POISSON							
Thin Trash Cover:							
Plot 3	16.06.97	182	131	120	63		
Plot 3	07.10.97	24	21	17	13	15	10
Average		103	76	69	38	15	10
CUL DE SAC: CHOPIN RIDGE							
Thick Trash Cover:							
	13.06.97	272	131	160	158	163	153
	– 16.06.97	40	28	38	39		
Average		156	80	99	99	163	153
Overall Average		100	67	49	42	52	42

Plot	Date	Infiltration rate (mm/hr) after the following minutes: 15	30	45	60	75+x	90+x
Bare Soil Surface:							
Plot 2	15.11.96	24	15	11	14		
Plot 2	15.11.96	33	10				
Plot 2	12.06.97	23	17	8			
Plot 2	01.07.97	52	49				
Plot 2	30.09.97	79	52	41	33	29	34
Plot 4	19.06.97	24	20				
Plot 4	30.09.97	27	18	11	8	12	10
Average		37	26	18	18	21	22
Bare Soil Surface:							
Plot 2	12.06.97	52	56				
Plot 2	02.10.97	34	34	21	15	17	18
Plot 4	04.10.97	30	21	14	9	13	16
Average		39	37	18	12	15	17
Bare Soil Surface:							
Plot 2	13.06.97	63	71				
Plot 2	16.06.97	99	64	48			
Plot 2	16.06.97	70	53	45			
Plot 2	07.10.97	24	12	12	7	18	6
Average		64	50	35	7	18	6
Bare Soil Surface:							
	13.06.97	23	31				
	13.06.97	103	36	30	31		
Average		63	34	30	31		
Overall Average		48	35	24	17	18	17

Note: Thin trash cover denoted –; Moderate trash cover denoted =.

. INFILTRATION EXPERIMENTS: SOIL CONSERVATION & RUN-OFF CONTROL TRIALS: DENNERY

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Time Start	Time Stop	Mins	Depth Measurements(mm) Rep1 ****	Rep2 ****	Rep3 ****	Mean (mm)	Sprinkler Intensity (avg over expermnt) (mm/min)	(mm/hr)	Surface Run-off (ml/sq m) ****	(accumulatd)	(mm)	Net Infiltration depth (mm)	(avg/expt) (mm/min)	(mm/hr)	(current rate) (mm/min)	(mm/hr)
***********	***********															
DENNERY: GLAVIER																
30-Sep-97			thick trash cover					Plot 1	New sprinkler:reduced flow rate							
10:58:35 AM	11:13:35 AM	15.00	30	34	20	36.0	2.4	144	0	0	0.0	36.0	2.4	144	2.4	144
11:20:20 AM	11:32:40 AM	34.08	49	60	39	57.3	1.7	101	20	20	0.0	57.3	1.7	101	1.1	67
11:41:30 AM	11:46:12 AM	47.62	58	67	43	64.0	1.3	81	26	46	0.1	63.9	1.3	81	0.9	51
11:51:00 AM	11:55:50 AM	57.25	72	80	59	78.3	1.4	82	48	94	0.2	78.1	1.4	82	0.9	54
11:59:05 AM	12:02:47 PM	64.20	79	88	74	88.3	1.4	83	14	108	0.2	88.1	1.4	82	1.5	88
01:42:30 PM	01:48:30 PM	6.00	11	11	9	18.3	3.1	183	70	70	0.2	18.2	3.0	182	3.0	182
01:57:00 PM	01:59:54 PM	17.40	23	24	18	29.7	1.7	102	126	196	0.4	29.2	1.7	101	1.0	58
02:07:05 PM	02:09:27 PM	26.95	32	32	23	37.0	1.4	82	38	234	0.5	36.5	1.4	81	0.9	52
02:13:35 PM	02:15:30 PM	33.00	38	36	28	42.0	1.3	76	57	291	0.6	41.4	1.3	75	0.8	47

ii) in 7 of the 8 samples worryingly low pH values were seen, at which responses to lime would be certain for both bananas and most other crops.

iii) significant differences were seen between the 8 samples in levels of the major nutrients, and thus soil analysis is essential in adjusting fertiliser application to optimum levels. This becomes even more important when crops other than bananas are being considered, as different N:K and P:K ratios would be applicable. (See table and discussion elsewhere on optimum fertiliser applications for different treecrops).

2.8 Discussion: infiltration rates

Although variation between replicates was large, very large differences were seen in both initial rates and terminal rates between the trash-covered surfaces and the no-trash surfaces. Taking the overall averages, the initial rates (first 15 minutes) were increased from an average of 48mm / hour to 100 mm /hour by the trash cover, and terminal rates were increased from an average of 17 to 42mm/hour. The average amount of water infiltrated over the 90 minute trial period (60+30 minutes) was increased from 40 mm to 88 mm respectively.

Differences were relatively larger for the two lower (and drier) sites, and no significant differences were observed at Pays Perdu for the latest measurements. Differences could be visually correlated with soil animal activity and macro-porosity: sites with an abundance of earthworms and other animals showed large continuous channels and very high infiltration rates. Sites with little or no animal activity usually showed no macro-pores and low infiltration rates. Pays Perdu showed surprisingly little burrowing-animal activity under the trash cover, which could be correlated with lower pH values and the fact the farmer was using more inputs, including nematicides. These matters deserve much further investigation: investing in lime would appear to have a favourable effect on earthworm activity and boost the infiltration benefits of the trash cover; investing in nematicides would appear to have the reverse effect. However, although farmers should definitely follow WIBDECO guidelines on balanced lime applications (1 bag lime to 3 bags fertiliser, applied after at least 1 month's gap), the Consultants would not advocate any cut-back on nematicides until thorough research had been done, (e.g. spending more on banana supports and string and less on nematicides may have the same overall effect in terms of topples.)

Many non-trash sites showed appreciable weed infestation, which although problematic for the bananas, did appear to increase infiltration. The development of a low, shade-loving cover crop for banana areas could be another fruitful line for long-term research, particularly if the species developed would have nematode-repelling root exudates. Work on nematode-trapping fungi would also deserve long-term study.

Extrapolating the overall average infiltration rates obtained in these experiments to the TSD event (using the Union Agricultural Station rainfall intensity figures), the immediate surface run-off would have been 160 mm for the non-trash treatments and 72mm for the trash treatments, out of a total rainfall figure of 270 mm measured over the 8-hour period. The balance of 88 mm would have been temporarily held in the macro-pores in the soil, and released over the following hours and days as lateral sub-surface water flow through the soil profile. [See V3TSDUNI.wk3, reported in Annex 5]. Even on calculations on terminal rates only, the difference in run-off due to trash would have been some 77 mm; 166 mm run-off for the non-trash and 89 mm for the trash-covered surfaces.

2.9 Potential Environmental Issues

Potential Environmental issues relating to the proposals on trash management are summarised in **Table 2.3.** Some 14 parameters were investigated: of these impacts were strongly positive in five; some positive but some negative effects were seen in three (lime application; fertiliser application and leafspot control); and negative impacts were seen with six (snails; snakes; blocking of drainage; trafficability; borer control; and nematode control). Mitigating measures were discussed on any negative impacts.

A large increase in snail population was observed, but no negative effect on fruit quality was observed. In other banana-growing countries a number of birds and animals will eat snails, but with lesser bio-diversity in the banana growing areas in St. Lucia similar natural predators may be absent. This possible problem needs careful monitoring, as does any increase in the snake population.

Blocking of drainage lines was observed only to a minor extent in the experiments, perhaps largely because of lack of heavy rainfall during most of the period. Where problems occur, installation of trash lines as well as trash cover would be beneficial, any washed-down material being trapped by the trash line.

Trafficability is a problem over all steep banana land in wet weather, and presence of trash would make this problem worse. The biggest problem was with partly decomposed pseudostems which were particularly slippery. These pseudostems should thus be cut into strips, and put on the trash lines: leaves should be used preferentially for trash cover. On steep land walking along the contour along the trash line was easy; paths should then be designed to intercept these lines, and to be constructed to throw drainage water into the lines.

Borer control is a problem with thick cut pseudostems, and for this reason the pseudostems should be cut into thin strips to facilitate rapid drying.

Trash application immediately around the banana mats is not advocated, as this hinders both fertiliser and particularly nematicide applications. Fertilisers may be broadcast, but should be applied immediately before detrashing - new trash layers would protect the fertiliser pellets from volatilization. Nematicide should be applied only to the area immediately adjacent to the banana mat, and for this a trash-free area of some 30-40cm radius could be maintained.

Some parties have emphasised these possible negative impacts of promoting trash management, regarding trash as unwanted material to be disposed of, rather than valuable material for protecting the soil surface and as a source of recycled nutrients. It should be emphasised that agronomic work on trash, and papers by soil scientists/land use planners, have emphasised its value as a mulch material (e.g. WINBAN Manual; Harris, 1991-94; Lang, 91). The main reason that little extension effort has been spent on this is that workers have been deflected into more tangible programmes elsewhere (e.g. banana quality and certification; hibiscus pink mealy bugs; propagation and distribution of seedlings of alternative crops). For soil and water conservation reasons, it is imperative that attention now be focused on banana trash management.

2.10 Investigation on Costs of Transport and Hand-carrying Costs for Bananas

Analysis undertaken on transport and labour costs of banana production per acre have produced average figures in the range of EC$335 - 350 and 1000 - 1470 respectively. This applies for the average holding, at an average yield of 7.0 tonnes bananas/acre.
However, as a result of fieldwork, it has become clear that the biggest variables in cost of production are:

TABLE 2.3: POTENTIAL ENVIRONMENTAL ISSUES, PHASE II PROPOSALS

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Proposed Measure	Status of Recommendation	Cost of Recommendation	Approx.Area(ac) or Distance (km)	Possible Impact: Parameter	Size	Major effect	Mitigating measures (for negative impacts)
Banana trash management: **1)uniform trash, aligned on contour**	Recommended by WINBAN/WIBDECO (Manual,p2–3). Implemented on steep land by best farmers. Needs major prom––otion by agric. extension officers & WMAFs. Farmers to supply labour: trash materials supplied in situ (plus some trash from nearby alluvial & colluvial banana areas?)	Aprox.4extra man–days/acre to set up, thereafter 3 man–days/acre/yr to maintain (in addition to routine detrashing) (ie 7 days in year1 –or EC$210/acre; 3 days in Yr2 etc or EC$90/acre)	All land,>5deg (c12,000acr)	i)Infiltration/runoff	+++	Infiltrn.rates increased 3x: run–off & erosion markedly decreased; nutrients retained in soil	
				ii)Nutrient recycling	+++	Uniform, more efficient	
				iii)Soil Ecology	++	Increased ecosystem buffering –reduced soil pathogens	
				iv)Rooting volume	++	Banana rooting to surface	
				v)Weed control	++	Much improved weed control	
				vi)Lime application	– ++	Adversely affecting broadcasting Improved incorpn by soil animals	Broadcast lime before trash application
				vii)Fertiliser applcn	– ++	May adversely affect b'casting Lower losses thru run–off	Apply in semi–circ.above mat, within 1.5ft radius.
				viii)Leafspot control	–/+	Increase in humidity & retention of possible diseased leaves	Maintain uniform thin trash cover; should dry v.quickly, not increasing air humidity
				ix)Nematode control	–	Problems w nematicide spraying	Maintain 1–1.5ft radius trash–free
				x)Borer control	–	Cut psuedostems attract borers	Psuedostems to be cut into strips to dry out quickly, then to be used mainly in trash lines.
				xi)Trafficability	–	Difficulty in walking/slipping in wet weather	Psuedostems to be cut into strips and used in trash lines.
				xii)Blocking drainage	–	Washing into drainage lines	Trash cover to be used also with trash lines
				xiii)Snakes	–	Possible increase in population	Workers to wear boots
				xiv)Snails & slugs	––	Big increase in population	Monitoring wr to population and damage:use of metaldehyde, slugit, or methiocarb if necessary
2)trash lines	Recommended by WINBAN/WIBDECO (Manual,p2–3). Implemented on steep land by some of the best farmers. Needs major prom––otion by agric. extension officers & WMAFs. Farmers to supply labour:trash materials supplied in situ (plus some trash from colluv. & alluv.areas?)Supply of stakes to be org–anised by agric.extn officers & WMAFs?	Aprox.4extra man–days/acre to set up, thereafter 3 man–days/acre/yr to maintain (in addition to routine detrashing) (ie 7 days in year1 –or EC$210/acre; 3 days in Yr2 etc or EC$90/acre)	All land,>5deg (c12,000acr)	as above, i–x, and xiii–xiv, but localised along contour lines			
				i)Retn.eroded soil	+++	Retention of soil materials	
				ii)Net nutrient increase	+++	N–fixation by glyricidia stakes	
				iii)Retn.trash material	++	Retention of trash materials debris, etc	

- carrying distance from field to nearest motorable track;
- the mean slope along this distance;
- the trucking distance, both from track to packing shed, and from shed to port.

Estimates were thus made by the Consultants, on the basis of their field observations, for three cases:

- the best 10% of land - [i.e. that with the shortest distances from field to motorable road (0.1km), from motorable road to packing shed (0), and from packing shed to port (10km)]
- the average land, with distances 0.3, 0.7 and 25km respectively, and
- the highest cost land, with distances 0.8, 2, and 40 km respectively.

Gradients were also rated at 5, 20 and 30 degrees in the three cases respectively. (Estimates of field to motorable track made by the BGA are fairly similar: average distances placed at some 250m.)

Average speeds were estimated at 40km/hr and 15km/hr for transport along surfaced roads and tracks respectively. For hand carrying of 20kg of bananas on pathways on clayey surfaces, walking speeds were estimated at 3.5km/hour at 5degrees reducing to 1.2km/hour at 30 degrees.

Costs were calculated per tonne of bananas, and per 7t/acre (average yield) and per 13t/acre (target yields). Costs were separated into transport costs, and labour carrying costs. The latter labour costs do not represent the total cost of harvesting, as in addition, there would be costs of cutting, de-handing, soaking, packing etc. Average transport costs for the average yield of 7t/acre were calculated at EC$386, varying between 228 and 483 in the best and worst cases respectively. Average labour carrying costs were $525, but these varied enormously from $100 to $2333 between the best and worst land.

Overall conclusions on transport and carrying costs are:

i) Sensitivity of profitability to carrying distance between field and motorable road, and mean slope for this distance, is very great, and together can reduce costs by $400, or increase costs by $1800 over average carrying costs. Excluding steep banana land (say over 25deg) and excluding land more than 500m from motorable tracks, will increase overall profitability by a large proportion.

ii) Profitability is not very sensitive to distance to port, or distance from motorable road to packing shed. Costs could be reduced by $160 from the average to the best case, and increased by $200 from the average to the worst case.

iii)The cost of waiting is high in relation to the cost of transport, and this ratio is particularly high in the case of the best land. Most of the waiting is done at the port. Improvement in port efficiency would have a big effect in reducing real transport costs. This factor has been recognised by WIBDECO and SLBGA, and their certification programme now enables their certified farmers to benefit from a 'fast track' line at the port.

2.11 Conclusions on the Agronomic Trials:

1. The presence of a uniform trash cover has a large positive effect on infiltration rates in comparison with an exposed trash-free soil surface. Initial rates (first 15 minutes) were increased from an average of 48 to 100 mm/hour; terminal rates were increased from an average of 17 to 42 mm/hour. The average amount of water infiltrated over the 90 minute trial period (60+30 minutes) was 40 and 88 mm respectively. [See **Table 2.2** for actual results over 32 tests on the 4 trial sites.]

TABLE 2.4: COMPARATIVE COSTS OF TRANSPORT AND CARRYING COSTS FOR BANANAS
(LOWEST, AVERAGE, AND HIGHEST COST LAND)

Lowest Cost Land:

Variables:			Speed	Time(hr)		Cost(EC$)			WaitingTime			Total Cost			Total Cost (EC$)		
			km/hr	/20kg	/tonne	/hr	/tonne	/13t	hrs/t	$/hr	$/t	/tonne	/13t		/tonne	/7t	/13t
1 Packing shed --> port	(km)	10	40	0.5	0.5	15	7.5	97.5	2.5	10	25	32.5	423	Transport	32.5	228	423
2 Motorable track --> packing shed	(km)	0	15	0	0	15	0	0	0	10	0	0	0				
3 Field --> motorable track	(km)	0.1	3.5	0.06	2.86	5	14.3	186	0		0	14.3	186	Labour	14.3	100	186
4 Slope, field --> motorable track	(deg)	5															
TOTAL COST							21.8	283				46.8	608	TOTAL	46.8	328	608

Average Cost Land:

Variables:			Speed	Time(hr)		Cost(EC$)			WaitingTime			Total Cost			Total Cost (EC$)		
			km/hr	/20kg	/tonne	/hr	/tonne	/13t	hrs/t	$/hr	$/t	/tonne	/13t		/tonne	/7t	/13t
1 Packing shed --> port	(km)	25	40	1.25	1.25	15	18.8	244	2.5	10	25	43.8	569	Transport	55.2	386	717
2 Motorable track --> packing shed	(km)	0.7	15	0.09	0.09	15	1.4	18.2	1	10	10	11.4	148				
3 Field --> motorable track	(km)	0.3	2	0.3	15	5	75	975	0		0	75	975	Labour	75	525	975
4 Slope, field --> motorable track	(deg)	20															
TOTAL COST							95.2	1237				130	1692	TOTAL	130	911	1692

Highest Cost Land:

Variables:			Speed	Time(hr)		Cost(EC$)			WaitingTime			Total Cost			Total Cost (EC$)		
			km/hr	/20kg	/tonne	/hr	/tonne	/13t	hrs/t	$/hr	$/t	/tonne	/13t		/tonne	/7t	/13t
1 Packing shed --> port	(km)	40	40	2	2	15	30	390	2.5	10	25	55	715	Transport	69	483	897
2 Motorable track --> packing shed	(km)	2	15	0.27	0.27	15	4	52	1	10	10	14	182				
3 Field --> motorable track	(km)	0.8	1.2	1.33	66.7	5	333	4333	0		0	333	4333	Labour	333	2333	4333
4 Slope, field --> motorable track	(deg)	30															
TOTAL COST							367	4775				402	5230	TOTAL	402	2816	5230

Variables:		Low	High	Avg	Slope:	Speed,km/hr
1 Packing shed --> port	(km)	10	40	25	Flat:	4
2 Motorable track --> packing shed	(km)	0	2	0.7	10deg	3
3 Field --> motorable track	(km)	0.1	0.8	0.3	20deg	2
4 Slope, field --> motorable track	(deg)	5	30	20	25deg	1.5
5 Slope, within field	(deg)	5	40	22	30deg	1.2
					35deg	1

Waiting time at port (/tonne carried)	2 hours	Vehicle speed: track --> shed	15 km/hr
Wating time at roadside (t/carried)	0.5	Vehicle speed: shed --> port	40 km/hr
Waiting time at shed (t/carried)	0.5		
Cost of vehicle waiting:	10 EC$/hour		

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2. Extrapolating these infiltration rates to the TSD event (Union Agric.Station rainfall intensity figures), the immediate surface run-off would have been 160 and 72mm respectively, out of a total rainfall figure of 270 mm measured over the 8-hour period. The balance of 88 mm would have been temporarily held in the macro-pores in the soil, and released over the following hours and days as lateral sub-surface water flow through the soil profile. [See **Figure 1.3** of Annex 4]

2. The main positive implications of the increase in infiltration rates over the sloping banana areas due to good trash management are:
   i) surface run-off and surface wash erosion would be very much less, directly benefiting the banana farmers in these areas;
   ii) the sharp peak of run-off and flood-flow would be very much reduced. Damage due to river bank scouring in downstream areas would be very much less, as would flood damage in these downstream areas.

4. Apart from the above benefits on infiltration / run-off / soil conservation, the most visible beneficial affects of a uniform trash cover are:
   i) banana roots extend to the surface of the mineral soil, and bind in the lower layers of the decomposing trash into the soil. Protection of the mineral soil against raindrop impact is hence greatly increased;
   ii) rooting volume for bananas are increased, with roots coming into closer contact with lime and fertiliser pellets;
   iii)weeds are suppressed;
   iv) greatly increased populations of soil fauna are observed, notably earthworms and centipedes, and these are probably largely responsible for the large increase in surface porosity and hence infiltration rates.

5. Some negative affects of uniform trash cover were observed. These included:
   i) a big increase in snail population;
   ii) some difficulty in walking over trash-covered surfaces, particularly up-and-down the slope;
   iii)some trash washed into drains at the bottom of the experiments;
   iv) some difficulties in application of chemicals (nematicides and fertilisers).

(These issues, their size, impacts and possible mitigating measures are given in **Table 2.3.**)

6. Trash lines show further benefits:
   i) they retain any eroded soil washed down the slope;
   ii) they retain any pieces of trash being washed off the trash-covered soil surfaces, including many coconuts rolling down the slope;
   iii)they represent a small contour-aligned terrace, facilitating walking along the contour.

7. Farmer reaction to the trash experiment was neutral. The experiment was not run for a long enough period, and weekly yield measurements by the farmer/extension officer were not carried out. The small size of the plots further made meaningful yield measurements difficult. However, it is strongly recommended that the experiments be continued and that the work is extended over a micro-watershed (say 50-100 acres) and linked with stream gauging measurements on run-off from both the treated, and a control, micro-watershed. One officer from the MALFF&E should be responsible for the experiment, and the project should be of high priority for an externally-funded TA.

8. The cost per acre of good trash management is minimal, and should be recovered by the farmers themselves in terms of requirement for less fertiliser, herbicide and the labour inputs required in applying these. Year 1 'labour costs' are 4 days / acre to set up the uniform trash cover (i.e. EC$120 /acre), and another 4 days for the trash lines. Maintenance of trash cover would be another 3-4 days/ year, and another 3-4 days for the trash lines. However, considerably less time would be required applying herbicides, currently estimated to require 7days/acre/year, and thus net labour

requirements for maintenance are likely to be 2-3 man days per year for both trash cover and trash lines.2

9. Local small glyricidia nurseries or tree lines would be required to supply stakes for the trash lines, and these would have to be organised by the agricultural officers on the WMAFs. Ideally glyricidia should be provided by contour planted trees, also acting as shade trees or windbreaks. Marking out contours with the farmers in the fields should be the joint responsibility of these officers and the SLBGA agricultural officers. Several 'M-frames' would be needed in each of the watersheds for this purpose.

10. The setting up and maintenance of trash cover and trash lines should be a requirement for the certified banana growers scheme, particularly for holdings of over 15-20 degrees slope. This could be assessed and assisted by the current officers assigned to the certified growers scheme. The 'carrot and stick' approach represented by this scheme should be ample to achieve good trash management island-wide. Any externally-funded project should seek to fund 2 additional officers for a 4-year period to cover the additional work that this would represent.

11. For the entire banana acreage on steeply sloping land, estimated at some 10,000 acres, the set-up cost would be EC$2.4m in terms of farmer's labour costed at EC$30/day. In addition there would be costs of glyricidia plantings, M-frames, additional certification officer's time (say 8 staff years), and additional SLBGA/MALFF&E soil conservation extension officers' time (say a further 8 staff years). Ideally this cost should be bourne by 3 parties: the downstream farmers and other land users, benefiting from lesser flooding damage; the government / economy of St. Lucia, benefiting from lower environmental damage, and the farmers themselves. External funding should be available to cover the costs of any materials, additional transport, and much of the local staff time, and any TA component involved in research, monitoring and evaluation.

Chapter 3

The Community Participation Trial

3.1 Dennery

This trial is the only one involving people and carries the highest risk. Before embarking upon the trial the Consultants sought an undertaking from the Permanent Secretaries of both Ministry of Planning and Agriculture, that the programme, if started would have governments support. Support needed was identified as

- budgetary support for a two year period for a coordinator and ancillary staff
- ratification of the formation of what became known as the Watershed Management Action Force (WMAF) by the Land Conservation Board (LCB).

The first issue is under discussion, but no progress has been made in resuscitating the LCB. At the outset it was pointed out that:

- "a strong government commitment would enable a full community participation programme to be developed which would yield important lessons within the timespan of Phase 2."

Initial survey work started in November 1996 and after a brief sensitisation programme aimed at influential local residents, the first public meeting was held in late January 1997. More meetings followed and the WMAF was elected office holders appointed and the process of defining and prioritising a programme started.

The programme has been strongly supported by AESD within which the Watershed Management Unit (WMU) will be formed and by a Technical Operations Team (TOT) a group of three government staff seconded on a part time basis to the WMAF. MCWT&PU has also been closely involved and it is from within this ministry that the River Management Unit (RMU) will be formed.

Further sensitisation sessions and a programme of technical education with external support, led to the completion of a master plan in August 1997.

In the absence of any legal status that would be afforded by the LCB, the authority of the WMAF is limited. Regular meetings continue, but strong support from the Coordinator is still essential. Some small communal projects have been undertaken with mixed success.

At this stage, with only ten months operation on which to assess performance, only limited lessons can be learned. The Consultants estimate that a minimum of two years operation is necessary before full impact evaluation can be made.

Provisional findings are:

- a general recognition is becoming evident that community involvement has great potential as a means of achieving progress.

- that a transfer of responsibility from dependency to self reliance takes time and patience, but any attempt to circumvent the essential learning process in the interest of quicker implementation must be resisted.

- the initial focus of the WMAF was on works which entailed mainly Ministry of Works inputs rather than on initiatives which they could accomplish from their own resources.

- while the cause/effect relationship of problems may be readily understood, at a personal level acceptance becomes difficult, particularly where necessary changes could cause a loss of income in the short term, with benefits occurring elsewhere in the watershed.

- a continuous sensitisation programme is essential in order to overcome cynicism at all levels of the community.

- strong and effective leadership is a prerequisite to success.

- a newly formed WMAF must be given physical identity by providing an adequate office in a good location.

- strong organisational support from a Coordinator is essential, as technical support from the Technical Operations Team. Careful selection of persons to fill these post must be accorded priority, and their availability not subjected to other conflicting duties.

- local knowledge and expertise is a valuable source of potential information, and must be used in developing plans.

While progress at Dennery can only be described as very encouraging, there is no room for complacency. Once the initial enthusiasm starts to fall, there is an accute danger that the WMAF could lose direction. A continuous programme of education and sensitisation can do much to ameliorate this tendency but more is required, if the full potential of the trial is to be exploited.

Without the support of the LCB, further real progress will be limited. The next essential step, is the allocations of limited funds, through the WMU for the execution of minor works. The works must be properly defined and costed, and under guidance, the WMAF would be encouraged to make local arrangements. The emphasis should be on involving the local community as a source of labour, and contracting works to them. Such works as river bank planting, river clearing, minor drainage and culvert maintenance would fall into this category. Proper accounting procedures would be observed by the WMAF, and accounts would be open to inspection by the WMU, who would be ultimately responsible to government. While there is an element of risk involved, WMAF's will not and cannot learn unless given the opportunity. Through the TOT, the Dennery WMAF should be encouraged to draw up and cost a modest programme, and funds should be made available through the 1998/1999 GoSL Budget.

3.2 Cul de Sac

Cul de Sac was also selected as a pilot watershed, but time and resources did not allow for a full programme. The watershed is also far more complex, has twenty centres of population and is the third largest in the island. As such, to have started the trial programme in Cul de Sac, would have carried a greater risk than Dennery.

Preliminary field investigations were carried out during December 1996, and as much background data as is readily available was accumulated.

A limited sensitisation programme was undertaken but concentrating on part only of the watershed. This was followed by a well attended public meeting on 9th September. A desire to proceed with the formation process towards their own WMAF was expressed and a further community meeting was planned.

To proceed however, additional support from government is essential. This would involve:
- the appointment/secondment of a Technical Operations Team.
- the provision of a budget.
- the renewal of the CPP Coordinators contract
- at least part time use of a vehicle.

With only a very limited time before the end of the Phase 2 Consultancy, action must be initiated by government.

Chapter 4

Results and Conclusions of the Engineering Trials

4.1 Introduction

The engineering trials were seen as an integrated part of the other activities under the Project assessing not only the engineering and bio-engineering elements but and the implementation approaches and social acceptability of particular interventions.

Trials were kept relatively simple employing local materials wherever possible and adopting designs which can be replicated without the need for either heavy engineering or considerable cost. The concept being to encourage local level participation in erosion control, sediment runoff entrapment, river alignment control and infrastructure protection from river channel erosion.

The design of the Project into two distinct components separated by a period of about 9 months enforced a process whereby the pilot studies or trials were designed during the first part of the consultancy period when the Consultants were in St Lucia, with the execution of the trials resting primarily with governement personel during the interregnum period when the Consultants were absent. The Consultants returning in October 1997 to assess the progress made on the trials and to assess the effectiveness and appropriateness of the works carried out. The bio-engineering trials were however, managed by St Lucian resident members of the Consultants and hence had continuous supervision.

The engineering trials were designed by the Consultant and were managed by the MCWT&PU unit. For the works, tender documents had to be prepared, tenders from contractors invited and contracts awarded. The process is relatively lengthy with the need for award of contract to pass through the Tender Evaluation Board. The original intention of executing the works using direct labour was not considered viable due to the shortage of staff available from MCWT&PU. It should be noted that during Phase 1 the tendering and contract award process was managed directly by Crown Agents which facilitated immediate appointment and payment of contractors and hence eased the implementation process and enabled works to be carried out swiftly.

The process of using standard government procedures was adopted as opposed to a more interventionalist and independent approach since the trials were also aimed at providing insight into implementation procedures, capacities and shortcomings of the government system in relation to minor river engineering works. It was also necessary to follow this approach since the funds used were from the World Bank Loan which was being managed by Ministry of Planning and the Environment (as then was) through the MCWT&PU.

Owing to the damage caused by the floods of October 1996 and the need to rehabilitate works, together with the disruption caused by the elections and change of Government, the recent budget cuts and expenditure checks, the implementation of the River Engineering trials have suffered delays.

The works which have been completed indicate that good workmanship can be achieved. It has also highlighted the fact that although bio-engineering elements were incorporated in the works, these were given scant attention. Bio-engineering is not a 'quick-fix' approach as is the case with most civil engineering works, hence it is difficult to get both 'client' and 'contractor' to accommodate such changes.

Where the bio-engineering has been applied by staff employed directly by the Consultants, this has shown promise. However, it will take time to assess the success of the planting of gliricidia on the steep slopes. It is hoped that the method adopted is followed up and refined by the WMU/RMU and WMAFs.

The approach of using normal engineering contractors will tend to lead to a standard engineering solution which tends to be expensive and often inappropriate. In addition, contracts are likely to be small and hence the 'overhead' associated with standard contracts could be disproportionate to the costs of the works. Small contacts are also likely to be unpopular with the contracting business since payment delays and invoice clearance costs could be a disincentive to a contractor tendering realistic bids for the work.

The fact that at least 3 of the trials are still in the 'implementation process' without any works having been carried out is a good indicator of the problem.

Since it is proposed that most river engineering works should be 'low-tech' and with a strong 'bio-engineering component, it is recommended that the majority of river engineering works are undertaken by direct labour through the RMU and WMAF with technical advice from MCWT&PU where necessary. This should facilitate a more rapid and timely execution of required works and enable them to be carried out when river conditions permit. This latter factor is also a problem with a standard contractor - claims for delays due to access difficulties during high flows. Direct works can be moved from task to task as conditions permit. However, the capacity (staffing levels) and capability (river engineering training) of the RMU to undertake such works will need to be gained quickly. A direct works procedures and approach needs also to be established.

A summary of the status of the trials at the end of the Project and the conclusions drawn is presented below for each of the Pilot Trials:

ENG 1 River Maintenance - Dennery River

Objective: To evaluate the mechanisms for the execution of a regular river channel maintenance programme.

Progress by the end of the Project:
This trial was included in the Dennery WMAF programme. The TOT together with MCWT&PU staff have completed the physical inspection and reported to the WMAF for action.

The Dennery River was inspected by AESD staff and the River Inspection Report written for submission to the WMAF in Dennery.

The River Survey over 5.25km of the River Dennery between the WASA water intake and the Dennery Highway Bridge was undertaken as part of the Pilot Trials undertaken during Phase 2 of the project.

The Survey indicated that the first 1.5km downstream from the intake is quite stable, both banks being well vegetated with only a few pockets of agricultural activity on either bank. The river bed was classified and stony and stable. Further down the channel, farming activities became more evident closer to the bank of the river.

The TOT team who undertook the survey identified the frequent and extensive use of weedicide in the banana plantation areas which extended close to the river as being a cause for the reduced coverage or density of natural vegetation near to the river bank, the vegetation which elsewhere was providing some protection against river bank erosion. This was aggravated by the uncontrolled drainage from the plantations into the river channel. No energy dissipation works, either stone or vegetal was provided, to reduce the erosion of the banks by the drainage flows.

The other issue which was reported as needing to be addressed was the disposal of farm refuse into the river system rather than composting on farm or for non-vegetation items such as plastic bags and containers, disposing of through the garbage collection system or by incineration.

The summary of the survey indicated that, over the surveyed length of 5.25km:

Element	Quantity Identified	Inferred recurrence density
River bed desilting	1.75 km	33% of surveyed channel
Unstable river banks	7.0 km	67% of surveyed channel
Overhanging trees	200 number	38 number / km
Logs impeding flow	20 number	3.8 number /km

The implications of the survey needs to be appreciated and put in the context of the formulation of a river maintenance programme. Problems were identified in the river channel, however, there is a need to prioritise the works.

The fact that the valley road survived the TSD flows which were extremely severe for Dennery would indicate that the channel form is relatively stable. However, this still needs regular monitoring by the annual river surveys.

River bed desilting was seen as a problem by the Pilot Study Survey in the reach of the river upstream from the main east coast road bridge, however, the severity of the problem has to be assessed in more detail before works should proceed. If considerable deposition of material has occurred in this reach, which properties are at risk from aggravated flooding? If the deposition has only taken place over the last few years as a result of high flood flows, will the material gradually be carried out into the estuary in the future? Before proceeding with the desilting works the benefits must be identified. If the channel were desilted in this identified reach, where would the excavated material be placed? Is there an area in Dennery requiring infilling with a 'gravelly' material?

The length of unstable banks need further classification into those at serious risk of collapse and those not. It is not possible to address 67% of the river banks immediately. All the numbers indicate is that there are potential stability problems over significant lengths of channel. It is not considered that it would be a wise investment to address 'all identified problem areas'. The mapping of the 'at risk' sites provides the benchmark for the long term monitoring of the river system for river maintenance work.

A similar ranking of 'risk severity' must be undertaken for the overhanging trees. It might be realised to lop perhaps 3 trees per km per year, identifying the most severe trees for attention. This would indicate a 10 year period for tackling the problem.

With the removal of logs from the river which would otherwise impede flows, it is more important to undertake the removal exercise. However, again the scale of the exercise is very difficult to predict and will vary from watershed to watershed, from year to year. The estimate of 4 per km/year is considered indicative.

A separate report was requested for submission to WEMP II. This was to include the following:

- Methodology used in the inspection together with comments and suggestions for improving the inspection technique. This is intended to provide a platform from which WMAF personnel and/or local farmers can be instructed in river inspection, what to look for, how to record observations, etc.

- The time taken and staff/vehicle resources used for the inspection. This is to allow for a per kilometer estimate to be made of the cost of river inspection by trained personnel.

- Agenda/programme for the meetings with WMAF recommended in the initial report. Ideally the WEMP river engineer would attend such meetings along with the socio-economists to monitor the engineering side of the project.

Most of these items were originally identified as being required as part of the reporting process.

Conclusions:

In relation to the future functioning of the RMU, this was an important trial. Although not undertaken to the level of thoroughness and reporting as had been hoped, it was a positive start and enabled the deficiencies in approach to be clearly identified enabling requests to be made for additional information.

The survey itself has provided a valuable baseline document for the elaboration of the Dennery Watershed Management Plan.

ENG 2 Gabion protection - Cul de Sac

Objective: To improve on the overall structural integrity of gabion work through the minimisation of damage caused by the erosion of backfill through the application of improved engineering and bio-engineering approach.

Progress by the end of the Project:
All engineering works have been completed but grass/ vegetation has not yet been planted. Early indications are that further minor works could be necessary in realigning gabion baskets and permeable membrane material should be located behind the gabion baskets.

Discussions on site in late October indicated that during the remodelling work, no filter cloth material had been placed between the backfill and the gabion boxes. The backfill material had not been specifically selected and little compaction had been undertaken. No signs of any bio-engineering work was evident. It was agreed that these shortcomings would be addressed by further modifications.

Conclusions:

Although works were undertaken, the modifications made have not fully addressed the basic problem of mis-alignment. Only a partial solution has been achieved. There is still danger of aggravated erosion on the right bank in response to the left bank gabion work.

More care, thought and thoroughness is required in undertaking what might appear to be minor works.

ENG 3 Road embankment protection from River Scour - Roseau/Cul de Sac

Objective: To establish a means of protecting a road embankment from the aggressive scour of a meandering stream using local labour and mainly local materials.

Progress by the end of the Project:
The works on this trial in the Cul de Sac Valley have been completed with the exception of the vetiver planting which is due to be undertaken in the near future. The earth coffer dam was overtopped and breached (22 June '97) but there was no damage to the works as the gabion placement has already been completed almost to the top level.

The Mac-Mat soil protection is made up of steel wire with a loose fine plastic mesh cushion. This is not biodegradable although the plastic wires may eventually break-up leading to disintegration of the cushion. Biodegradable (jute-based) textiles are available that reportedly last about 2 to 4 years which would be adequate for vegetative growth to become well established. This could be a preferable form of protection where aggressive flows are absent.

This trial has been very well implemented and is a good indicator of what can be done.
Tender documents for the more complicated works to protect the road in the Roseau Valley have been prepared and are awaiting the floating of the tender.

Conclusions:

The Cul-de-Sac scheme illustrates that good work can be carried out. The site was deliberately selected because it was strategically located and important as opposed to the Roseau site which is not so critical. No priority rating was put on the Trials by the Consultants. The execution of the Cul de Sac works illustrates the priorities placed by the Government in the 'works' proposed under the whole trials programme.

The designs undertaken incorporated an extensive filter cloth backing to the gabion work which had not (reportedly) been used on some of the other river engineering works undertaken in the past. This has proven to be effective in creating a stable retaining wall structure and 'Works' intend using such cloth on all future gabion work, especially river works.

See photos of 'before' and 'after'.

ENG 4 Rock and vegetation crib design - Cul de Sac

Objective: To establish a construction method using local materials, vegetation and labour to create a resilient hard point in a river to discourage river movement in all but the most extreme floods flows.

Progress by end of Project:
Although sketch designs were prepared for these very basic works, two problems arose:
- there is reportedly no suitable hard wood available locally for palisading;
- no mechanical means of boring holes in the ground is available.

Alternative approaches need to be investigated. It is evident that more local discussions and enthusiasm is required to take this forward.

Conclusions:

More consideration is required with regard to the materials and work methods. The basic concept is relatively simple and it should be feasible for local engineers to identify a suitable method of reaching the required end product.

The nature of the works means that it is unlikely to be attractive to a contractor and hence might not have been rated high in the prioritisation of works to execute. Further efforts should be made to implement these types of works probably through direct labour using the RMU and WMAF avoiding the use of contractors.

If the Consultants had been in post for the duration of the Project, it is believed such works would have been completed. However, probably only through a direct works approach with funds passing directly from the Consultants.

ENG 5 Resectioning channel at loop cut site - Roseau

Objective : To improve on the existing construction technique of a regular trapezoidal section for any new channel. The intention being to reduce slips and loss of section which can cause an irregular bed profile.

Progress as of end of Project:
Not accomplished due to excess workload on Government staff. Section of channel selected was visited in November 1997, bank stability was still evident although natural vegetation coverage was increasing. However, without proper profiling and benching the bank will continue to slip and erode into the river.

Conclusions:

Few. Implementation capacity? Priority given to river engineering works?

ENG 6 Head loss structure associated with loop cutting - Roseau

Objective: To identify a cheap option for providing head loss control in the context of loop cutting.

Progress by the end of the Project:
Sites were inspected, specifications drawn up and a contract covering both trials signed. Works should not take longer than three weeks. (Originally it was suggested that only one weir should be attempted owing to the lack of funds). Weir design was undertaken by the Supplementary Engineering input (not originally planned but deemed to be acceptable assistance)..

A gabion weir was selected by the local engineers over a wooden structure for the following reasons:

1. There are no local hardwoods that are water resistant. Greenheart would therefore need to be imported from Guyana which would eliminate any potential cost savings over the gabion structure.
2. The wooden stakes would need to be piled into the ground requiring heavy equipment. Such piling would become exceptionally difficult if large stones or boulders were encountered.

Conclusions:

Further investigations should be undertaken in identifying a native hardwood which can survive submerged in water.

The assembly of a basic pile driving mechanism can be achieved simply. A simple A-frame structure in wooden poles with a block and tackle and a heavy weight could accomplish the task. For the length of poles being considered, the use of an excavator bucket, slightly adapted could also be employed.

Again, the lack of a continuous engineering input by the Consultants has possibly reduced the amount of lateral thinking and problem solving which might have been otherwise possible.

ENG 7 Sediment Detention Basins: Abandoned.

Least relevant of those proposed, difficult to implement within time and resource constraints.

4.2 Design and Construction Guidelines for River Erosion Protection Works

4.2.1 Definition

In this note 'erosion protection works' refers to methods of preventing erosion of river, canal or drainage channel banks due to flow or wave attack.

It also includes protection of flood embankments against similar attack. Coastal defence works are not included.

4.2.2 Options

The main options available are (in ascending order of effectivenes):

- grass cover
- geotextile (e.g. Enkamat)
- concrete blocks
- articulated concrete block mattress
- gabion mattress
- dumped rock (rip-rap)

All of the above are 'flexible', in that they can accommodate some movement of the subgrade without failure. Rigid systems such as concrete lining and steel piling are not covered by this note.

4.2.3 Composition of the Protection System

With the exception of the grass and geotextile options, it is normal to provide the protective layer with an underlayer of finer material and/or a geotextile. This layer is referred to as a filter, a drainage layer, or simply an underlayer – the latter term being preferred. The purpose of the underlayer is to bridge the gap between the larger elements, which make up the protection system, and the soil beneath it. It prevents fine material being washed out of the soil by the action of flowing water, waves, and seepage flow returning to the river on a falling flood. It also provides an even surface on to which to place the protection system.

The outer layer of the protection system is designed such that the forces applied by the water are not sufficient to dislodge individual elements. This is achieved by selection of the appropriate size/weight of elements which make up the protection system, and/or by linking the elements in some way (articulate concrete mattress, gabion mattress).

4.2.4 Environmental Considerations

Concrete and steel are often considered inappropriate these days, because they are recognised as environmentally unfriendly (with some justification).

Stone can also be rather stark in large quantities speaking any system which has gaps and crevices will be colonised by vegetation which can considerably reduce the impact. This applies to open concrete block systems and to gabions, as well as dumped stone.

Another factor which needs to be considered is selecting the appropriate system is the use of which the protected bank might be put. Damage caused by cattle (at drinking sites), anglers and boats may preclude the use of certain options. Conversely, boat users will not welcome the use of dumped rock which does not provide user-friendly moorings and can cause damage below the water-line.

It is essential to consider fully the potential environmental impact of any protection system proposed taking into account the local circumstances peculiar to the site in question.

4.2.5 Data Requirements

To carry out an engineering design of an erosion protection system, you will need the following:

- range of water level (maximum and minimum);
- flow velocities;
- indicative wave heights (wind generated) NB the design of coastal defence works, where waves are the dominant factor, is not covered by this note;
- site geometry (plan and cross-sections);
- at least an indication of the nature of the soil in the bank/embankment (preferably a particle size analysis).

In addition, the following information will help you to select the appropriate protection syste:

- details of access to the site (for construction);
- local availability of materials (especially rock) and indicative costs;
- environmental factors (see Section 4).

4.2.6 The Design Process; Grass, Geotextile and Concrete Blocks

These can all be designed on the basis of:

(a) the CIRIA report 'Design of Reinforced Grass Waterways' (Report 116);
(b) manufacturers' guidelines.

Grass

With grass, the duration of the attacking flow is as important at its velocity, because:

- once soil starts to be eroded the removal of vegetative cover from large areas can be rapid, and
- grass can only withstand limited periods of inundation if it is to survive.

Maintenance regimes are also important with grass cover since a short, dense growth is mot effective in resisting erosion. This can be achieved by selection of an appropriate grass seed mix, and by providing for regular mowing or animal grazing (sheep in preference to cattle as the latter case much more damage).

Where rapid establishment is important, the use of turf is recommended. This should be pegged down to prevent lifting off of curves before the roots have penetrated the soil below.

Grass reinforced by geotextile gives even greater strength and this can be obtained in rolls with the grass already established, or the seed can be sown after placing of the geotextile. Again, pegging down of the fabric is recommended.

Slopes steeper than 1(V) to 2 (H) should be avoided if possible because of the increased difficulty of maintenance.

Geotextiles

There are quite a number of offer which fall into three main types:

I. biodegradable(e.g. geojute) – can be obtained pre-seeded;
II. three dimensional at of plastic fivers (e.g. Enkamat) – can be obtained complete with grass (e.g. Enkazon) or bitumen bound (e.g. Enkaat A);
III. cellular mats (e.g. armater) – best used on horizontal surfaces which may be trafficked.

With I and especially with II preparation the subgrade is quite important so that optimum contact between the protective layer and the soil below is achieved. Otherwise the geotextile may 'bridge' hollows reducing the effectiveness of the system and making it unsightly.

Concrete block System

There are many proprietary systems which are generally either hand place individual elements (e.g. Armorloc) or mattresses comprising blocks interconnected by Steel or plastic ropes (e.g. armorflex).

The latter are more appropriate for large, regular areas and the former for smaller more complex areas.

Gabion attreses

Refer to the detailed information provided by Maccaferri.

Be aware of possible drawbacks:

- corrosion of wires (PVC coated wires can be specified);
- vandalism (for various reasons, cutting of gabion wires is a common problem);
- cost of appropriate stone filling (sound and appropriately sized/graded material is essential).

Dumped Stone

General

Dumped stone/rock (or rip-rap) is one of the most popular bank protection systems where rock of the right size and durability is available at a reasonable cost.

It can be very effective and the environmental impact can be reduced by encouraging vegetative growth.

For river erosion protection, the design is most often based on an assessment o the flow velocity to which the revetment will be exposed.

The most commonly used design equation is that development by the Highway Division of the Department of Public Works in California. Expressed in metric units this is:

$$W=(0.011\ V^6 s)/((s-1)^3 \sin^3(d-a))$$

Where:
W= critical weight of stone [kg] – two-thirds of stones to be heavier than this.
V= maximum flow velocity anticipated, calculated as an average over the whole channel section (i.e. flow/area) –[m/s]

s = stone specific gravity
d = a stability factor, normally taken as 700 for randomly dumped stone
a = slope of bank in degrees.

In cases where the erosive forces are expected to be high, for example on the outside of bends or in turbulent flow downstream of a structure, the value of V should be increased by a factor of 1.33.

It can be seen that the weight of the appropriate stone is proportional to the sixth power of velocity, which means that weights go up rapidly as velocity increases. However, it is as well to remember that weight is proportional to the cube of the stone 'size' (when expressed as radius, diameter or equivalent), so the size of the stone only goes up with the square of the velocity.

The other significant variable in the equation is slope of the bank protection works. The flatter the slope, the more inherently stable the stones will be. Slopes steeper than 1 (vertical) to 1.5 (horizontal) should be avoided.

Grading and Stone Shape

Complex specification of source of stone size/weight grading should be avoided because it will be difficult to achieve and very difficult to test for conformity.

It is suggested that the grading is specified by means of:

W_{100} (maximum weight) – no stones to be heavier
and either W_{50} – half stones to be heavier
or W_{33}-two thirds stones to be heavier
and W_{15}-15% of stones can be smaller.

As a rough guide:

$W_{100} = 2\ W_{50}$ to $5\ W_{50}$
$W_{15} = 0.1\ W_{50}$ to $0.4\ W_{50}$
$W_{50} = 2\ W_{33}$

Stone shapes should ideally be cuboid or irregular (rounded stones are less stable), with the longest dimension no more that twice the shortest.

Depth of revetment

The thickness of the stone layer should be at least 1.5 D_{50} or 1.5 D_{100} whichever the greater).

How D_{50} is defined another matter. Generally D_{50} is taken as the diameter of a spherical stone with weight W_{50}. Alternatively, it can be taken as the side of a cubic stone weight W, or the average dimension of typical stone of weight W_{50}.

Preferably the depth of revetment should be 2 D_{50} or 1.5 D_{100}.

Underlayer

The design of the underlayer is generally even less scientific. A graded gravel blanket 200 to 300m thick with stones in the range 5 to 75 mm will usually be adequate.

The grading and thickness can be varied to suit local conditions (and, indeed, available materials).

If the underlying soil is very fine, the provision of a geotextile under the gravel can be considered. In certain circumstances, the gravel underlayer can be omitted, and the stones dumped directly on to the geotextile. This requires a composite or thick geotextile with considerable strength as well as separation/drainage properties.

In extremis, the rip-rap can be dumped with no underlayer at all, but the grading should preferably be wider and the thickness increased by 50%.

Placing

Rip-rap stone is dumped, not hand placed. Its distribution is therefore random, but the operation should be controlled to ensure that the layer thickness is even and that design slopes and tolerances are maintained. For stone placed below water, the thickness should be increased say by 50%).

Hand placed stone is termed pitching. This has its place for canal and river banks above the low water level, and can be ver effective where labour is cheap. Generally speaking, pitching can be done with smaller stone sizes and thinner layers, because hand placing ensures a degree of 'interlocking' which cannot be achieved with rip-rap.

4.3.6 Gabion Construction

Gabions are straightforward to erect and construction is rapid. Workers can quickly learn the procedure for high quality construction. A few key points must always e remembered:

- good preparation of the formation to give a firm foundation;
- careful laying and protection of geotextiles and filter layers so there are o gaps or tears;
- mesh and wiring should be kept tight all the time;
- lacing panels together should be done in a continuous operation, not using separate twist;
- careful filing so stone is packed tightly and the gabion is slightly overfilled;
- good lacing down of the lid and proper connection with adjacent units is essential.

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A Guide to Good Practice for gabion construction is given on the following pages.

Tools

The simple tools needed are: long nosed fencing pliers and crowbars. These should be flat or round nosed to avoid damaging the wire coating. In addition metal bars and timber pegs are needed for tensioning the mesh, staking down mattresses and aiding the closing lids.

Cutting

Two methods are used to fit gabions to curves and different shapes;

Cut to shape: The cut edge is then butt-joined to the intact edge of the previous gabion.
Overlap: Place in sequence around the curve and overlap to fit the curve. The sides of the units that ate on top are raised. Diaphragms, back and front faces and lids are then cut so that they can be laced to these sides and construction proceeds normal. In either case it is very important that cut edges and overlapping mesh are carefully laced to ensure a strong join.

Laying details

If gabion boxes of 1.0 m height form a stilling basin floor or will be subject to high velocity flow then they should be braced in the vertical direction from box base to lid with at least two connections per compartment.

I Preparing the formation
The surface which the gabions or filter layer is placed on should be even and firm. Excavate any soft or unsuitable material and backfill with sound material. Fill any holes, ruts or uneven areas with good material such as granular fill. Grade and compact the formation to the correct line and level. Where the surface is very uneven or soft a layer of sand or gravel (say 200 mm thick) may be placed to provide a firm and even surface.

ii) Laying mesh boxes
Gabion voxes arrive on site folede flat in budles for easy transportation. Each box should be carefully opened out, laid flat and straightened out so the mesh is not creased. The sides of the boxes can then be laced together to form the box.

The selvedge wire along each edge is laced to the adjacent selvedge wire with lacing wire to give a continuous join. Lace the edges with single loops in turn at intervals of one mesh length. Secure the ends of the lacing wire at each corner with triple loops and turn the ends of the wire into the box.

Carry out the same procedure for each f the internal diaphragms. Several boxes can be laced together and then moved into place.

iii) Lacing together
Adjacent boxes or mattresses should be connected using the same procedure. Always lace selvedge wire to selvedge wire. Lace all four edges of each face to their adjacent boxes. It is easier to lace them together when the boxes are empty. Make sure lacing is carried out in a continuous sequence, not in individual loops.

Do not forget to also lace each box to the boxes below and behind it so that the whole structure is laced together.

The mesh should then be tensioned to remove kinks so each panel is square and true.

iv) Stone
Stone for gabions shall be clean natural hard and durable with a minimum density of 2 400 kg/m*. Stone shall be well graded within the following limits:

Mesh size	Minimum dimension (mm)	Maximum dimension (mm)
60 x 80 mm mesh	70	180
80 x 100 mm mesh	90	240

v) Filling

Before filling gabions shall be accurately positioned in their required location, straightened to remove all kinks in the wire mesh and tensioned. Gabions may be filled by hand or machine. Stone shall be tightly packed to minimise the formation of voids.. Where machine filled, stone shall not be dropped from a height of greater than 1.0 metre. The difference in the level of stone fill between adjacent units shall not exceed 0.5 m. Gabions shall be overfilled by 25 to 50 mm to allow for settlement. Lids shall be stretched tightly over the stone fill and securely wired down.

Wher gabions are paced on geotextiles care shall be tsken to avoid puncturing the material during construction. Damage shall be made good.

Where angles, cures or slopes are required which are not possible to obtain with standard units the gabions amy be cut, folded and wired together. Mesh shall be cleanly cut out or folded back and wired to an adjacent gabion. Cut edges shall be securely laced together.

For mattresses on a slope start filling from the bottom ot the slop upwards. Also peg the mattresses at the top of the slope at 2 meter centres to hold the mattresses in place during filling.

vi) Bracing

Metre high boxes should be braced when filled to the third and two thirds of a metre height. Partially fill to a third of a metre height and the brace by forming a 'Figure of 8' using tie wire, twist to tighten and so tension the faces. Repeat at two thirds of a metre height. Two braces shoul be made at each height. The loops of the brace should pass through the face of the gabion for at least tow mesh lengths.

For greater rigidity and where more than one face will be exposed bracing can be fixed to all four verticla faces.

For 0.5 m high boxes brace when half full. Matresses 0.23 and 0.30 m high do not need bracing.

vii) Closing lidds

Gabions should be overfilled by 25 to 50 mm before closing to allow for settlement. The lids are then stretched over the stone fill and laced down. Secure the corners first to make sure the lid cab be laced down without over-stretching the mesh. Remover or redistribute some of the stones at this stage if necessary. The lids are then laced down securely. Lace selvedge wire to selvedge wire using the same procedure as above.

Chapter 5

GROUNG BIO ENGINEERING TRIALS ENG 8 & 10

5.1 INTRODUCTION

Selected species of natural tropical vegetation have been used on a limited basis by land owners for several decades in St. Lucia to assist in the control of soil erosion and slope instability along road cuts, steep slopes and river banks. The common plant species are Glyricidia sepium (Glory Cedar), Bambusa vulgaris (Bamgoo, Hibiscus pernambucnsis (Mahoe mang), Pennisetum purpureum (Elephant grass) and Vetiveria zizanioiodes (Vetiver grass). Since the onset of tropical storm 'Debbie' in 1994 and the resulting devastation caused by extensive landmass wasting from landslides and surface erosion mainly in cultivated areas, there is urgent need to address the problem of slope instability and to seek solutions that will be beneficial to the land owner and the environment. Conventional slope stabilisation requires the design of civil structures which are costly and impose tremendous strain on the budget of small economies like St. Lucia. The use of local building materials of their nearest equivalent should be given preference in the construction of slope retaining structures. Ecologically valuable areas and landscapes of great attraction for eco-tourism should not be unnecessarily disturbed, in particular, forest and woodland reserves, wetlands and river courses.

5.1.1 Minimising Landscape Disturbance

The following aspects of landscape-awareness construction methods are recommended when attempting to minimising the disturbance of the natural landscape:

- selection of suitable construction machinery and tools: they should be technically suitable, but also suitable sized to fit the task. For example, the use of excavators and similar equipment for the construction of roads in forests.

- limited removal of solid rock, avoiding scattering of rock by the use of restricted blasting techniques. Partly decomposed and well-jointed rock is often rippable using jack hammers.

- excessive material should not be dumped downslope, but removed to predetermined dump sites.

- adequate drainage to prevent subsequent damage from excess run-off and to reduce maintenance costs.

- stable embankments to fit the terrain, avoidance of steep side slopes and provision of protection structures preferably using vegetation methods.

- conservation of any woodland, wetland or forest reserves.

- In closed forests, completely cleared areas must be kept to an absolute minimum.

5.1.2 Planning Bio-engineering Protection Programmes

Although there is marked reluctance in using vegetation methods in preference to well-established practices employed in conventional civil engineering, ground bio-engineering provides an alternative approach in slope stabilisation and soil erosion. Bio-engineering involves the use of natural vegetation in implementing protection and stabilisation measures for unstable slopes, river banks, embankments and other natural or manmade features within the landscape. Some time is required, however, in selecting the proper construction procedure and the relevant species of vegetation for a specific site.

In preparing a bio-engineering project the following steps are recommended:

i) desk study of the site using topographic maps, aerial photography, and available drawings.

ii) geotechnical and geological site investigations

iii) pedological investigations – soil types

iv) survey and mapping of all vegetation types

v) collection of ecological data

vi) investigation of the cause of failures in the case of remedial works

vii) outline objectives of remedial works

viii) selection of appropriate plant and grass species to be used

ix) method of construction to be used

x) land ownership, land use rights and other legal aspects

5.2 Site Location

Two sites were selected for the bio-engineering trials for this project. One site is located on the south east of the island at Mahaut in the district of Micoud and the other at Combat, Babonneau to the north east of Castries. The criteria used in the selection of the sites was as follows:

i) accessibility

ii) instability

iii) banana farmland

iv) watershed environment

v) co-operation of owner

5.3 TOPOGRAPHY AND GEOLOGY

5.3.1 Mahaut (Eng 10)

The Mahaut trial location is the site of an old landslide resulting from undercutting of the right embankment (looking downstream) of the Troumasee River during Tropical Storm 'Debbie' in 1994. The embankment slope had been under banana cultivation and there was no permanent vegetation on the failed slope.

In terms of topographic profile the site comprises a fairly steep overall slope of 45 degrees and an approximate height of 30.0 meters.

The site consists of an underlying geologic structure dating to Middle Tertiary volcanic rocks (Central Series) of andesitic origin which exhibit variable degrees of weathering. The identifiable bedrock geology is expected to give rise to residual soils of the clayey silt type in which drainage is slow;

moisture supplying capacity is good; erosion hazards moderate with high natural fertility but acidic in chemical composition. These soils will require a special management regime with respect to agricultural land use potential as they exhibit a great drainage problem.

5.3.2 Combat (Eng 8)

The landslide at this site is located in a banana cultivated area and was also initiated by Tropical Storm 'Debbie' in October 1994. The area lies within a valley with slopes at 35 and 40 degrees to the east and west respectively. A feeder road utilised by banana farmers in the region exists along the crest of the failed slope and this access is critical to the farming community. A row of well established permanent trees of the species Hibiscus elatus (Blue Mahoe) are arranged along the crest of the slope to assist in the stabilisation of the road. A few plants of Mangifera indica (Mango) are also visible on the slopes.

The local geology is Early Tertiary (Northern Series) volcanic rocks usually basaltic and andesitic in composition and are the most highly folded and oldest rocks on the island. A large portion of the site is covered by clayey silt colluvium of variable thickness and consistency. Drainage of the are is facilitated by a small stream some distance from the toe of the slope.

5.4 Ground Bio-Engineering Techniques

5.4.1 General

The following are general specifications used for the bio-engineering programme for this project. Some alterations were made as a result of specific site conditions.

5.4.2 Specifications for the preparation of Slopes prior to Planting

The objective of preparing the slope is to ensure that the vegetation has a higher chance of becoming established. Vegetation needs to be protected from minor slope failures and slumps.

The following procedures were utilised during slope preparation:

- all loose material was removed from the slope
- the head of the slope was rounded and not left overhanging
- the toe of the slope was protected from undercutting
- all loose material trimmed from the site was disposed of with care in a location recommended by the engineer.

5.4.3 Specifications for Live Pole planting

- vegetation incorporated into the works was healthy, free from defects and protected after delivery on site from excess heat, excess moisture and damage by burial or impacts; rooted stock was installed by inexperienced personnel using planting tools.
- vegetation established was only carried out after planting sequence was approved by engineer.
- all cuttings were sourced from an approved supplier, freshly cut and after arrival on site were wrapped in wet sacks until immediately before use.

- live poles were 2.5m – 3.0m long, Glyricidia sepium (Glory Cedar), Hibiscus pernambucensis (Mahomang) and Bambusa vulgaris (Bamboo) of minimum 40 mm diameter at the top and up to 100 mm at the butt end. They were inserted 1.0 –1.5 m into the slope at ten(10) degrees below the horizontal on 1.5 m centres staggered horizontally and vertically, butt end first into pre-drilled holes, then hammered into the slope until refusal. The ends of the poles were pointed.

- in soft ground, it was possible to drive poles without predrilling using manual post hammers with extension handles. Driving was done until the height of the stem above ground was 0.3 – 0.5 m after removal of damaged portions of the pole and trimmed off with a 30 degree slanting cut.

- after driving, all ends of the live poles were trimmed cleanly at an angle of 60 degrees to the longitudinal axis of the pole; all splintered portions at the ends were cut off cleanly first before trimming at an angle of 60 degrees to the longitudinal axis of the pole.

- void spaces around the lives poles were backfilled with augered site soil.

5.4.4 Specifications for Planting Live Cuttings

- live cuttings were unbranched and healthy one year or older stems of glyricidia, mahoemang and bamboo plants of diameter 10 –50 mm and a minimum length of 400 mm.

- a metal rod was used to punch narrow holes into the ground into which the cuttings was placed; the soil was then firmed down around it. Some cuttings with a slanted basal cut were hammered in.

- about one-quarter (1/4) of the cutting protruded above the ground surface to prevent it from drying. The cutting was placed at 1.5 m contour spacings and 150 – 200 mm contour centres. Mahoemang cuttings were placed at 0.5 m contour centres.

5.4.5 Specifications for Planting Vertiver Grass

The planting of grasses on slopes is intended to create a strengthened slope surface that is resistant to soil erosion. The following procedures were used in planting Vertiver grass:

- the plants were kept moist and cool while on site

- plants started at the top of the slope and worked down taking care not to disturb newly established plants.

- the plants were arranged at a close spacing of 150 mm to develop into an effective barrier to surface run-off sooner than widely spaced plants.

- by using a cutlass, a planting hole approximately 70 – 100 mm deep and 50 mm wide was prepared. The vertiver plant was placed in the hole without bending the roots. The hole was then backfilled and compacted around the plant.

- survival checks were made one month after planting.

5.5 Field Procedures at Trial Sites

5.5.1 Mahaut (Eng 10)

Very little information was available about suitable plant species, about slope failure mechanisms in tropical residual soils or about the effectiveness in St. Lucia of low cost engineering measures used in Europe and North America. The approach, thereof was to make regular observation of sites on which a wide range of techniques and species were implemented, on the assumption that the relative success of these would, in time indicate those that tended to be most positive.

The tasks here were basically twofold:

- identify 'low cost' engineering techniques suitable for reducing and controlling shallow failures on slopes.
- define a role for vegetation in slope protection in St. Lucia.

The field programme was initiated in June 1997, with the construction of a 3.0 m high rip rap buttress along the toe of the slope for a distance of approximately 200 metres using boulders up to 4.0 m in diameter from the river bed utilising a 225 excavator.

Three rows of vertiver grass were planted in shallow holes dug with cutlasses approximately 0.5m above the rip rap at 10 cm spacings to control surface erosion. Four rows of live poles, 2.5 m long, straight mahoemang cuttings of minimum 40 mm diameter were inserted along the slope contour above the vertiver grass using a power auger to pre-drill the 1.0 m deep holes. They were placed at 1.5 m centres and staggered at 10 degrees below the horizontal. Glory cedar cuttings of 20 mm diameter and 400 mm length were planted at 1.5 m contour spacings and 150 mm contour centres on the upper portion of the slope. Vertiver grass was planted at the crest of the slope in close proximity to the banana plants.

5.5.2 Combat (Eng 8)

Field work at Combat commenced in November and continued in December, 1997. The slope was prepared by rounding of the crest and installing a drainage ditch at the crest to facilitate surface run-off away from the slope. A hedge of vertiver grass was planted 0.5 m below the crest at 100 mm contour centres. Glory cedar cuttings were planted at 1.5 m contour spacings and 150 mm contour centres. The first row of mahoemang cuttings were planted at slope mid-height at 0.5 m contour centres and 1.5 m contour spacings. The first vertiver contour hedge is at the 50-60 degree slope line. Mahoemang live poles and bamboo rhyzomes were planted in the slope debris zone on contours alternating at 2.0 m contour centres downslope along contour. Vertiver grass lined the side slopes of the exit gully in addition to rubble or stone for erosion control. Vertiver weirs were established across the exit gully and across a drainage ditch along the east slope of the gully.

5.5.3 Monitoring

The Department of Engineering in the Ministry of Agriculture has acknowledged the responsibility to monitor the progress of both sides on a monthly basis to replace any unsuccessful plants and to observe the rate of establishment of the different plant species. Unsuccessful plants may have to be replaced with new plant species as the species selection experimental program conducted by the Department of Forestry dictates.

5.6. Management of Bio-Engineering Programme

5.6.1 Plant Species for Slope Stabilisation

The selection of the most suitable plant species for bio-engineering application is imperative for the success of the programme. For best results only plants that grow in similar habitats should be used; the simplest and best suited method for plant selection should be based on the results of plant sociological surveys of nearby similar habitats. Most vegetative stabilisation works are carried out on the slopes of man-made cuts and fills devoid of topsoil or on the exposed bare surface of landslide areas, i.e. on relatively inert subsoils or decomposed rock of very poor fertility.

Only well-adapted pioneer plant associations with a large spectrum of species, each tolerant of a wide range of adverse factors with regard to soil quality, micro-climate and mechnaicl stress, have any chance of establishing themselves under such rigorous conditions. Together with the aim of obtaining the desired effective stabilisation, the choice of plants should also aim at the establishment of easily maintained and, preferably, economically valuable woodland and grassland.

The bio-technical character of a plant species encompasses the following attributes:

i) The ability to take root in and colonise immature soil, subsoil or any king of material exposed in cuts and fills.

ii) Roots and surface parts must be resistant to the mechanical forces of erosion and aggradation, the forces exerted by rock fall, as well as subsoil movement. Internal soil movement (friction and shear) must be specially considered for slope stabilisation measures and combined construction methods.

iii) Soil strengthening or soil binding effect – this depends on the type of roots, the intensity of root penetration and on the total root mass.

iv) Soil improvement – this concerns the ability of the planted vegetation to improve the soil quality, which in turn leads to the natural progression from the pioneer stage to the next higher plant stage.

Not much is currently known of the ability of the variable plant species in St. Lucia to meet the above criteria and there is need for some plant research in this capacity. In January 1997, the Department of Forestry in the Ministry of Agriculture, Forestry, Lands and Fisheries initiated a programme of plant species selection for bio-engineering at its forest reserve station at Forestierre. Twelve (12) plant species were selected for this trial phase of the programme namely:

PLANT SPECIES		DEPTH (M)	SHOOT GROWTH	
			(2 mths.)	(9 mths.)
Hibuscus elatus	(Blue Mahoe)	1.0	*	
Sapium caribeum	(La Glu)	1.0		
Glyricidia sepium	(Glory Cedar)	1.0	*	*
Bursera simaruba	(Gommier Modie)	1.0	*	*
Lonchocarpus violaceus	(Savonette)	1.0		
Hibiscus pernambcenis	(Mahoemang)	1.0		
Pithecellobium saman	(Saman)	1.0	*	
Leucaena leucocephala	(Leucaena)	1.0	*	
Gemelina	(Gmelina)	1.0	*	*
Fterculia caribaea	(Mahoe cochon)	1.0		
Simarubu amara	(White Cedar)	1.0		
Bambusa vulgaris	(Bamboo)	1.0	*	

Live poles of 50-75 mm diameter and 2.0 m length were installed in pre- drilled boreholes at 1.0 m spacing to a depth of 1.0 m. Two live poles of each species were used to allow for growth failure. After a two month period shoot growth was observed in seven (7) species compared to three (3) species after nine (9) months. The rate of growth of the aerial part of a plant belies the much slower development of an extensive root system. At least three seasons must pass before a plant is capable of performing an engineering function. A site containing immature plants can be wiped out by a single heavy storm.

The objective of the experiment is to determine the local plant species that will meet the following criteria:

i) aggressive growth from a planted live pole

ii) short time period for plant succession

iii) develop aggressive root system at 1.0 m depth of embedment in the long term.

Additional plant species will be experimented with in the future at greater depth of embedment after the root growth of the current species are examined. The stabilisation of slopes with vegetation in some cases requires the planting of live poles to depth that will intersect the slope failure plane which has been observed to be at a depth of at least 1.0 m in a large number of landslides in St. Lucia. The aim of this programme is to identify those local plant species that will meet the criteria outlined above.

5.6.2 Plant Propagation

Once the most suitable plant species have been identified, tree farms should be established within the watersheds to supply the required amounts of plants for slope stabilisation projects. Because of the necessity to have large quantities of plant material at one's disposal for bio-engineering projects, economic considerations demand the easy propagation of the plants involved to prevent shortages during construction. The use of shooting or rooting plant parts would be of great advantage to the engineer. The most important live materials for slope stabilisation and combined construction measures are parts of woody plants with adventitious buds.

Such plant parts capable of vegetative propagation are:

- cuttings; unbranched stems, approximately 12 – 60 mm in diameter, 250 – 600 mm long.
- branches and twigs; should be at least 600 mm long and of various thicknesses
- stems; slim, flexible, poorly unbranched shoots with a minimum length of 1200 mm
- poles and stakes: straight, mainly unbranched sections of large branches 1 – 2.5 m long.

Ideally, fairly thick and long branches should be used, suited to the construction method envisaged as the more substantial cuttings will ensure successful sprouting and rooting.

5.6.3 Method and Type of Construction

The method and type of construction will set the criteria for plant species selection. A summary of the conditions that decide the choice is as follows:

- objective of the works; the immediate aim is to stabilise the slope. In addition, a short time period for plant succession and low maintenance cost is required.
- technical effects: the protection of erodible slopes by means of effective plant cover.
- the ecology of the site: site conditions influence the choice of plants, which in turn determines the type of construction.

- availability of relevant building materials

The stabilising effect of vegetative protection works is influenced by a series of different parameters:

- type of works (cutting, embankment, etc.)
- slope dimensions
- slope shape
- soil type
- soil – water relationships
- rooting characteristics of the established vegetative cover

The bio-engineering programme established in St. Lucia under the Watershed and Environmental Management project has set the stage for expansion into the new engineering disciplines of bio-engineering and eco-engineering which must be pursued in this part of the world because of the easy access to the extensive lush tropical vegetation and variable plant species that are available. Bio-engineering provide the most cost effective approach to resolving these problems.

Chapter 6

The Development of a landslide Hazard Warning System for Evacuation of Populated Areas (ENG 9)

6.1 Introduction

Historically, the Ravine Poisson region has been the site of massive landsliding that resulted in loss of human life and extensive damage to property. More recently, several rural communities have sprung up on San de Feur and Chopin ridges on government lands reserved for future development. These communities comprise persons who have selected parcels of land at random on steep slopes and have built their homes in excavated lost in the hillside and at the toe of unstable slopes. Household wastewater is readily discharged on the slopes and the natural vegetation has been replaced by agricultural crops, mainly bananas. These human activities have been observed by team members involved in this project after several tea discussions, a concensus was arrived at to establish a trial site in the area to monitor the stability of the slopes and to initiate a long term field programme to develop correlation between rainfall intensity, ground pore water pressure fluctuations and slope instability.

The study will include a field instrumentation and monitoring programme to achieve the following:

(i) Provide data relevant to the stability of potential landslide area or areas of known past instability.

(ii) Control human activities and minimise risk during critical periods of intensive rainfall.

(iii) Provide advance warning to persons who may be affected by instability, or prevent use of an area affected by instability.

(iv) Provide research data to advance our understanding of landslide mechanisms.

The basic objectives of the instrumentation and monitoring programme are to confirm the expected behaviour by direct measurement, to modify or refine such expectations as might be required, and to check for gross variation to this behaviour.

Standpipe piexometers and slope inclinometers were installed at strategic locations at the crest of steep slopes on San de Feur and Chopin ridges to monitor pore water pressures and subsurface movement, respectively. Extensive data is required to evaluate slope failure mechanisms which can assist in developing criteria for a landslide hazard warming system for evacuation of populated areas located in the immediate vicinity of unstable slopes.

6.2 Site Location

The trial site at Ravine Poisson is located within the Cul de Sac Watershed 12 kilometers south of Castries. The San de Feur ridge extends northward from the Barre de L'isle ridge and is separated from Chopin ridge to the north by a road which leads to the community of Sarot.

6.3 Topography and Geology

The Ravine Poisson Ridge under study is sub-divided into Chopin ridge to the north and San de Feur ridge to the south. The ridge rises to an elevation of about 100m above the Cul de Sac river floodplain to the east and the Roseau river floodplain to the west with slopes of 35 to 50 degrees. The crest of the ridge is approximately 5 m wide and is an access road to community residents and banana farmers. Several erosion channels have been cut into the slopes and contribute to flooding of the lowlands during the rainy season. Tension cracks are evident on some slopes where instruments were installed.

The general subsoil stratigraphy at Chopin and San de Feur ridges consist of a brown, low plastic, residual clayey silt deposit of firm to hard consistency overlying bedrock. The underlying bedrock geologic structure dates to Middle Teritary volcanic rocks of andesitic origin which show evidence of extensive chemical weathering. Several landslide scars were observed along the ridge resulting in the deposition of weak colluvium debris on the lower areas of the slopes. This colluvium deposit consists mainly of a silt/sand and clay matrix with some gravel and cobbles. These materials were encountered in the boreholes during the site investigation programme.

Detailed borehole logs are included in Appendix C.

6.4 Field Investigation and Instrumentation

6.4.1 General

The field investigation is the central and decisive part of a study of landslides and landslide prone areas. The investigation serves two essential purposes:

i) To identify areas subject to sliding when future construction is being planned and

ii) To define features of and environmental factors involved in an existing slide.

Unstable areas prone to sliding usually exhibit symptoms of past movement and incipient failure; most of these can be identified in a detailed field investigation before design. Such investigations can show how to prevent or at least minimise future movements and they can suggest alternative areas that are less likely to slide. Ideally, field investigations should commence long before construction is anticipated and sometimes continue long after the area has been changed by the anticipated construction.

A number of these require study in a field investigation including:

i) topography
ii) geology
iii) groundwater
iv) weather conditions
v) history of slope alterations

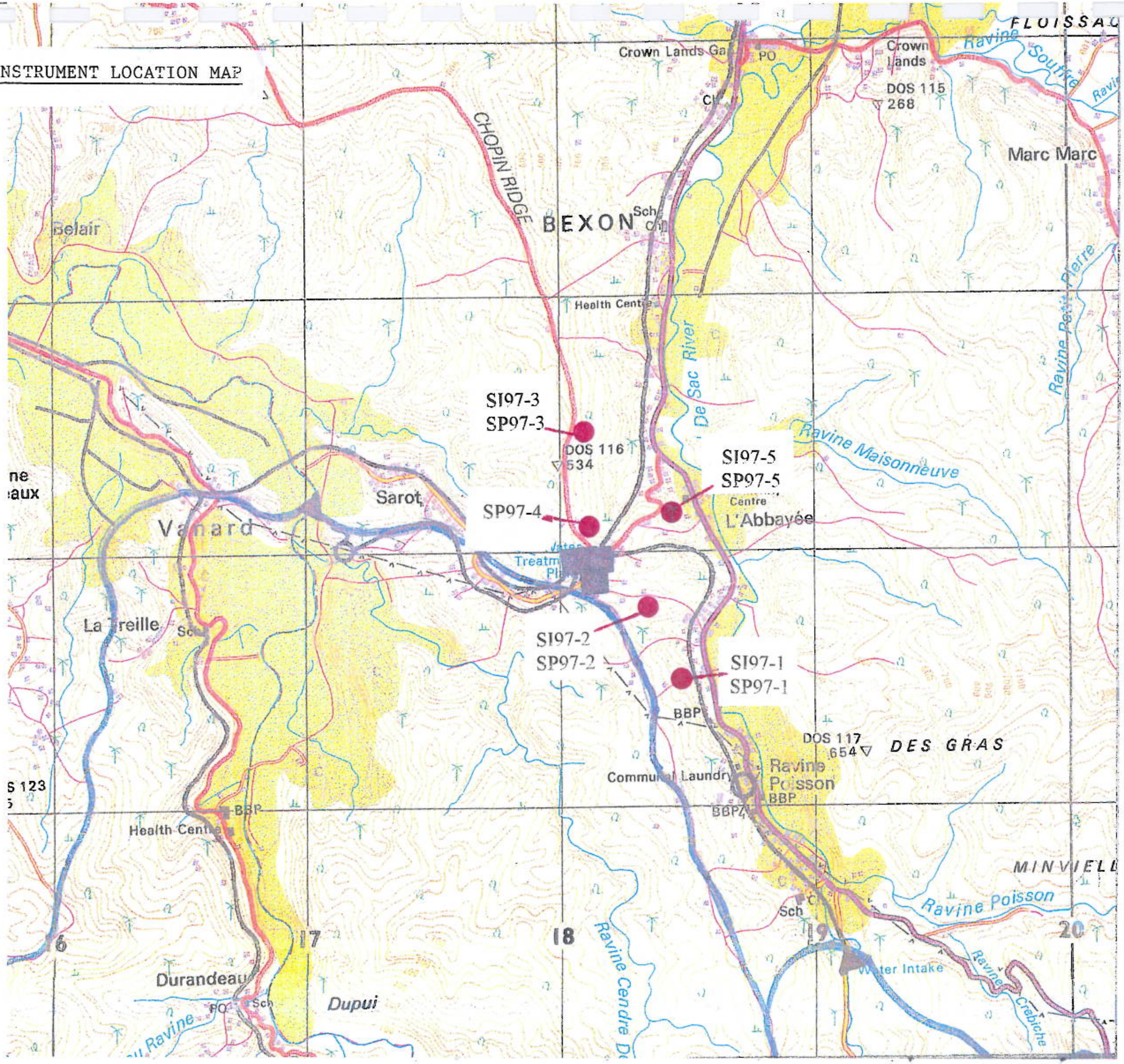
6.4.2 Standpipe Piezometer (SP) Installation

The field investigations at Ravine Poisson was conducted during May and July, 1997. Five piezometer boreholes (SP97-1 to SP97-5) were drilled to depths varying from 12.0 metres to 21.0 metres below ground elevation at selected locations on Chopin and San de Feur ridges (see Instrument Location Map), utilising a tripod mounted wash-boring drill rig with a motorised cathead. Standard Penetration Test (SPT) were conducted at regular intervals of depth in all the boreholes by driving a split barrel sampler into the ground with a 64 kilogram weight drive hammer dropped 760 mm. The recovered disturbed soil samples were visually classified in the field.

Undisturbed shelby tube samples recovered at selected depths in each borehole. The boreholes were advanced by driving a 75 mm diameter steel casing tot he required depth then retracted and the required soil samples recovered. On completion of drilling a perforated, 30 m diameter plastic PVC standpipe piezometer was installed in all the boreholes to monitor groundwater levels and to conduct hydraulic conductivity tests if required. The piezometer installation procedure was as follows:

The lower 3.0 m of the 30 mm diameter PVC pipe was slotted at 150 mm intervals with a hacksaw and the sealed end lowered to the bottom of the borehole by adding 6.0 m lengths of pipe connected on ends by couplings and sealed with PVC glue. The borehole was backfilled to within 2.0m of ground surface with 12 mm diameter clean, crushed rock placed around the piezometer. A bentonite

INSTRUMENT LOCATION MAP



slurry was used to top the borehole and form an impermeable seal to prevent the ingress of surface water into the piezometer. A cap was placed over the protruding end of the piezometer.

6.4.3 Slope Inclinometer (SI) Installation

The slope inclinometer is a device used for monitoring deformation normal to the axis of a casing by means of a probe passing along the casing. It is used to determine the extent, rate and zone of landslide movement.

The slope inclinometer system has four major components:

i) A permanently installed guide casing made of plastic, aluminum allow, fiberglass, or steel and contains longitudinal grooves or slots for orientation of the sensor unit.
ii) A portable probe containing a gravity-sensing transducer which is mounted in a carriage designed for operation in the guide casing.
iii) A portable control readout unit at the surface supplies power, receives electrical signals, and displays readings in digital format.
iv) A graduated electrical cable linking the probe to the readout unit and is raised or lowered in the casing and transmits electrical signals to the surface.

The plastic casing used for this project is of 70 mm diameter and 3.0 lengths and is made of an ABS (acrylonitrile/butadiene/styrene) compound. The casing is manufactured with aligning grooves for controlling the orientation of the probe and are joined together with rigid couplings.

Five boreholes (SI97-1 to SI97-5) were drilled without soil sampling to depths varying from 10.0 m (SI97-1) to 27.0 m (SI97-4) for slope inclinometer installation. Borehole SI97-4 collapsed during the installation process and was abandoned. The boreholes were drilled a distance of approximately 1.5 m from the piezometer locations to observe any correlation between groundwater fluctuations and subsurface movement.

The slope inclinometer casing was installed in a near vertical borehole that passes through a zone of suspected movement. The bottom of the casing was anchored in stable ground and serves as a reference. The inclinometer probe is used to survey the casing and establish its initial position.

The plastic casing sections were layed out and couplings marked to show location of the alignment key. A bottom cap was placed at one end of the first section, sealed with ABS cement and taped to prevent soil or grout form entering the casing. The remainder of the casing was assembled by adding on sections connected with couplings and sealed with ABS cement. During the installation process, the axis of one pair of grooves was kept parallel to the anticipated direction of movement; i.e. downslope. The orientation was maintained throughout the installation process. A grout slurry composed of Portland cement, sand, bentonite and water was used to backfill the borehole and to provide stability to the casing.

Slope inclinometer data is included in Appendix C.

6.5 Laboratory Procedures

The recovered disturbed and undisturbed soil samples were wrapped in plastic bags in the field to retain the natural moisture content. The disturbed samples were utilised in the laboratory to determine insitu moisture content, grain size distribution, Atterberg limits, and to confirm the field classification of the subsoil. Undisturbed shelby tube samples were packaged and transported to the University of the West Indies in Trinidad for shear strength testing in their laboratory.

The surficial residue soils encountered in all the boreholes had insitu moisture contents ranging for 9 to 60 per cent. The higher moisture content values were found in samples with high clay content. Atterberg limits performed on the fines content of selected samples ranged from 29 to 56 per cent. The Plasticity Index ranged from 7 to 25. Some values fall below the 'A'-line. These samples may contain some organic inclusions. The plasticity chart shows that fines content of the residual soils has low plasticity values.
The results of the shear strength tests are incomplete at this time and will be included later.

The grain size distribution curves show the material to contain 5 to 25 percent sand and 75 to 95 percent silt and clay content.

The 'N' values from the Standard Penetration Test (SPT) ranged from 10 to over 100 blows per 0.3 m in insitu material indicative of a stiff to hard consistency. The 'N' values recorded for fill material averaged 4 blows per 0.3 m which represents soft to firm material.

Laboratory test results are included on the borehole logs.

Grain size distributor curves are included in Appendix C.

6.6 Instrumentation Monitoring

A knowledge of pore (ground) water pressure is required for calculation of the factor of safely of a slope. The measurement of porewater pressure in the saturated zone is most commonly carried out using piezometers installed in boreholes. The time taken for the piezometer to respond to the change in pore pressure in the ground should be sufficiently short to give a meaningful accurate measure of the actual pore pressure. The response time required will depend on the rate of change of gorundwater pressures due to seasonal rainfall and individual storm events and the accuracy required. Due to the various factors within the hydrological cycle that affect groundwater flows, and hence peizometic levels, a wide range of piezometric responses can be anticipated. The principle ways in which piezometers may respond to rainfall can be considered as either:

i) A storm response, being short term – hours to days

ii) A seasonal response, being longer term – months to years, or

iii) A combination of both effects.

Therefore, by monitoring piezometer responses over a period of time it may be possible to estimate likely response to particular design storm events that could be expected within the design period being considered. The estimate would be based on the assumption that piezometric response is proportional to total rainfall but with due regard to factors such as storm duration, distribution of rainfall during the storm, antecedent groundwater conditions, timing of the storm relative to seasonal fluctuations. Such monitoring provides the first step in obtaining data necessary for analysis. Long term groundwater level records would allow a liable estimate to be made of the effect of pore pressure fluctuations on the stability of slopes.

The piezometric levels recorded since the installations were completed are as follows:

BOREHOLE No	DEPTH (m)	INITIAL PIEZOMETRIC level (m) (19/5/97)	CURRENT PIEZOMETRIC level (m) (23/10/97)
SP97-1	16.0	Dry	12.7
SP97-2	17.0	Dry	15.6
SP97-3	11.7	Dry	9.5
SP97-4	18.0	Dry	10.8
SP97-5	20.0	Dry	11.0

6.6.2 Slope Inclinometers

The slope inclinometer provides useful quantitative information by defining the level of maximum lateral movement. It provides the most definitive early warning system of an impending slope failure in comparison with other forms of instrumentation. Ground movement causes the slope inclinometer casing to move from its initial position to a new position. The rate, depth, and the magnitude of this displacement is calculated by comparing data from the initial survey to data from subsequent surveys. The inclinometer probe measures the tilt of the casing which is converted to a lateral distance. Deviation at on interval is called incremental displacement and the sum of the deviations is called cumulative displacement.

The inclinometer probe, control cable and readout unit are used to survey the casing. The probe measures the inclination or tilt of the casing. The inclination is measured by two force-balanced servo-accelerometers. One accelerometer measures tilt in the plane of the inclinometer wheels (the 'A' axis). The other accelerometer measures tilt in the vertical plane perpendicular to the wheels (the 'B' axis).

During the survey, the probe is drawn upwards from the bottom of the casing to the top. It is halted at half meter intervals for inclination measurements (two-foot intervals are used for English probes). To eliminate the offset errors, the probe is drawn through the casing twice. On the second pass, the probe is rotated in 180 degrees. During data deduction, the 0 and 180 degrees data are merged.

The Digitilt DateMate is a compact inclinometer readout that records data from the inclinometer probe. The DateMate stores over 10 000 data points in up to forty sets. The Datamate Manager software (DMM) creates a project database that holds records of inclinometer installations and data from inclinometer surveys. The data is transferred from he DataMate to the project database on the computer and is used to generate reports and simple graphs of displacement.

The results of the inclinometer survey at the Ravine Poisson site are included on the next few pages. An explanation of the calculation in the report is warranted. For example, for slope inclinometer installation SI97-1, the incremental displacement at 9.0m (30 ft) is 0.55 mm (0.0216 inches). See appendix C.

Incremental displacement = Deviation (current) - Deviation (initial)
= -0.0720 inches - (-0.0936) inches
= 0.0216 inches (0.549 mm)

Cumulative displacement Depth (n) = D1 + D2+.....+Dn
= 0.0072 + 0.0144+.....+0.0384
= 0.0036 inches (0.091 mm)

Slope inclinometter data is in Appendix C.

6.7 Evaluation and Interpretation

6.7.1 Rainfall Data

Transient slope movements and pore water pressures are essentially controlled by climate. if the monitored slope movements or pore pressures are to be used for prediction of stability under extreme design conditions, then it is necessary to be able to relate the measurements to the climatic events experienced. Rainfall is the simplest climatic variable to measure. Rainfall data is available from the nearby Bexon weather station for use in this study. The use of site specific rainfall measurements is likely to lead to the best correlation between rainfall, piezometer response and slope inclinometer movement.

6.7.2 Standpipe Piezometers Data

As peizometric data is collected after several readings, peizometric heads should be plotted on time graphs showing rainfall and other data that may influence the pore pressure response. If possible, piezometers should be monitored after each period of substantial rainfall during the rainy season to check pore pressure response. Monitoring in the dry season should be conducted once a month.

6.7.3 Slope Inclinometer Data

The slope inclinometer measures the change in slope over a certain depth interval during a period of time. It will record this change in slope at any depth within the limitations of the cable on which the probe is lowered. Once the active zone has been detected from successive sets of data, the rate of deformation can be determined by plotting the change versus time. Usually, the slide zone is only a few centimeters thick; hence, the sum of the changes over a few consecutive intervals will often be representative of the magnitude and rate of movement of the entire slide.

The deformation, slope change and casing profile most frequently are plotted versus depth. These plots, particularly those of change (different) and cumulative change (deflection) versus depth, are important steps in detecting movement and visualising what is occurring. The most useful plots are those that show changes in inclination; the zones of movement can most readily be detected and time plots at each zone can be initiated. The greatest asset of the slope inclinometer is its ability to measure change in inclination at a specific depth rather than to survey an exact profile of the borehole.

Slope inclinometer surveys should be conducted immediately after piezometer surveys are carried out during the wet and dry seasons.

6.8 Long Term Monitoring of Instrumentation

At the completion of the Watershed and Environmental Management Project, the responsibility of monitoring the instrumentation will be passed on to the Department of Engineering in the Ministry of Agriculture, Fisheries, Forestry and Environment. A period of training is currently ongoing for technicians and engineers who will be involved in this study over the long term. They are being trained to collect field data from the piezometers and slope inclinometers and to reduce he data on the computer for reports. The resident Geotechnical Engineer, Roosevelt Isaac, will be available in St. Lucia for consultation when necessary.

Annex 7

Appendix A

TO: Permanent Secretary, Ministry of Finance, Planning, Information Service and Public Service

27 November 1996

THE FIELD TRIAL PROGRAMME

1. Introduction

This document has been prepared at in order to highlight the problems which might be caused by the heavy rain, flooding and damage which occurred on the 25/26 October. At this stage it is intended to promote discussion, leading to an agreed programme.

The Consultants state in the Inception Report for Phase II of the Watershed and Environmental Management Project, submitted to the Government of St. Lucia (GoSL) on 30th October 1996.

"our concern at this stage related to the availability of sufficient staff and financial resources to carry out the programme between February and August 1997"

Much of the experience in the two Pilot Watersheds and hence the basis for extrapolation Island-wide, will occur when the consultants are away from St. Lucia. The importance of controlling progress during the period from February to the end of August 1997, already a matter for concern by the third week of the project, has been exacerbated by: the storm damage on 25th and 26th October. We believe that Government may wish to use the US$ 360,000 left over from Phase I of the Project to finance remedial works rather than fund the Phase II field trial programme.

2. Government of St. Lucia Obligations

Assuming these proposals are acceptable, GoSL's direct contribution would be limited to the following resources, most of which are already available to the Consultants;

- Staff for filed supervision together with material resources
- Fully equipped office and all services
- Secretary
- Two vehicles fully fueled and maintained
- Two drivers for the vehicles
- A reasonable level of GoSL co-operation in the execution of the project

3. The Trials Programme

An outline of the proposed trial programme was included in the Inception Report. This has been further developed and provisionally costed, but has yet to be discussed and agreed by GoSL.

The total cost of the full trials programme amounts to **EC$ 554,953,** but it must be emphasised that the actual extent of the programme will be affected by:

- the availability of funds;
- staff resources for supervision;
- relative value of the trials.

The final programme can only be agreed after a discussion involving all parties. The detailed costs are presented in appendix A.

3.1 Engineering and Bioengineering Trials

The engineering trials are seen as a integrated part of the other activities under the project comprising bio-engineering and the social and ecological acceptability of particular interventions.

As outlined in the Inception Report, a number of different types of trials are currently being investigated for possible implementation. A total of 11 different trial types have been outlined and descriptions and cost estimates accompany on individual 'Trial Description Sheets' attached at Appendix A. It is proposed that these trial options be discussed with Government in the context of funding, implementation and monitoring support which various government agencies can provide and the philosophy and relevance of the trial options from the Government's perspective. Thereafter a selection of trials to be implemented will be made, detailed topographical surveys carried out where necessary and each river channel erosion.

The total cost of engineering trials cold be **EC$ 319,153,** however there is a need for prioritising the work and it might be possible to eliminate some 40 percent of the proposals in the context of affordability and management capacity.

3.1 Agricultural Field Trials

3.1.1 Erosion and Run-off Control Trials

Sites would be under mature banana cultivation and under standard control conditions including:

- slopes within the range 20-35 degrees,
- application of fertiliser and lime at the recommended rate
- some surface drainage
- management at typical levels.

These 'standard conditions' typically lead to the following problems:

- the soil surface is not adequately protected against raindrop impact;
- the unprotected surface quickly suffers soil structure breakdown and a reduction in infiltration rate;
- surface wash movements then occur over the surface, removing fertiliser and topsoil;
- existing drains remove excess surface water, but also nutrient-rich topsoil;
- poor drain construction leads to slumping, gullying, etc.

At each field experiment site the following parameters would be measured:

- composite topsoil analysis: exchangeable cations, CEC, total and available P, organic C and N;
- sprinkler infiltrometer measurements;
- fresh banana root density;
- soil run-off;
- banana fruit yield;
- banana fresh-trash weight;
- Leaf Area Index (LAI).

At each site the following treatments would be investigated:

i) Control Conditions: involving some shallow surface drainage and banana trash left at random I piles;
ii) Even coverage of banana trash, pseudostems being cut into strips, and oriented along the contour; (trash would be obtained from production in situ).
iii) Even coverage of banana trash, but at double the density; (further trash brought in from flatter areas).
iv) Banana trash placed in lines on contour, and held by short stakes (trash obtained from production in situ)
v) As (iv) above, but with installation of tied contour drains (silt traps)

vi) As (v) above, but with banana trash also brought in from flatter areas to give double the standard application, (half of the trash would be used to cover the ground surface, the other half placed in lines on the contour and held by short stakes).

The design of the tied contour drains (silt traps) as in (v) and (vi) above, needs careful consideration and would not be advocated for the landslide-risk areas, as water retained o the contour could further increase landslide risk. The assessment of benefits of soils conservation (i.e. control of surface wash erosion) against the slightly increased risk of mass movements (landslides, etc) will be considered by the project.

3.1.2 Erosion and run-off measurements from natural forest, as a comparison to data from banana cultivated areas

Both sprinkler infiltrometer measurements and soil run-off measurements would be undertaken as a further control on the experiments on the banana fields. It seems likely that surface wash erosion losses are very low, and that surface infiltration rates are very much higher than in the case of banana cultivation on similar land. Because of increased infiltration rates, landslide risk for these areas may actually be higher than in the case of banana cultivation, particularly if some of the larger trees, with the strongest anchoring roots, are removed. (This correlated with the observation that recently reafforested land often shows the greatest landslide risk: deep tap roots anchoring the trees into the bedrock are not yet established, but the higher infiltration afforded by the good vegetation and litter cover increased water content of the subsoil and hence risk of mass movements).

3.1.3 Investigation of banana yield/profitability with respect to gradient

Banana yields, quality ratings and labour inputs would be measured from a number of sites covering the slope range 15-35 degrees. Net profitability would then be related to the following:

- slope gradient;
- age of holding, fertilizer use, and soil fertility status;
- distance of road access to boxing plant;
- distance of boxing plant to lading point.

Much of the very steep land (say over 25 degrees) now cultivated to bananas would be very marginal, and with falling banana prices land may come out of cultivation in the next few years. However, figures to support this premise are required, both in terms of yields per acre, and in use of labour and transportation resources per ton of bananas. For steep areas near motorable roads, it is likely that labour costs will be low irrespective of slope: these lands may need particular attention, as inappropriate land use practises may still be profitable.

Cost detailed in Appendix A total **EC$ 41,000**

A2 Agricultural Trials

Transport

Assuming that both government vehicles were used full time on the trials programme, this would leave the consultants without transport during the September to November 197 period. This can only be rectified by hiring vehicles. The cost would be;

150 vehicle days at EC$140/day		21,000
Fuel 20 weeks at EC$100/week		2,000
	Sub-total	EC$ 23,000

Materials

Miscellaneous locally purchased equipment
for the Erosion and Run-off Control Trials

	Sub-total	EC$ 5,000

Soil Samples

2 watersheds x 2 sites x 7 treatments x 2 time intervals x EC$100/sample	Sub-total	EC$ 5,600

Water Samples

2 watersheds x 2 locations x 4 time intervals at EC$100/sample	Sub-total	EC$ 1,600

Labor

1 field labourer would be required to accompany the extension officer during routine activities plus 3 labourers at each site to set up trials.

Total requirements:2 watershed x 3 sites x 6 mandays @ EC$25/manday		900
2 watersheds x 1 manday/week x 50 weeks EC$ 25/manday		2,500
Honoraria to Farmers (for Rainguage Measurements, etc)		
4 farmers x EC$50/month x 12 months		4,400
	Sub-total	EC$ 5,800

Supervision

Trials would be undertaken by the extension staff from the Dennery Office (Dennery Watershed) and the Bexon Office (Cul de Sac Watershed). After the first few weeks when apporx. 2-3 days work/week would be required from each office, approx. 1 day per week at each watershed would be required.

Total requirements for **Extension staff:**

2 watersheds x 2 days/week x 4 weeks		16 staff days
2 watersheds x 1 day/week x 50 weeks		100 staff days
Field days/seminars: 2 watersheds x 4 staff x 3 days		24 staff days
	Total	140 staff days

Total requirement from **Local Consultants**

2 day/month for each watershed: i.e. 4 days/month x 9 months		
	Total	36 staff days

Summary

Transport			EC$ 23,000
Materials			5,000
Sample Analysis			7,200
Labor			5,800
Supervision:	Extension Officers		140 staff days
	Local Consultants		36 staff days
		Total	**EC$ 41,000**

3.2 Institutions and Socio-Economic Investigations

3.2.1 The Programme

The Land Conservation and Improvement Act of 1992 provides an appropriate legislative vehicle for the institutions/socio-economic investigations in the two watersheds. Unfortunately the Land Conservation Board (LCB), which should spearhead land conservation and improvement work has only met once (in November 1995) and is unlikely to be of much help during the lifetime of the Project. The proposed approach, which has the blessing of the Chairman of the LCB (Permanent Secretary, Ministry of Agriculture, Fisheries, Forestry and Environment), is to attempt to involve the stakeholders by the establishment and steady development of Land Conservation and Drainage Committees LCDCs) in the two Pilot Watersheds.

Unlike the physical trials programme, community participatory programmes such as those envisaged, can not be simply terminated at the end of a year (the catastrophic results of an early withdrawal of support are well documented as are the difficulties of re-staring programmes amongst discouraged and cynical communities). The ENCORE project, has been involved in participatory management work in the Soufriere, Anse La Raye and Canaries areas since 1992, and would be the first to emphasise the difficulties involved.

We proposed to appoint a full time LCDC Co-ordinator (Ms J Raynold) and for the reason set out above, a two year institutions/socio-economic programme is desirable, which would allow one year for the Consultant's final report to be considered and the subsequent implementation programme agreed. It should be noted that the second year of the programme would not involve expatriate staff inputs and could for instance, be linked to the ENCORE project/OECS or GoSL.

3.2.2 Costs

a) Staff Costs

		EC$/Year	
		Yr1	Yr2
LCDC Co-ordinator		75,000	
LCDC Co-ordinator			79,000
On cost @ 20 percent		15,000	15,800
	TOTAL	**90,000**	**94,800**

b) Other Costs

Vehicle mileage and incidental costs		3,000	3,000
LCDC Operating costs (workshops, travelling costs and incidentals)		2,000	2,000
	TOTAL	**95,00**	**99,800**

St Lucia Watershed and Environmetal Management Project

Field Trial Title : River Maintenance Programme

Field Trial Number: ENG.1

Basis: Engineering

River Catchment: Dennery

Location: Dennery main channel from Main Bridge to Ravine Saut (approx 5kms)

Objective: To evaluate the mechanisms for the execution of a regular river channel maintenance programme.

Scope:

To evaluate:
- staffing requirements;
- equipment requirements;
- method of working;
- level of acceptance and approval necessary from riverine landowners;
- reporting methods;
- cost details (cost/km of channel of different types);
- time requirements;
- budget needs.

Requirements for Trial:

	Unit	Quantity	Unit Rate $	Cost
Staff				
Supervisor	mm	0.5	10,000	5,000
Technician	mm	1	4,000	4,000
Labourers (2 number)	mm	2	2,000	4,000
Logistics				
Vehicle & driver	v.month	1	5,000	5,000
Equipment				
50m tape	Sum	2	30	60
Notebooks/diary	Sum	1	20	20
Chain saw	Number	1	2,000	2,000
Heavy Machinery				
Truck (rental)	days	5	500	2,500
Excavator (rental)	days	5	1,000	5,000
		Estimated cost		27,580

Issues:

Activity is currently undertaken by Government but not systematically. Trials could be extended to different river channels to assess input and cost differences.

4.2.2 Detailed Description

A Objective

To evaluate mechanisms of the improvement of river maintenance activities through the establishment of regular channel inspections, reporting and maintenance work. it is intended that this will alleviate flooding problems and flood damage during storm events.

B River Channel Inspection

On a regular basis, a predetermined length of river channel will be 'walked' by a river maintenance technician and a labourer. The equipment to be carried during an inspection shall include:

I. Notebook, pens, measuring tape;
II. Pot of orange (or other colour) paint plus paintbrush (plus turpentine, rage etc);
III. Machete.

It will be useful if a 1:10,000 map (or 1:2, 500) map of the river system is obtained to enable locations to be defined. A standard map should be produced indicating key features in the vicinity of the river channel to provide key location markers. Either location names or chainages can be used to identify positions on the river network. These should be marked on the map and easily identifiable on the ground. (It is easiest if the River Technical Officer does this and provides an explanation plus map o the WMAF). One of the first tasks will be to locate on the map the property boundaries which reach the river's boundary (and floodplain where appropriate) with owners names and farmers names.

(Note LB: Left bank of the river looking downstream; RB right bank of the rive looking downstream).

Prior to the field inspection, the WMAF should be consulted of the proposed dates or period of the inspection. Particular problems known to the WMAF should be brought to the attention of the Inspection Team prior to the inspection visit.

The inspection will look out for and note the following:

- The existence of landslide which could have blocked part of all of the channel. During a low flow situation, this might not appear to be a problem, however, the technician must judge as to whether the slip will impede a flood flow or result in a high movement of soil down the river system; (the location needs to be noted in the 'Field book' together with the estimated man-power required to remove the material and whether equipment, excavator or truck is for the removal. The implications on the stability of the rest of the bank will need to be assessed and the landowner contacted and a solution obtained. Should any problems arise, then this should be noted and the WMAF be notified).

- The existence of fallen trees or poles which could cause a partial blockage of the channel as floating debris collects on the branches or trunk. Again the flood flow scenario needs to be envisaged; (the location needs to be noted and the manpower and equipment requirements to clear the debris is to be noted. The possible need for chain saw should be noted. A check on the ownership of the tree should be made. However, if it is lying in the river, then it should generally be assumed that there is no owner. (The WMAF need to pass this message out into their Watershed area during their activities).

- The existence of trees overhanging the channel. Overhanging trees which look unstable or where it is considered the removal of upper branches/canopy might reduce the risk of the tree toppling into the channel should be noted. Branches should be removed that overhang the river whilst those on the opposite side of the tree need to be left. It will normally be important to leave the main art of the tree in place since the root structure plays an important role in bank stabilisation; (the location is to be noted whilst the landowner on whose property should where possible be contacted and the need for lopping etc explained and approval sought. If difficulty arises, a note should be made to inform the WAMF of the issue should be made. The tree in need of lopping/trimming should be marked with the orange paint, ideally at the cut points proposed. The need for chain saw and other equipment should be noted. A note should be made of the need for a truck to help movement should be made. If the lopped portion has a financial value, such should be noted and intimated to the owner to resolve the mechanism for sale or handling across to the owner).

- Any road bridges or culverts on the main river should be checked for integrity, this should include a visual inspection of the piers and abutments as well as the existence of accumulated debris. (Any evidence of structural failure or deteriorating condition of mortar or concrete needs to be noted and intimated to the relevant staff of the Ministry of Communications, Works, Transport and Public Utilities. Any major debris accumulation should be cross drainage structure is under capacity, this should also be noted and intimated to the WAMF and MCWT&PU).

- The condition of river banks should be inspected, especially where vegetation has been removed or where farming practices have moved very close to the river bank causing potential risks to the stability of the bank. (Any evidence of such activities should be noted and brought to the attention of the WMAF for them to discuss the issue with the relevant farmer at a later date).

- The stability of river banks should be assessed during the reconnaissance visits particularly where river movement and river bank erosion is compromising the integrity of roads, services, buildings or other infrastructure. (This should be noted and brought to the attention of the WAMF in case a rapid deterioration cases damage and disruption. Plans should be put n place to instigate emergency protective measures. This could include palisading, gabion work, dumped stone and/or bio-engineering works (separate trials are being carried out to investigate the manner of undertaking and the effectiveness of these measures). Designs and implementation of the work then be undertaken either local labour/materials or through a contract arrangement with a local contractor).

- A reconnaissance of the flood plain should be undertaken to ensure that no new physical works have been undertaken or are planned to be undertaken (by discussion with local people) in the floodplain. New major drainage channels built by farmers or others are also important. (Any evidence or new or proposed development should be noted and brought to the attention of the WAMF. Any major new development such as school or large building must be brought to the attention of the planning authority).

- A visual inspection should be made of the quality of the water in the river system, particularly of inflows form minor tributaries or drains from /households. (This condition should be noted and if a deterioration is evidenced between one visit and another the WAMF should be notified).

C River Inspection Report

Upon completion of the river survey and River Inspection Report should be produced summarising the findings of the survey and detailing the works which need to be carried out during a maintenance programme. This maintenance programme should be costed in terms of time and expense and identify the need for heavy equipment and separate contracts for major works. The report should also note the time it took to undertake the river inspection.

The Report should be brief and take advantage of a standardised reporting form. An tentative proposal is given herein.

D Maintenance Activities

Based on the recommendations of the brief 'River Inspection Report' a programme of maintenance would be put together.

Prior to the execution of the maintenance programme, contact should be made with the WMAF to confirm that the works proposed were acceptable and that, if farmer/landowner permision was required for some of the activities, that the WMAF had or would undertake this liaison exercise before the particular works were undertaken.

The programme would be based on minimising the use of heavy equipment by taking most of the manual work in the first place. Heavy equipment and a truck would next be brought in to clear away debris or assist in some of the activities.

Upon completion of the maintenance works, a note indicating completeness should be sent to the WMAF together with a note of any problems encountered during the execution of the works. This could include the need to further discuss activities with local landowners and/or farmers or the need to monitor particular areas on a regular basis. If disputes arose during the works, these should also be reported to the WMAF.

E River Maintenance Programme

It is recommended that the River Maintenance Inspection is carried out in

- early October;
- late January;
- late July.

At any other time as requested by the WAMF.

It probable that the major maintenance programme will be undertaken as a result of the late January inspection. This would be the major preventative maintenance programme.

Emergency programmes, being mainly river channel clearance would be the main activity in early October and as a result of WMAF requests.

Dennery River Maintenance Programme

River Inspection Summary

Period of Inspection ______

Sheet ______ **of** ______

River Technical Officer : ______

Work Technician : ______

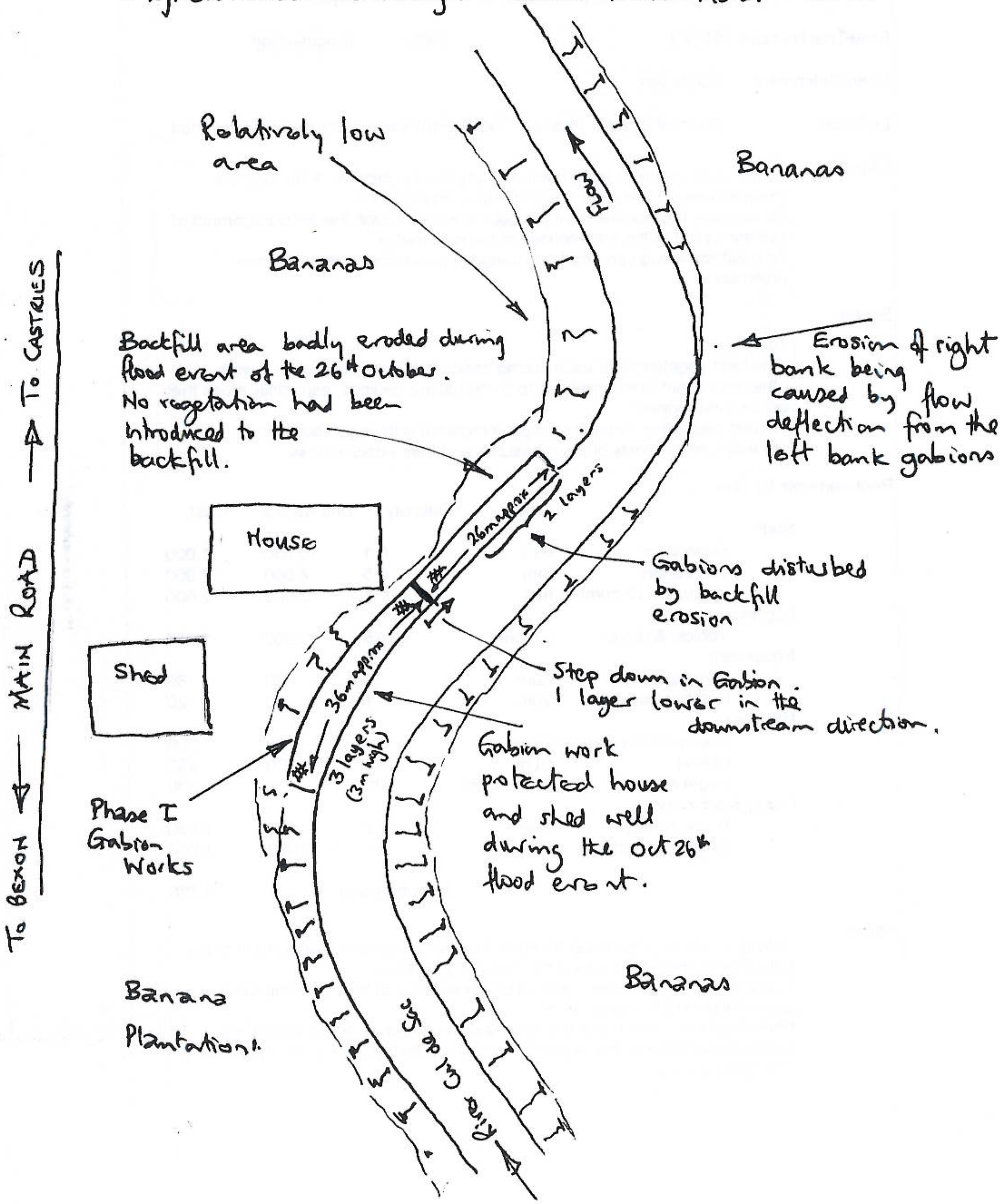
Chain--age	Description of Location {including name of farmer /owner)	LB	RB	Landslide	Trees Fallen	Trees Overhang	Slope Stability	Risk to Services	Risk to Buildings	Road Bridge	Road Culvert	Floodplain Development	Water Quality	Other

Notes:

Comments for columns: urgent / severe/ major/ average/ slight >>

File : river-m.wk4

MODIFICATION TO PHASE I WORKS AND PROTECTION OF RIVER BANK: EXISTING – Agricultural Setting: ENG. TRIAL No.2.



St Lucia Watershed and Environmetal Management Project

Field Trial Title : Vegetation and protection of Gabion Mattresses

Field Trial Number: ENG.2 — Basis: Engineering

River Catchment: Cul de Sac

Location: South of Bexon : Phase 1 Gabion Protection of house and main road

Objectives:

To improve on the overall structural integrity of gabion work through the minimisation of damage through the erosion of backfill.
To increase the 'solidness' of the gabion work through the encouragement of sedimentation within the intercies of the rock matrix.
To establish design and material usage in palisading + vegetal slope protection.

Scope:

To evaluate:
- the best vegetation for establishing itself within gabion protection work;
- the form of protective material to place behind gabions, especially those that will be over-topped;
- to test palisading design concepts integrated with vegetation work;
- to estimate the costs of the measures and their effectiveness.

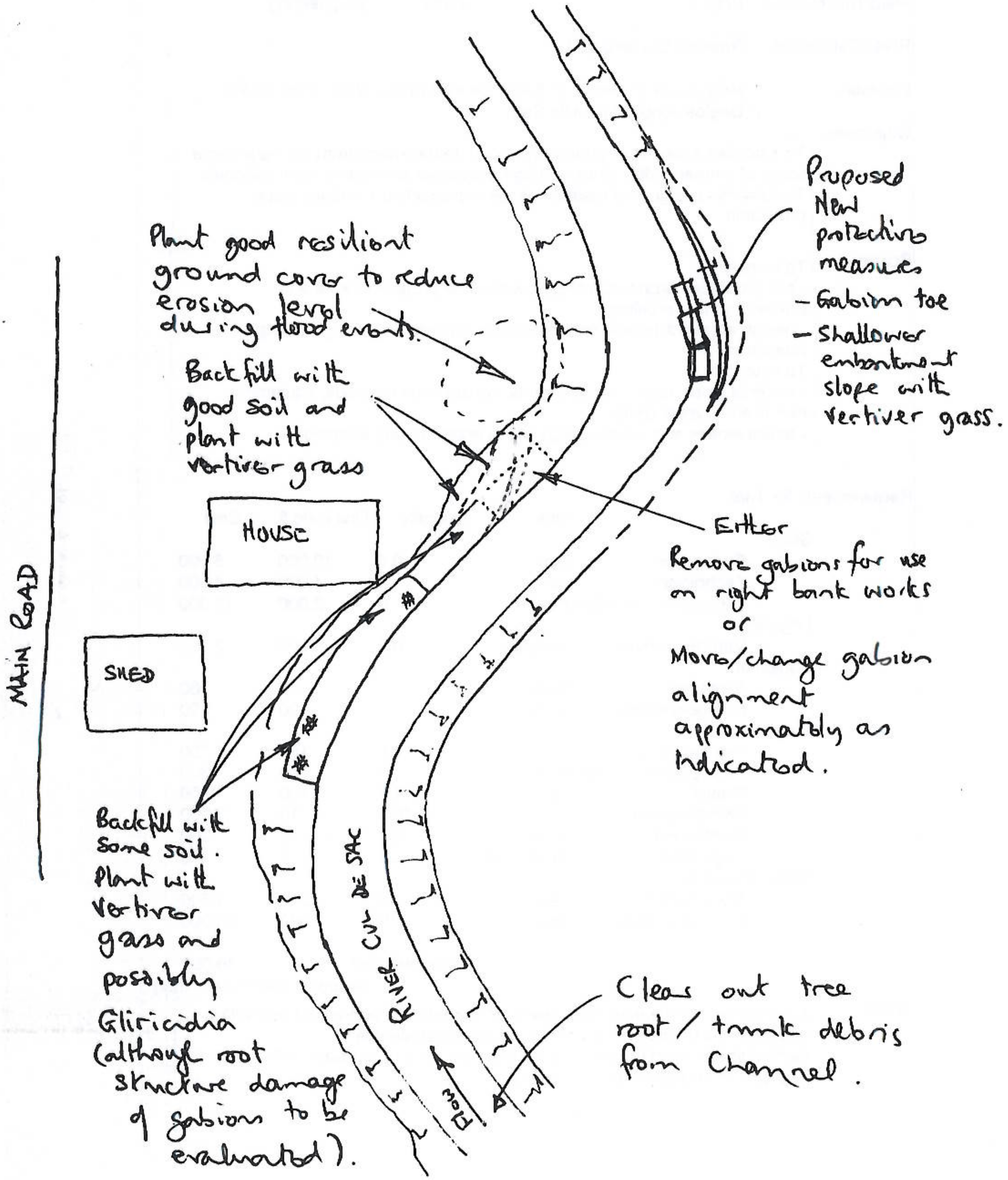
Requirements for Trial:

		Unit	Quantity	Unit Rate $	Cost
Staff					
	Supervisor	mm	0.1	10,000	1,000
	Technician	mm	0.5	4,000	2,000
	Labourers (2 number)	mm	1	2,000	2,000
Logistics					
	Vehicle & driver	v.month	0.25	5,000	1,250
Equipment					
	50m tape	Sum	2	30	60
	Notebooks/diary	Sum	1	20	20
Materials					
	Rock pitching materia	cu.m	3	100	300
	Gravel	cu.m	4.5	100	450
	Vegetation	Nr of plants	100	2	200
Heavy Machinery					
	Truck (rental)	days	3	500	1,500
	Excavator (rental)	days	1	1,000	1,000
			Estimated cost		9,780

Issues:

Activity would be seen to be linked to the shortening and re-alignment of the gabion work dislodged during the October 26th flows.
Some palisading protection should be undertaken of the right embankment downstream of the gabion work.
Photographic monitoring of the work should be carried out to assess the establishment rate of the vegetation and the effectiveness of the measures during flood events.

MODIFICATION TO PHASE I WORKS AND PROTECTION OF RIVER BANK : PLANNED – Agricultural Setting : ENG. TRIAL No. 2.



St Lucia Watershed and Environmetal Management Project

Field Trial Title : **Vegetation and protection of steep riverbank adjacent to road**

Field Trial Number: ENG.3 — Basis: Engineering

River Catchment: Roseau/ Cul de Sac

Location:
1 Morne d'Or (Roseau) {0.5 km due east of the West Coast Road}
2 Deglos Junction (Cul de Sac)

Objectives:

To establish a means of protecting a road embankment from the aggressive scour of a meandering stream using local labour and mainly local materials.
To establish design and material usage in palisading + vegetal slope protection.

Scope:

To identify:
- soil properties, slope stabilities, low cost toe protection work and embankment re-profiling;
- design approaches and material usage in palisading + vegetal slope protection.

To evaluate:
- material types, labour requirements, construction methods, equipment needs and overall costs;
- effectiveness and shortcomings of the approach(es) adopted.

Requirements for Trial:

		Unit	Quantity	Unit Rate $	Cost
Staff					
	Supervisor	mm	0.5	10,000	5,000
	Technician	mm	1	4,000	4,000
	Labourers (4 number	mm	6	2,000	12,000
Logistics					
	Vehicle & driver	v.month	0.5	5,000	2,500
Equipment					
	50m tape	Sum	2	30	60
	Notebooks/diary	Sum	1	20	20
Materials					
	Toe gabion work	cu.m	45	150	6,750
	Rock pitching materia	cu.m	3	100	300
	Gravel	cu.m	4.5	100	450
	Wooden poles	l.m	300	10	3,000
	Brushwood	sq.m	150	2	300
	Vegetation	Nr of plants	100	2	200
Heavy Machinery					
	Truck (rental)	days	3	500	1,500
	Excavator (rental)	days	10	1,000	10,000
			Estimated cost		46,080

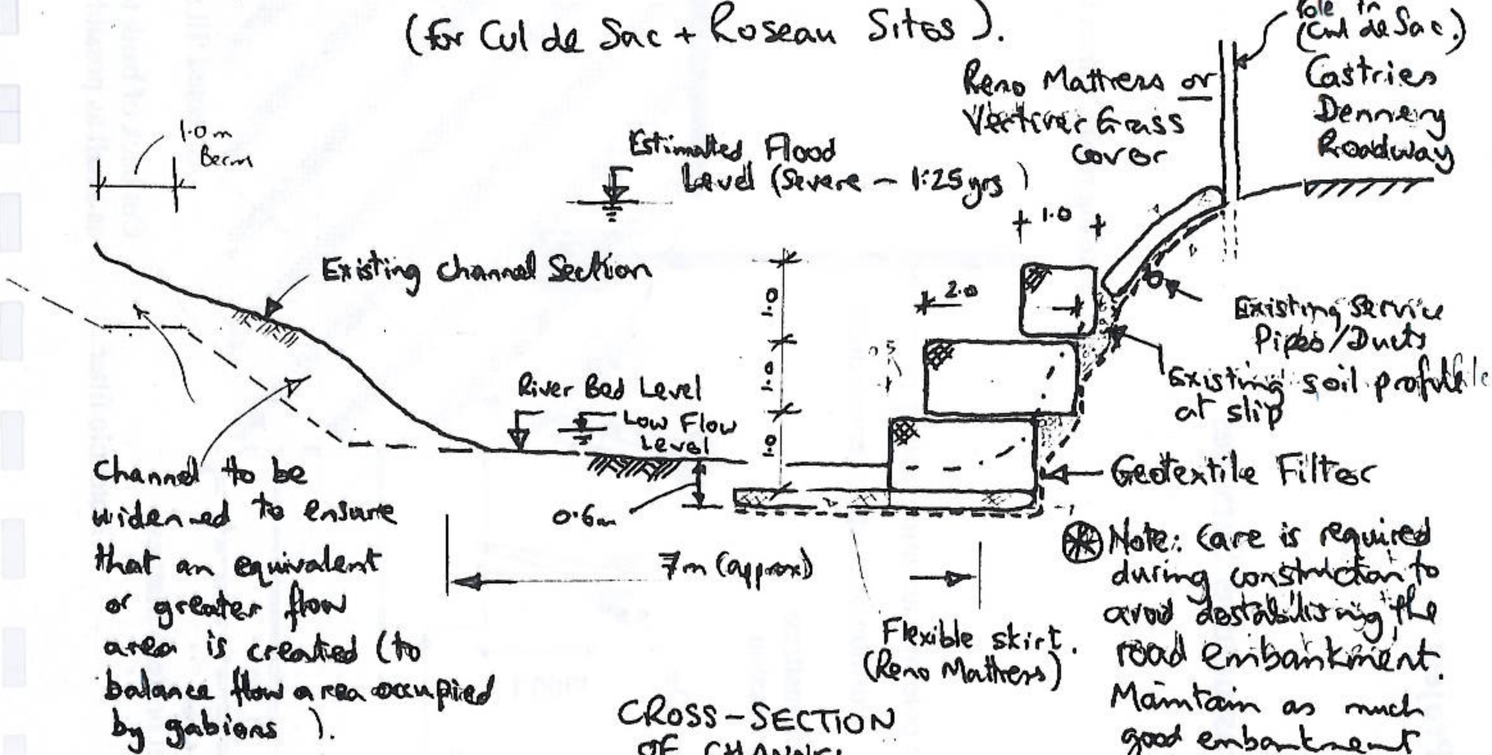
{approximate for each trial}

Issues:

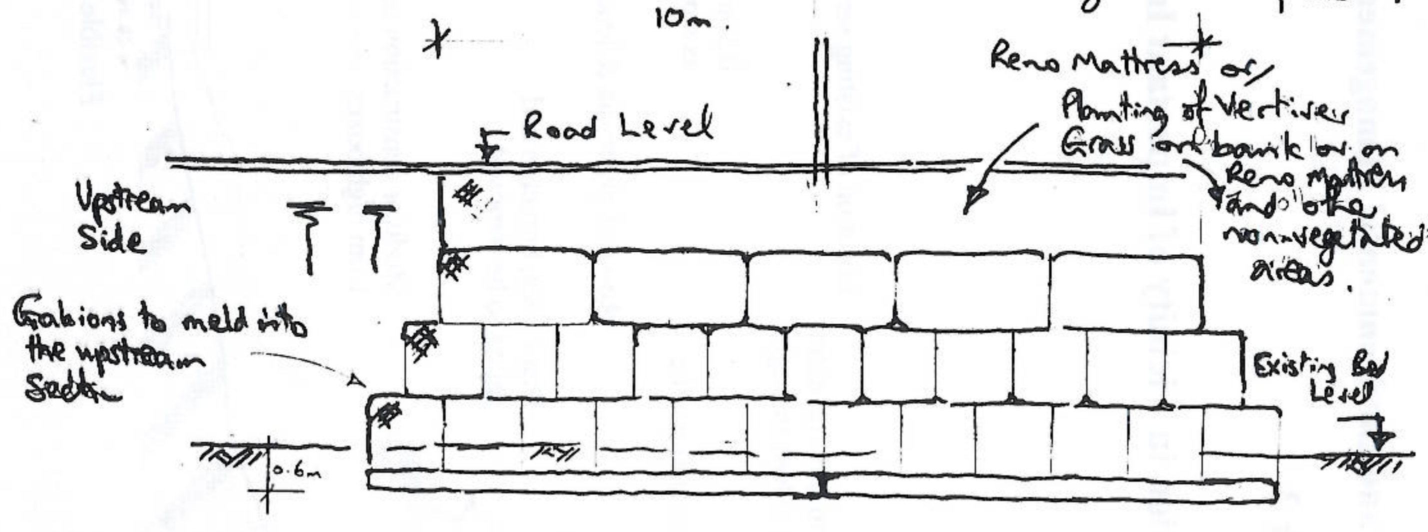
An essential intervention. One which will probably be addressed by PWD in any case. Costs to the 'Field Trials' therefore debateable.
Gabion shells could be obtained from the cut back units from the River Cul de Sac gabion vegetation protection trial.

ENGINEERING TRIAL NUMBER 3.

Protection of Steep River Bank near Major Road and/or and Services Area
(for Cul de Sac + Roseau Sites).



CROSS-SECTION OF CHANNEL



Note – designed for 12m protected length. Increase in steps of 6m (?).

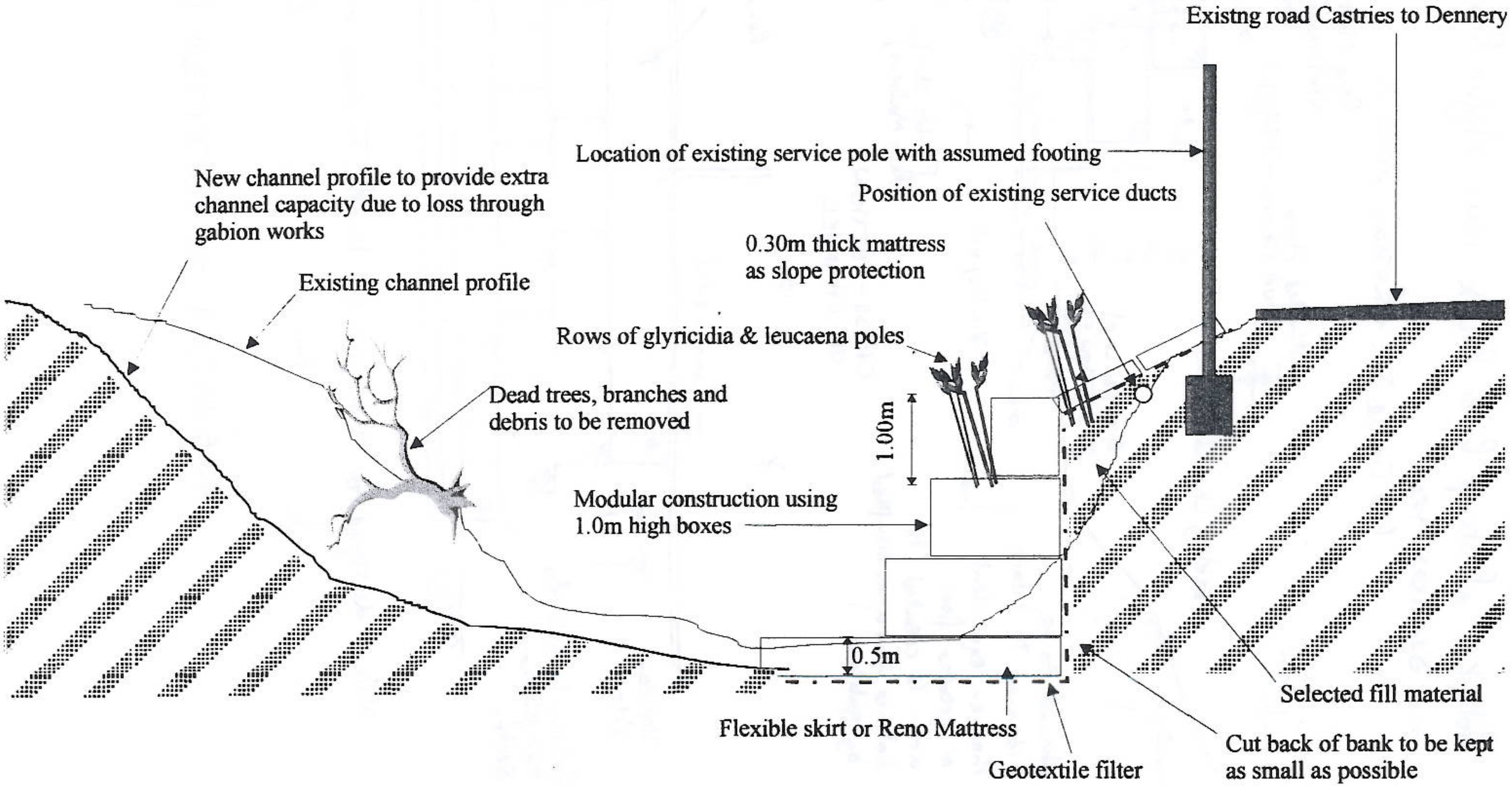
6m 6m

ELEVATION ON PROTECTED RIVER BANK.

St Lucia Watershed and Environmental Management Project

Engineering Trial Nr 3

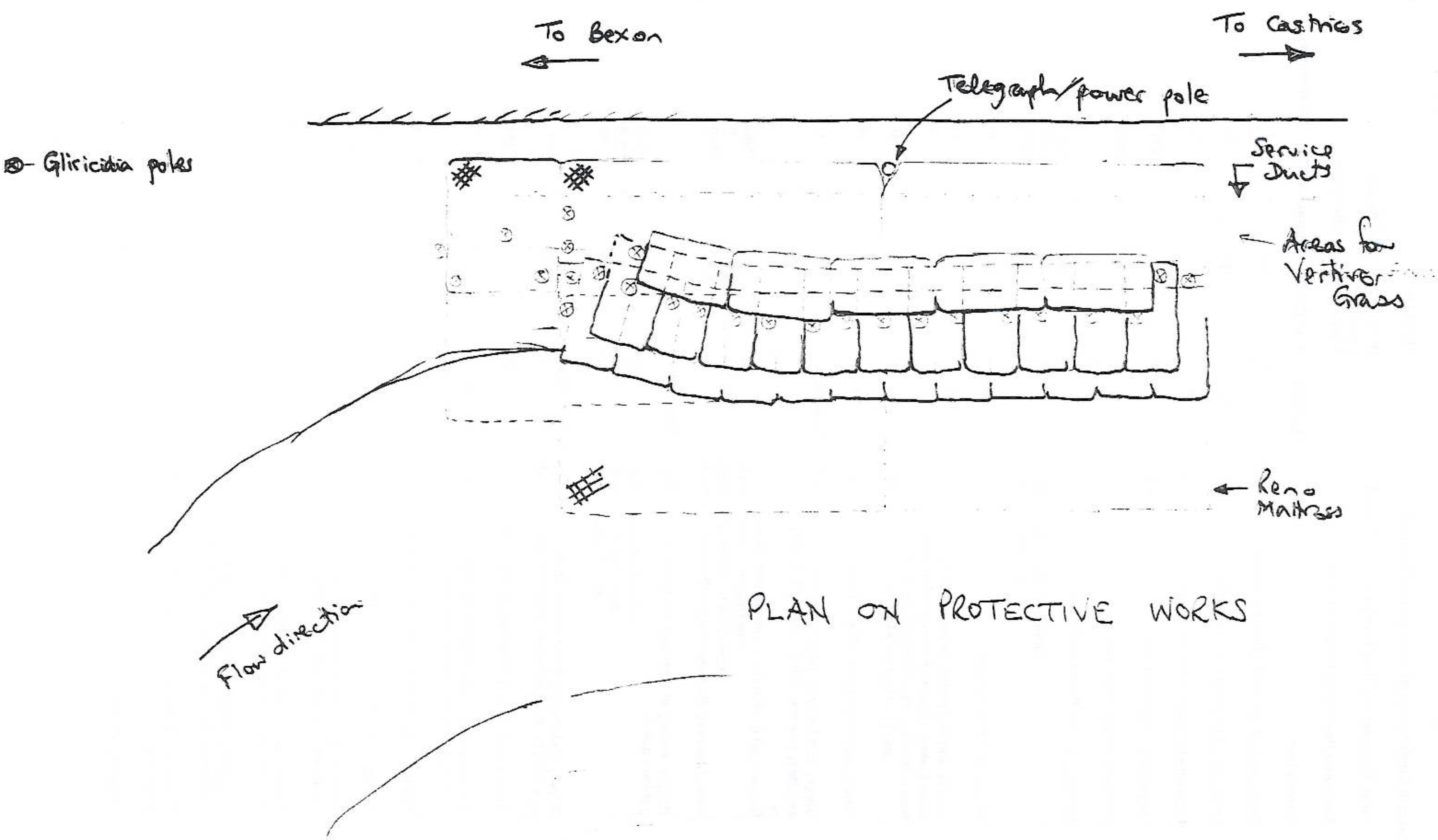
River Bank Protection in Vicinity of Important Infrastucture/ Services



Watershed and Environmental Management Project

River Engineering Trial Number	**Eng 3.**	**Sheet Nr**	
Assumed Protective length of 12m		**River Location**	**Cul de Sac**
			South of Bexon : Services

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)	Comments
	Excavation of topsoil & place for re-use	m3	20	25	500	
	Excavation in river bed to 1m depth	m3	Nil	60	0	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	20	15	300	
	Removal of light vegetation	m2	50	2	100	
	Removal of tree (by girth of tree)					
	>1m	Nr	4	400	1600	
	200mm to 1000mm	Nr	10	300	3000	
	<200mm	Nr	20	200	4000	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) (installation by driving stakes into soil)	m	Nil	12	0	
	ditto but 150mm diameter	m	6	25	150	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking or	m3	See below	150	0	
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	28	280	7840	
	0.5mx1mx1m (0.5m3)	each	Nil	260	0	
	Reno Mattress 200mmx2mx6m (2.4m3)	each	7	1030	7210	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	56	45	2520	
	60 to 199mm	m3	16.8	42	705.6	
	20 to 59mm	m3	2	41	82	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under 2	110	220	
	Supply and placing of geotextile material	m2	118	19	2242	
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.import)	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets with approved soil with specified compaction.	m3	5	25	125	
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2	20	25	500	
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr	22	14	308	
	Supplying, placing and fixing brushwood or similar.	m3	Nil	?	0	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	31,402.6	



PLAN ON PROTECTIVE WORKS

Watershed and Environmental Management Project | **Sheet Nr** |

River Engineering Trial Number Eng 4. A

River Cul de Sac

Location Upstream of Marc Marc Br.

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)	Comments
	Excavation of topsoil & place for re-use	m3	Nil	25	0	
	Excavation in river bed to 1m depth	m3	Nil	60	0	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	Nil	15	0	
	Removal of light vegetation	m2	20	2	40	
	Removal of tree (by girth of tree)					
	>1m	Nr	Nil	400	0	
	200mm to 1000mm	Nr	Nil	300	0	
	<200mm	Nr	Nil	200	0	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) {installation by driving stakes into soil}	m	27	12	324	
	ditto but 150mm diameter	m	136	25	3400	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking or	m3	See below	150	0	
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	Nil	280	0	
	0.5mx1mx1m (0.5m3)	each	Nil	260	0	
	Reno Mattress 200mmx2mx6m (2.4m3)	each	Nil	1030	0	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	Nil	45	0	
	60 to 199mm	m3	Nil	42	0	
	20 to 59mm	m3	Nil	41	0	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under 3	110	330	
	Supply and placing of geotextile material	m2	Nil	19	0	
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.import)	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets or other with approved soil with specified compaction.	m3	3	25	75	
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2	4	25	100	
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr	6	14	84	
	Supplying, placing and fixing brushwood or similar.	m3	1	5	5	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	4,358.0	

St Lucia Watershed and Environmetal Management Project

Field Trial Title : Rock and Vegetation Crib Design as a Hard Point in a River

Field Trial Number: ENG.4 — Basis: Engineering

River Catchment: Cul de Sac

Location:

Objectives: To establish a construction method using local materials, vegetation and labour to create a resilient hard point in a river to discourage river movement in all but the most extreme flood flows.

Scope:

To evaluate:
- availability and adaptability of materials of different types to a crib type structure;
- the undertake design of structure for a specific location;
- to identify construction methods, costs and time factors;
- to design method of linking structure to existing major trees;
- to recommend improved approaches.

Monitor performance of the structure during flood events; estimate fllod severity level..

Requirements for Trial (each site):

		Unit	Quantity	Unit Rate $	Cost
Staff					
	Supervisor	mm	0.1	10,000	1,000
	Technician	mm	0.4	4,000	1,600
	Labourers (3 number)	mm	1	2,000	2,000
Logistics					
	Vehicle & driver	v.month	0.15	5,000	750
Equipment					
	50m tape	Sum	2	30	60
	Notebooks/diary	Sum	1	20	20
Materials					
	Rock pitching materia	cu.m	3	100	300
	Wooden poles	l.m	70	10	700
	Brushwood	sq.m	100	2	200
	Vegetation	Nr of plants	50	2	100
Heavy Machinery					
	Truck (rental)	days	2	500	1,000
	Excavator (rental)	days	0	1,000	0
			Estimated cost		7,730

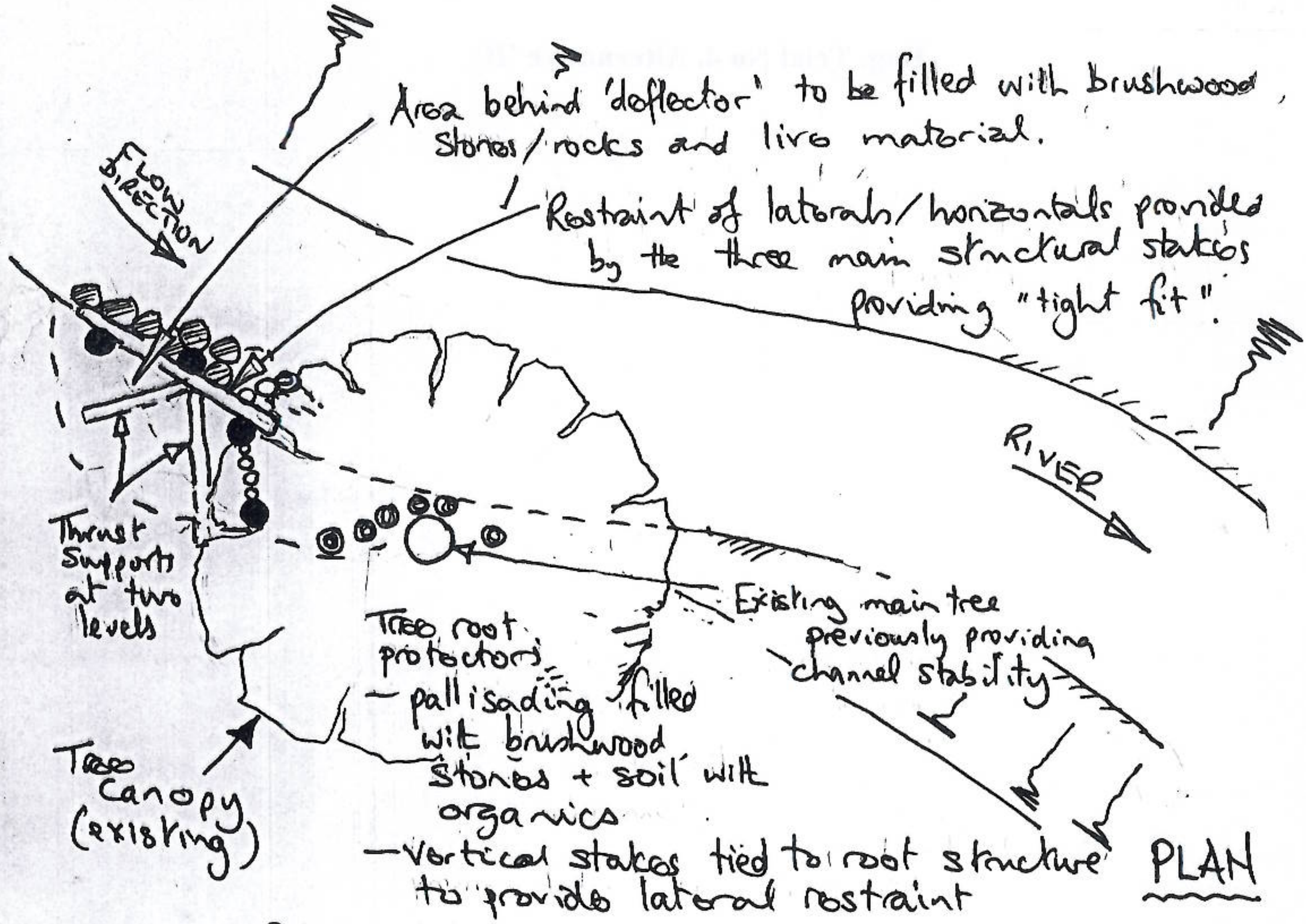
{Several types at different locations}

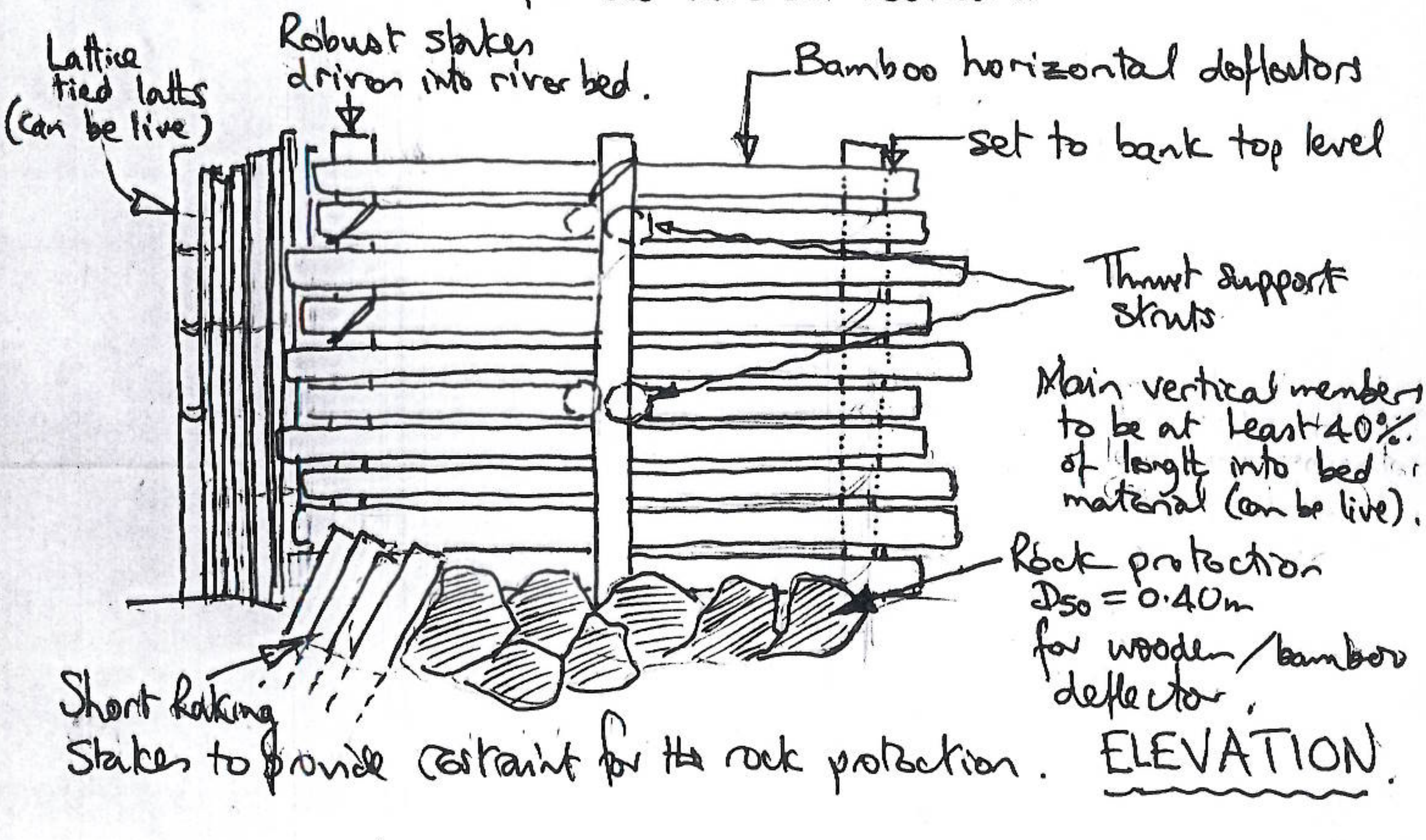
Issues: Although only one trial is initially proposed, several different designs could be tried if funds, management capacity and time permit.

Typical Layout of Double Crib arrangement for protection of a section of a river bank.

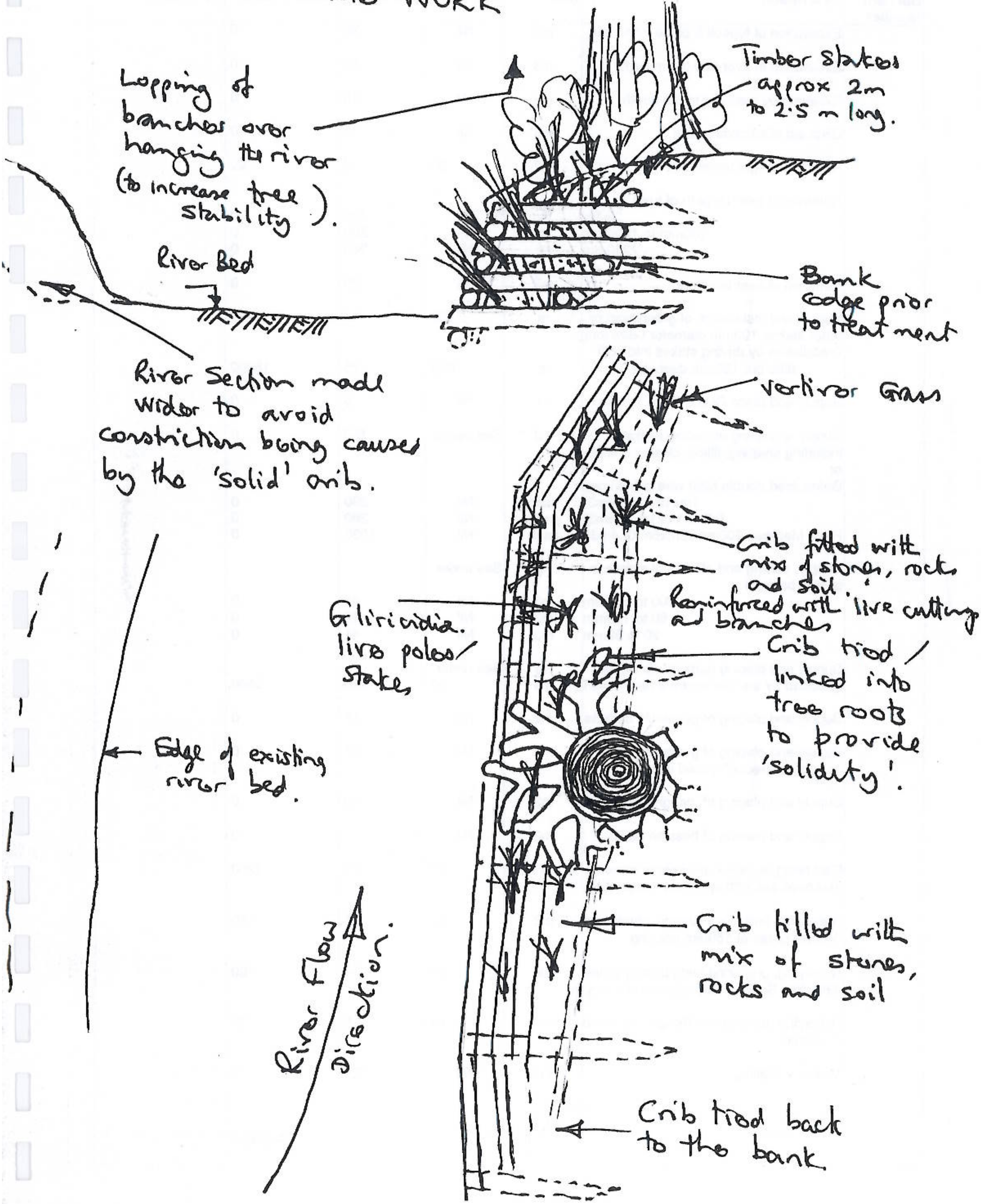
Eng. Trial No 4. Alternative 'B'.

DEFLECTOR STRUCTURES TO PROTECT MAJOR FEATURES AND TO "RESTABILISE" RIVER SECTIONS.





PROTECTION OF MAJOR TREES THROUGH INTEGRATION OF DOUBLE TIMBER CRIB WORK



Watershed and Environmental Management Project | **Sheet Nr** |

River Engineering Trial Number Eng 4. B | **River Location** Cul de Sac

Estimate for 30m of double crib protection | Upstream of Marc Marc Br.

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)	Comments
	Excavation of topsoil & place for re-use	m3	Nil	25	0	
	Excavation in river bed to 1m depth	m3	Nil	60	0	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	Nil	15	0	
	Removal of light vegetation	m2	30	2	60	
	Removal of tree (by girth of tree)					
	>1m	Nr	Nil	400	0	
	200mm to 1000mm	Nr	Nil	300	0	
	<200mm	Nr	Nil	200	0	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) {installation by driving stakes into soil}	m	160	12	1920	
	ditto but 150mm diameter	m	600	25	15000	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking or	m3	See below	150	0	
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	Nil	280	0	
	0.5mx1mx1m (0.5m3)	each	Nil	260	0	
	Reno Mattress 200mmx2mx6m (2.4m3)	each	Nil	1030	0	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	Nil	45	0	
	60 to 199mm	m3	Nil	42	0	
	20 to 59mm	m3	Nil	41	0	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under 50	110	5500	
	Supply and placing of geotextile materia	m2	Nil	19	0	
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.impor	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets or other wi approved soil with specified compaction.	m3	50	25	1250	
	Supplying, preparing surface, planting o Vetiver grass at 150mm spacing	m2	30	25	750	
	Supplying, preparing and planting 'poles Gliricidia Sepium (1m approximate length)	Nr	50	14	700	
	Supplying, placing and fixing brushwood or similar.	m3	13	5	65	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	25,245.0	

St Lucia Watershed and Environmental Management Project

Field Trial Title : Bank Stabilisation in New Cut or Re-aligned Section of River

Field Trial Number: ENG.5 — Basis: Engineering

River Catchment: Roseau

Location: Current Loop Cut

Objectives: To improve on the existing construction technique of a regular trapezoidal section for any new channel.
The intention being to reduce slips and loss of section which cause an irregular bed profile.

Scope:
To:
- reprofile the side slopes of the river to a more realistic side slope profile with the inclusion of a berm to reduce susceptibility to slips;
- introduction of vertiver grass or similar on the new profile to provide an erosion resistant cover and a rooting system to help reduce slip tendencies;
- where required, identify lateral drain inflow locations and make energy dissipation provisions for the entry of such lateral flows
- monitor the establishment of the vegetation and the performance of the channel section during subsequent flood events against previously identified

Requirements for Trial (each site):

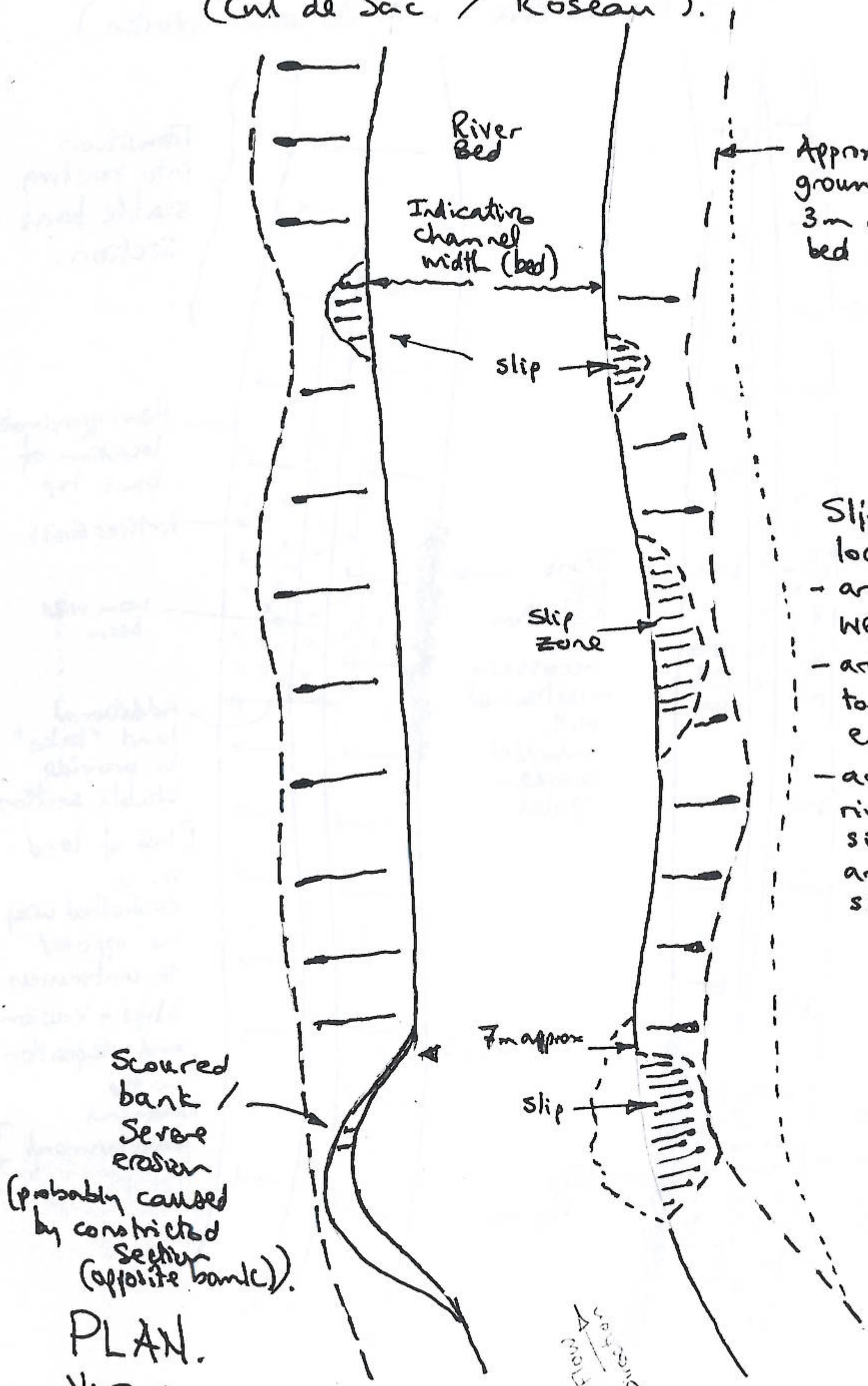
		Unit	Quantity	Unit Rate $	Cost
Staff					
	Supervisor	mm	0.1	10,000	1,000
	Technician	mm	0.2	4,000	800
	Labourers (2 number)	mm	1	2,000	2,000
Logistics					
	Vehicle & driver	v.month	0.15	5,000	750
Equipment					
	50m tape	Sum	2	30	60
	Notebooks/diary	Sum	1	20	20
Materials					
	Rock pitching materia	cu.m	0.3	100	30
	Wooden poles	l.m	10	10	100
	Brushwood	sq.m	10	2	20
	Vegetation	Nr of plants	1000	2	2,000
Heavy Machinery					
	Truck (rental)	days	0.5	500	250
	Excavator (rental)	days	0	1,000	0
			Estimated cost		7,030

Issues: Where river side slopes are too steep and a shallowing of the slope is required, there will be a loss of agricultural land. The steep slopes on some of the channel sections are probably because of this socio-economic factor. The implications of the trial in this context would need to be assessed.

River Section Remedial Works.
River bank slips/ instabilities

Eng. Trial No 5.

RIVER CHANNEL REMEDIAL WORKS
TYPICAL CONFIGURATION
(Cul de Sac / Roseau).



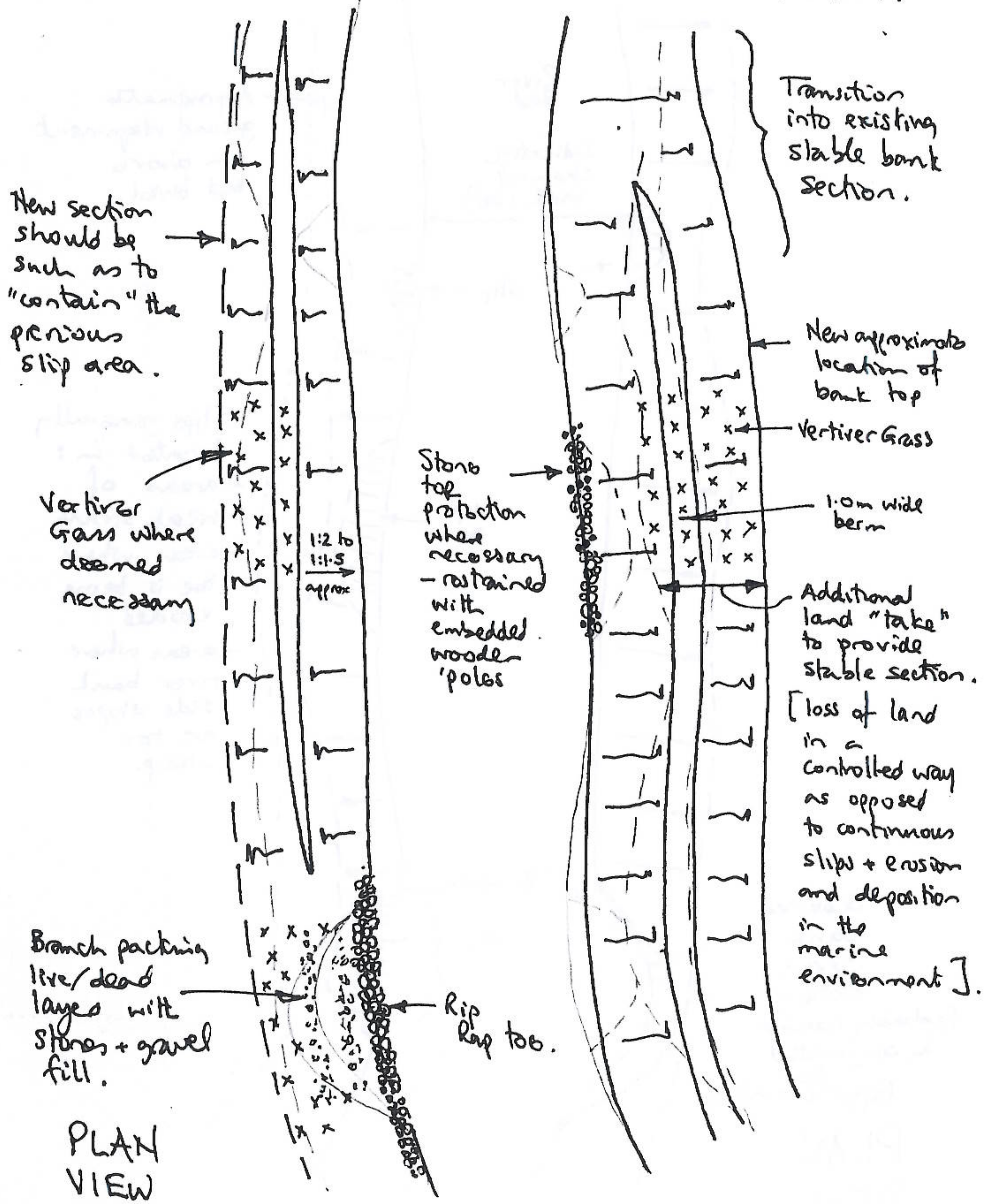
Slips generally located in:
- areas of weak strata
- areas where toe is being eroded
- areas where river bank side slopes are too steep.

PLAN.
VIEW

RIVER CHANNEL REMEDIAL WORKS

TYPICAL CONFIGURATION

(e.g. Roseau River - with Remedial Works).



PLAN VIEW

With Remedial Works

Watershed and Environmental Management Project

River Engineering Trial Number Eng 5

Estimate for 50m of Bank Stabilisation

Sheet Nr

River Roseau

Location In new loop cut.

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)	Comments
	Excavation of topsoil & place for re-use	m3	Nil	25	0	
	Excavation in river bed to 1m depth	m3	350	60	21000	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	Nil	15	0	
	Removal of light vegetation	m2	150	2	300	
	Removal of tree (by girth of tree)					
	>1m	Nr	Nil	400	0	
	200mm to 1000mm	Nr	Nil	300	0	
	<200mm	Nr	Nil	200	0	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) (installation by driving stakes into soil)	m	Nil	12	0	
	ditto but 150mm diameter	m	Nil	25	0	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking	m3	See below	150	0	
	or					
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	Nil	280	0	
	0.5mx1mx1m (0.5m3)	each	Nil	260	0	
	Reno Mattress 200mmx2mx6m (2.4m3)	each	Nil	1030	0	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	Nil	45	0	
	60 to 199mm	m3	Nil	42	0	
	20 to 59mm	m3	Nil	41	0	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under 10	110	1100	
	Supply and placing of geotextile material	m2	Nil	19	0	
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.import)	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets or other with approved soil with specified compaction.	m3	Nil	25	0	
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2	275	25	6875	
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr	100	14	1400	
	Supplying, placing and fixing brushwood or similar.	m3	Nil	5	0	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	30,675.0	

Watershed and Environmental Management Project | **Sheet Nr** |

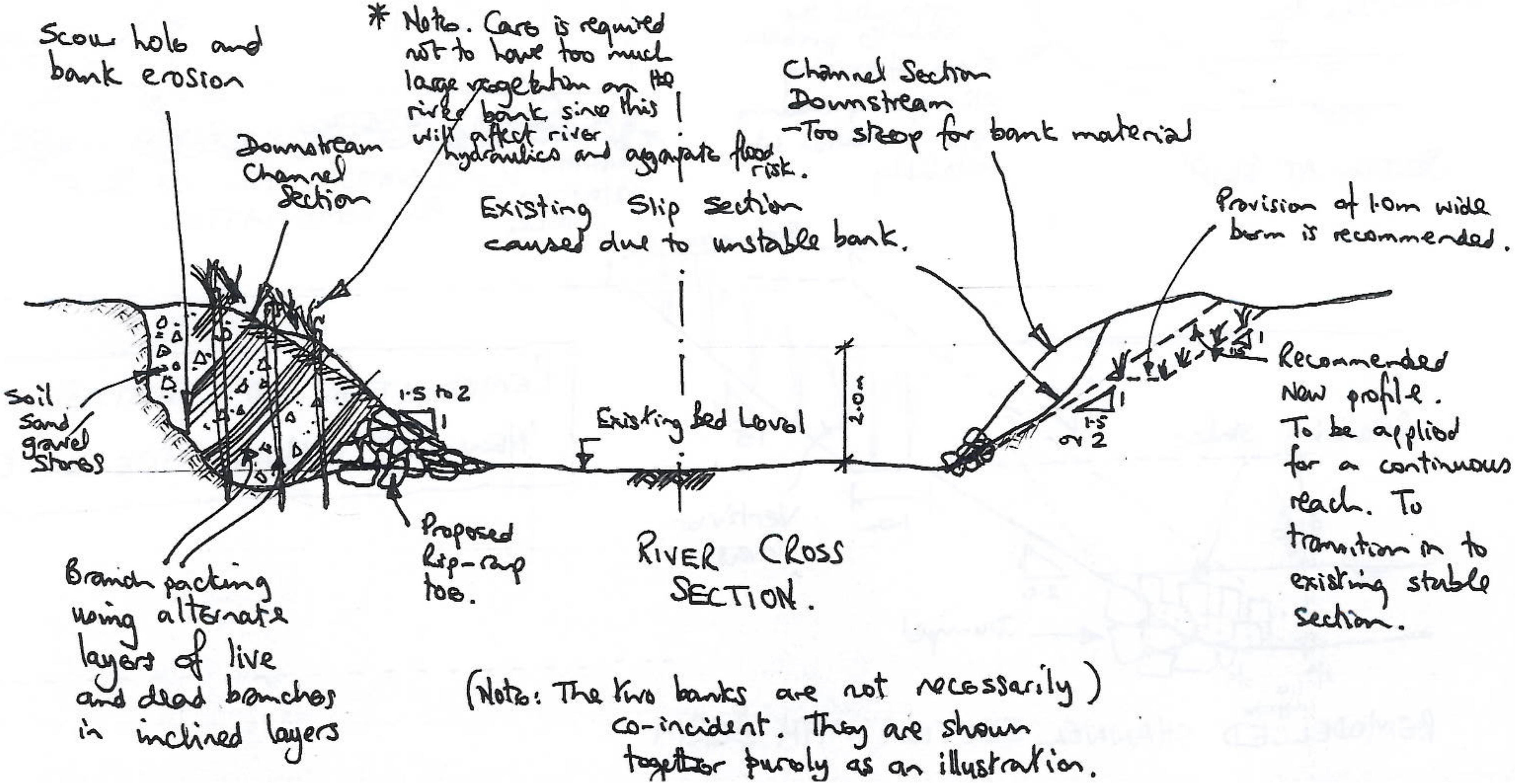
River Engineering Trial Number Eng 5 | **River** Roseau | **Location** In new loop cut.

Estimate for 50m of Bank Stabilisation {estimated for less work and no toe rip rap}

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$	Comments
	Excavation of topsoil & place for re-use	m3	Nil	25	0	
	Excavation in river bed to 1m depth	m3	200	60	12000	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	Nil	15	0	
	Removal of light vegetation	m2	50	2	100	
	Removal of tree (by girth of tree)					
	>1m	Nr	Nil	400	0	
	200mm to 1000mm	Nr	Nil	300	0	
	<200mm	Nr	Nil	200	0	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) {installation by driving stakes into soil}	m	Nil	12	0	
	ditto but 150mm diameter	m	Nil	25	0	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking or	m3	See below	150	0	
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	Nil	280	0	
	0.5mx1mx1m (0.5m3)	each	Nil	260	0	
	Reno Mattress 200mmx2mx6m (2.4m3)	each	Nil	1030	0	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	Nil	45	0	
	60 to 199mm	m3	Nil	42	0	
	20 to 59mm	m3	Nil	41	0	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under Nil	110	0	
	Supply and placing of geotextile material	m2	Nil	19	0	
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.import)	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets or other with approved soil with specified compaction.	m3	Nil	25	0	
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2	137.5	25	3437.5	
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr	50	14	700	
	Supplying, placing and fixing brushwood or similar.	m3	Nil	5	0	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	16,237.5	

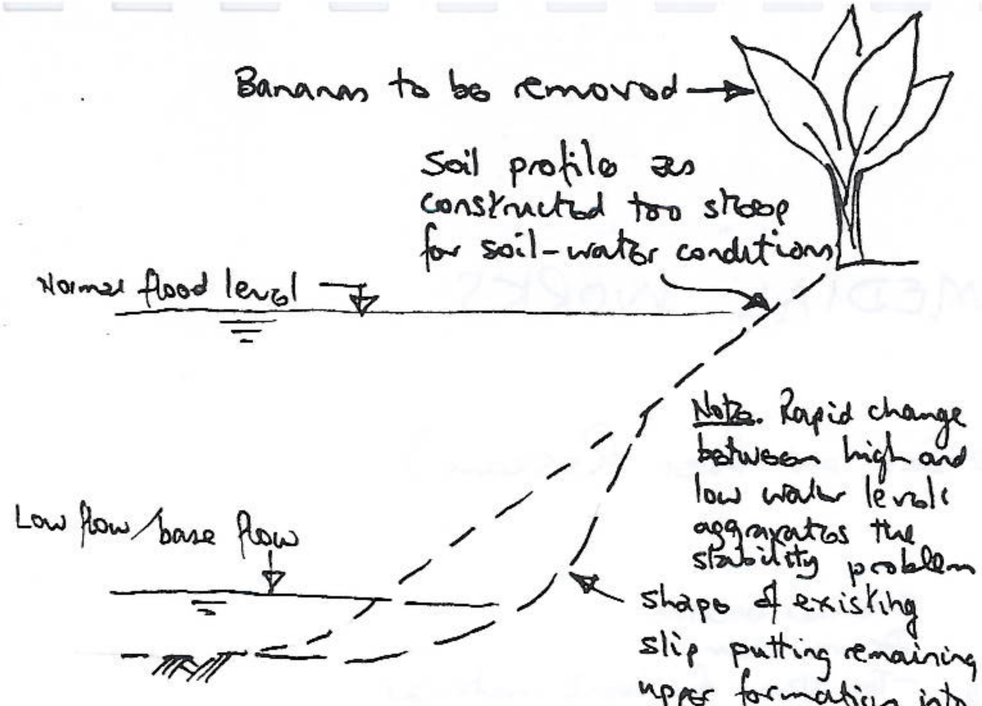
RIVER CHANNEL REMEDIAL WORKS

(as pertaining to River Cul de Sac and River Roseau).

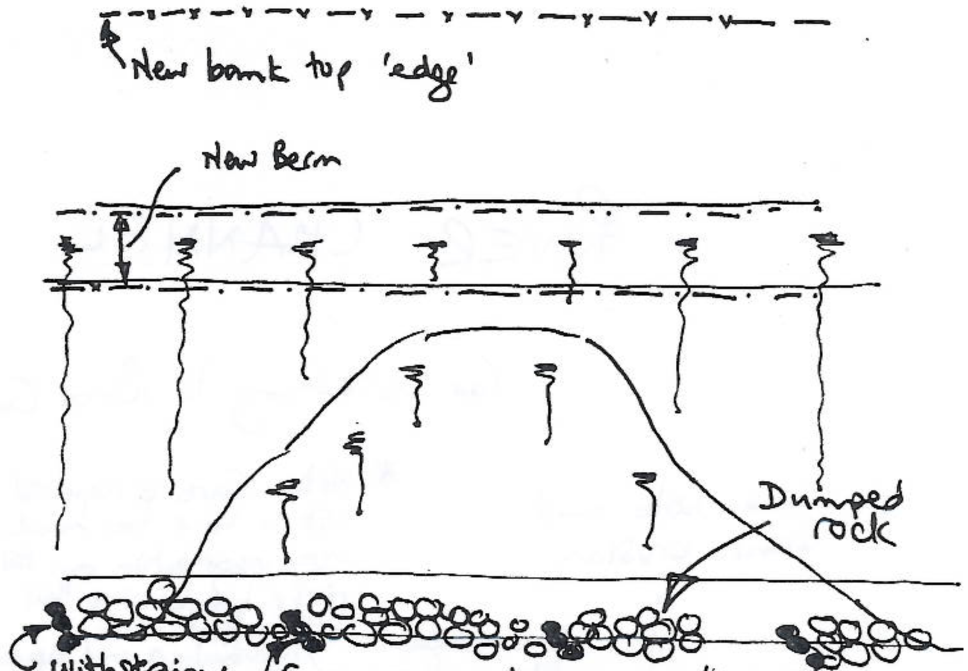


RIVER CROSS SECTION.

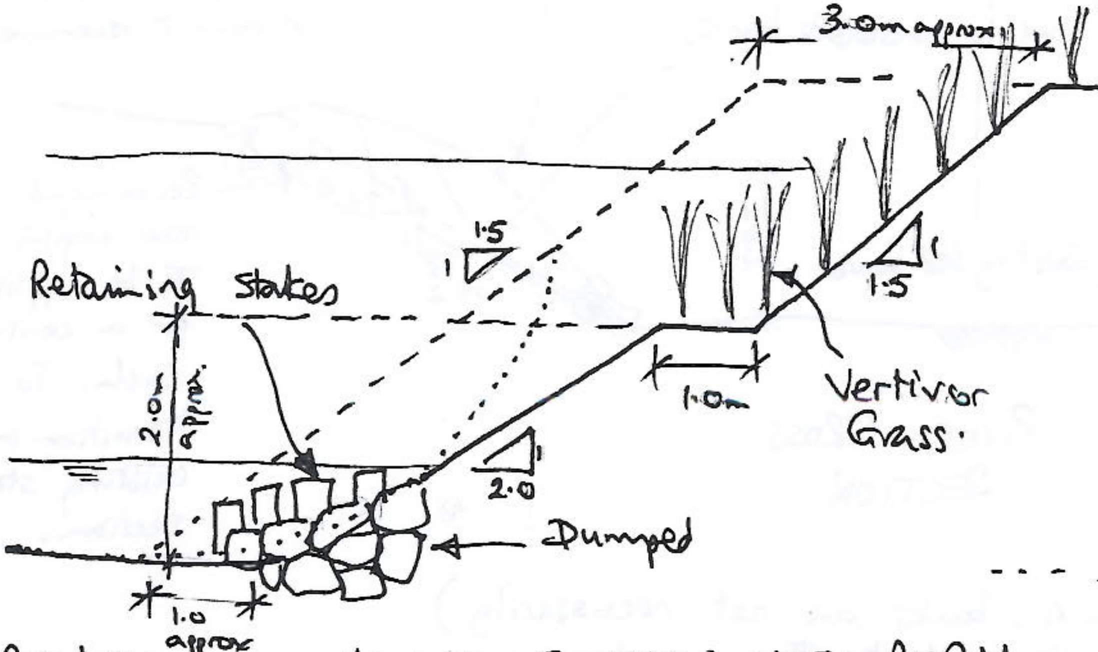
(Note: The two banks are not necessarily co-incident. They are shown together purely as an illustration.)



SECTION AT 'SLIP'



ELEVATION VIEW ON 'SLIP' PLUS REMEDIATION.

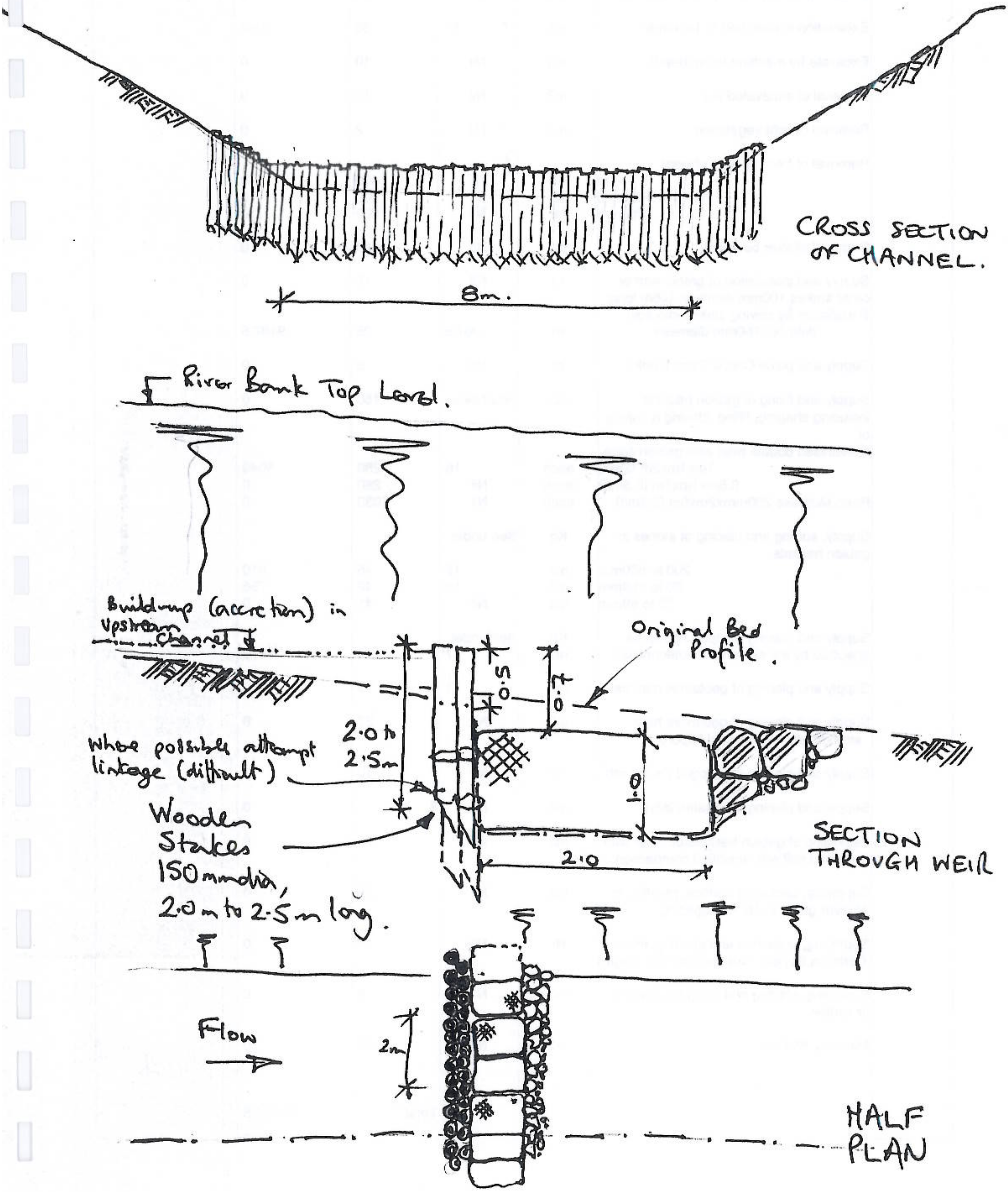


REMODELLED CHANNEL SECTION WITH BERM

REMEDIATION OF UNSTABLE 'NEW CUT CHANNEL' SIDE SLOPES

Low Head Weir – to Accompany Loop Cutting

Alternative 'A'.



Watershed and Environmental Management Project

Sheet Nr	
River Engineering Trial Number	Eng 6.A
River Location	Roseau
Estimate for Low Head Weir Type 'A' (14m timber wall) {Performance in high flood needs to be monitored}	Downstream of new loop cut.

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)	Comments
	Excavation of topsoil & place for re-use	m3	Nil	25	0	
	Excavation in river bed to 1m depth	m3	51	60	3060	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	Nil	15	0	
	Removal of light vegetation	m2	Nil	2	0	
	Removal of tree (by girth of tree)					
	>1m	Nr	Nil	400	0	
	200mm to 1000mm	Nr	Nil	300	0	
	<200mm	Nr	Nil	200	0	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) {installation by driving stakes into soil}	m	Nil	12	0	
	ditto but 150mm diameter	m	367.5	25	9187.5	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking or	m3	See below	150	0	
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	18	280	5040	
	0.5mx1mx1m (0.5m3)	each	Nil	260	0	
	Reno Mattress 200mmx2mx6m (2.4m3)	each	Nil	1030	0	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	18	45	810	
	60 to 199mm	m3	18	42	756	
	20 to 59mm	m3	Nil	41	0	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under 17	110	1870	
	Supply and placing of geotextile material	m2	51	19	969	
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.import)	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets or other with approved soil with specified compaction.	m3	Nil	25	0	
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2	Nil	25	0	
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr	Nil	14	0	
	Supplying, placing and fixing brushwood or similar.	m3	Nil	5	0	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	21,692.5	

St Lucia Watershed and Environmental Management Project

Field Trial Title : **Low head weir design to accompany loop cutting**

Field Trial Number: ENG.6 | Basis: Engineering

River Catchment: Roseau

Location: Downstream of Phase 1 Loop Cutting

Objectives

To identify a cheap option for providing head loss control or reinsttement in the context of loopcutting.
{Gabion mattress or concrete structures are possible but their cost is normally prohibitive where only agriculture is the beneficiary}

Scope:

Undertake survey of river channel. Identify most suitable location(s) for the trial weir through hydraulic analysis under different flow conditions.
Identify depth of alluvium at potential sites through use of metal probe of 3m length (approx).
Undertake design of weir based on durable poles or concrete stakes to be piled into the channel bed. A twin row system at different levels may be the preferred option.
Assess construction programme time and actual costs.
Monitor performance of the weir(s) taking into account the erosion of the channel being experienced in different flow events.

Requirements for Trial (each site):

		Unit	Quantity	Unit Rate $	Cost
Staff					
	Supervisor	mm	0.3	10,000	3,000
	Technician	mm	0.75	4,000	3,000
	Labourers (3 number	mm	2	2,000	4,000
Logistics					
	Vehicle & driver	v.month	0.75	5,000	3,750
Equipment					
	50m tape	Sum	2	30	60
	Notebooks/diary	Sum	1	20	20
Materials					
	Rock pitching materia	cu.m	30	100	3,000
	Wooden poles	l.m	250	10	2,500
	Brushwood	sq.m	0	2	0
	Vegetation	Nr of plants	0	2	0
Heavy Machinery					
	Truck (rental)	days	2	500	1,000
	Excavator (rental)	days	3	1,000	3,000
			Estimated cost		23,330

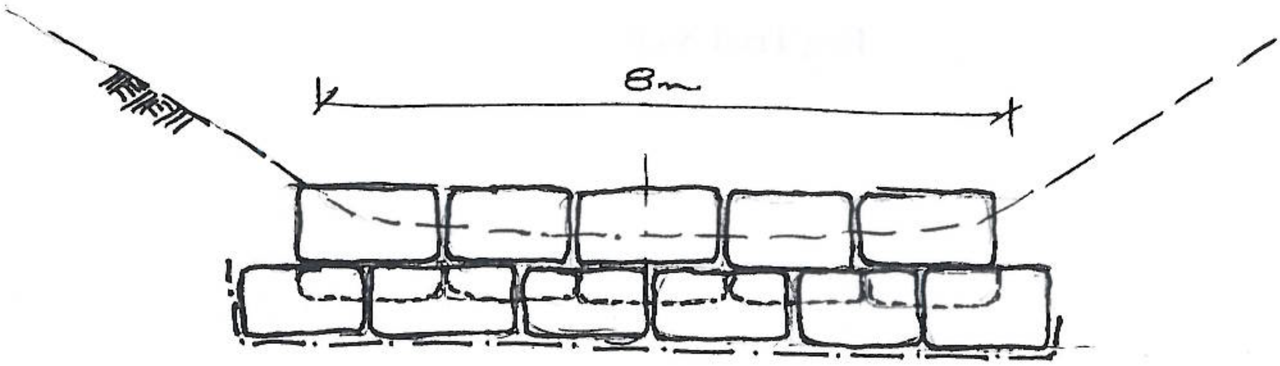
Issues:

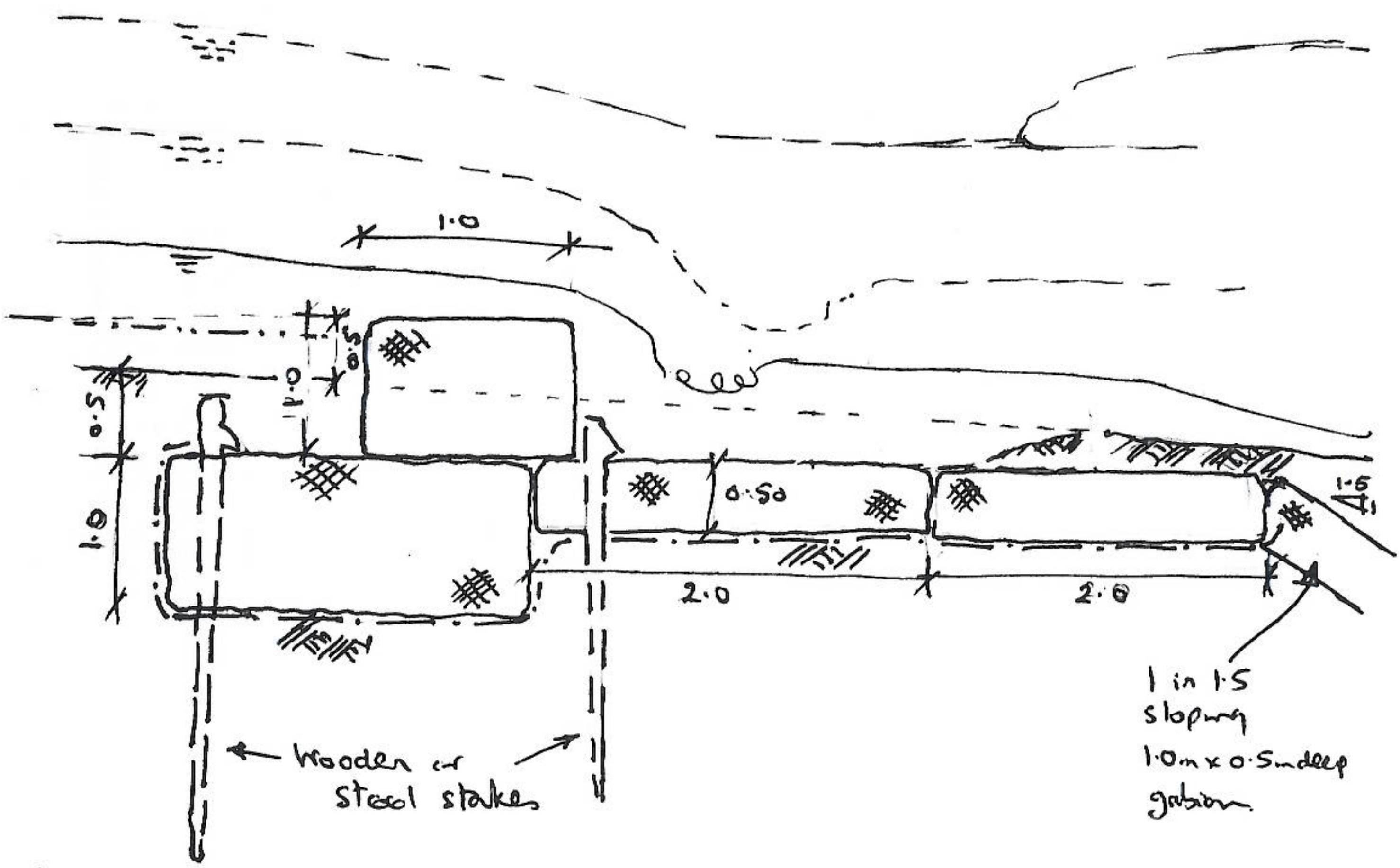
The form of the weir is yet to be decided upon, hence costs could be significantly different.
The approach intended is one of low cost owing to the instability of the channel system (how long will the river pass over the weir?) and the need to identify cost effective structures.

Low Head Weir/ Head Loss Structure to accommodate loop cutting action. Alternative 'A' Timber Weir.

Eng Trial No.6

Low Head Weir – to Accompany Loop Cutting
Alternative 'B'.





Low Head Weir/ Head Loss Structure to accommodate loop cutting action.
Alternative 'B'
Light Gabion Weir.

Eng Trial No.6

Watershed and Environmental Management Project | **Sheet Nr** [ ]

River Engineering Trial Number Eng 6.B | **River** Roseau

Location Downstream of new loop cut.

Estimate for Low Head Weir Type 'B' (14m gabion wall)
{Performance in high flood needs to be monitored}

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)	Comments
	Excavation of topsoil & place for re-use	m3	Nil	25	0	
	Excavation in river bed to 1m depth	m3	138	60	8280	
	Excavate by machine to 3m depth	m3	Nil	10	0	
	Disposal of excavated soil	m3	Nil	15	0	
	Removal of light vegetation	m2	Nil	2	0	
	Removal of tree (by girth of tree)					
	>1m	Nr	Nil	400	0	
	200mm to 1000mm	Nr	Nil	300	0	
	<200mm	Nr	Nil	200	0	
	Removal of river boulders	m3	Nil	25	0	
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) {installation by driving stakes into soil}	m	90	12	1080	
	ditto but 150mm diameter	m	Nil	25	0	
	Supply and place Cocoa Palm Trunks	m	Nil	5	0	
	Supply and fixing of gabion baskets including shaping, filling, closing & linking or	m3	See below	150	0	
	Galvanised double twist wire gabion cage					
	1mx1mx2m (2m3)	each	34	280	9520	
	0.5mx1mx2m (1m3)	each	8	260	2080	
	0.5mx2mx2m (2m3)	each	16	270		
	Reno Mattress 200mmx2mx6m (2.4m3)	each	Nil	1030	0	
	Supply, sorting and placing of stones in gabion baskets	Kg	See under			
	200 to 500mm	m3	54	45	2430	
	60 to 199mm	m3	54	42	2268	
	20 to 59mm	m3	Nil	41	0	
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3	See under Nil?	110	0	
	Supply and placing of geotextile material	m2	160	19	3040	Required?
	Supply and placing of geotextile high strength sheets(*special import)	m2	Nil	37	0	
	Supply and placing of geogrid (*s.import)	m2	Nil	10	0	
	Supply and placing of hessian fabric	m2	Nil	?	0	
	Backfilling of gabion baskets or other with approved soil with specified compaction.	m3	6	25	150	
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2	Nil	25	0	
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr	Nil	14	0	
	Supplying, placing and fixing brushwood or similar.	m3	Nil	5	0	
	Masonry Walling	m3	Nil	325	0	
	....					
				Total:	28,848.0	

St. Lucia Watershed and Environmental Management Project

Field Trial Title: **Trash Removal from River Systems**

Field Trial Number: ENG 7

Basis: Engineering

River Catchment: Cul de Sac/Choc

Location: Near Main Road Bridges at downstream reaches

Objectives: To identify an effective mechanism for reducing the quantity of debris entering the coastal areas and polluting the marine environmental and beaches.

Scope: To design and fabricate a front end attachment for a hydraulic ecavator similar item of hydraulic equipment to enable it to remove floating debris main river during a flood event.

To establishment a mechanism for deploying a hydraulic excavator with a specially designed (?) front end attachment to predfine locations along the main river channel to enable floating debris to be removed by scimming from the flow and either deposited in an adjacent 'safe site' or alternatively directly into a waiting truck/lorry.

Requirements for Trial (each site):

		UNIT	QUANTITY	UNIT RATE $	COST
Staff					
	Supervisor	mm	0.5	6,000	3,000
	Technician	mm	0.5	3,000	1,500
	Labourers (3 number)	mm	1	2,000	2,000
Logistics					
	Vehicle and driver	v.month	0.5	3,000	1,500
Equipment					
	Grill attachment to hydraulic excavator or similar	sum		8,000	8,000
	Notebooks/diary	sum	1	20	20
Materials					
	None				
Heavy Machinery					
	Truck (rental)	days	2	400	800
	Excavator (rental)	days	4	1,800	7,200
(Note: Quantities depend on pre-work surveys)			Estimated Cost		24,020
				Say	**24,000**

Issues: Research of manufacturers literature needs to be undertaken to assess the possibility of availability of standard unit. If not available, a unit needs to be designed and fabricated locally. To be deployed in September 1997.

St. Lucia Watershed and Environmental Management Project

Field Trial Title: **Landslide Re-vegetation**

Field Trial Number: ENG 8

Basis: Engineering

River Catchment: Marquis

Location: Combat in Babonneau

Objectives: To improve the overall stability of a large rotational landslide by re-vegetation.

Scope: To evaluate the best vegetation suitable for slope stabilisaton at this site.

To identify soil properties for analytical analysis

Requirements for Trial (each site):

		UNIT	QUANTITY	UNIT RATE $	COST
Staff					
	Supervisor	mm	0.5	6,000	3,000
	Technician	mm	0.5	3,000	1,500
	Labourers (6 number)	mm	1	6,000	6,000
Logistics					
	Vehicle and driver	v.month	0.5	3,000	1,500
Equipment					
	Notebook	sum	1	20	20
	50 m tape	sum	2	210	420
	18m ladders	sum	2	1,300	2,600
	Cutlass	sum	2	18	36
	Forks	sum	2	180	360
	Picks	sum	2	35	70
	Shovels	sum	2	41	82
	Hand auger	sum	1	2,500	2,500
Materials					
	Gravel	cum	3	53	159
	Brushwood	sq. m	100	2	200
	Vegetation	no of plant:	400	8	3,200
	Geotextile (roll)	sum	2	1,110	2,220
Soil Test					
	Moisture content	sum	20	20	40
	Atterberg limits	sum	8	100	800
	Grain Size analysis	sum	4	150	600
	Triaxial strength	sum	2	500	1,000
				Estimated Cost	**27,807**

St. Lucia Watershed and Environmental Management Project

Field Trial Title: **Landslide Hazard Warning System**

Field Trial Number: ENG 9

Basis: Engineering

River Catchment: Cul de Sac

Location: Ravine Poisson

Objectives: To initiate a long term study for a landslide hazard evacuation system for populated areas.

Scope: To correlate:
- rainfall intensity, pore water pressure fluctuations and subsurface movement
- to develop the best erosion control conservation techniques for this site
- to determine soil engineering properties
- to evaluate the vegetation cover best suited to assist in slope stabilisation at this site.

Requirements for Trial (each site):

	UNIT	QUANTITY	UNIT RATE $	COST
Staff				
Supervisor	mm	0.5	6,000	3,000
Technician	mm	1	3,000	3,000
Labourers (4 number)	mm	1	4,000	4,000
Logistics				
Vehicle and driver	v.month	1	3,000	3,000
Equipment				
Notebook	sum	1	20	20
50 m tape	sum	2	210	420
Drill rig Mobilisation	sum	1	7,500	7,500
Slope Indicator (installed)	sum	6	4,000	24,000
Piezometer (installed)	sum	6	3,300	19,800
30m Dipmeter	sum	1	1,550	1,550
Inclinometer probe	sum	1	12,335	12,335
30m Control cable	sum	1	1,970	1,970
Connectors	sum	2	564	1,128
Pulley assembly	sum	1	544	544
Data logger	sum	1	9,238	9,238
Software	sum	1	544	544
Hand Tools	sum	8	70	560
Materials				
Cement	sum	10	14	140
PVC glue	sum	4	20	80
Vegetation	no of plant	200	8	1,600
Gravel	cum	4.5	6,000	6,000
Laboratory Test	sum		6,000	6,000
			Estimated Cost	**100,668**

St. Lucia Watershed and Environmental Management Project

Field Trial Title: **Landslide Re-vegetation**

Field Trial Number: ENG 10

Basis: Engineering

River Catchment: Praslin

Location: Pelouse

Objectives: To evaluate the best vegetation suitable for slope stabilitsation

Scope: To monitor the establishment of the vegetation.
To evaluate the effect of vegetation ont eh overall stability of the slope.

Requirements for Trial (each site):

		UNIT	QUANTITY	UNIT RATE $	COST
Staff					
	Supervisor	mm	0.25	6,000	1,500
	Technician	mm	0.5	3,000	1,500
	Labourers (4 number)	mm	1	4,000	4,000
Logistics					
	Vehicle and driver	v.month	0.5	3,000	1,500
Equipment					
	Notebook	sum	1	20	20
	50 m tape	sum	2	210	420
	Cutlass	sum	2	18	36
	Forks	sum	2	180	360
	Shovels	sum	2	41	82
Materials					
	Bushwood	sq. m	150	2	300
	Vegetation	no.of plants	200	6	1,200
	Geotextile (roll)	sum	2	1,100	2,200
				Estimated Cost	**13,118**

St. Lucia Watershed and Environmental Management Project

Field Trial Title: **Landslide Re-vegetation**

Field Trial Number: ENG 11

Basis: Engineering

River Catchment: Anse La Raye

Location: West Coast Road (WCR)

Objectives: To develop Infrastructural and Highway slope stabilisation techniques using vegetation

Scope: To evaluate
the best vegetation suitable for slope protection and stabilisation at this site.
to monitor the establishment of the vegetation

Requirements for Trial:

	UNIT	QUANTITY	UNIT RATE $	COST
Staff				
Supervisor	mm	0.25	6,000	1,500
Technician	mm	0.5	3,000	1,500
Labourers (2 number)	mm	1	2,000	2,000
Logistics				
Vehicle and driver	v.month	0.5	3,000	1,500
Equipment				
Notebook	sum	1	20	20
50 m tape	sum	2	210	210
Hand shovels	sum	3	10	30
Materials				
Vegetation	no.of plants	100	5	500
			Estimated Cost	**7,260**

RIVER and BIO-ENGINEERING TRIALS

TYPICAL CONTRACT AGREEMENT FOR WORKS CONSTRUCTION

{To be used where direct labour is deemed inappropriate}

CONTRACT AGREEMENT

This Agreement is made the __________ day of _________ 1997 between the Chief Engineer, Ministry of Communications, Works and Transport, St. Lucia (hereinafter called the **Employer**) herein represented by ______________________ of _________________________ hereinafter (called the **Project Manager**) on one part

and _________________________ of ___________________________ (hereinafter called **The Contractor**) of the other part.

Whereas

Recitals - 1st: The Employer wishes the following work namely: **The Construction of River bank retaining structures under the Watershed and Environmental Management Project** consisting of:

- ***(1) gabion basket walls**
- ***(2) reinforced concrete foundations**
- ***(3) reinforced concrete wall**
- ***(4) random rubble wall**
- ***(5) others (specify)** ____

***(Delete where not appropriate and parties initial)**

hereinafter called **"The Works"** located at _________________________ and has caused drawing Nos. _______________ Specifications and Bill of Quantities showing, describing and pricing the works to be prepared under conditions annexed hereto all forming part of this Agreement herein after called **the Contract Documents**

2nd: The Contractor has visited the site, examined the documents and have provided and satisfy the Employer of adequate evidence that he can fund at least 60 percent of the cost of the works valued at __________________ECD or such other sums shall become payable hereunder.

3rd: The Contractor have provided and satisfy the Employer of adequate evidence of high quality work and workmanship namely the construction and execution of ____ works.

4th: The Contractor have provided and satisfy the Employer that he have resided within the approved recruiting boundaries namely ______________________ ____________________________ for a period of _________________ years.

5th: The Supervising Officer appointed in connection with this contract shall be: ____ of _______________________ or such other persons so appointed by the Employer.

6th: The Contract Document have been signed by or on behalf of the parties thereto:

Now It Hereby Agreed As Follows

Article 1

For the consideration herein mentioned the Contractor will in accordance with the Contract Documents carry out and complete the works.

Article 2

The Employer will pay the contractor the contract sum or such other sums as shall become payable hereunder at the times and in the manner specified base on the work instructed and executed in accordance with the Contract Document.

Article 3

If any disputes or differences concerning this contract shall arise between the Employer and the Contractor such disputes or differences shall be and is hereby referred to an arbitration for a decision of a person (s) to be agreed between the parties or failing on agreement within 14 days after either party has given to each other a written request to concur in the appointment of an arbitrator a request from either party to the President or Vice President of the St. Lucia Bar Association for the appointment of such person.

As Witness, the hands of the parties hereto

Signed for and on behalf of the Employer ____________________

(For the Employer)

in the presence of ____________________

Witness

Signed for and on behalf of the Contractor ____________________

Contractor

in the presence of ____________________

Witness

____

Address

Seals:

1.0 CONDITIION HEREIN BEFORE REFERRED TO

Intentions of the Parties

Contractor Obligations

1.1 The Contractor shall with due diligence and in good and workmanlike manner carry out and complete the works in accordance with the Contract Document using material and workmanship of the quality and standard herein specified provided that where and to the extent that the approval of the quality of material or of the standard of workmanship is a matter for the opinion of the Project Manager and Supervising Officer such quality and standards shall be to the reasonable satisfaction of the Project Manager and/or the Supervising Officer.

The standard of workmanship shall comply with normal and acceptable workmanship practices in the state for such works and shall include the following:

(1) Concrete works to British standards or ASTM standard.

(2) Gabion basket and Reno mattress to Macafarri standards and techniques. Boulder infill shall be hard and durable and should be quite resistant to crushing when charged with superimposed heavy loads. No weathered rock shall be ued.

(3) Random Rubble Masonry to comply with BS5390.

(4) Steel rod and fabric reinforcement to comply with BS785 and B1221 part A respectively.

Project Manager/Supervising Officers Duties

1.2 The Project Manager and or Supervising Officer shall issue any further information necessary for the proper carrying out of the works. Issue all certificate and confirm all instructions in writing as far as necessary in accordance with these conditions.

2.0 COMMENCEMENT AND COMPLETION

Commencement and Completion

2.1 The works may be commenced on ______________________ and shall be completed

by______________________________

Extension of contract period

2.2 If it becomes apparent that the Works will not be completed by the time for completion contained in clause 2.1 hereof (or any later date fixed in accordance with the provisions of this clause 2.2) for reasons beyond the control of the Contractor. then the Contractor shall notify the Employer who shall make, in writing, such extension of the time for completion as may be reasonable.

Completion date

2.3 The Project Manager shall certify the date when in his opinion the works have reached practical completion.

Defects Liability

2.4 Any defects, excessive shrinkages or other faults which appear within __________ months of the date of practical completion and are due to materials or workmanship not in accordance with the Contract occurring before practical completion shall be made good by the Contractor entirely at his own cost.

Any defects, excessive shrinkage or other faults arising out of material supplied by the Employer shall not be the liability of the Contractor. The Contractor shall give notice to the Employer, any defects which in his opinion is of materials supplied by him.

3.0 CONTROL WORKS

Assignments

3.1 Neither the Employer nor the Contractor shall, without the written consent of the other. assign this Contract.

3.2 The Contractor shall not sub-contract or sublet the Works or any part thereof without the written consent of the Employer whose consent shall not unreasonably be withheld.

Contractor's Representative/Labour Force etc.

3.3 (a) The Contractor shall at all reasonable times keep upon the Works a competent person in charge and any instructions given to him by the Supervising Officer or Project Manager shall be deemed to have been issued to the Contractor.

(b) The Contractor as far as possible and practical employ persons from _______________________ and immediate environs to make up his labour force.

(c) The rates of wages established under any collective agreement between employers, employers association and workers organization representatives respectively or substantial proportions of employers and workers engaged in the trade, whether or not the contractor is a party to such agreement. shall apply.

(d) The Contractor shall pay all his employees on a timely basis and shall not transfer this obligation to the Employer.

3.4 (a) The Supervising Officer/Project Manager may (but not unreasonably or vexatiously) issue instructions requiring the exclusion from the Works of any person employed thereon.

(b) The Employer shall have power at any time to execute other works (whether or not in connection with the Works) on the Site contemporaneously with the execution of the Works and the Contractor shall give reasonable facilities for such purpose.

Exclusive from the Works/Facilities for other works

3.5 The Supervising Officer/Project Manager may issue written instructions which the Contractor shall forthwith carry out. If instructions are given orally they shall. in two days, be confirmed in writing by the Supervising Officer/Project Manager.

If within 7 days after receipt of a written notice from the Supervising Officer/Project Manager requiring compliance with an instruction the Contractor does not comply therewith then the Employer and pay other persons to carry out the work and all costs incurred thereby may be deducted by him from any monies due or to become due to the Contractor under this Contract or shall be recoverable from the Contractor by the Employer as a debt.

Variations

3.6 The Supervising Officer may. without invalidating the contract. order an addition or omission from or order change in the Works or the orderor period in which they are to be carried out and any such instruction shall be valued on a fair and reasonable basis.

Instead of the valuation referred to above. the price may be agreed between the Project Manager. Supervising Officer and the Contractor prior to the Contractor carrying out any such instruction.

4.0 PAYMENT

4.1 Any inconsistency in or between the Contract Drawings, Bill of Quantities and the Contract Specification shall be corrected and any such correction which results in an addition, omission or other change shall be treated as a variation under clause 3.6 hereof. Nothing contained in the Contract Drawing or the Contract Specification or the Bill o Quantities shall override, modify or affect in any way whatsoever the application or interpretation of that which is contained in these Conditions.

4.2 (a) The Project Manager or Supervising Officer shall subject to verification, reasonable satisfaction and/or approval that the work has been properly executed, certify payments in accordance with the Contract.

(b) Payment will be made within __15__ days of a __28__ day payment certification.

(c) Interim Payments will not be made however in extenuating any circumstance the Employer upon the request of the Contractor and the satisfactory completion of 50% of the works shall consider such payment.

(d) **Bill of Quantities** (or as appended*)

No	Item Description	Unit	Quantity	Rate	Amount (EC$)
	Total				

*: Delete where necessary.

4.0 PAYMENT

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(d) **Bill of Quantities** (or as appended*)

No	Item Description	Unit	Quantity	Rate	Amount (EC$)
	Total				

*: Delete where necessary.

Fixed Price

4.3 No account shall be taken in any payment to the Contractor under this Contract of any change in the cost to the Contractor of the labour, materials plant and other resources employed in carrying out the Works.

4.4 All payments made under the contract shall be subjected to a 5% retention deduction to be held by the Employer in Fiduciary trust without obligation to invest. Upon practical completion, 50% of the retention will be made payable to the Contractor and the other 50% will be made payable at the end but subject to clause 2.4.

5.0 EMPLOYER SUPPLIED ITEMS

If not stated in the Bill of Quantities the Employer shall give written notice of not less than __2__ days of an item/material which he wishes to supply before that item or part thereof to become part of the permanent work. Such notice shall be deemed to be a variation under the contract and subject to clause
2.4, 3.5, 3.6 and 4.0 and assumed delivered to site.

6.0 DETERMINATION

Determination by Employer

6.1 The Employer may but not unreasonably or vexatiously by notice by registered post or recorded delivery to the Contractor forthwith determine the employment of the Contractor under this Contract if the Contractor shall make default in any one or more of the following:

1 (a) If the Contractor without reasonable cause fails to proceed diligently with the Works or wholly suspends the carrying out of the Works before completion. save for causes under clause 5.1.

2 (b) If the Contractor and or his Employees abuse, threaten or intemidate in any form the Employer's personnel.

If the Contractor becomes bankrupt or makes any composition or arrangement with his creditors or has a winding up order made or (except for the purposes of reconstruction) a resolution for voluntary winding op order made or (except for the purposes of reconstruction) a resolution for voluntary winding up passed or receiver or manager of his business or undertaking is duly appointed or possession is taken by or on behalf of any creditor of any property the subject of a charge.

In the event of the Employer determining the employment of the Contractor as aforesaid the Contractor shall immediately give up possession of the site of the Works and the Employer shall not be bound to make any further payment to the Contractor until after completion of the Works. Provided always that the right of determination shall be without prejudice to any other rights or remedies which the Employer may possess.

Determination by Contractor

6.2 The Contractor may but not unreasonably or vexatiously by notice by registered post or recorded delivery to the Employer forthwith determine the employment of the Contractor under this Contract if the Employer shall make default in any one or more of the following respects:

(1) If the Employer or any persons for whom he is responsible interferes with or obstruct the carrying out of the Works or fails to make the premises available for the Contractor in accordance with clause 2.1 hereof;

(2) If the Employer suspends the carrying out of the Works for a continuous period of at least one month.

(3) If the Employer becomes bankrupt or makes a composition or arrangement with his creditors, or has a winding up order made or a resolution for voluntary winding up passed or a receiver or manager of his business in appointed or possession is taken by or on behalf any creditor of any property by the subject of a charge.

Provided that the employment of the Contractor shall not be determined under clauses 6.2.1, 6.2.2 or 6.2.3 hereof unless the Employer has continued the default for seven days after receipt by registered post or recorded delivery of a notice from the Contractor specifying such default.

In the event of the Employer determining the Employment of the Contractor as aforesaid the Employer shall pay to the Contractor, after taking into account amounts previously paid, materials on site and the removal of all temporary buildings, plants tools and equipment. Provided always that the right of determination shall be without prejudice to any other rights or remedies which the Contractor may possess.

7.0 INDEMNITY FOR INSURANCE

7.1 Without prejudice to any right and remedies, the Employer and Contractor may possess they shall indemnify each other against any claims in respect of insurance as required for such works.

8.0 APPENDICIES

Watershed and Environmental Management Project

River Engineering Trial Number ____

Sheet Nr ____

River Location ____

Bill Item Number	Description	Unit	Quantity	Rate (EC$)	Amount (EC$)
	Excavation of topsoil & place for re-use	m3		25	0
	Excavation in river bed to 1m depth	m3		60	0
	Excavate by machine to 3m depth	m3		10	0
	Disposal of excavated soil	m3		15	0
	Removal of light vegetation	m2		2	0
	Removal of tree (by girth of tree)				
	>1m	Nr		400	0
	200mm to 1000mm	Nr		300	0
	<200mm	Nr		200	0
	Removal of river boulders	m3		25	0
	Supply and installation of greenheart or other stakes 100mm diameter (<6m long) {installation by driving stakes into soil}	m		12	0
	ditto but 150mm diameter	m		25	0
	Supply and place Cocoa Palm Trunks	m		5	0
	Supply and fixing of gabion baskets including shaping, filling, closing & linking	m3		150	0
	or				
	Galvanised double twist wire gabion cage				
	1mx1mx2m (2m3)	each		280	0
	0.5mx1mx1m (0.5m3)	each		260	0
	Reno Mattress 200mmx2mx6m (2.4m3)	each		1030	0
	Supply, sorting and placing of stones in gabion baskets	Kg			
	200 to 500mm	m3		45	0
	60 to 199mm	m3		42	0
	20 to 59mm	m3		41	0
	Supply and placing dumped rip-rap as specified by the site engineer/technician	Kg m3		110	0
	Supply and placing of geotextile material	m2		19	0
	Supply and placing of geotextile high strength sheets(*special import)	m2		37	0
	Supply and placing of geogrid (*s.import)	m2		10	0
	Supply and placing of hessian fabric	m2		?	0
	Backfilling of gabion baskets with approved soil with specified compaction.	m3		25	0
	Supplying, preparing surface, planting of Vetiver grass at 150mm spacing	m2		25	0
	Supplying, preparing and planting 'poles' Gliricidia Sepium (1m approximate length)	Nr		14	0
	Supplying, placing and fixing brushwood or similar.	m3		?	0
	Masonry Walling	m3		325	0
	....				
				Total:	0

Annex 7

Appendix B

TABLE . :SOIL CONSERVATION AND RUN–OFF CONTROL TRIALS: RECORD OF TREATMENTS, NOV.96–OCT97

CUL DE SAC: CHOPIN RIDGE Farmer: Mr Frankie Agricultural Officer: Miss Antonia Felix

	13–Nov	18–Nov	21–Nov	17–Dec	23–Dec	09–Jan	14–Jan	20–Jan	22–Jan	20–Feb	12–Mar	17–Mar	02–Apr	17–Apr	08–May	13–May	04–Jun	16–Jun	19–Jun
1 Spray application	–	–	–	–	–	Leafspot	–	–	–	–	–	–	–	–	–	Leafspot	–	–	Leafspot
2 Nematicide applcn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3 Lime application/plot	–	–	25kg/plot	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4 Fertiliser applcn/plot	–	–	–	–	25kg/plot	–	–	–	–	–	N aplcn	–	–	–	–	–	–	–	–
5 Trash applcn/maintnce	x	x	–	–	–	–	x	–	x	x	–	–	x	–	x	–	x	x	–
6 Contour drain mntnce	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7 Topples(mats)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Fruit harvstd: bunches	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
boxes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
lbs	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
				*		*		*					*					#	

Remarks: Fertilizer applcn of Mar was made by farmer.
* Supervisory visits made by senior staff
# Supervisory visits/field tests made by Consultant
Additional visits made by Agric.Officer on 13–Feb, 13–May

CUL DE SAC: RAVINE POISSON Farmer: Mr T. Perineau Agricultural Officer: Mr Aloysius Lesfloris

	25–Nov	10–Dec	17–Dec	07–Jan	20–Jan	21–Jan	18–Feb	25–Feb	25–Mar	07–Apr	12–Mar	06–May	20–May	13–Jun	16–Jun	24–Jun	30–Jul	01–Sep	26–Sep	07–Oct
1 Spray application	–	–	–	Herbicide	–	–	–	–	–	–	–	–	–	–	Gramocil	–	–	–	–	–
2 Nematicide applcn	–	–	–	–	–	–	–	–	–	–	Furadan	–	–	–	–	–	–	–	–	–
3 Lime application/plot	–	25kg/plot	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4 Fertiliser applcn/plot	–	–	–	–	–	25kg/plot	–	–	–	–	25kg/plot	–	–	–	–	–	–	–	–	–
5 Trash applcn/maintnce	x	x	–	x	–	x	–	x	x	–	–	x	x	–	x	–	x	x	–	x
6 Contour drain mntnce	–	x	x	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7 Topples(mats)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Fruit harvstd: bunches	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
boxes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
lbs	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
					*			+		*			*	*	*		+		*	*

Remarks: +Farmer partially replanted his field on 25 Feb..
* Supervisory visits made by senior staff
# Supervisory visits/field tests made by Consultant

File: V2AGTREC.wk3

TABLE : INFILTRATION EXPERIMENTS: SOIL CONSERVATION & RUN–OFF CONTROL TRIALS: DENNERY File:INFXPDG.wk3

Time Start	Time Stop	Mins	Depth Measurements(mm) Rep1	Rep2	Rep3	Mean (mm)	Sprinkler Intensity (avg over expermnt) (mm/min)	(mm/hr)	Surface Run–off (ml/sq m)	(accumulatd)	(mm)	Net Infiltration depth (mm)	(avg/expt) (mm//min)	(mm//hr)	(current rate) (mm//min)	(mm//hr)
***********	***********		****	****	****				****							
DENNERY: GLAVIER																
12–Nov–96				thick banana trash cover				Plot 1								
12:35:00 PM	12:40:00 PM	5.00	20	19	21	23.0	4.6	276	0	0	0.0	23.0	4.6	276	4.6	276
12:48:00 PM	12:57:00 PM	22.00	56	55	63	61.0	2.8	166	0	0	0.0	61.0	2.8	166	2.2	134
15–Nov–96		35deg slope		mod thick banana trash				Plot 1								
09:30:00 AM	09:35:20 AM	5.33	21	21	22	24.3	4.6	274	0	0	0.0	24.3	4.6	274	4.6	274
09:41:00 AM	09:42:15 AM	12.25	28	24	27	29.3	2.4	144	0	0	0.0	29.3	2.4	144	0.7	43
09:49:55 AM	09:51:55 AM	21.92	40	35	39	41.0	1.9	112	0	0	0.0	41.0	1.9	112	1.0	60
09:58:00 AM	09:59:30 AM	29.50	47	40	45	47.0	1.6	96	384	384	0.5	46.5	1.6	95	1.0	60
10:05:00 AM	10:06:20 AM	36.33	58	44	51	54.0	1.5	89	68	452	0.6	53.4	1.5	88	0.9	52
12–Jun–97				thick trash cover				Plot 1								
12:16:00 PM	12:23:30 PM	7.50	46	49	38	52.3	7.0	419	11	11	0.0	52.3	7.0	419	7.0	419
12:31:40 PM	12:34:00 PM	18.00	58	67	57	68.7	3.8	229	1	12	0.0	68.7	3.8	229	1.6	93
12:39:29 PM	12:44:06 PM	28.10	91	96	90	100.3	3.6	214	5	17	0.0	100.3	3.6	214	2.3	140
12:47:30 PM	12:51:50 PM	35.83	131	132	126	137.7	3.8	231	5	22	0.0	137.6	3.8	230	3.9	232
01–Jul–97				thick trash cover				Plot 1	New sprinkler:reduced flow rate							
10:11:00 AM	10:24:30 AM	13.50	22	24	25	31.7	2.3	141	0	0	0.0	31.7	2.3	141	2.3	141
10:28:30 AM	10:47:47 AM	36.78	54	65	62	68.3	1.9	111	0	0	0.0	68.3	1.9	111	1.6	94
30–Sep–97				thick trash cover				Plot 1	New sprinkler:reduced flow rate							
10:58:35 AM	11:13:35 AM	15.00	30	34	20	36.0	2.4	144	0	0	0.0	36.0	2.4	144	2.4	144
11:20:20 AM	11:32:40 AM	34.08	49	60	39	57.3	1.7	101	20	20	0.0	57.3	1.7	101	1.1	67
11:41:30 AM	11:46:12 AM	47.62	58	67	43	64.0	1.3	81	26	46	0.1	63.9	1.3	81	0.9	51
11:51:00 AM	11:55:50 AM	57.25	72	80	59	78.3	1.4	82	48	94	0.2	78.1	1.4	82	0.9	54
11:59:05 AM	12:02:47 PM	64.20	79	88	74	88.3	1.4	83	14	108	0.2	88.1	1.4	82	1.5	88
01:42:30 PM	01:48:30 PM	6.00	11	11	9	18.3	3.1	183	70	70	0.2	18.2	3.0	182	3.0	182
01:57:00 PM	01:59:54 PM	17.40	23	24	18	29.7	1.7	102	126	196	0.4	29.2	1.7	101	1.0	58
02:07:05 PM	02:09:27 PM	26.95	32	32	23	37.0	1.4	82	38	234	0.5	36.5	1.4	81	0.9	52
02:13:35 PM	02:15:30 PM	33.00	38	36	28	42.0	1.3	76	57	291	0.6	41.4	1.3	75	0.8	47
15–Nov–96		33deg slope		bare soil surface				Plot 2								
11:52:00 AM	11:53:10 AM	1.17	2	2	2	5.0	4.3	257	48	48	0.1	4.9	4.2	254	4.2	254
11:59:01 AM	11:59:40 AM	7.67	5	4	4	7.3	1.0	57	60	108	0.1	7.2	0.9	56	0.3	21
12:07:26 PM	12:07:52 PM	15.87	10	8	6	11.0	0.7	42	70	178	0.2	10.8	0.7	41	0.4	24
12:21:03 PM	12:22:00 PM	30.00	12	10	9	13.3	0.4	27	140	318	0.4	12.9	0.4	26	0.3	15
12:39:36 PM	12:39:55 PM	47.92	15	14	13	17.0	0.4	21	100	418	0.6	16.4	0.3	21	0.2	11
12:47:29 PM	12:47:54 PM	55.90	18	16	15	19.3	0.3	21	192	610	0.8	18.5	0.3	20	0.2	13
15–Nov–96		28deg slope		95% bare soil surface				Plot 2								
01:02:04 PM	01:02:32 PM	0.47	2	2	3	5.3	11.4	686	42	42	0.1	5.3	11.3	679	11.3	679
01:05:26 PM	01:05:42 PM	3.63	5	8	6	9.3	2.6	154	358	400	0.5	8.8	2.4	145	1.1	67
01:13:10 PM	01:13:26 PM	11.37	10	10	12	13.7	1.2	72	218	618	0.8	12.8	1.1	68	0.7	42
01:20:34 PM	01:20:50 PM	18.77	13	11	15	16.0	0.9	51	210	828	1.1	14.9	0.8	48	0.4	24
01:28:22 PM	01:28:40 PM	26.60	16	14	15	18.0	0.7	41	316	1144	1.5	16.5	0.6	37	0.2	14
12–Jun–97		26deg slope		bare soil surface				Plot 2								
01:08:06 PM	01:09:06 PM	1.00	−3	0	0	7.0	7.0	420	94	94	0.1	6.9	6.9	412	6.9	412
01:13:00 PM	01:13:43 PM	5.62	3	6	3	12.0	2.1	128	330	424	0.6	11.4	2.0	122	1.0	59
01:18:00 PM	01:18:20 PM	10.23	4	8	4	13.3	1.3	78	150	574	0.8	12.6	1.2	74	0.2	15
01:23:45 PM	01:24:05 PM	15.98	6	12	8	16.7	1.0	63	135	709	0.9	15.7	1.0	59	0.4	25
01:52:00 PM	01:52:20 PM	44.23	9	13	9	18.3	0.4	25	135	844	1.1	17.2	0.4	23	0.1	8
01–Jul–97		26deg slope		bare soil surface				Plot 2	New sprinkler:reduced flow rate							
11:03:00 AM	11:08:46 AM	5.77	9	11	11	18.3	3.2	191	46	46	0.1	18.3	3.2	190	3.2	190
11:12:00 AM	11:13:58 AM	10.97	14	18	15	23.7	2.2	129	40	86	0.1	23.6	2.1	129	1.0	61
11:17:00 AM	11:19:43 AM	16.72	19	24	18	28.3	1.7	102	30	116	0.2	28.2	1.7	101	0.8	48
11:25:30 AM	11:28:05 AM	25.08	24	30	25	34.3	1.4	82	16	132	0.2	34.2	1.4	82	0.8	45
11:32:30 AM	11:36:00 AM	33.00	31	40	32	42.3	1.3	77	18	150	0.2	42.1	1.3	77	0.9	51
30–Sep–97				bare soil surface				Plot 2	New sprinkler:reduced flow rate							
09:30:00 AM	09:38:00 AM	8.00	5	9	6	14.7	1.8	110	136	136	0.3	14.4	1.8	108	1.8	108
09:41:30 AM	09:48:30 AM	18.50	17	20	18	26.3	1.4	85	156	292	0.6	25.7	1.4	83	1.1	65
09:51:40 AM	09:55:30 AM	25.50	24	29	24	33.7	1.3	79	267	559	1.2	32.4	1.3	76	1.0	58
10:02:10 AM	10:06:20 AM	36.33	31	35	31	40.3	1.1	67	112	671	1.5	38.8	1.1	64	0.7	44
10:12:35 AM	10:16:20 AM	46.33	40	43	38	48.3	1.0	63	106	777	1.7	46.6	1.0	60	0.7	41
10:22:35 AM	10:25:40 AM	55.67	44	47	42	52.3	0.9	56	160	937	2.1	50.3	0.9	54	0.6	35
10:31:30 AM	10:33:10 AM	63.17	49	52	48	57.7	0.9	55	80	1017	2.3	55.4	0.9	53	0.5	31
01:01:00 PM	01:02:50 PM	1.83	−3	−2	−2	5.7	3.1	185	68	68	0.2	5.5	3.0	181	3.0	181
01:06:00 PM	01:06:55 PM	5.92	0	1	0	8.3	1.4	85	76	144	0.3	8.0	1.4	81	0.6	37
01:11:05 PM	01:12:50 PM	11.83	3	3	2	10.7	0.9	54	68	212	0.5	10.2	0.9	52	0.5	28
01:19:20 PM	01:20:28 PM	19.47	6	10	6	15.3	0.8	47	62	274	0.6	14.7	0.8	45	0.5	30
01:29:40 PM	01:31:06 PM	30.10	12	16	12	21.3	0.7	43	70	344	0.8	20.6	0.7	41	0.6	34

TABLE . :SOIL CONSERVATION AND RUN–OFF CONTROL TRIALS: RECORD OF TREATMENTS, NOV.96–OCT97

DENNERY: GLAVIER (E) Farmer: Mr Francois Constantine Agricultural Officer: Mr Faucher

	11–Dec	16–Jan	27–Jan	12–Feb	26–Feb	12–Mar	15–Apr	14–May	05–Jun	12–Jun
	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
1 Spray application	–	–	–	–	Grmoxon	–	–	–	–	–
2 Nematicide applcn	–	–	–	–	–	–	–	–	–	–
3 Lime application/plot	25kg	–	–	–	–	–	–	–	–	–
4 Fertiliser applcn/plot	–	25kg	–	–	–	–	25kg	–	–	–
5 Trash applcn/maintnce	x	x	–	x	x	–	x	–	–	–
6 Contour drain mntnce	x	x	–	–	–	–	x	–	–	–
7 Topples(mats)	8	4	0	0	0	0	0	7	7	–
8 Fruit harvstd: bunches	4		–		–	–	–	–	–	–
boxes	4	24	–	7	–	–	–	–	–	–
lbs	85		–	241	–	–	–	–	–	–

Remarks: Gramoxone applcn made on 26Feb to control water grass.

DENNERY: PAYS PERDU Farmer: Mr Cuthbert Sealy Agricultural Officer: Mr Faucher

	11–Dec	16–Jan	27–Jan	12–Feb	26–Feb	12–Mar	15–Apr	14–May	05–Jun	12–Jun
	*********	*********	*********	*********	*********	*********	*********	*********	*********	*********
1 Spray application	–	–		–	–	–	–	–	–	–
2 Nematicide applcn	–	–		–	–	–	–	–	–	–
3 Lime application/plot	–	–		–	–	–	–	–	–	–
4 Fertiliser applcn/plot	.1kg/mat	.1kg/mat*		–	–	–	25kg/plot	–	–	–
5 Trash applcn/maintnce	x	x		–	x	x	x	x	–	–
6 Contour drain mntnce	x	x		–	–	–	x	x	–	–
7 Topples(mats)	0	0		0	0	0	0	2	2	–
8 Fruit harvstd: bunches	–				–	2	–	–		–
boxes	–	8			–		–	–	1	–
lbs	–	264			–		–	–		–

Remarks: Fertilizer applcns of Dec and Jan were made by farmer. Jan applcn made on 10Jan97.

Key: x denotes treatment made on this date: – denotes no treatment made.
Records of yield and applications obtained from farmers.

File: V2AGTREC.wk3

DENNERY: PAYS PERDUE / BAZILE

12-Jun-97		28deg slope thick trash cover						Plot 3								
02:31:30 PM	02:34:42 PM	3.20	8	7	13	17.3	5.4	325	75	75	0.1	17.2	5.4	323	5.4	323
02:37:40 PM	02:38:40 PM	7.17	18	14	27	27.7	3.9	232	250	325	0.4	27.2	3.8	228	2.5	151
02:42:07 PM	02:42:56 PM	11.43	24	20	32	33.3	2.9	175	137	462	0.6	32.7	2.9	172	1.3	77
02:47:45 PM	02:48:30 PM	17.00	29	24	41	39.3	2.3	139	71	533	0.7	38.6	2.3	136	1.2	69
02:52:45 PM	02:53:40 PM	22.17	38	32	46	46.7	2.1	126	114	647	0.9	45.8	2.1	124	1.2	73
02:58:05 PM	02:58:53 PM	27.38	42	41	52	53.0	1.9	116	280	927	1.2	51.8	1.9	113	1.3	76
03:05:37 PM	03:06:10 PM	34.67	46	44	57	57.0	1.6	99	177	1104	1.5	55.5	1.6	96	0.8	47
03:10:18 PM	03:10:50 PM	39.33	54	49	60	62.3	1.6	95	111	1215	1.6	60.7	1.5	93	0.7	45
02-Oct-97		c32deg slope-moderate trash cover						Plot 1	New sprinkler:reduced flow rate							
12:07:30 PM	12:09:18 PM	1.80	−1	0	0	5.7	3.1	189	284	284	0.6	5.0	2.8	168	2.8	168
12:15:30 PM	12:16:44 PM	9.23	1	5	3	9.0	1.0	112	112	396	0.9	8.1	0.9	53	0.4	25
12:23:30 PM	12:24:30 PM	17.00	5	7	5	11.7	0.7	122	122	518	1.2	10.5	0.6	37	0.3	19
12:31:55 PM	12:33:03 PM	25.55	6	10	8	14.0	0.5	166	166	684	1.5	12.5	0.5	29	0.3	16
12:40:20 PM	12:41:20 PM	33.83	9	12	9	16.0	0.5	134	134	818	1.8	14.2	0.4	25	0.2	13
12:48:30 PM	12:49:23 PM	41.88	11	15	11	18.3	0.4	26	258	1076	2.4	15.9	0.4	23	0.2	13
12:58:25 PM	12:59:20 PM	51.83	14	19	13	21.3	0.4	25	395	1471	3.3	18.1	0.3	21	0.2	13
01:08:35 PM	01:09:35 PM	62.08	17	21	15	23.7	0.4	23	275	1746	3.9	19.8	0.3	19	0.2	11
02:43:50 PM	02:45:05 PM	1.25	−2	−3	−3	3.3	2.7	160	325	325	0.7	2.6	2.1	125	2.1	125
02:54:00 PM	02:54:44 PM	10.90	3	2	1	8.0	0.7	44	270	595	1.3	6.7	0.6	37	0.4	25
03:04:30 PM	03:04:08 PM	20.30	5	5	4	10.7	0.5	32	370	965	2.1	8.5	0.4	25	0.2	12
03:14:40 PM	03:15:37 PM	31.78	9	10	8	15.0	0.5	28	165	1130	2.5	12.5	0.4	24	0.3	17
04-Oct-97		c28deg slope-moderate trash cover						Plot 1	New sprinkler:reduced flow rate							
11:19:00 AM	11:21:15 AM	2.25	1	1	5	8.3	3.7	222	70	70	0.2	8.2	3.6	218	3.6	218
11:24:40 AM	11:26:04 AM	7.07	8	7	10	14.3	2.0	112	130	200	0.4	13.9	2.0	118	1.2	71
11:31:30 AM	11:33:10 AM	14.17	10	11	15	18.0	1.3	122	100	300	0.7	17.3	1.2	73	0.5	29
11:39:15 AM	11:40:19 AM	21.32	15	15	16	21.3	1.0	166	102	402	0.9	20.4	1.0	58	0.5	28
11:48:10 AM	11:49:18 AM	30.30	18	19	20	25.0	0.8	134	255	657	1.5	23.5	0.8	47	0.4	23
12:00:13 PM	12:01:30 PM	42.50	21	21	26	28.7	0.7	40	132	789	1.8	26.9	0.6	38	0.3	18
12:10:30 PM	12:11:33 PM	52.55	24	22	28	30.7	0.6	35	130	919	2.0	28.6	0.5	33	0.2	14
12:23:11 PM	12:24:14 PM	65.23	26	25	30	33.0	0.5	30	120	1039	2.3	30.7	0.5	28	0.2	10
02:49:30 PM	02:51:00 PM	1.50	−2	−3	−1	4.0	2.7	160	80	80	0.2	3.8	2.5	153	2.5	153
02:57:20 PM	02:58:08 PM	8.63	0	0	3	7.0	0.8	49	114	194	0.4	6.6	0.8	46	0.4	23
03:04:45 PM	03:05:40 PM	16.17	3	3	5	9.7	0.6	36	130	324	0.7	8.9	0.6	33	0.3	19
03:15:20 PM	03:16:05 PM	26.58	7	5	8	12.7	0.5	29	55	379	0.8	11.8	0.4	27	0.3	18
03:24:30 PM	03:25:17 PM	35.78	9	8	10	15.0	0.4	25	50	429	1.0	14.0	0.4	24	0.3	16
04-Oct-97		c30deg slope-moderate trash cover						Plot 3	New sprinkler:reduced flow rate							
09:38:00 AM	09:39:30 AM	1.50	−2	0	−2	4.7	3.1	187	240	240	0.5	4.1	2.8	165	2.8	165
09:45:03 AM	09:46:03 AM	8.05	0	3	2	7.7	1.0	112	245	485	1.1	6.6	0.8	49	0.4	22
09:52:50 AM	09:53:44 AM	15.73	4	5	5	10.7	0.7	122	300	785	1.7	8.9	0.6	34	0.3	18
10:02:02 AM	10:02:50 AM	24.83	6	7	6	12.3	0.5	166	320	1105	2.5	9.9	0.4	24	0.2	12
10:11:25 AM	10:12:05 AM	34.08	8	9	9	14.7	0.4	134	140	1245	2.8	11.9	0.3	21	0.2	10
10:23:00 AM	10:23:40 AM	45.67	9	10	10	15.7	0.3	21	250	1495	3.3	12.3	0.3	16	0.1	7
10:38:10 AM	10:38:53 AM	60.88	10	11	12	17.0	0.3	17	344	1839	4.1	12.9	0.2	13	0.0	2
10:52:00 AM	10:52:47 AM	74.78	12	13	15	19.3	0.3	16	280	2119	4.7	14.6	0.2	12	0.1	5
02:03:00 PM	02:04:26 PM	1.43	−3	−3	−2	3.3	2.3	140	240	240	0.5	2.8	2.0	117	2.0	117
02:10:30 PM	02:11:17 PM	8.28	0	1	1	6.7	0.8	48	305	545	1.2	5.5	0.7	40	0.4	23
02:18:00 PM	02:18:44 PM	15.73	2	2	4	8.7	0.6	33	350	895	2.0	6.7	0.4	25	0.2	10
02:28:07 PM	02:29:03 PM	26.05	5	6	7	12.0	0.5	28	520	1415	3.1	8.9	0.3	20	0.2	11
02:38:20 PM	02:39:00 PM	36.00	7	10	10	15.0	0.4	25	390	1805	4.0	11.0	0.3	18	0.2	13
12-Jun-97		28deg slope 95% bare soil surface														
03:20:30 PM	03:21:14 PM	0.73	1	0	1	8.7	11.8	709	11	11	0.0	8.7	11.8	708	11.8	708
03:24:00 PM	03:24:48 PM	4.30	8	8	8	16.0	3.7	223	107	118	0.2	15.8	3.7	221	2.0	121
03:28:25 PM	03:28:57 PM	8.45	11	13	13	20.3	2.4	144	130	248	0.3	20.0	2.4	142	1.0	60
03:34:42 PM	03:35:17 PM	14.78	18	15	19	25.3	1.7	103	113	361	0.5	24.9	1.7	101	0.9	52
03:40:00 PM	03:40:36 PM	20.10	21	23	24	30.7	1.5	92	140	501	0.7	30.0	1.5	90	0.9	51
03:45:42 PM	03:45:04 PM	24.57	25	27	27	34.3	1.4	84	64	565	0.8	33.6	1.4	82	0.9	54
02-Oct-97		c20deg slope-no trash:80% bare soil						Plot 2	New sprinkler:reduced flow rate							
01:29:15 PM	01:31:15 PM	2.00	2	3	4	9.0	4.5	270	224	224	0.5	8.5	4.3	255	4.3	255
01:37:15 PM	01:38:15 PM	9.00	5	6	8	12.3	1.4	112	200	424	0.9	11.4	1.3	76	0.4	25
01:45:10 PM	01:46:12 PM	16.95	11	10	14	17.7	1.0	122	180	604	1.3	16.3	1.0	58	0.6	37
01:53:30 PM	01:53:26 PM	24.18	15	15	20	22.7	0.9	166	310	914	2.0	20.6	0.9	51	0.6	37
02:02:00 PM	02:02:53 PM	33.63	21	20	25	28.0	0.8	134	335	1249	2.8	25.2	0.7	45	0.5	32
02:12:30 PM	02:13:25 PM	44.17	24	23	29	31.3	0.7	43	375	1624	3.6	27.7	0.6	38	0.4	21
02:22:30 PM	02:23:20 PM	54.08	26	25	31	33.3	0.6	37	232	1856	4.1	29.2	0.5	32	0.2	12
02:33:40 PM	02:34:35 PM	65.33	30	29	36	38.3	0.6	35	200	2056	4.6	33.8	0.5	31	0.3	17
03:25:00 PM	03:26:00 PM	1.00	−3	−1	−2	4.0	4.0	240	145	145	0.3	3.7	3.7	221	3.7	221
03:34:06 PM	03:35:00 PM	10.00	1	2	1	7.3	0.7	44	290	435	1.0	6.4	0.6	38	0.3	18
03:45:35 PM	03:46:30 PM	21.50	5	5	5	11.0	0.5	31	260	695	1.5	9.5	0.4	26	0.3	16
03:55:35 PM	03:55:37 PM	30.62	9	8	9	14.7	0.5	29	280	975	2.2	12.5	0.4	24	0.3	18
04-Oct-97		c29deg slope-bare soil surface: weeds						Plot 4	New sprinkler:reduced flow rate							
12:49:40 PM	12:51:15 PM	1.58	0	1	1	6.7	4.2	253	140	140	0.3	6.4	4.0	241	4.0	241
12:54:40 PM	12:55:36 PM	5.93	5	5	4	10.7	1.8	112	54	194	0.4	10.2	1.7	104	0.9	54
01:00:00 PM	01:00:50 PM	11.17	10	8	7	14.3	1.3	122	250	444	1.0	13.3	1.2	72	0.6	36
01:05:00 PM	01:05:10 PM	15.50	11	10	10	16.3	1.1	166	180	624	1.4	14.9	1.0	58	0.5	30
01:13:00 PM	01:13:51 PM	24.18	14	13	14	19.7	0.8	134	240	864	1.9	17.7	0.7	44	0.3	20
01:21:40 AM	01:22:25 PM	32.75	19	18	16	23.7	0.7	43	395	1259	2.8	20.9	0.6	38	0.3	21
01:32:00 PM	01:32:45 PM	43.08	20	20	19	25.7	0.6	36	190	1449	3.2	22.4	0.5	31	0.2	15
01:40:15 PM	01:41:00 PM	51.33	22	22	21	27.7	0.5	32	345	1794	4.0	23.7	0.5	28	0.2	9
01:53:00 PM	01:53:42 PM	64.03	24	25	23	30.0	0.5	28	280	2074	4.6	25.4	0.4	24	0.1	8
03:34:40 PM	03:35:50 PM	1.17	−3	−3	−2	3.3	2.9	171	400	400	0.9	2.4	2.1	126	2.1	126
03:41:40 PM	03:42:20 PM	7.67	0	1	1	6.7	0.9	52	375	775	1.7	4.9	0.6	39	0.4	23
03:49:50 PM	03:50:32 PM	15.67	2	2	4	8.7	0.5	33	162	937	2.1	6.6	0.4	25	0.2	12
03:58:15 PM	03:59:15 PM	24.58	5	6	7	12.0	0.5	29	345	1282	2.8	9.2	0.4	22	0.2	15
04:07:30 PM	04:08:28 PM	33.80	7	10	10	15.0	0.4	27	280	1562	3.5	11.5	0.3	20	0.3	17

Time Start	Time Stop	Mins	Depth Measurements(mm) Rep1	Rep2	Rep3	Mean (mm)	Sprinkler Intensity (avg over expermnt) (mm/min)	(mm/hr)	Surface Run-off (ml/sq m)	(accumulatd)	(mm)	Net Infiltration depth (mm)	(avg/expt) (mm/ /min)	(mm/ /hr)	(current rate) (mm/ /min)	(mm/ /hr)
***********	***********		****	****	****				****							
DENNERY: GLAVIER (Cont.)																
15-Nov-96		29deg slope	thin cover of banana trash					Plot 3								
10:41:15 AM	10:42:15 AM	1.00	8	5	2	8.0	8.0	480	228	228	0.3	7.7	7.7	462	7.7	462
10:45:01 AM	10:46:30 AM	5.25	11	10	5	11.7	2.2	133	454	682	0.9	10.8	2.0	123	0.7	43
10:54:45 AM	10:55:45 AM	14.50	19	14	8	16.7	1.1	69	248	930	1.2	15.4	1.1	64	0.5	30
11:06:30 AM	11:07:10 AM	25.92	26	21	11	22.3	0.9	52	34	964	1.3	21.0	0.8	49	0.5	30
11:14:22 AM	11:15:02 AM	33.78	31	25	15	26.7	0.8	47	362	1326	1.8	24.9	0.7	44	0.5	29
11:26:11 AM	11:26:44 AM	45.48	35	30	18	30.7	0.7	40	134	1460	1.9	28.7	0.6	38	0.4	24
11:36:00 AM	11:36:28 AM	55.22	36	32	20	32.3	0.6	35	90	1550	2.1	30.3	0.5	33	0.3	15
19-Jun-97			thick trash cover					Plot 3								
10:06:00 AM	10:10:40 AM	4.67	24	28	20	32.0	6.9	411	0	0	0.0	32.0	6.9	411	6.9	411
10:21:21 AM	10:27:11 AM	21.18	59	69	61	71.0	3.4	201	5	5	0.0	71.0	3.4	201	2.4	142
10:35:30 AM	10:38:20 AM	32.33	78	89	82	91.0	2.8	169	32	37	0.1	90.9	2.8	169	2.1	128
10:44:00 AM	10:47:40 AM	41.67	99	89	104	105.3	2.5	152	28	65	0.1	105.2	2.5	152	1.7	100
02-Oct-97		c30deg slope-moderate trash cover						Plot 3	New sprinkler:reduced flow rate							
09:34:00 AM	09:37:33 AM	3.55	4	9	9	13.3	3.8	225	68	68	0.2	13.2	3.7	223	3.7	223
09:41:10 AM	09:42:30 AM	8.50	9	14	15	18.7	2.2	132	130	198	0.4	18.2	2.1	129	1.0	61
09:48:30 AM	09:49:30 AM	15.50	11	20	19	22.7	1.5	88	150	348	0.8	21.9	1.4	85	0.5	31
09:57:30 AM	09:58:40 AM	24.67	16	25	24	27.7	1.1	67	105	453	1.0	26.7	1.1	65	0.5	31
10:08:40 AM	10:09:50 AM	35.83	21	30	27	32.0	0.9	54	110	563	1.3	30.7	0.9	51	0.4	26
10:16:35 AM	10:16:37 AM	42.62	27	35	31	37.0	0.9	52	92	655	1.5	35.5	0.8	50	0.5	30
10:25:00 AM	10:26:10 AM	52.17	34	42	36	43.3	0.8	50	74	729	1.6	41.7	0.8	48	0.7	40
10:35:07 AM	10:36:50 AM	62.83	42	52	43	51.7	0.8	49	80	809	1.8	49.9	0.8	48	0.7	43
04:24:50 PM	04:28:50 PM	4.00	8	10	6	14.0	3.5	210	50	50	0.1	13.9	3.5	208	3.5	208
04:33:00 PM	04:34:45 PM	9.92	11	18	13	20.0	2.0	121	34	84	0.2	19.8	2.0	120	1.0	60
04:40:00 PM	04:41:18 PM	16.47	15	23	19	25.0	1.5	91	130	214	0.5	24.5	1.5	89	0.9	51
04:45:10 PM	04:46:10 PM	21.33	20	25	22	28.3	1.3	80	74	288	0.6	27.7	1.3	78	0.7	41
04:50:00 PM	04:51:00 PM	26.17	22	28	25	31.0	1.2	71	110	398	0.9	30.1	1.2	69	0.6	35
04:55:00 PM	04:56:00 PM	31.17	27	30	30	35.0	1.1	67	125	523	1.2	33.8	1.1	65	0.6	37
19-Jun-97		29deg slope	bare soil surface					Plot 4								
10:59:00 AM	11:00:00 AM	1.00	-4	-4	-6	3.3	3.3	200	100	100	0.1	3.2	3.2	192	3.2	192
11:04:35 AM	11:04:52 AM	5.87	-1	0	-3	6.7	1.1	68	124	224	0.3	6.4	1.1	65	0.7	39
11:11:00 AM	11:11:13 AM	12.22	2	3	0	9.7	0.8	47	100	324	0.4	9.2	0.8	45	0.5	27
11:16:00 AM	11:16:17 AM	17.28	4	5	0	11.0	0.6	38	180	504	0.7	10.3	0.6	36	0.3	21
11:22:21 AM	11:22:48 AM	23.80	9	9	3	15.0	0.6	38	90	594	0.8	14.2	0.6	36	0.4	26
11:29:02 AM	11:29:17 AM	30.28	9	10	4	15.7	0.5	31	150	744	1.0	14.7	0.5	29	0.3	20
30-Sep-97			bare soil surface					Plot 4	New sprinkler:reduced flow rate							
02:35:30 PM	02:38:10 PM	2.67	-1	-2	-1	6.7	2.5	150	32	32	0.1	6.6	2.5	148	2.5	148
02:46:15 PM	02:48:15 PM	12.75	3	3	5	11.7	0.9	55	86	118	0.3	11.4	0.9	54	0.5	29
02:56:40 PM	02:58:30 PM	23.00	8	8	6	15.3	0.7	40	80	198	0.4	14.9	0.6	39	0.3	20
03:06:30 PM	03:07:30 PM	32.00	10	10	9	17.7	0.6	33	80	278	0.6	17.0	0.5	32	0.3	18
03:16:20 PM	03:17:25 PM	41.92	11	12	11	19.3	0.5	28	81	359	0.8	18.5	0.4	27	0.2	12
03:26:40 PM	03:27:45 PM	52.25	13	14	11	20.7	0.4	24	56	415	0.9	19.7	0.4	23	0.1	8
03:36:20 PM	03:37:28 PM	61.97	14	16	13	22.3	0.4	22	72	487	1.1	21.3	0.3	21	0.1	8
02-Oct-97			bare soil surface					Plot 4	New sprinkler:reduced flow rate							
08:42:30 AM	08:43:24 AM	0.90	-3	-4	-4	2.3	2.6	156	71	71	0.2	2.2	2.4	145	2.4	145
08:47:40 AM	08:48:18 AM	5.80	-1	-2	-2	4.3	0.7	45	144	215	0.5	3.9	0.7	40	0.3	21
08:56:10 AM	08:56:47 AM	14.28	1	0	0	6.3	0.4	27	142	357	0.8	5.5	0.4	23	0.2	12
09:06:00 AM	09:06:34 AM	24.07	3	2	2	8.3	0.3	21	112	469	1.0	7.3	0.3	18	0.2	11
09:15:50 AM	09:16:29 AM	33.98	4	4	4	10.0	0.3	18	185	654	1.5	8.5	0.3	15	0.2	9

TABLE : INFILTRATION EXPERIMENTS: SOIL CONSERVATION & RUN-OFF CONTROL TRIALS: CUL DE SAC

File:INFXCRP.wk3

Time Start	Time Stop	Mins	Depth Measurements(mm) Rep1	Rep2	Rep3	Mean (mm)	Sprinkler Intensity (avg over expermnt) (mm/min)	(mm/hr)	Surface Run-off (ml/sq m)	**** (accumulatd)	(mm)	Net Infiltration depth (mm)	(avg/expt) (mm/	(mm/	(current rate) (mm/	(mm/
***********	***********		****	****	****											
CUL DE SAC: RAVINE POISSON																
13-Jun-97		28deg slope	thin trash cover													
01:49:20 PM	01:56:50 PM	7.50	69	90	68	83.7	11.2	669	2	2	0.0	83.7	11.2	669	11.2	669
02:06:48 PM	02:10:50 PM	21.50	109	134	110	125.7	5.8	351	10	12	0.0	125.6	5.8	351	3.0	180
03:13:00 PM	03:17:42 PM	4.70	49	55	41	56.3	12.0	719	140	152	0.3	56.1	11.9	716	11.9	716
16-Jun-97		28deg slope	thin trash cover													
10:02:30 AM	10:06:25 AM	3.92	41	41	48	51.3	13.1	786	8	8	0.0	51.3	13.1	786	13.1	786
10:12:40 AM	10:15:50 AM	13.33	71	69	81	81.7	6.1	367	16	24	0.0	81.6	6.1	367	3.2	193
10:25:02 AM	10:27:35 AM	25.08	94	92	104	104.7	4.2	250	20	44	0.1	104.6	4.2	250	2.0	117
10:34:10 AM	10:36:10 AM	33.67	121	118	126	129.7	3.9	231	30	74	0.1	129.5	3.8	231	2.4	141
10:43:00 AM	10:44:07 AM	41.62	132	128	140	141.3	3.4	204	17	91	0.2	141.2	3.4	204	2.2	133
10:51:50 AM	10:53:50 AM	51.33	150	141	159	158.0	3.1	185	10	101	0.2	157.8	3.1	184	1.6	96
07-Oct-97		c32deg slope-thin trash cover						Plot 3	New sprinkler: somewhat reduced flow rate							
11:13:30 AM	11:15:20 AM	1.83	0	2	2	7.3	4.0	240	243	243	0.5	6.8	3.7	222	3.7	222
11:18:55 AM	11:19:45 AM	6.25	3	5	5	10.3	1.7	112	211	454	1.0	9.3	1.5	90	0.6	34
11:23:55 AM	11:24:55 AM	11.42	5	7	7	12.3	1.1	122	220	674	1.5	10.8	0.9	57	0.4	25
11:29:45 AM	11:30:35 AM	17.08	8	10	10	15.3	0.9	166	164	838	1.9	13.5	0.8	47	0.4	23
11:37:30 AM	11:38:30 AM	25.00	10	12	14	18.0	0.7	134	320	1158	2.6	15.4	0.6	37	0.3	20
11:44:40 AM	11:45:40 AM	32.17	15	16	17	22.0	0.7	41	250	1408	3.1	18.9	0.6	35	0.4	21
11:55:10 AM	11:55:55 AM	42.42	17	19	21	25.0	0.6	35	390	1798	4.0	21.0	0.5	30	0.3	19
12:03:50 PM	12:04:45 PM	51.25	21	23	22	28.0	0.5	33	470	2268	5.0	23.0	0.4	27	0.2	13
12:15:15 PM	12:16:10 PM	62.67	25	25	25	31.0	0.5	30	290	2558	5.7	25.3	0.4	24	0.2	13
01:08:10 PM	01:09:22 PM	1.20	-2	0	0	5.3	4.4	267	295	295	0.7	4.7	3.9	234	3.9	234
01:18:00 PM	01:18:54 PM	10.73	2	4	4	9.3	0.9	52	520	815	1.8	7.5	0.7	42	0.3	18
01:28:15 PM	01:29:10 PM	21.00	4	6	7	11.7	0.6	33	170	985	2.2	9.5	0.5	27	0.2	11
01:38:20 PM	01:39:00 PM	30.83	6	7	10	13.7	0.4	27	230	1215	2.7	11.0	0.4	21	0.2	10
13-Jun-97		28deg slope	90% bare soil surface													
02:39:30 PM	02:40:30 PM	1.00	1	1	1	9.0	9.0	540	140	140	0.3	8.7	8.7	524	8.7	524
02:44:30 PM	02:45:24 PM	5.90	11	10	7	17.3	2.9	176	202	342	0.6	16.7	2.8	170	1.6	97
02:49:54 PM	02:50:30 PM	11.00	16	15	10	21.7	2.0	118	90	432	0.8	20.9	1.9	114	1.2	73
02:54:20 PM	02:54:59 PM	15.48	24	22	13	27.7	1.8	107	146	578	1.1	26.6	1.7	103	1.0	62
02:58:00 PM	02:58:29 PM	18.98	28	27	20	33.0	1.7	104	40	618	1.1	31.9	1.7	101	1.4	83
03:01:20 PM	03:01:47 PM	22.28	31	32	22	36.3	1.6	98	40	658	1.2	35.1	1.6	95	1.3	75
03:04:26 PM	03:04:54 PM	25.40	37	34	23	39.3	1.5	93	84	742	1.4	38.0	1.5	90	1.0	57
03:08:00 PM	03:08:30 PM	29.00	40	40	29	44.3	1.5	92	128	870	1.6	42.7	1.5	88	1.1	68
16-Jun-97		25deg slope	90% bare soil surface: local translocation													
08:53:00 AM	08:55:25 AM	2.42	9	6	9	16.0	6.6	397	0	0	0.0	16.0	6.6	397	6.6	397
08:59:12 AM	09:00:19 AM	7.32	16	16	21	25.7	3.5	210	40	40	0.1	25.6	3.5	210	2.0	117
09:04:00 AM	09:05:00 AM	12.00	20	25	29	32.7	2.7	163	28	68	0.1	32.5	2.7	163	1.5	89
09:08:30 AM	09:09:18 AM	16.30	27	40	33	41.3	2.5	152	28	96	0.2	41.2	2.5	151	1.7	104
09:13:10 AM	09:13:50 AM	20.83	33	51	39	49.0	2.4	141	57	153	0.3	48.7	2.3	140	1.8	110
09:19:00 AM	09:19:40 AM	26.67	39	56	44	54.3	2.0	122	24	177	0.3	54.0	2.0	122	1.2	74
09:25:30 AM	09:26:10 AM	33.17	45	61	51	60.3	1.8	109	80	257	0.5	59.9	1.8	108	0.9	54
09:31:30 AM	09:32:15 AM	39.25	49	67	56	65.3	1.7	100	106	363	0.7	64.7	1.6	99	0.8	51
16-Jun-97		30deg slope	90-95% bare soil surface													
11:26:00 AM	11:27:40 AM	1.67	2	3	7	12.0	7.2	432	16	16	0.0	12.0	7.2	431	7.2	431
11:32:06 AM	11:32:50 AM	6.83	6	7	9	15.3	2.2	135	40	56	0.1	15.2	2.2	134	0.6	38
11:35:30 AM	11:36:05 AM	10.08	12	12	14	20.7	2.0	123	15	71	0.1	20.5	2.0	122	1.6	98
11:40:30 AM	11:41:15 AM	15.25	17	14	20	25.0	1.6	98	20	91	0.2	24.8	1.6	98	1.1	68
11:46:20 AM	11:46:51 AM	20.85	20	20	25	29.7	1.4	85	14	105	0.2	29.5	1.4	85	0.8	50
11:51:00 AM	11:51:20 AM	25.33	21	21	26	30.7	1.2	73	0	105	0.2	30.5	1.2	72	0.6	34
11:54:20 AM	11:54:56 AM	28.93	26	29	31	36.7	1.3	76	28	133	0.2	36.4	1.3	76	0.9	52
12:00:35 PM	12:01:30 PM	35.50	31	32	35	40.7	1.1	69	16	149	0.3	40.4	1.1	68	1.0	59
12:06:30 PM	12:07:14 PM	41.23	37	40	40	47.0	1.1	68	10	159	0.3	46.7	1.1	68	0.8	50
07-Oct-97		c28deg slope-bare soil surfc:common weeds						Plot 2	New sprinkler: somewhat reduced flow rate							
09:50:00 AM	09:51:05 AM	1.08	-5	-2	-5	2.0	1.8	111	200	200	0.4	1.6	1.4	86	1.4	86
09:55:15 AM	09:56:10 AM	6.17	-1	1	-4	4.7	0.8	112	160	360	0.8	3.9	0.6	38	0.5	27
10:01:40 AM	10:02:35 AM	12.58	2	3	1	8.0	0.6	122	270	630	1.4	6.6	0.5	31	0.4	26
10:07:15 AM	10:07:55 AM	17.92	4	4	4	10.0	0.6	166	240	870	1.9	8.1	0.5	27	0.4	21
10:13:35 AM	10:14:33 AM	24.55	5	6	6	11.7	0.5	134	250	1120	2.5	9.2	0.4	22	0.2	13
10:21:10 AM	10:22:00 AM	32.00	7	8	8	13.7	0.4	26	230	1350	3.0	10.7	0.3	20	0.2	11
10:34:20 AM	10:35:10 AM	45.17	10	11	11	16.7	0.4	22	194	1544	3.4	13.2	0.3	18	0.2	12
10:50:15 AM	10:51:05 AM	61.08	11	12	13	18.0	0.3	18	203	1747	3.9	14.1	0.2	14	0.1	7
12:28:45 PM	12:29:50 PM	1.08	-3	-2	-2	3.7	3.4	203	245	245	0.5	3.1	2.9	173	2.9	173
12:39:13 PM	12:40:15 PM	11.50	0	0	1	6.3	0.6	33	110	355	0.8	5.5	0.5	29	0.2	14
12:49:00 PM	12:49:48 PM	21.05	5	4	5	10.7	0.5	30	200	555	1.2	9.4	0.4	27	0.4	24
12:59:00 PM	12:59:56 PM	31.18	5	6	6	11.7	0.4	22	140	695	1.5	10.1	0.3	19	0.1	4

TABLE . : INFILTRATION EXPERIMENTS: SOIL CONSERVATION & RUN-OFF CONTROL TRIALS: CHOPIN RIDGE

Time Start	Time Stop	Mins	Depth Measurements(mm) Rep1	Rep2	Rep3	Mean (mm)	Sprinkler Intensity (avg over expermnt) (mm/min)	(mm/hr)	Surface Run-off (ml/sq m)	(accumulatd)	(mm)	Net Infiltration depth (mm)	(avg/expt) (mm/	(mm/	(current rate) (mm/	(mm/
***********	***********		****	****	****				****							
CUL DE SAC: CHOPPIN RIDGE																
13-Jun-97		26deg slope	thick banana trash cover													
08:44:30 AM	08:45:25 AM	0.92	11	6	5	15.3	16.7	1004	98	98	0.2	15.1	16.5	991	16.5	991
08:48:20 AM	08:49:37 AM	5.12	31	15	21	30.3	5.9	356	38	136	0.3	30.1	5.9	353	3.6	213
08:53:00 AM	08:53:30 AM	9.00	41	25	29	39.7	4.4	264	45	181	0.3	39.3	4.4	262	3.0	179
08:57:00 AM	08:58:20 AM	13.83	60	41	41	55.3	4.0	240	76	257	0.5	54.8	4.0	238	2.8	170
09:02:40 AM	09:03:30 AM	19.00	70	45	49	62.7	3.3	198	34	291	0.6	62.1	3.3	196	2.3	137
09:08:40 AM	09:10:20 AM	25.83	90	60	63	79.0	3.1	183	14	305	0.6	78.4	3.0	182	2.0	118
09:15:00 AM	09:16:40 AM	32.17	113	80	84	100.3	3.1	187	1	306	0.6	99.7	3.1	186	2.9	172
16-Jun-97		(above site -	thick banana trash cover)					(second day of infiltration)								
01:23:30 PM	01:29:25 PM	5.92	32	31	33	40.0	6.8	406	0	0	0.0	40.0	6.8	406	6.8	406
01:44:50 PM	01:48:50 PM	25.33	71	66	75	78.7	3.1	186	0	0	0.0	78.7	3.1	186	2.0	119
01:58:54 PM	02:05:40 PM	42.17	117	106	124	123.7	2.9	176	0	0	0.0	123.7	2.9	176	2.7	160
02:15:35 PM	02:20:55 PM	57.42	157	144	167	164.0	2.9	171	1	1	0.0	164.0	2.9	171	2.6	159
16-Jun-97		26deg slope	30%trash cover, 40%weed cover													
02:40:30 PM	02:41:20 PM	0.83	-6	-5	-5	2.7	3.2	192	134	134	0.3	2.4	2.9	173	2.9	173
02:44:50 PM	02:45:20 PM	4.83	-4	-2	-2	5.3	1.1	66	100	234	0.5	4.9	1.0	61	0.6	37
02:48:45 PM	02:49:15 PM	8.75	0	1	1	8.7	1.0	59	52	286	0.6	8.1	0.9	56	0.7	43
02:53:00 PM	02:53:25 PM	12.92	2	4	4	11.3	0.9	53	28	314	0.6	10.7	0.8	50	0.7	43
02:56:40 PM	02:57:02 PM	16.53	5	6	6	13.7	0.8	50	46	360	0.7	13.0	0.8	47	0.6	37
03:01:00 PM	03:01:20 PM	20.83	9	9	9	17.0	0.8	49	45	405	0.8	16.2	0.8	47	0.7	42
03:05:00 PM	03:05:22 PM	24.87	10	11	11	18.7	0.8	45	12	417	0.8	17.9	0.7	43	0.6	35
03:09:00 PM	03:09:20 PM	28.83	12	13	13	20.7	0.7	43	150	567	1.1	19.6	0.7	41	0.4	25
03:14:30 PM	03:15:12 PM	34.70	15	19	18	25.3	0.7	44	24	591	1.1	24.2	0.7	42	0.6	39
03:19:30 PM	03:20:13 PM	39.72	21	21	22	29.3	0.7	44	70	661	1.3	28.1	0.7	42	0.8	47
03:24:00 PM	03:24:30 PM	44.00	22	24	24	31.3	0.7	43	12	673	1.3	30.0	0.7	41	0.6	38
03:31:10 PM	03:32:05 PM	51.58	28	29	30	37.0	0.7	43	34	707	1.4	35.6	0.7	41	0.6	38
03:37:40 PM	03:38:14 PM	57.73	31	33	33	40.3	0.7	42	42	749	1.4	38.9	0.7	40	0.6	39
13-Jun-97		26deg slope	bare soil surface: 15% weed cover													
09:39:30 AM	09:39:50 AM	0.33	-5	-5	-6	2.7	8.0	480	30	30	0.1	2.6	7.8	470	7.8	470
09:42:17 AM	09:42:33 AM	3.05	-2	-2	-4	5.3	1.7	105	85	115	0.2	5.1	1.7	101	0.9	55
09;45:28 AM	09:45:42 AM	6.20	0	1	1	8.7	1.4	84	50	165	0.3	8.4	1.3	81	1.0	59
09:52:15 AM	09:52:30 AM	13.00	1	2	3	10.0	0.8	46	26	191	0.4	9.6	0.7	45	0.5	27
09:58:45 AM	09:59:00 AM	19.50	3	5	3	11.7	0.6	36	14	205	0.4	11.3	0.6	35	0.2	13
10:02:00 AM	10:02:15 AM	22.75	5	7	5	13.7	0.6	36	46	251	0.5	13.2	0.6	35	0.4	22
10:06:40 AM	10:06:56 AM	27.43	9	9	8	16.7	0.6	36	30	281	0.5	16.1	0.6	35	0.6	37
10:11:40 AM	10:11:54 AM	32.40	10	11	9	18.0	0.6	33	30	311	0.6	17.4	0.5	32	0.4	26
13-Jun-97		26deg slope	almost bare soil surface: 40% weed cover													
11:23:03 AM	11:23:49 AM	0.77	0	1	1	8.7	11.3	678	40	40	0.1	8.6	11.2	672	11.2	672
11:28:00 AM	11:29:20 AM	6.28	12	17	14	22.3	3.6	213	60	100	0.2	22.1	3.5	211	2.5	147
11:33:40 AM	11:34:30 AM	11.45	22	31	21	32.7	2.9	171	31	131	0.2	32.4	2.8	170	2.2	134
11:40:15 AM	11:40:53 AM	17.83	28	35	26	37.7	2.1	127	27	158	0.3	37.4	2.1	126	1.3	79
11:48:40 AM	11:49:05 AM	26.03	31	38	32	41.7	1.6	96	38	196	0.4	41.3	1.6	95	0.6	37
11:54:00 AM	11:54:27 AM	31.40	36	44	34	46.0	1.5	88	50	246	0.5	45.5	1.5	87	0.6	36
12:00:30 PM	12:01:05 PM	38.03	39	47	39	49.7	1.3	78	110	356	0.7	49.0	1.3	77	0.6	39
12:09:10 PM	12:09:40 PM	46.62	42	51	43	53.3	1.1	69	60	416	0.8	52.6	1.1	68	0.5	28
12:17:08 PM	12:17:35 PM	54.53	46	55	47	57.3	1.1	63	36	452	0.8	56.5	1.0	62	0.5	27
12:25:03 PM	12:25:34 PM	62.52	53	59	50	62.0	1.0	60	67	519	1.0	61.0	1.0	59	0.5	32

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Annex 7

Appendix C

Borehole Logs
Grain Size Distribution Curves

EXPLANATION OF SOIL DESCRIPTION SHOWN ON BORE HOLE LOGS

1. DEFINITION OF SOIL TYPES (ASTM)

Material	Definition	Fractions	Sieve Limit
Boulders	Greater than 200mm (diam)	-	-
Cobbles	76.2mm to 200mm	-	-
Gravel	4.76mm to 76.2mm	Coarse	19.1mm to 76.2mm
		Fine	4.76mm to 19.1mm
Sand	0.074mm to 4.76mm	Coarse	2.0mm to 4.76mm
		Medium	0.42mm to 2.0mm
		Fine	0.074mm to 0.42mm
Silt	Material finer than 0.074mm		
Clay	Material finer than 0.074mm which exhibits plasticity.		

11 COMPOSITION OF SOIL

A. Principle Soil Type

The principle soil type in each stratum represents at least 50% by weight of the material in the stratum.

B. Minor Soil Types

The descriptive terms "trace", "little", "some", "and" indicate the percentages by weight of the minor soil types in each stratum as follows:

Trace:	<10%	Some:	21 - 35%
Little:	11 - 20%	And:	35 - 50%

e.g. - 30% silt is described as "some" silt
12% sand is described as "little" sand

111 DENSITY AND CONSISTENCY OF SOILS

(Terzaghi and Peck - Split barrel 50.0mm O.D., 35.0mm I.D. 64kg hammer, free falling 76cm.)

A. Relative Density of Sand and Silt

No. of blows (N)	Relative Density
0 - 4	Very loose
4 - 10	Loose
10 - 30	Compact
30 - 50	Dense
Over 50	Very Dense

B. Consistency of Clayey Soils

No. of blows (N)	Consistency
< 2	Very soft
2 - 4	Soft
4 - 8	Firm
8 - 15	Stiff
15 - 30	Very stiff
Over 30	Hard

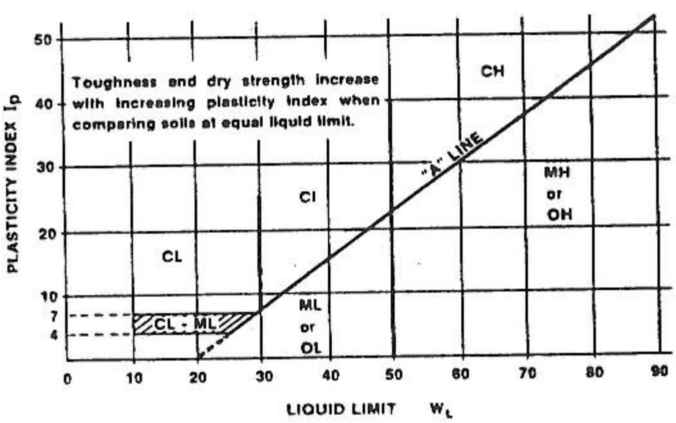
SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.)

MAJOR DIVISION			GROUP SYMBOL	GRAPHIC SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE SIZE)	GRAVELS MORE THAN HALF COARSE FRACTION LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS	GW		RED	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, < 5% FINES	$C_u = \frac{D_{60}}{D_{10}} > 4$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP		RED	POORLY-GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, < 5% FINES	NOT MEETING ALL ABOVE REQUIREMENTS	
		DIRTY GRAVELS	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES > 12% FINES	ATTERBERG LIMITS BELOW "A" LINE OR $I_p < 4$	
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES > 12% FINES	ATTERBERG LIMITS ABOVE "A" LINE, $I_p > 7$	
	SANDS MORE THAN HALF COARSE FRACTION SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS	SW		RED	WELL-GRADED SANDS, GRAVELLY SANDS, < 5% FINES	$C_u = \frac{D_{60}}{D_{10}} > 6$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP		RED	POORLY-GRADED SANDS, OR GRAVELLY SANDS, < 5% FINES	NOT MEETING ALL ABOVE REQUIREMENTS	
		DIRTY SANDS	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES > 12% FINES	ATTERBERG LIMITS BELOW "A" LINE OR $I_p < 4$	
			SC		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES > 12% FINES	ATTERBERG LIMITS ABOVE "A" LINE OR $I_p > 7$	
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES NO. 200 SIEVE SIZE)	SILTS BELOW "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	$W_L < 50$	SEE CHART BELOW
			MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS	$W_L > 50$	
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS	$W_L < 30$	
			CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY SILTY CLAYS	$W_L > 30, < 50$	
			CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	$W_L > 50$	
	ORGANIC SILTS & ORGANIC CLAYS BELOW "A" LINE ON PLASTICITY CHART		OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	$W_L < 50$	
			OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY	$W_L > 50$	

1. All sieve sizes mentioned on this chart are U.S. Standard, ASTM E11.
2. Boundary classifications possessing characteristics of two groups are given combined group symbols eg GW-GC is a well-graded gravel-sand mixture with clay binder between 5% and 12%.
3. Soil fractions and limiting textural boundaries are in accordance with the Unified Soil Classification System, except that an inorganic clay of medium plasticity (CI) is recognized.
4. The following adjectives may be employed to define percentage ranges by weight of minor components:

and	50 - 36%
some	35 - 21%
little	20 - 11%
trace	10 - 1%

PLASTICITY CHART



STRATA ENGINEERING CONSULTANTS
CASTRIES, ST LUCIA WEST INDIES

STRATA ENGINEERING
Castries, St.Lucia

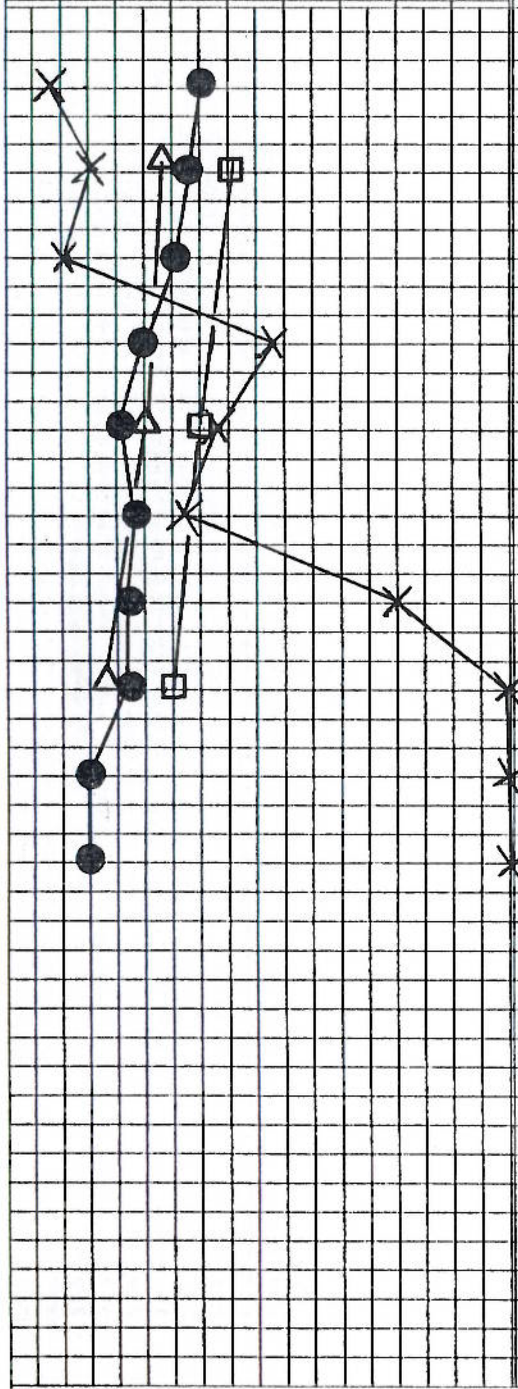
TEST HOLE LOG AND LABORATORY TEST DATA

PROJECT: St.Lucia Watershed & Environment Management

DWN.	CKD.	JOB NO.	DATE June'97	HOLE NO. BH-1	CHAIN.

NATURAL MOISTURE CONTENT ●——●
LIQUID LIMIT (L.L.) ▫——▫
PLASTIC LIMIT (P.L.) △——△
STANDARD PENETRATION TEST X——X

MOISTURE CONTENT(%) & STANDARD PENETRATION(N)



SOIL PROFILE

DEPTH / ELEV. (m) — CLASSIFICATION — DATUM — GROUND SURFACE ELEVATION

RESIDUAL SOIL

- SILT
- little clay
- little sand
- low plasticity
- some oxidation
- black specks
- stiff to hard
- moist
- brown

SAMPLES

Depth (m)	Other Tests	Unconfined Compressive Strength kg/cm²	Sample Cond.	Type
2	N=9	Pp=1	Disturbed	DS
	N=17	Pp=2	Disturbed	DS, U
4				U
	N=12		Disturbed	DS
6	N=48	Pp=3.0	Disturbed	DS
8	N=39		Disturbed	DS
	N=33		Disturbed	DS
10	N=70	Pp=5+	Disturbed	DS
12	N=100		Disturbed	DS
14	N=100		Disturbed	DS
	N=100		Disturbed	DS

End of borehole at 16.0m
No water encountered
Standpipe piezometer installed to 16.0m
▽ - groundwater level 10 days after drilling
Pp= pocket penetrometer reading

PENETRATION RESISTANCE	SOIL TYPES	LABORATORY TEST SYMBOLS	CONDITION	SAMPLE TYPES
(N)=No. OF BLOWS OF A 64kg HAMMER DROPPED 760mm (FREE FALL) REQUIRED TO DRIVE A 50mm DIA. O.D. RAYMOND TYPE SAMPLER 300mm INTO THE SOIL.	TOPSOIL, SILT, PEAT, SAND, FILL, GRAVEL, CLAY, BEDROCK	Qu-UNCONFINED COMP.STR. kg/m² ; -DRY UNIT WEIGHT kn/m³ ; C--CONSOLIDATION TEST ; MA-GRAIN SIZE ANALYSIS	UNDISTURBED ; DISTURBED ; LOST SAMPLE	U--76mmDIA. SHELBY TUBE ; D.S.--DRIVE SAMPLE ; M--MOISTURE CONTENT ; R.C.--ROCK CORE

PLATE NO.

STRATA ENGINEERING
Castries, St.Lucia

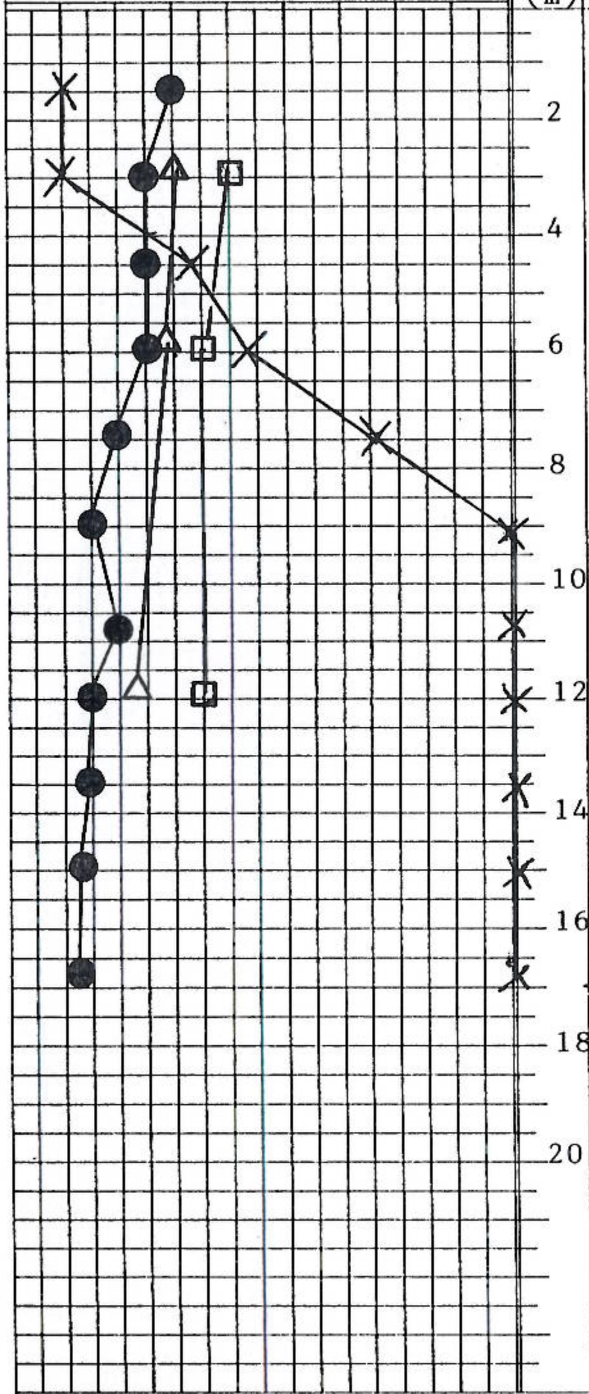
TEST HOLE LOG AND LABORATORY TEST DATA

PROJECT: St.Lucia Watershed & Environmental Management

DWN.	CKD.	JOB NO.	DATE June '97	HOLE NO. BH-2	CHAIN.

NATURAL MOISTURE CONTENT ●——●
LIQUID LIMIT (L.L.) □——□
PLASTIC LIMIT (P.L.) △——△
STANDARD PENETRATION TEST ×——×

MOISTURE CONTENT(%) & STANDARD PENETRATION(N)



SOIL PROFILE

DEPTH ELEV. (m)	CLASSIFICATION — DATUM — GROUND SURFACE ELEVATION	SOIL SYMBOL	OTHER TESTS	UNCONFINED COMPRESSIVE STRENGTH kg/cm²	SAMPLE COND.	TYPE	DEPTH SCALE
2	**RESIDUAL SOIL**		N=12	Pp=3	⊠	DS	2
	- SILT - little clay - little sand		N=10	Pp=3	⊠	U DS	
4	- low plasticity - trace organics		N=34		⊠	DS	4
6	- oxidation - stiff to hard - moist - brown		N=44		⊠	DS	6
8			N=66		⊠	DS	8
			N=100		⊠	DS	
10			N=100		⊠	DS	10
12	**SILT**		N=100		⊠	DS	12
14	- some sand - non plastic		N=102		⊠	DS	14
	- very dense - moist		▽ N=100		⊠	DS	
16	- greyish white		N=107		⊠	DS	16
18	End of borehole at 17.0m						18
20	No water encountered. Standpipe piezometer installed to 17.0m						20

▽ - groundwater level 21 days after drilling

Pp=Pocket penetrometer reading

PENETRATION RESISTANCE	SOIL TYPES	LABORATORY TEST SYMBOLS	CONDITION	SAMPLE TYPES
(N)=No. OF BLOWS OF A 64kg HAMMER DROPPED 760mm (FREE FALL) REQUIRED TO DRIVE A 50mm DIA. O.D. RAYMOND TYPE SAMPLER 300mm INTO THE SOIL.	TOPSOIL, SILT, PEAT, SAND, FILL, GRAVEL, CLAY, BEDROCK	Qu-UNCONFINED COMP.STR.kg/m² -DRY UNIT WEIGHT kn/m³ C--CONSOLIDATION TEST MA-GRAIN SIZE ANALYSIS	UNDISTURBED, DISTURBED, LOST SAMPLE	U--76mmDIA.SHELBY TUBE D.S.--DRIVE SAMPLE M--MOISTURE CONTENT R.C.--ROCK CORE

PLATE NO.

STRATA ENGINEERING
Castries, St. Lucia

DWN.	CKD.

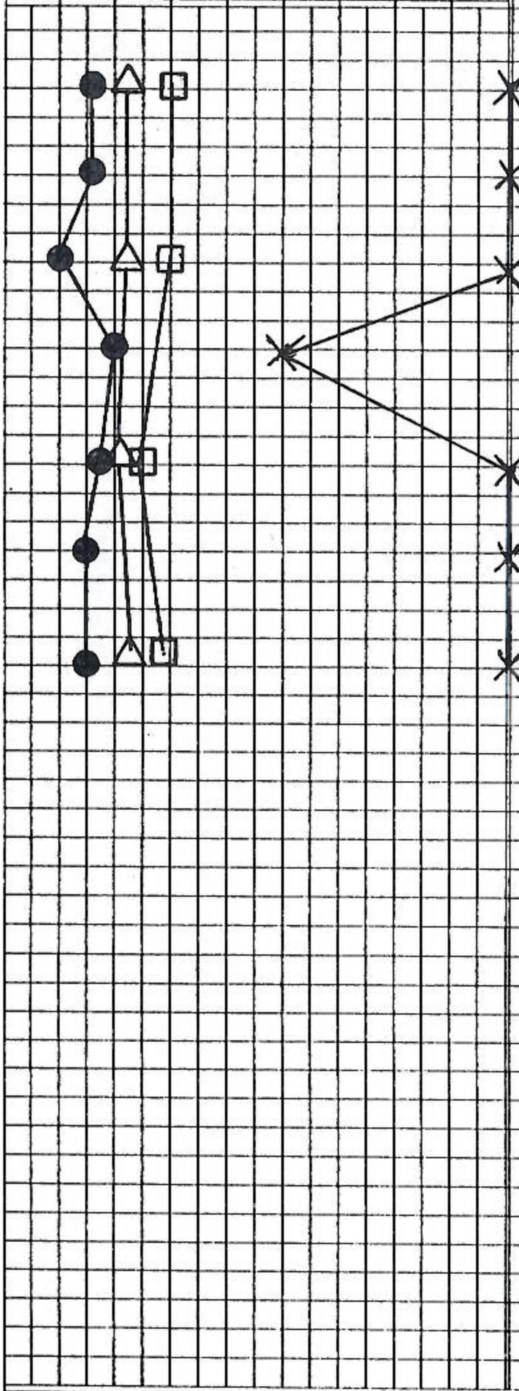
TEST HOLE LOG AND LABORATORY TEST DATA

PROJECT St.Lucia Watershed & Environment Management

JOB NO.	DATE June '97	HOLE NO BH-3	CHAIN.

NATURAL MOISTURE CONTENT ●——●
LIQUID LIMIT (L.L.) □——□
PLASTIC LIMIT (P.L.) △——△
STANDARD PENETRATION TEST X——X

MOISTURE CONTENT(%) & STANDARD PENETRATION(N)
10 20 30 40 50 60 70 80



SOIL PROFILE

DEPTH ELEV. (m)	CLASSIFICATION DATUM GROUND SURFACE ELEVATION
0–12	**RESIDUAL SOIL** **SILT** - trace of clay - little sand - non plastic - black specks - very dense - oxidation - moist - light brown
12	End of borehole at 12.0m No water encountered Standpipe piezometer installed to 11.7m ∇ - groundwater level 21 days after drilling

SAMPLES

SOIL SYMBOL	OTHER TESTS	UNCONFINED COMPRESSIVE STRENGTH kg/cm^2	SAMPLE COND.	TYPE	DEPTH SCALE
SILT	N=97		Disturbed	DS	2
SILT	N=105		Disturbed	DS	
SILT	N=101		Disturbed	DS	4
SILT	N=51		Disturbed	DS	6
SILT	N=90		Disturbed	DS	8
SILT	N=100 ∇		Disturbed	DS	10
SILT	N=100		Disturbed	DS	12

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18

PENETRATION RESISTANCE	SOIL TYPES	LABORATORY TEST SYMBOLS	CONDITION	SAMPLE TYPES
(N)=No. OF BLOWS OF A 64kg HAMMER DROPPED 760mm (FREE FALL) REQUIRED TO DRIVE A 50mm DIA. O.D. RAYMOND TYPE SAMPLER 300mm INTO THE SOIL.	TOPSOIL, SILT, PEAT, SAND, FILL, GRAVEL, CLAY, BEDROCK	Qu-UNCONFINED COMP.STR. kg/m^2 -DRY UNIT WEIGHT kn/m^3 C--CONSOLIDATION TEST MA-GRAIN SIZE ANALYSIS	— UNDISTURBED — DISTURBED — LOST SAMPLE	U--76mmDIA.SHELBY TUBE D.S.--DRIVE SAMPLE M--MOISTURE CONTENT R.C.--ROCK CORE

PLATE NO.

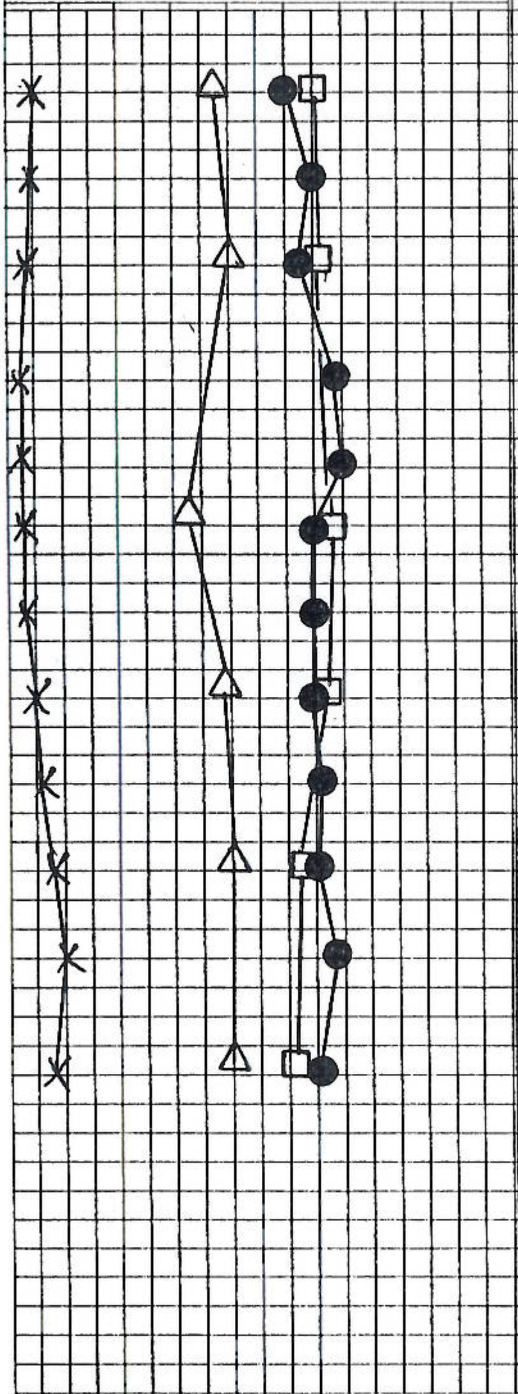
STRATA ENGINEERING
Castries, St.Lucia

TEST HOLE LOG AND LABORATORY TEST DATA

PROJECT	St. Lucia Watershed & Environmental Management			
DWN.	CKD.	JOB NO.	DATE June'97	HOLE NO BH-4	CHAIN.

NATURAL MOISTURE CONTENT ●—●
LIQUID LIMIT (L.L.) □—□
PLASTIC LIMIT (P.L.) △—△
STANDARD PENETRATION TEST X—X

MOISTURE CONTENT(%) & STANDARD PENETRATION(N)
10 20 30 40 50 60 70 80



SOIL PROFILE

DEPTH / ELEV. (m)	CLASSIFICATION	SOIL SYMBOL	OTHER TESTS	UNCONFINED COMPRESSIVE STRENGTH kg/cm²	SAMPLE COND.	TYPE	DEPTH SCALE
	DATUM / GROUND SURFACE ELEVATION						
2	RESIDUAL SOIL (FILL)		N=5		☒	DS	2
	- SILT - some clay - trace of sand		N=4		☒	U DS	
4	- medium to high plasticity		N=4		☒	DS	4
6	- excessive oxidation - soft to stiff - moist - reddish brown		N=3		☒	U DS	6
8			N=3		☒	DS	8
	- trace of organics		N=4		☒	DS	
10			N=4		☒	DS	10
12			▽ N=5		☒	DS	12
14			N=4		☒	U DS	14
			N=6		☒	DS	
16			N=4		☒	U DS	16
18							18
	End of borehole at 20.0m No water encountered Standpipe piezometer installed to 18.0m ▽ - groundwater level 21 days after drilling		N=9		☒	DS	
20							20
22							22
24							24

PENETRATION RESISTANCE	SOIL TYPES	LABORATORY TEST SYMBOLS	CONDITION	SAMPLE TYPES
(N)=No. OF BLOWS OF A 64kg HAMMER DROPPED 760mm (FREE FALL) REQUIRED TO DRIVE A 50mm DIA. O.D. RAYMOND TYPE SAMPLER 300mm INTO THE SOIL.	TOPSOIL, SILT, PEAT, SAND, FILL, GRAVEL, CLAY, BEDROCK	Qu-UNCONFINED COMP.STR. kg/m² -DRY UNIT WEIGHT kn/m³ C--CONSOLIDATION TEST MA-GRAIN SIZE ANALYSIS	UNDISTURBED DISTURBED LOST SAMPLE	U--76mmDIA.SHELBY TUBE D.S.--DRIVE SAMPLE M--MOISTURE CONTENT R.C.--ROCK CORE

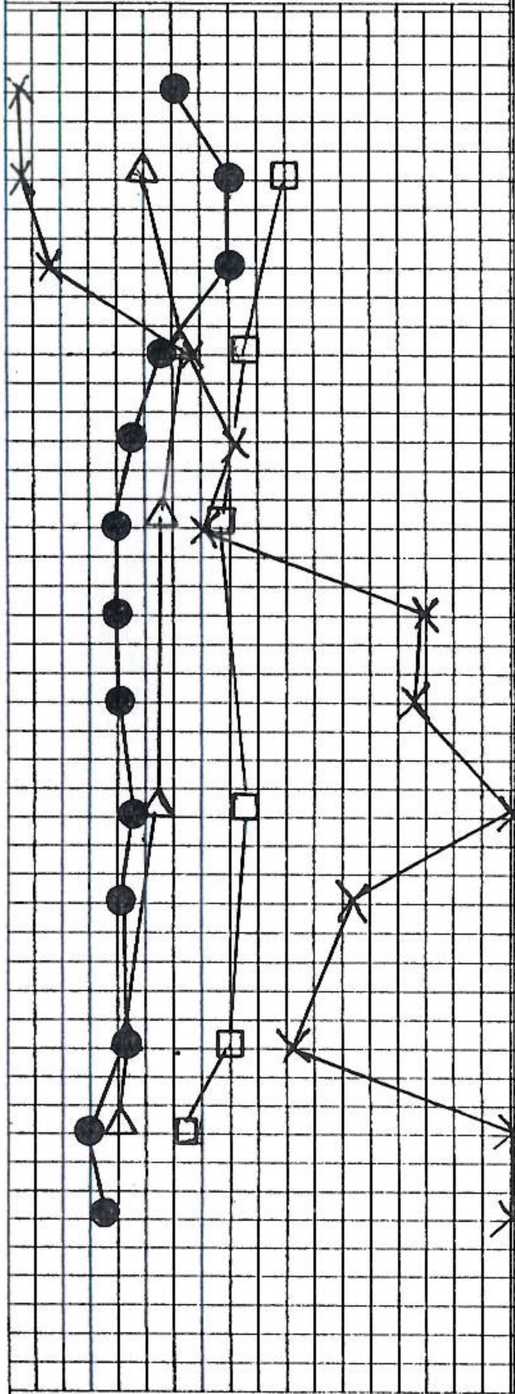
PLATE NO.

STRATA ENGINEERING Castries, St.Lucia	TEST HOLE LOG AND LABORATORY TEST DATA PROJECT St.Lucia Watershed & Environmental Management

DWN.	CKD.	JOB NO.	DATE	HOLE NO BH-5	CHAIN.

NATURAL MOISTURE CONTENT ●——●
LIQUID LIMIT (L.L.) □——□
PLASTIC LIMIT (P.L.) △——△
STANDARD PENETRATION TEST X——X

MOISTURE CONTENT(%) & STANDARD PENETRATION(N)
10 20 30 40 50 60 70 80



SOIL PROFILE

DEPTH / ELEV. (m) — CLASSIFICATION
DATUM
GROUND SURFACE ELEVATION

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

RESIDUAL SOIL
- SILT
- little clay
- little sand
- low plasticity
- excessive oxidation
- white specks
- black specks
- firm to hard
- moist
- reddish brown

SILT
- little clay
- trace of sand
- low plasticity
- moist
- hard
- grey

End of borehole at 21.0m
Standpipe piezometer installed to 20.0m
▽ - groundwater level

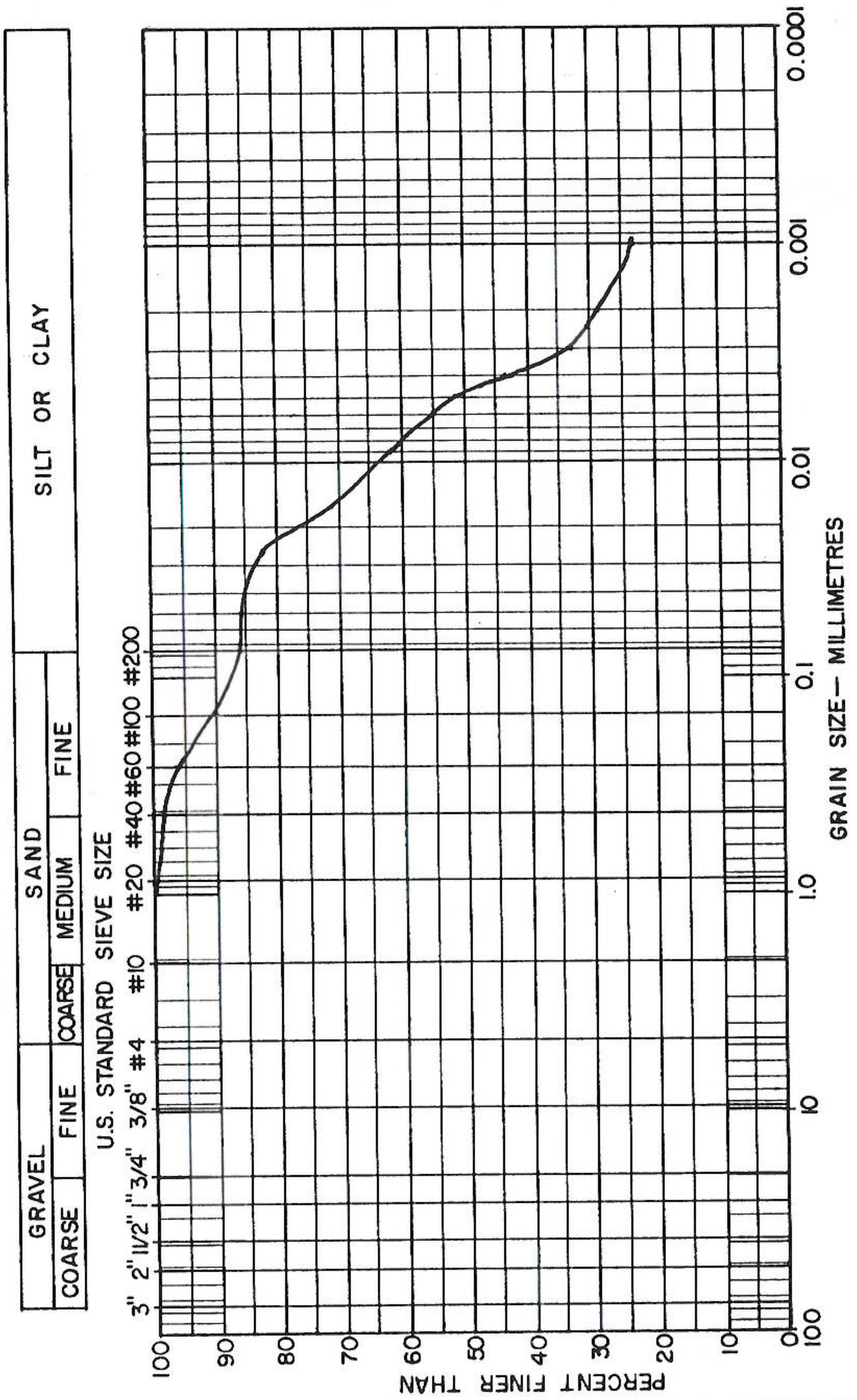
SAMPLES

SOIL SYMBOL	OTHER TESTS	UNCONFINED COMPRESSIVE STRENGTH kg/cm²	SAMPLE COND.	TYPE	DEPTH SCALE
	N=3	Pp=1	⊠	DS	2
				U	
	N=4	Pp=1	⊠	DS	
				U	4
	N=8	Pp=3	⊠	DS	
	N=34		⊠	DS	6
	N=41		⊠	DS	8
	N=36		⊠	DS	
	N=75		⊠	DS	10
	▽				
	N=73		⊠	DS	12
	N=119		⊠	DS	14
	N=61		⊠	DS	
	N=51		⊠	DS	16
	N=50		⊠	DS	18
	N=100		⊠	DS	20
	N=100		⊠	DS	
					22
					24

PENETRATION RESISTANCE	SOIL TYPES	LABORATORY TEST SYMBOLS	CONDITION	SAMPLE TYPES
(N)=No. OF BLOWS OF A 64kg HAMMER DROPPED 760mm (FREE FALL) REQUIRED TO DRIVE A 50mm DIA. O.D. RAYMOND TYPE SAMPLER 300mm INTO THE SOIL.	TOPSOIL, SILT, PEAT, SAND, FILL, GRAVEL, CLAY, BEDROCK	Qu-UNCONFINED COMP.STR.kg/m² -DRY UNIT WEIGHT kn/m³ C--CONSOLIDATION TEST MA-GRAIN SIZE ANALYSIS	▱ — UNDISTURBED ⊠ — DISTURBED ■ — LOST SAMPLE	U--76mmDIA.SHELBY TUBE D.S.--DRIVE SAMPLE M--MOISTURE CONTENT R.C.--ROCK CORE

PLATE NO.

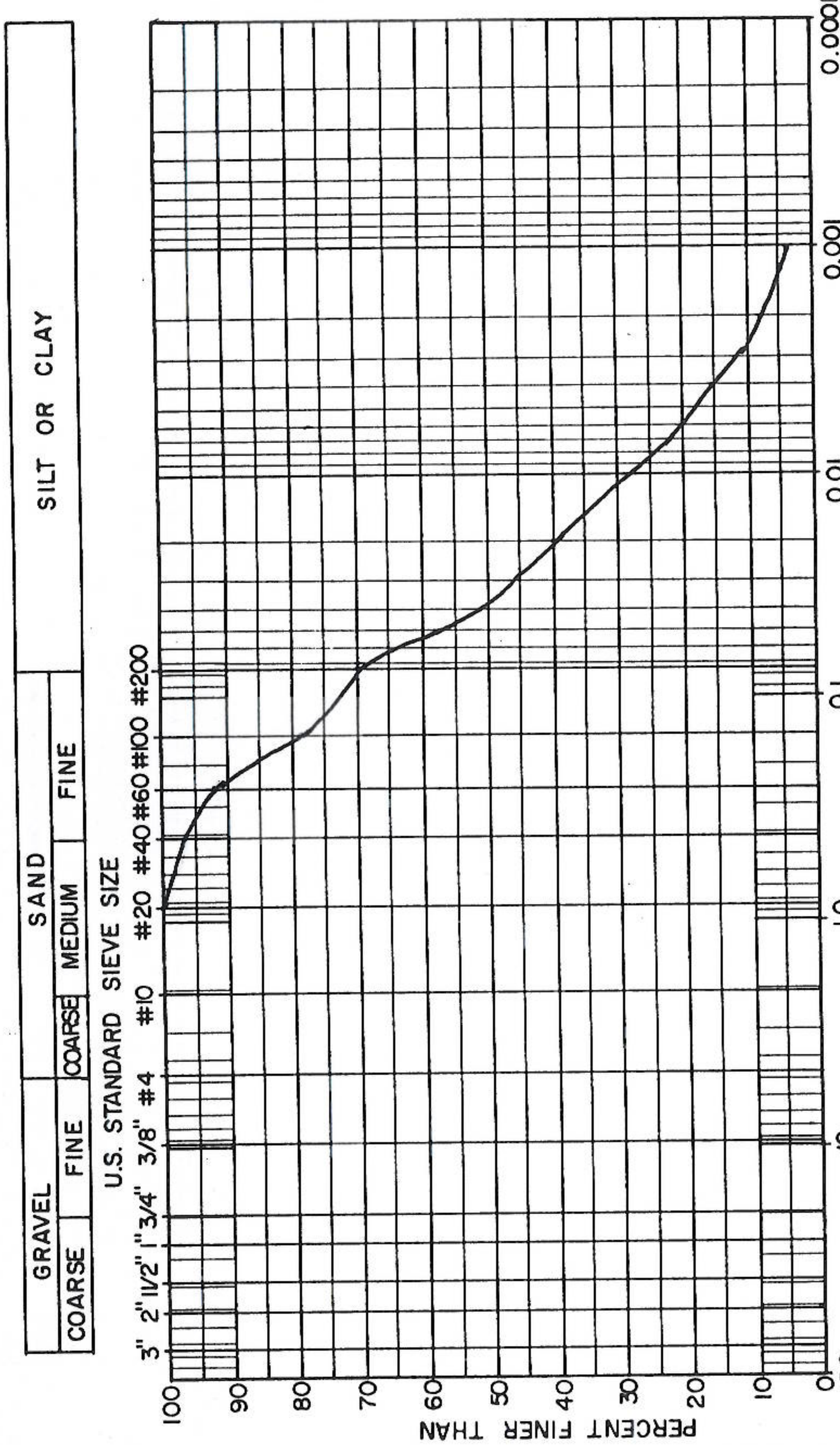
GRAIN SIZE CURVE



REMARKS: clayey SILT, trace of sand, low plasticity, moist, brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-1 DEPTH 3.0-3.5m
	DATE 21 June 1997

GRAIN SIZE CURVE

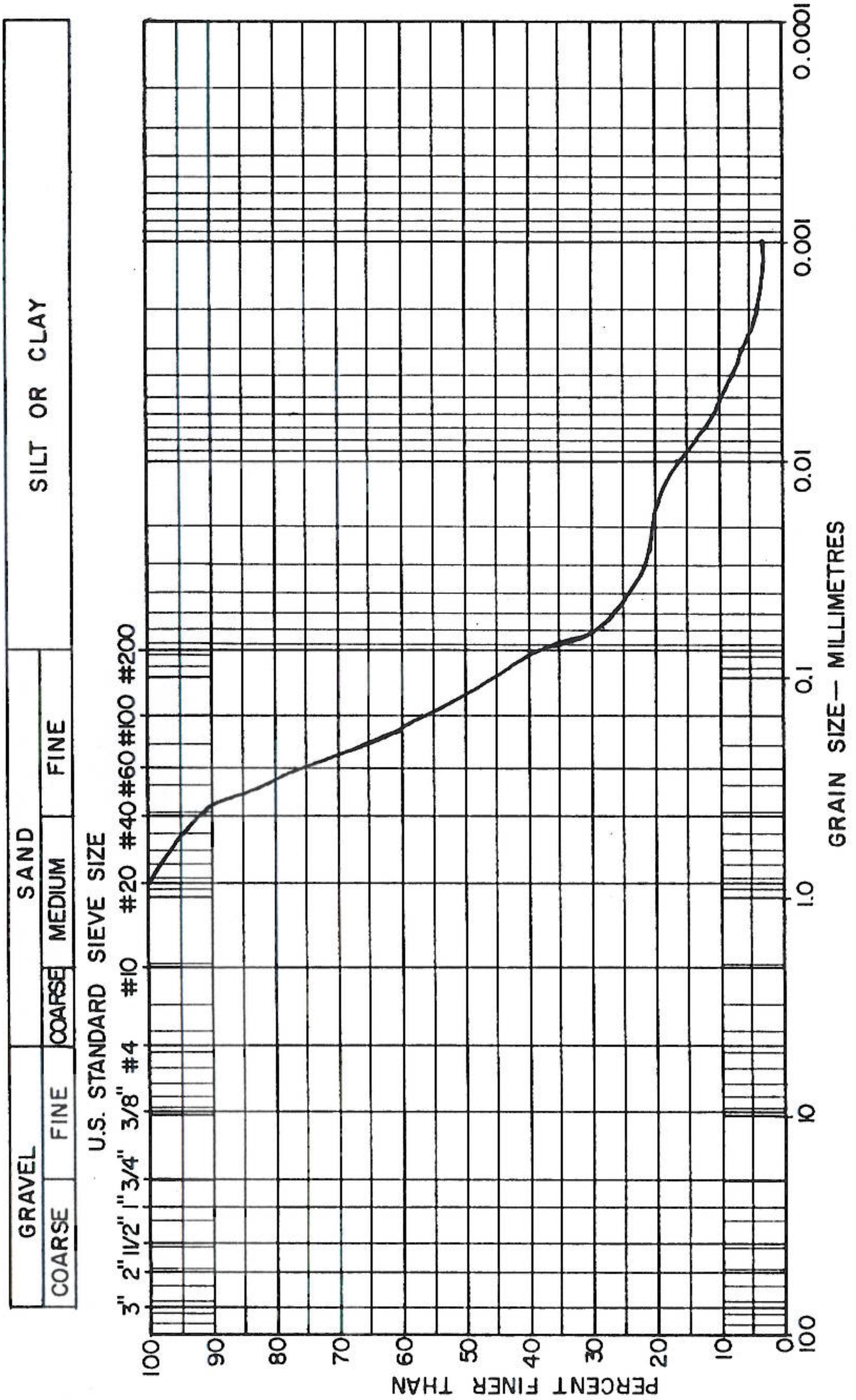


REMARKS: clayey SILT, some sand, low to non plastic, moist, brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.
PROJECT St.Lucia Watershed
LOCATION Ravine Poisson
HOLE No. 97-1 DEPTH 7.5-8.0m
DATE 21 June 1997

GRAIN SIZE CURVE

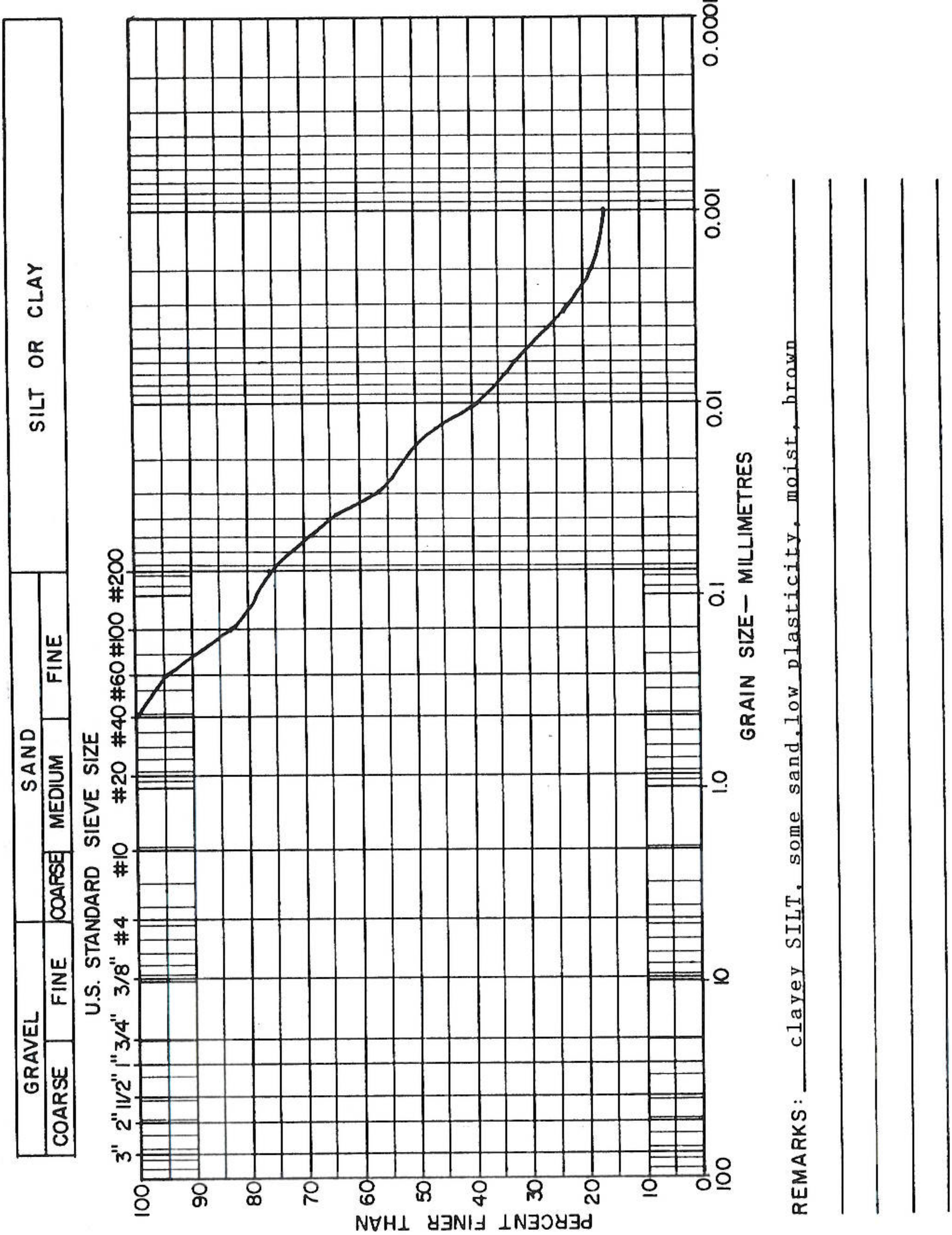


REMARKS: SAND & SILT, trace of clay, non plastic, moist, brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

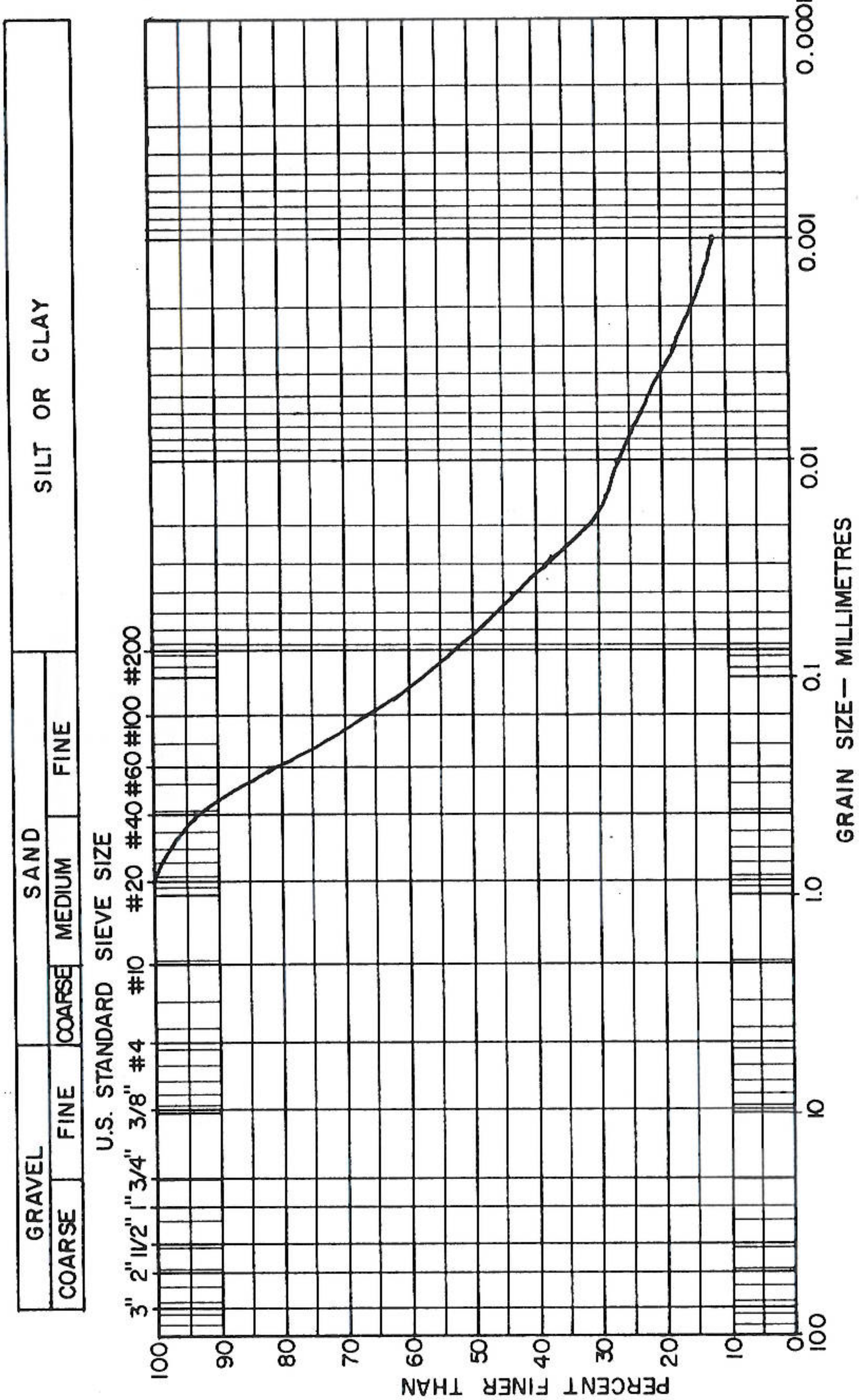
JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-1	DEPTH 12-12.5m
DATE	21 June 1997

GRAIN SIZE CURVE



STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-2 DEPTH 6 -6.5m
	DATE 27 June 1997

GRAIN SIZE CURVE

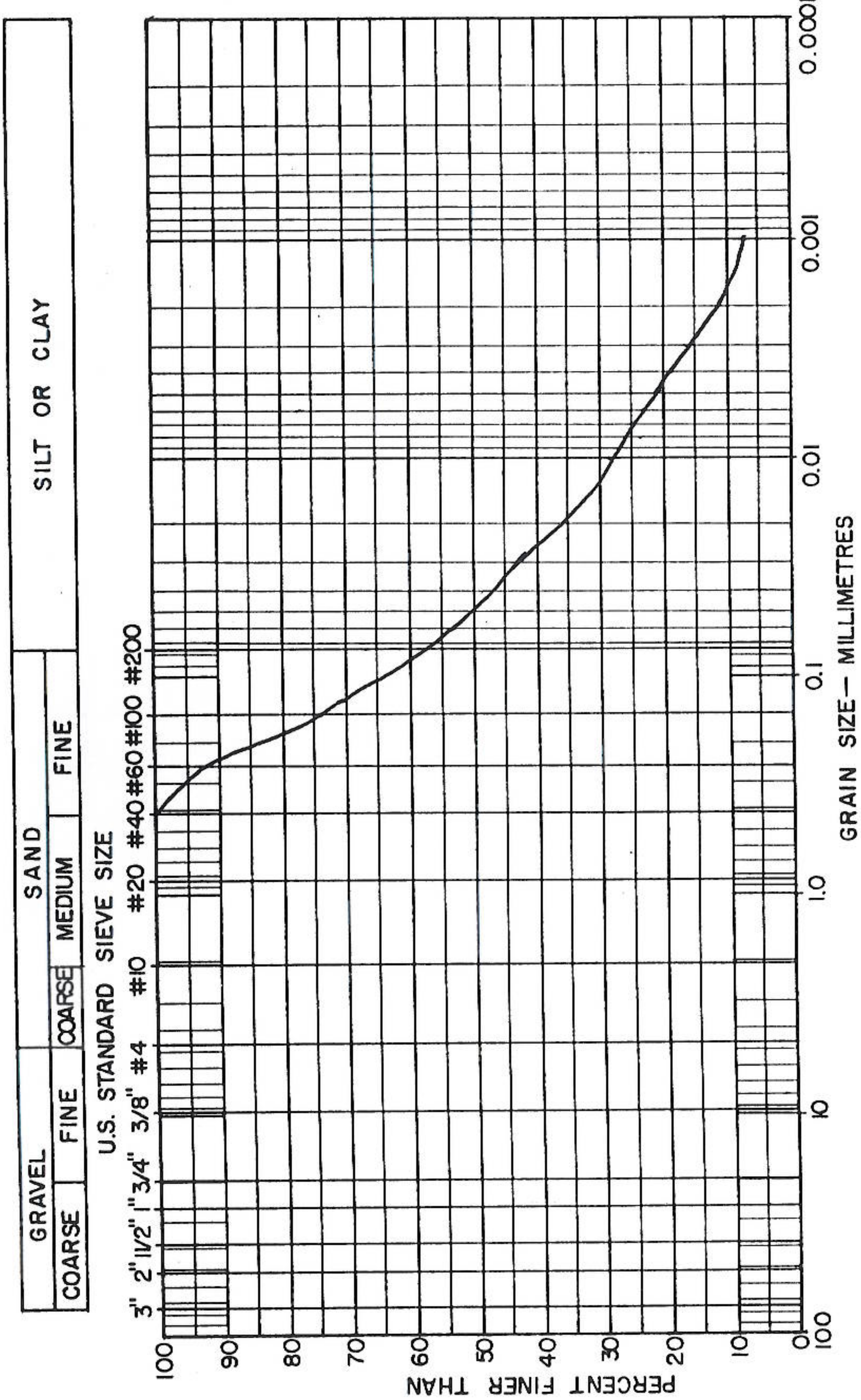


REMARKS: clayey SAND & SILT, low to non plastic, moist, greyish white

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-2	DEPTH 12-12.5m
DATE	27 June 1997

GRAIN SIZE CURVE

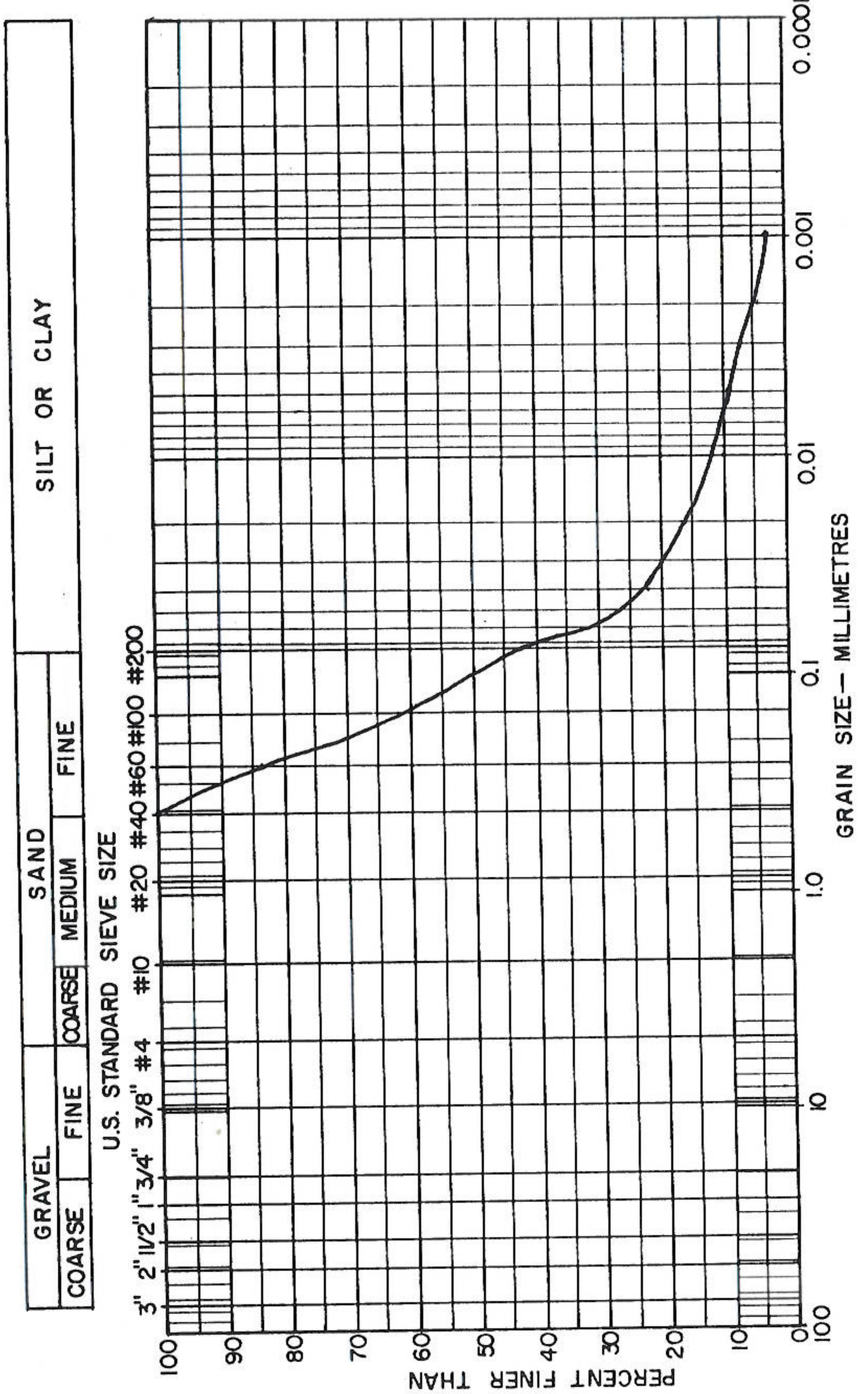


REMARKS: clayey SILT, some sand, non plastic, moist, light brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-3	DEPTH 1.5-2.0m
DATE	12 August 1997

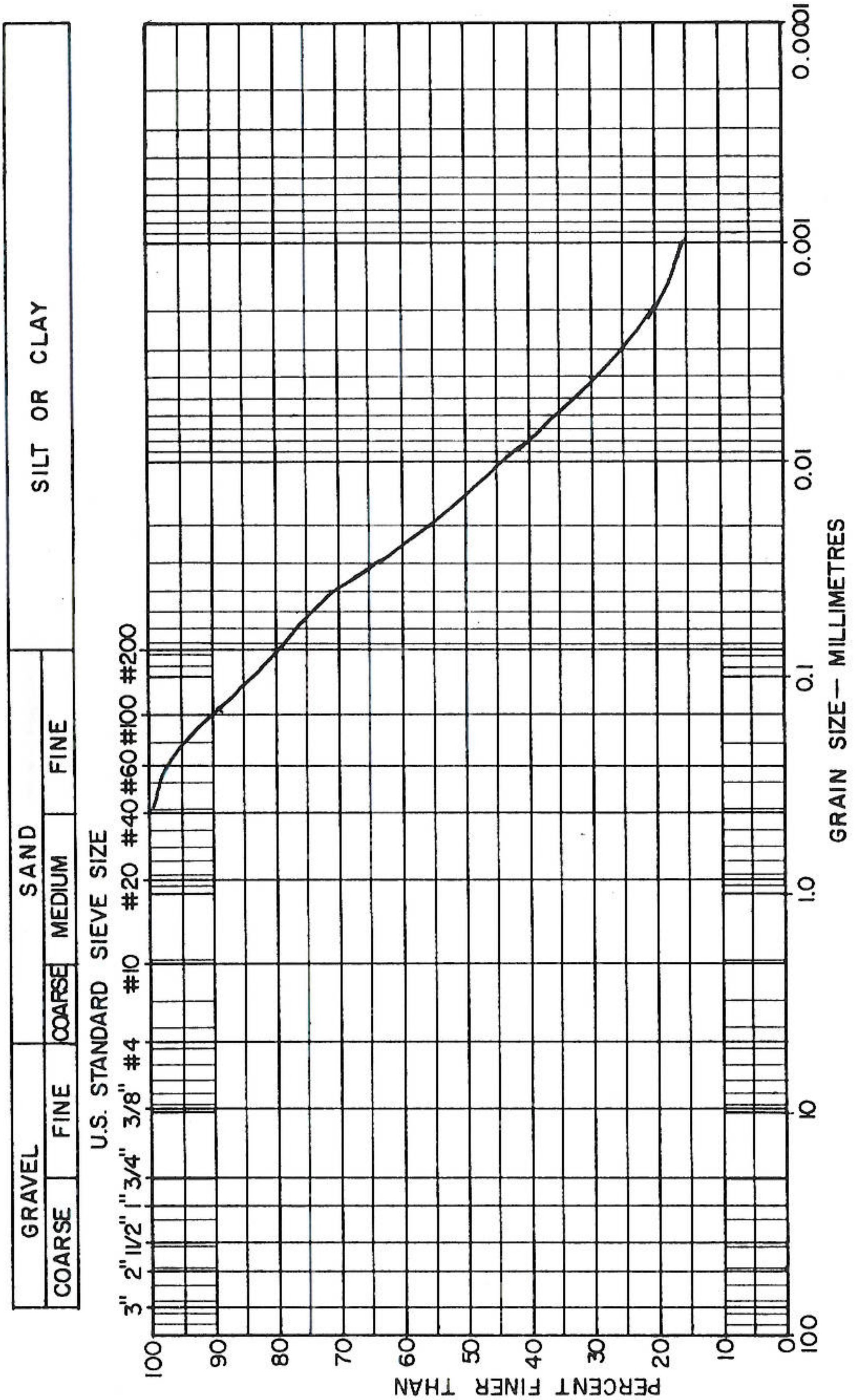
GRAIN SIZE CURVE



REMARKS: clayey SAND & SILT, non plastic, moist, light brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-3 DEPTH 4.5-5.0m
	DATE 12 August 1997

GRAIN SIZE CURVE

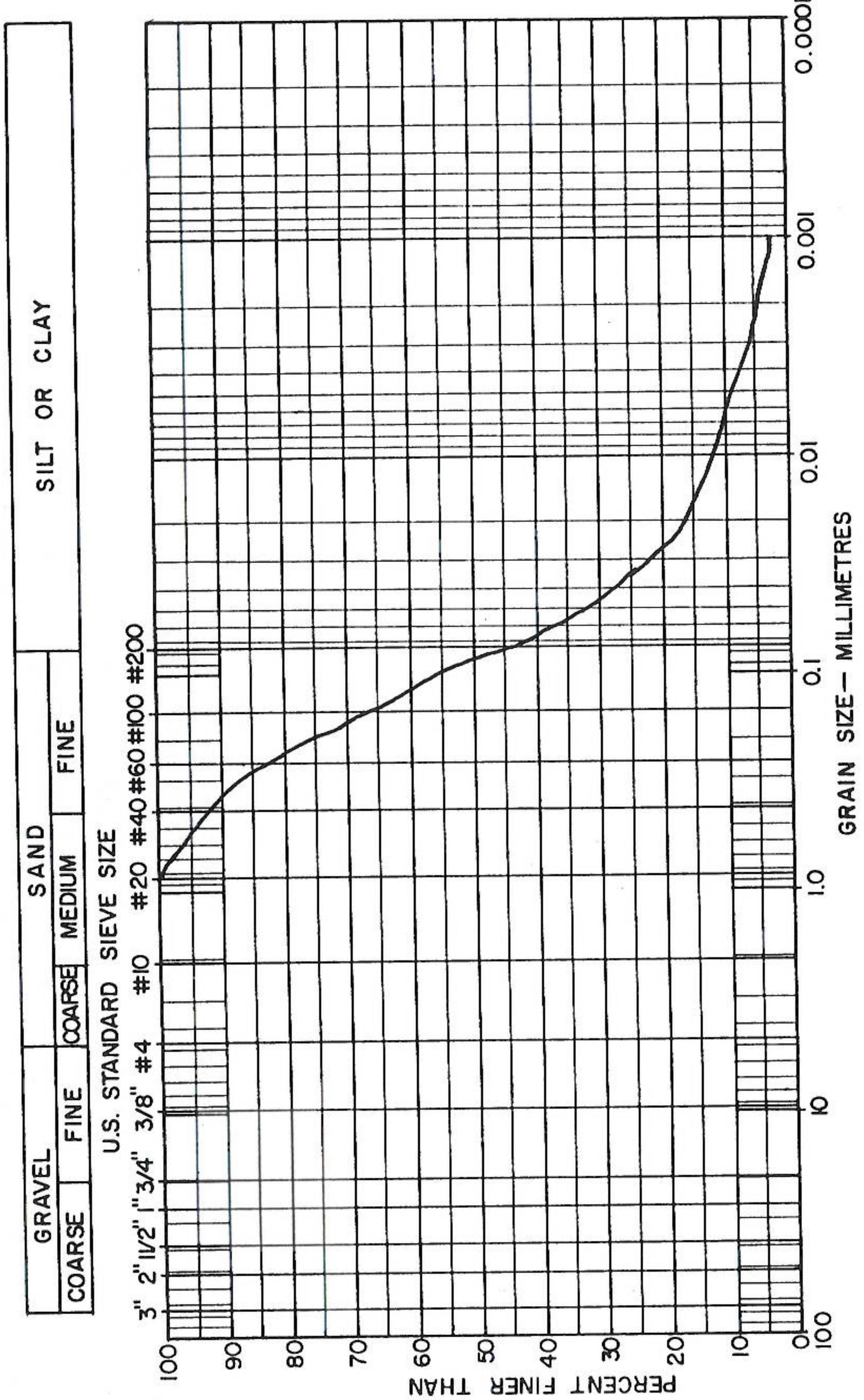


REMARKS: clayey SILT, little sand, low to non plastic, moist, brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-3	DEPTH 7.5-8.0m
DATE	14 August 1997

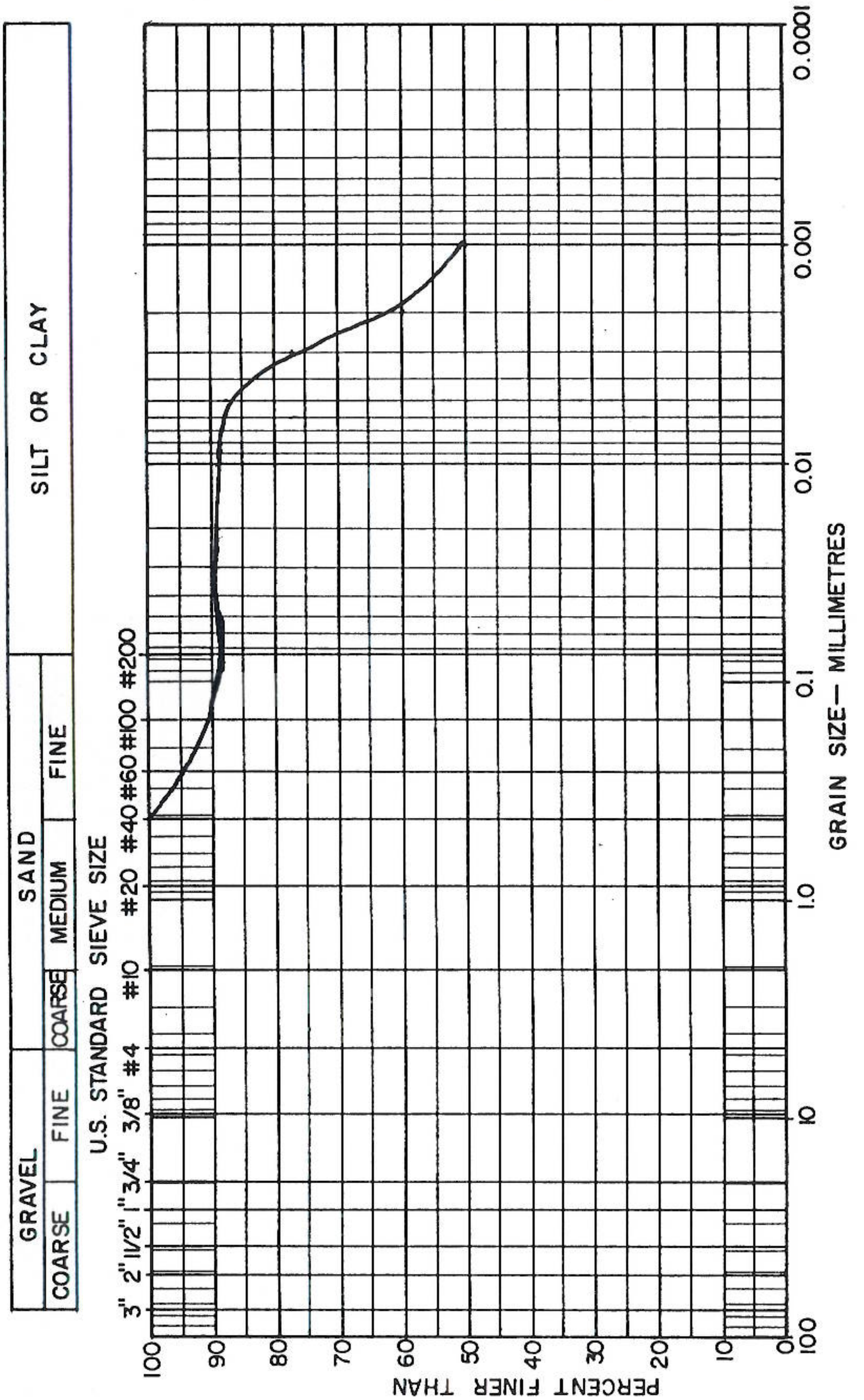
GRAIN SIZE CURVE



REMARKS: sand & SILT, trace of clay, non plastic, moist, light brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-3 DEPTH 10.5-11.0m
	DATE 14 August 1997

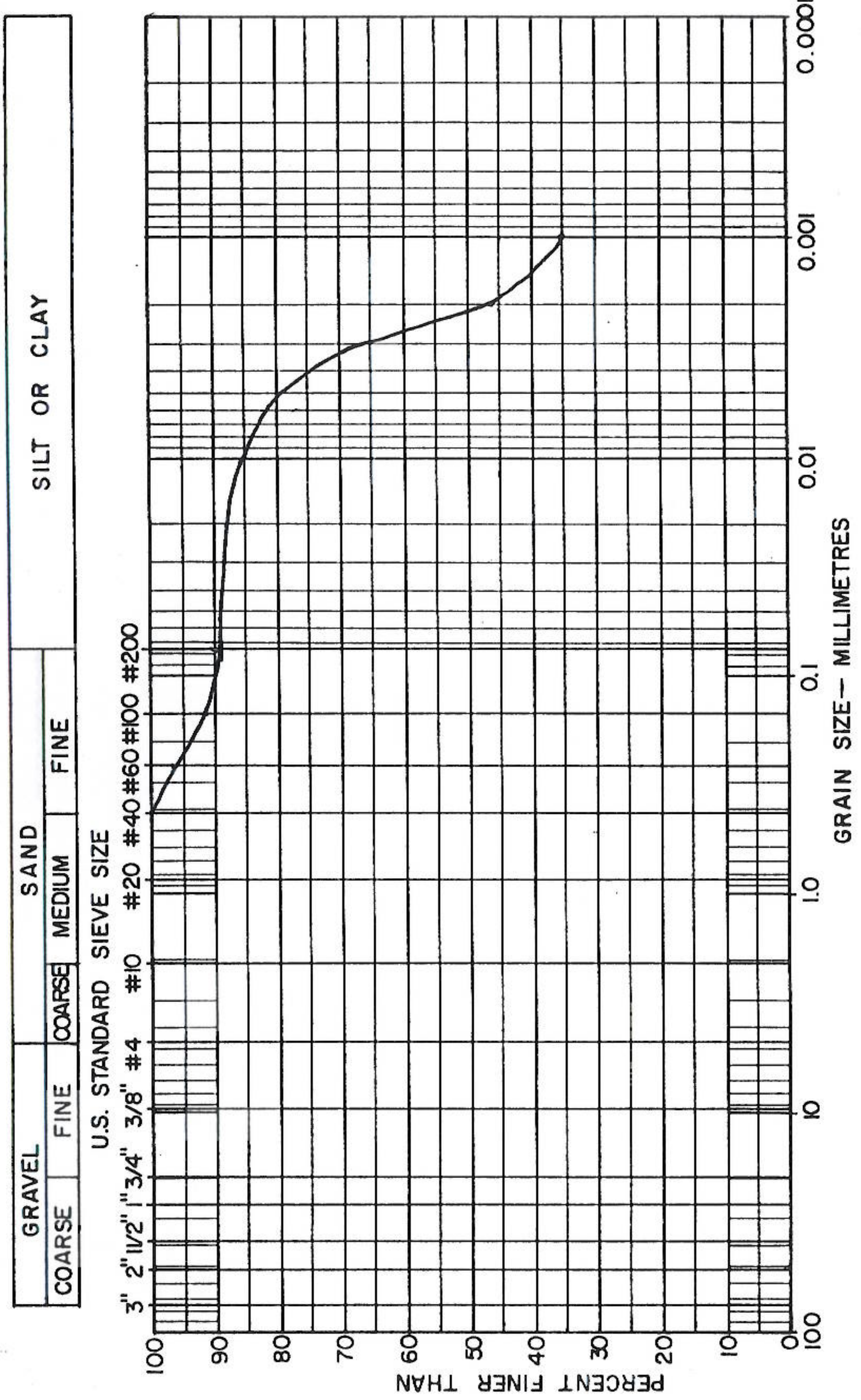
GRAIN SIZE CURVE



REMARKS: silty CLAY, trace of sand, high plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	
	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-4 DEPTH 1.5-2.0m
	DATE 15 August 1997

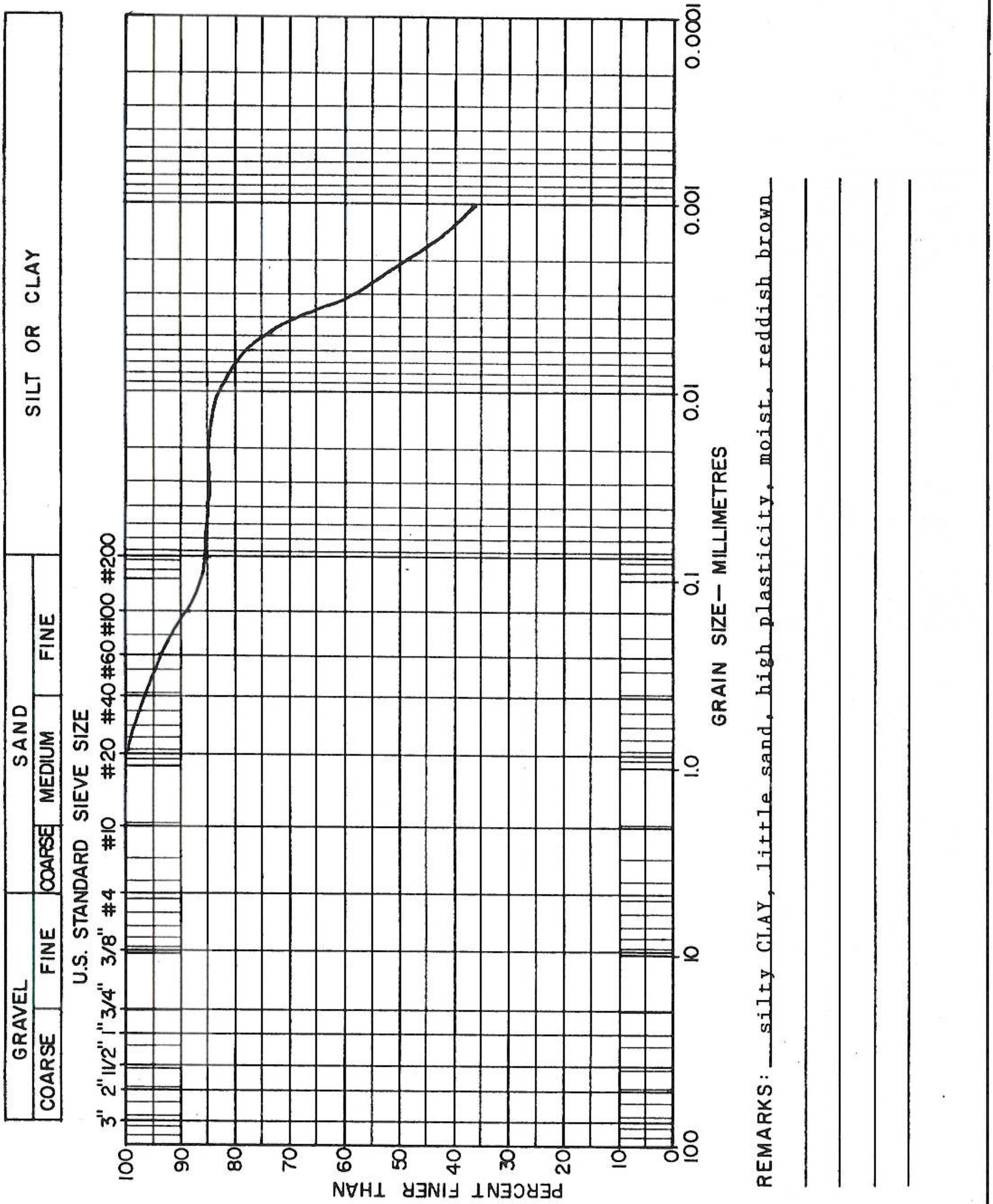
GRAIN SIZE CURVE



REMARKS: silty CLAY, trace of sand, high plasticity, moist, reddish brown

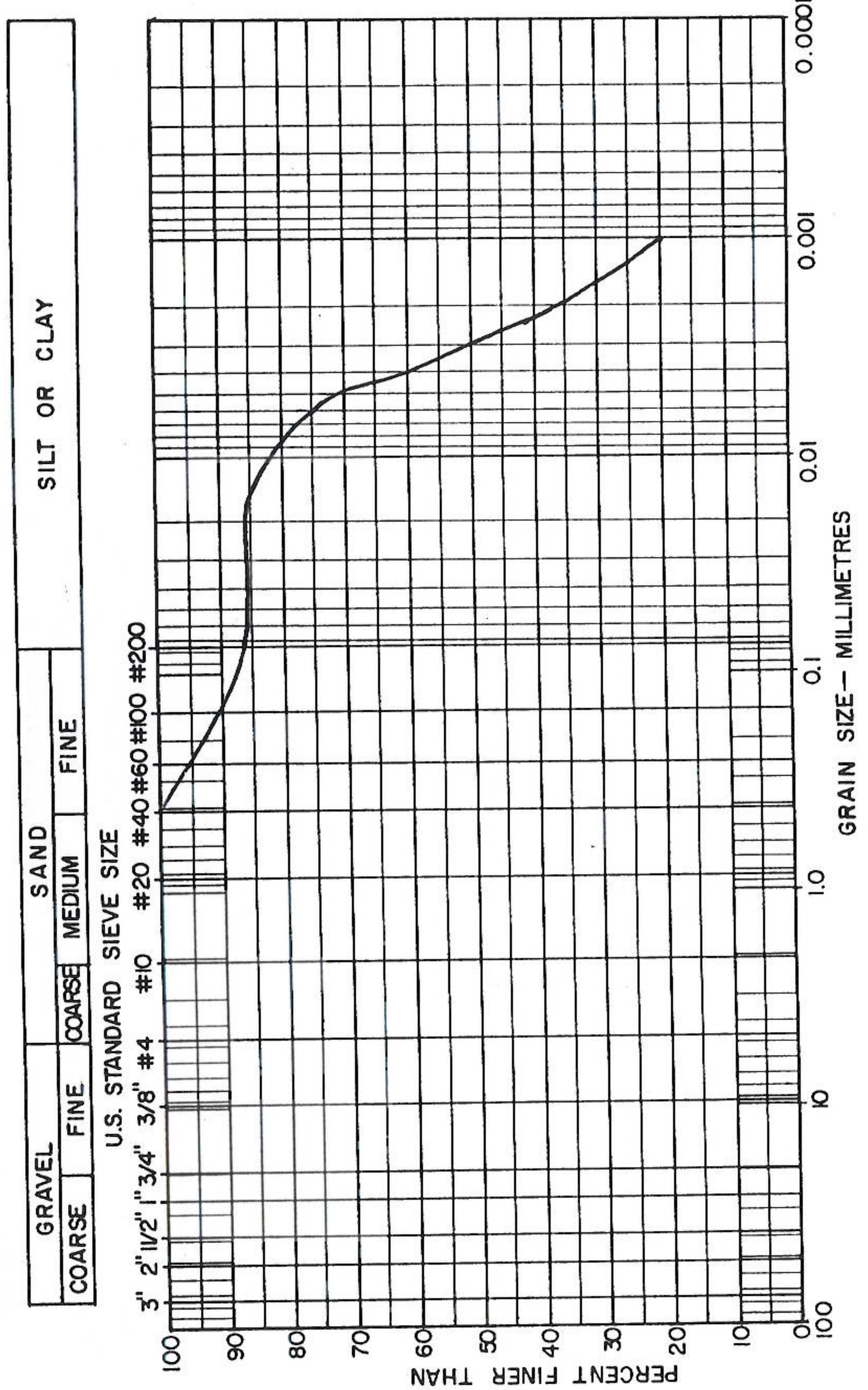
STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-4 DEPTH 4.5-5.0m
	DATE 16 August 1997

GRAIN SIZE CURVE



STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-4 DEPTH 9.0-9.5m
	DATE 16 August 1997

GRAIN SIZE CURVE

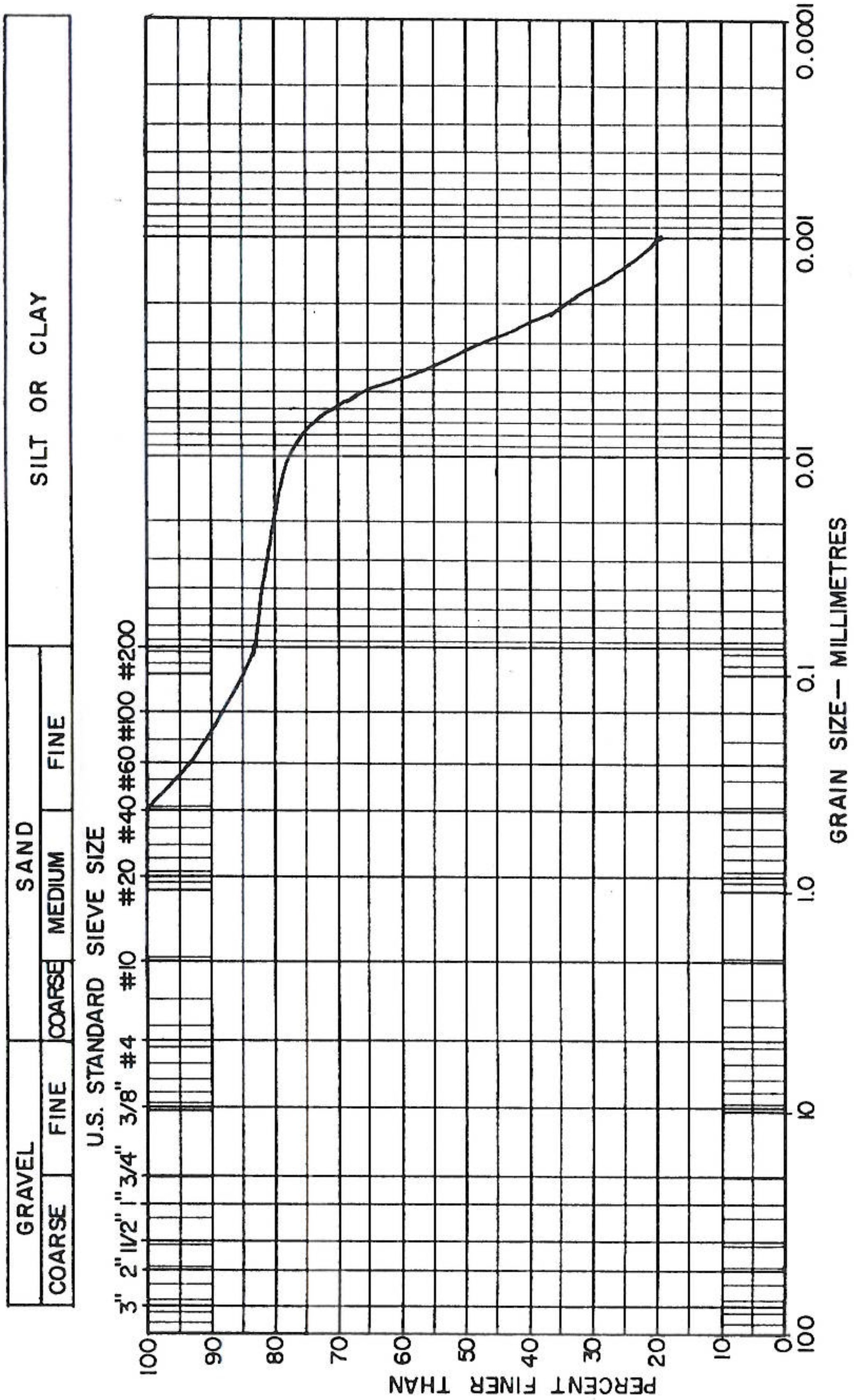


REMARKS: silty CLAY, little sand, high plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-4	DEPTH 12-12.5m
DATE	18 August 1997

GRAIN SIZE CURVE

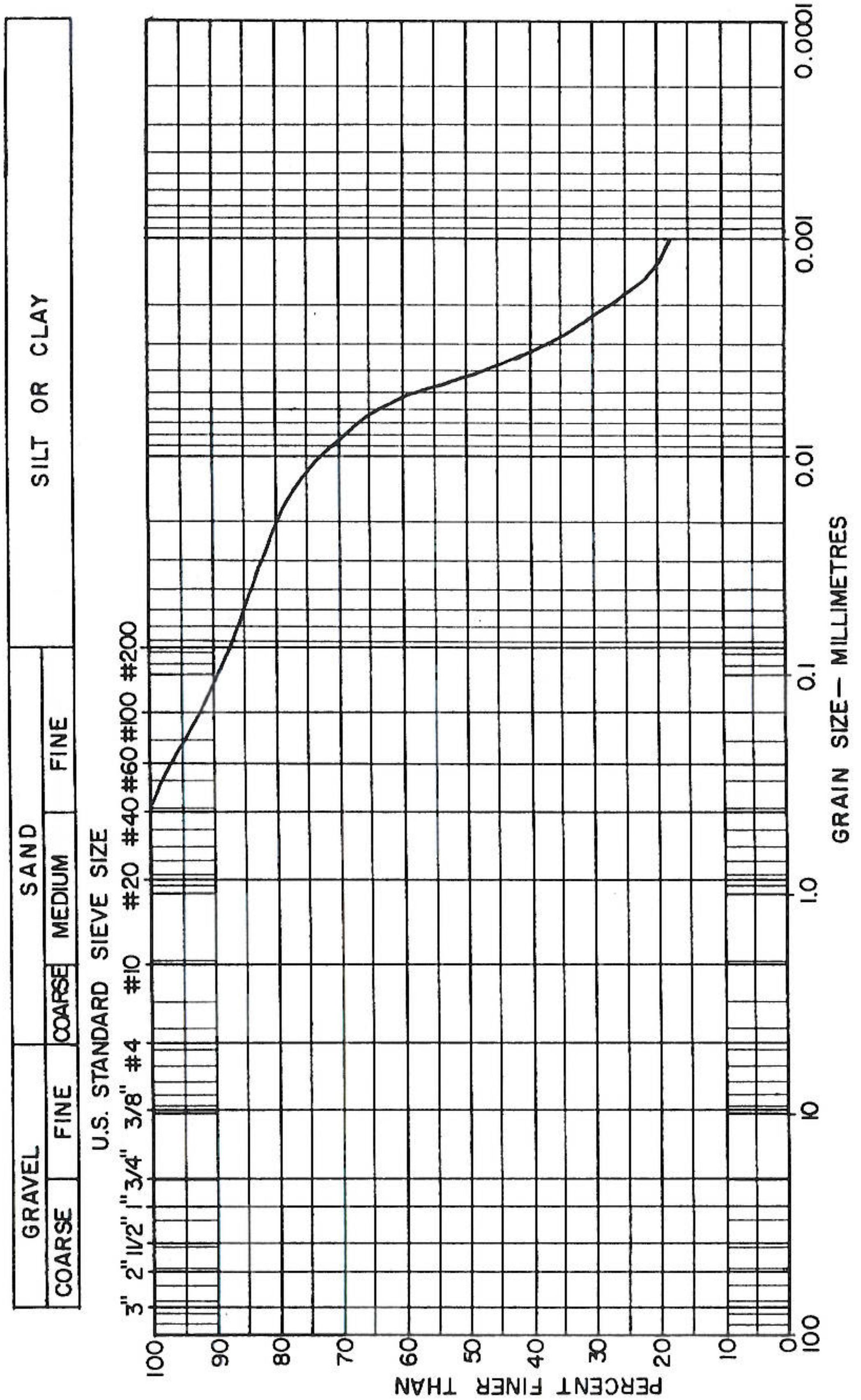


REMARKS: silty CLAY, little sand, high plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-4	DEPTH 15-15.5m
DATE	18 August 1997

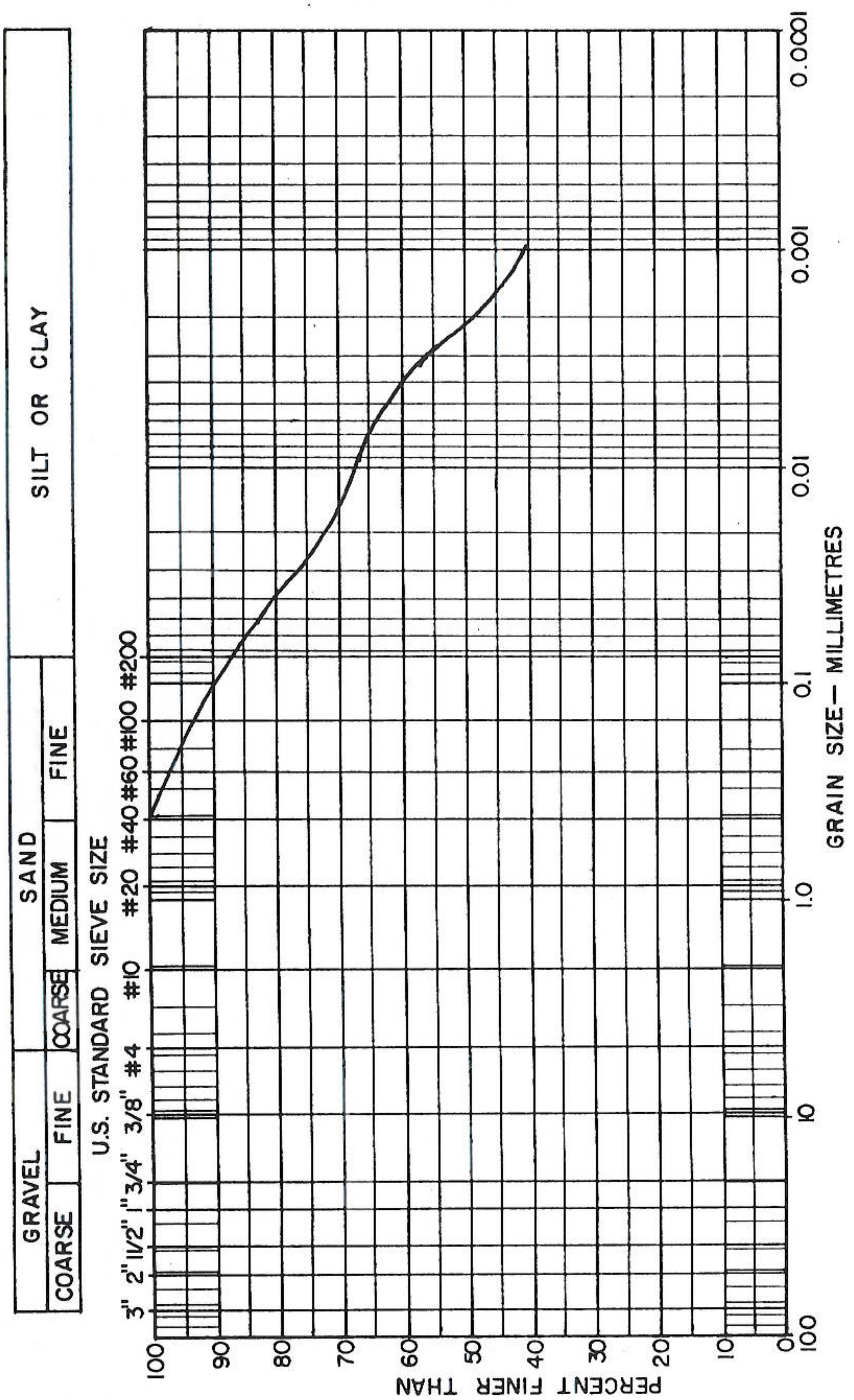
GRAIN SIZE CURVE



REMARKS: silty CLAY, little sand, high plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-4 DEPTH 18-18.5m
	DATE 21 August 1997

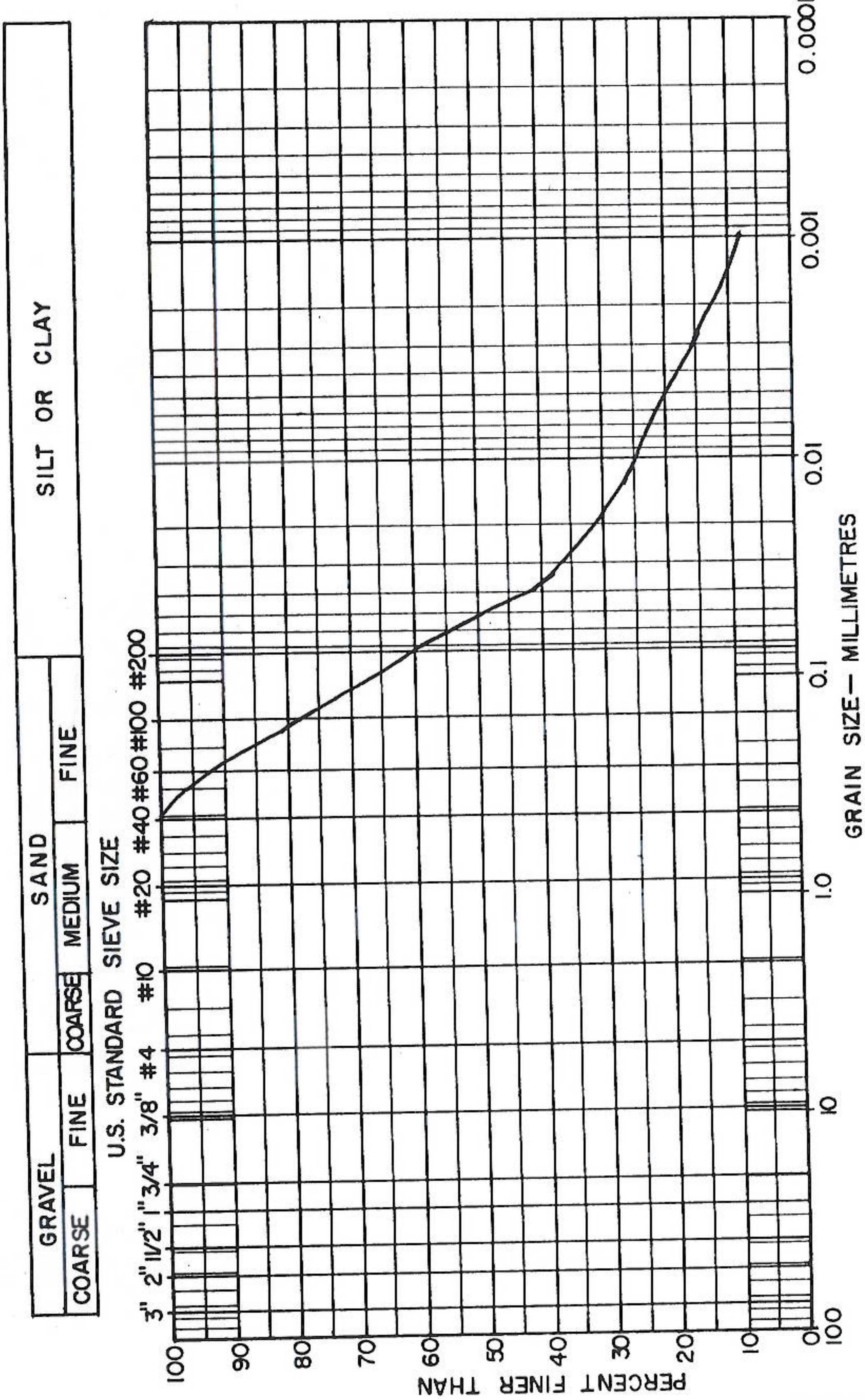
GRAIN SIZE CURVE



REMARKS: SILT & CLAY, little sand, medium to low plastic, moist, reddish brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-5 DEPTH 3.0-3.5m
	DATE 21 August 1997

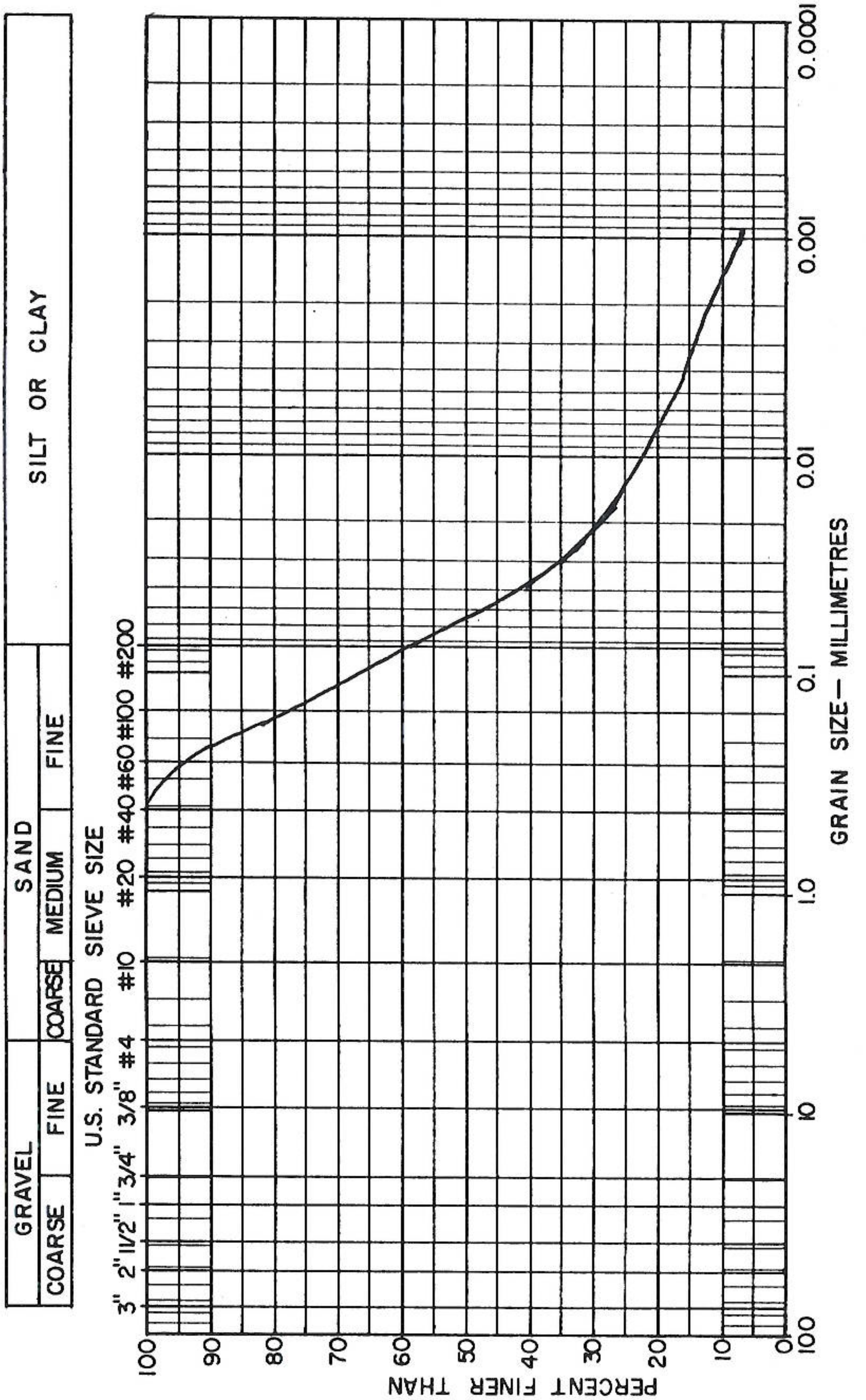
GRAIN SIZE CURVE



REMARKS: clayay SILT & SAND, low plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-5 DEPTH 6.0-6.5m
	DATE 22 August 1997

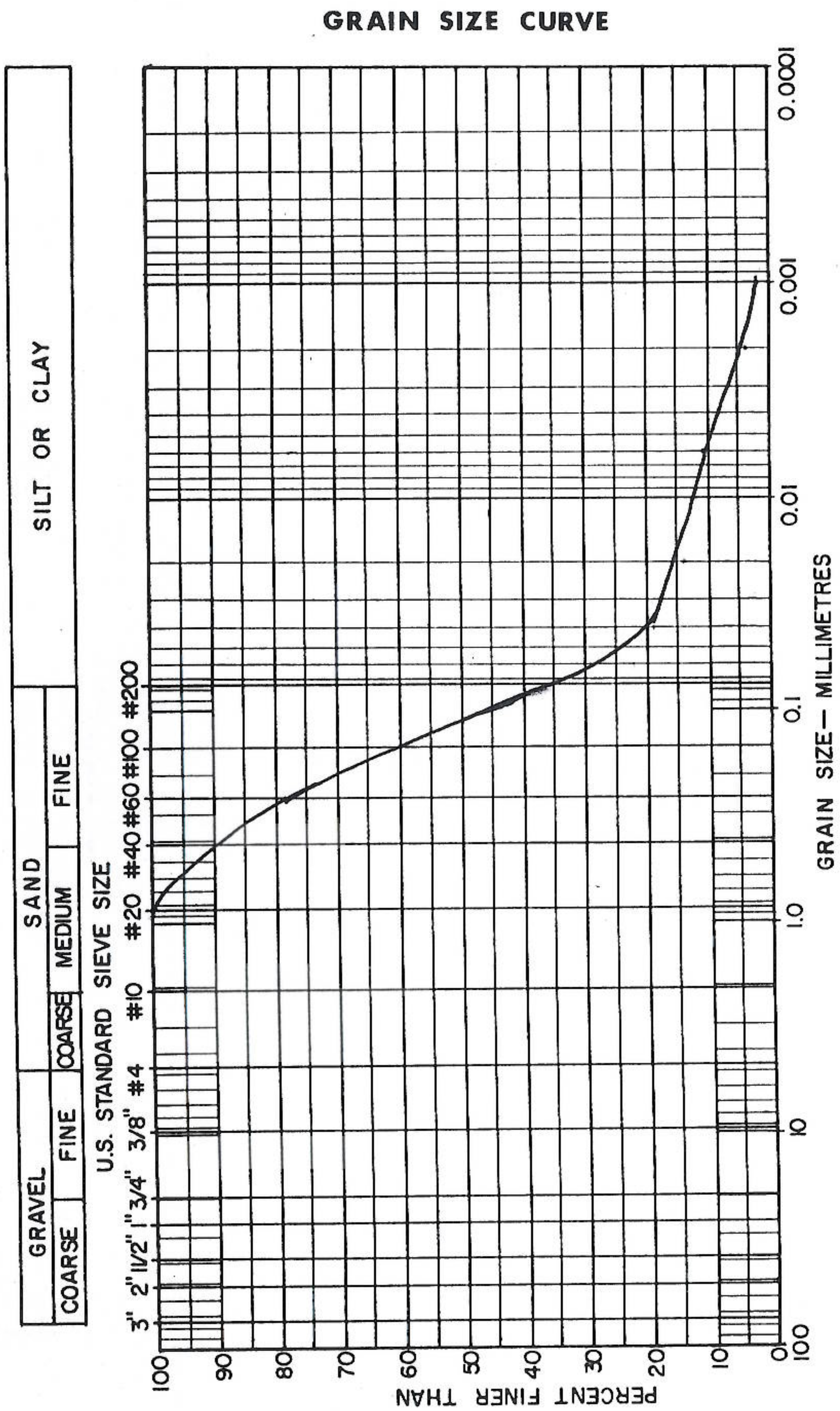
GRAIN SIZE CURVE



REMARKS: clayey SILT & SAND, low plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-5 DEPTH 9.0-9.5m
	DATE 22 August 1997

GRAIN SIZE CURVE

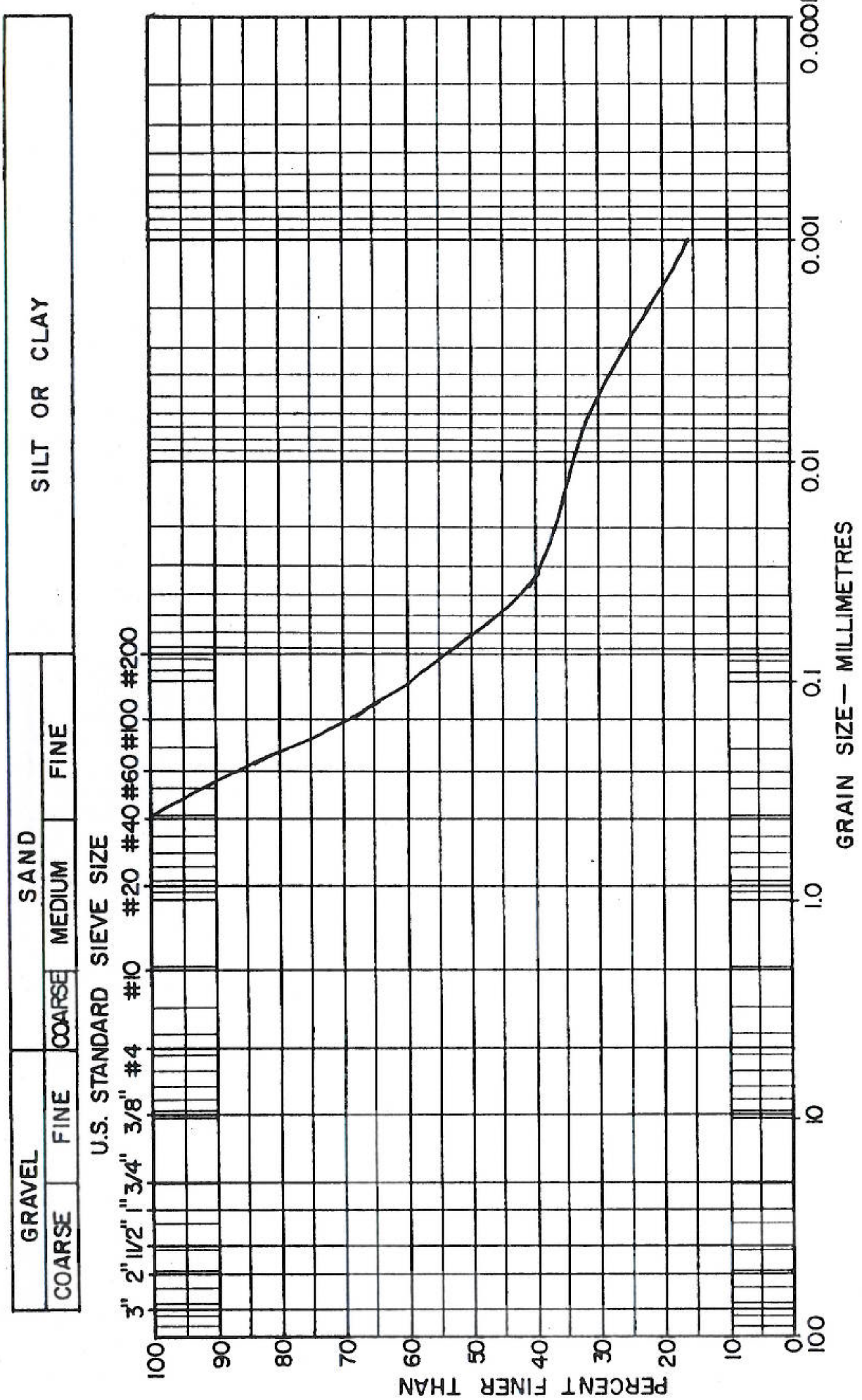


REMARKS: clayey SAND, some silt, low plasticity, moist, reddish brown

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	~~St.Lucia Watershed~~
LOCATION	Ravine Poisson
HOLE No. 97-5	DEPTH 13.5-14m
DATE	1 September 1997

GRAIN SIZE CURVE

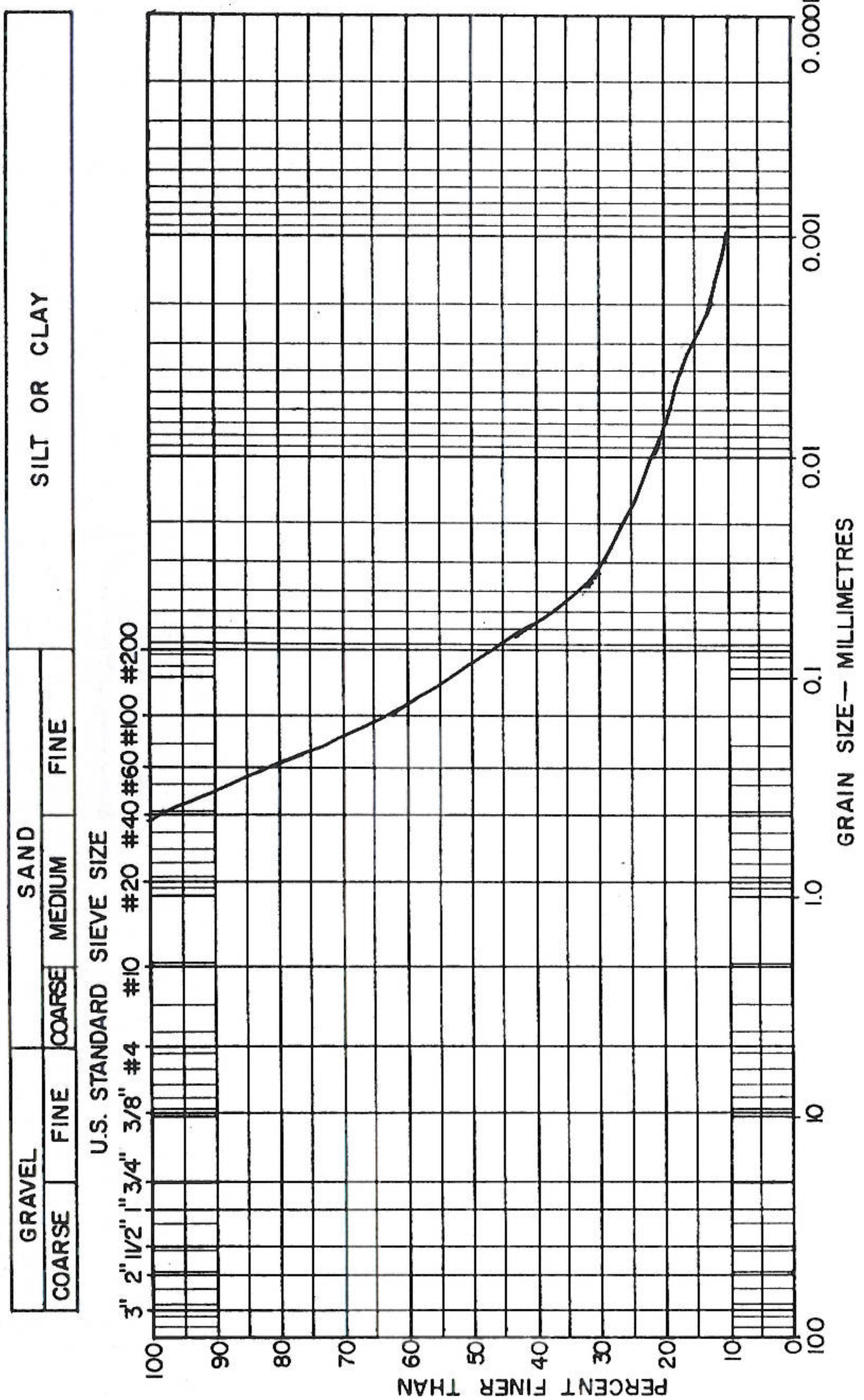


REMARKS: clayey SILT & SAND, low plasticity, moist, grey

STRATA ENGINEERING SERVICES
CONSULTING ENGINEERS

JOB No.	
PROJECT	St.Lucia Watershed
LOCATION	Ravine Poisson
HOLE No. 97-5	DEPTH 16.5-17.0m
DATE	1 September 1997

GRAIN SIZE CURVE



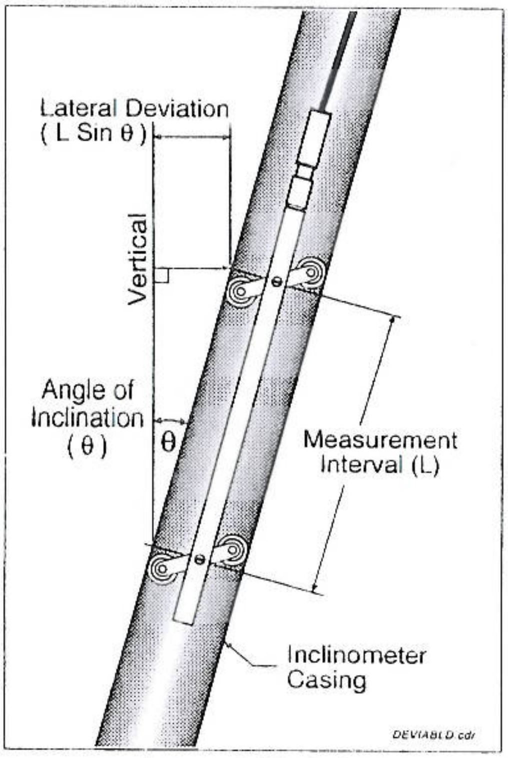
REMARKS: clayey SAND & SILT, low plasticity, moist, grey

STRATA ENGINEERING SERVICES CONSULTING ENGINEERS	JOB No.
	PROJECT St.Lucia Watershed
	LOCATION Ravine Poisson
	HOLE No. 97-5 DEPTH 18-18.5m
	DATE 1 September 1997

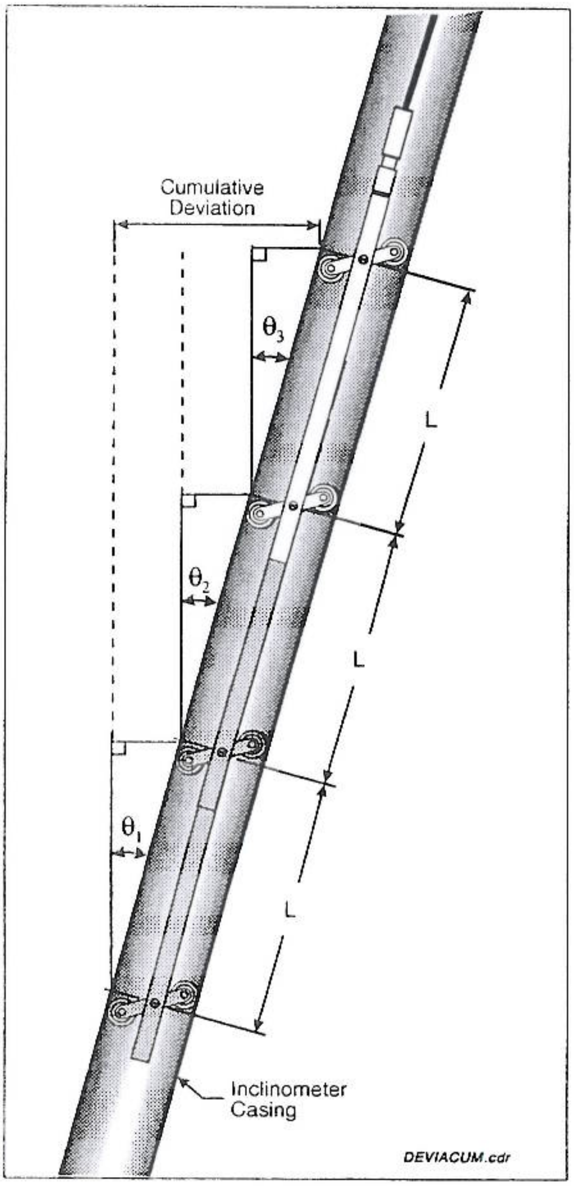
Slope Inclinometer Data

Inclination Measurements The inclinometer probe does not measure displacement directly. Instead, it measures the tilt of the casing.

Lateral Deviation Tilt is converted to a lateral distance as shown below. Deviation at one interval is called *incremental* deviation. The sum of incremental deviations is called *cumulative* deviation.



Incremental Deviation



Cumulative Deviation

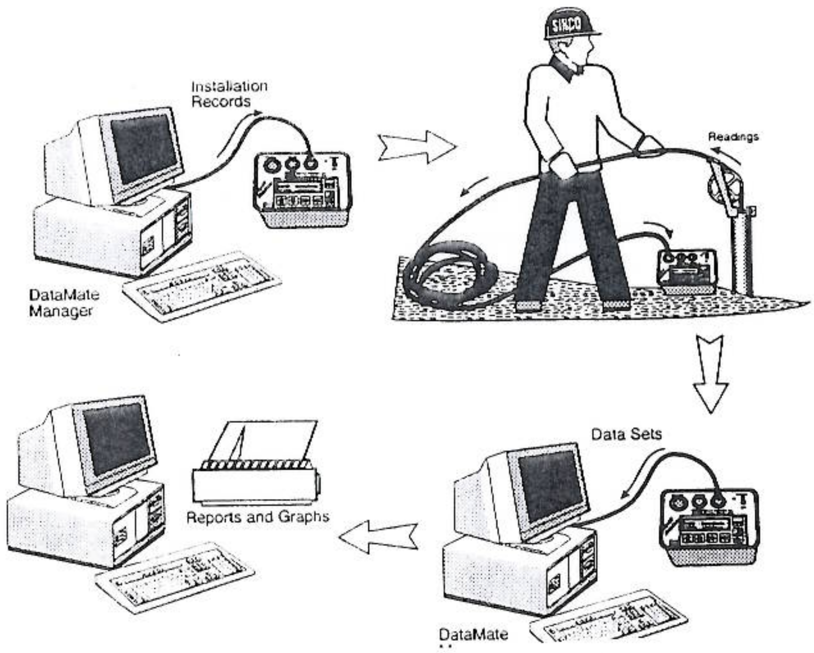
The DataMate

The Digitilt® DataMate is a compact inclinometer readout that records data from a Digitilt inclinometer probe, tiltmeter, or spiral sensor. The DataMate stores over 10,000 data points in up to 40 data sets.

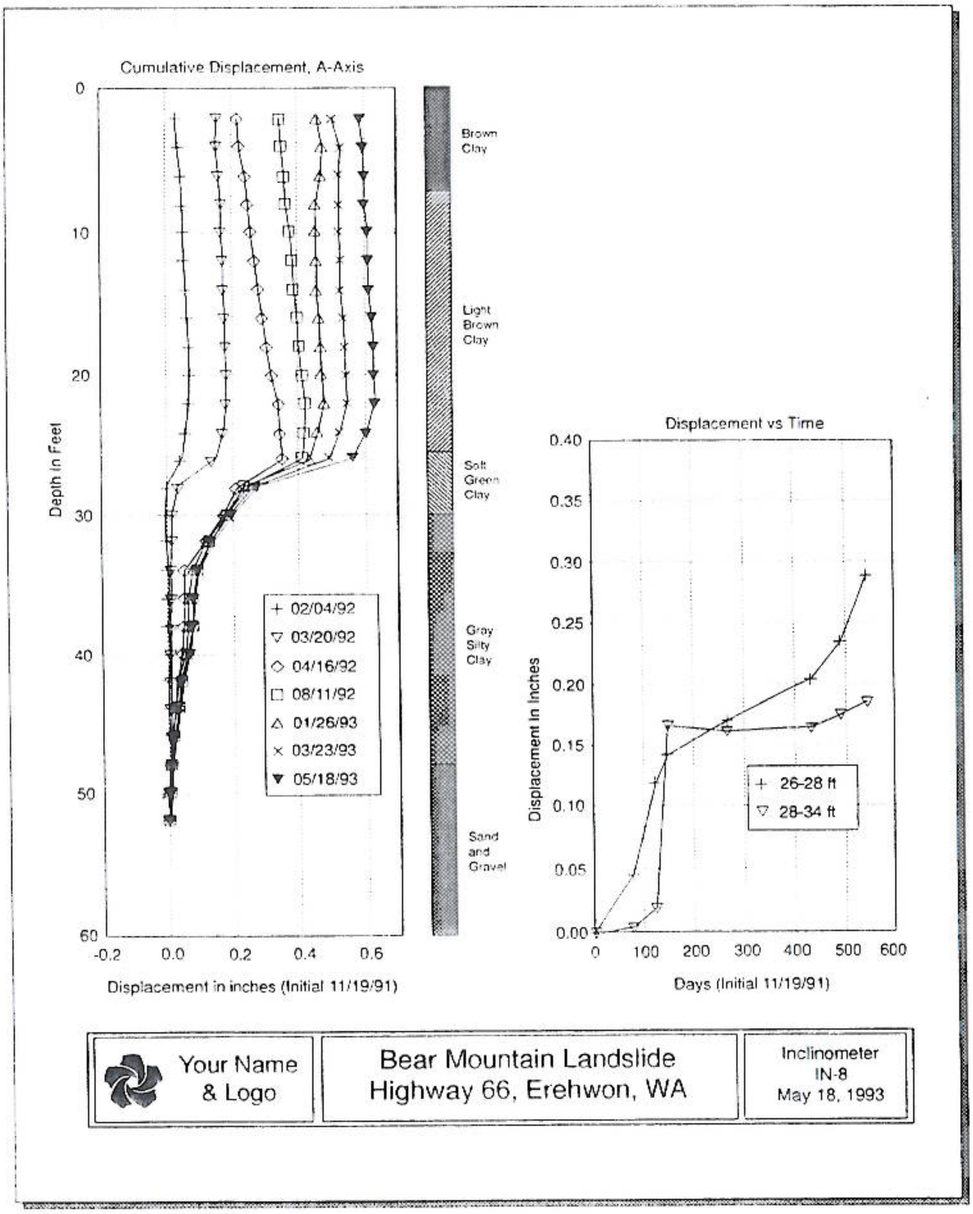
The DMM Program

The DataMate Manager software (DMM) is an integral part of the DataMate system. DMM creates a project database that holds records of inclinometer installations and data from inclinometer surveys.

Before you take the DataMate into the field, you will use DMM to transfer a list of inclinometer installations to the DataMate. When you return from the field, you will use DMM to transfer data from the DataMate to the project database on the PC. DMM can also generate simple reports and graphs. For more sophisticated data reduction and graphing, use Slope Indicator's DigiPro software.



Displacement Changes in deviation, i.e. changes in the position of the casing, are called displacements. The change at one interval is called incremental displacement. The sum of incremental displacements is called *cumulative* displacement. DMM can produce reports and simple graphs of displacement. Slope Indicator's DigiPro program can produce more sophisticated graphs for up to 21 datasets.



Graphs of Displacement Generated by the DigiPro Program

SLOPE INDICATOR DATA REDUCTION

Printed by DMM on 10/26/1997
Site: RAP-SI   Installation: 97-01
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	5	21
SENSOR:	28051	28051
DATE	05/30/199712:40	10/23/199709:50
READINGS PER DIRECTION	23	23

SENSOR: 28051

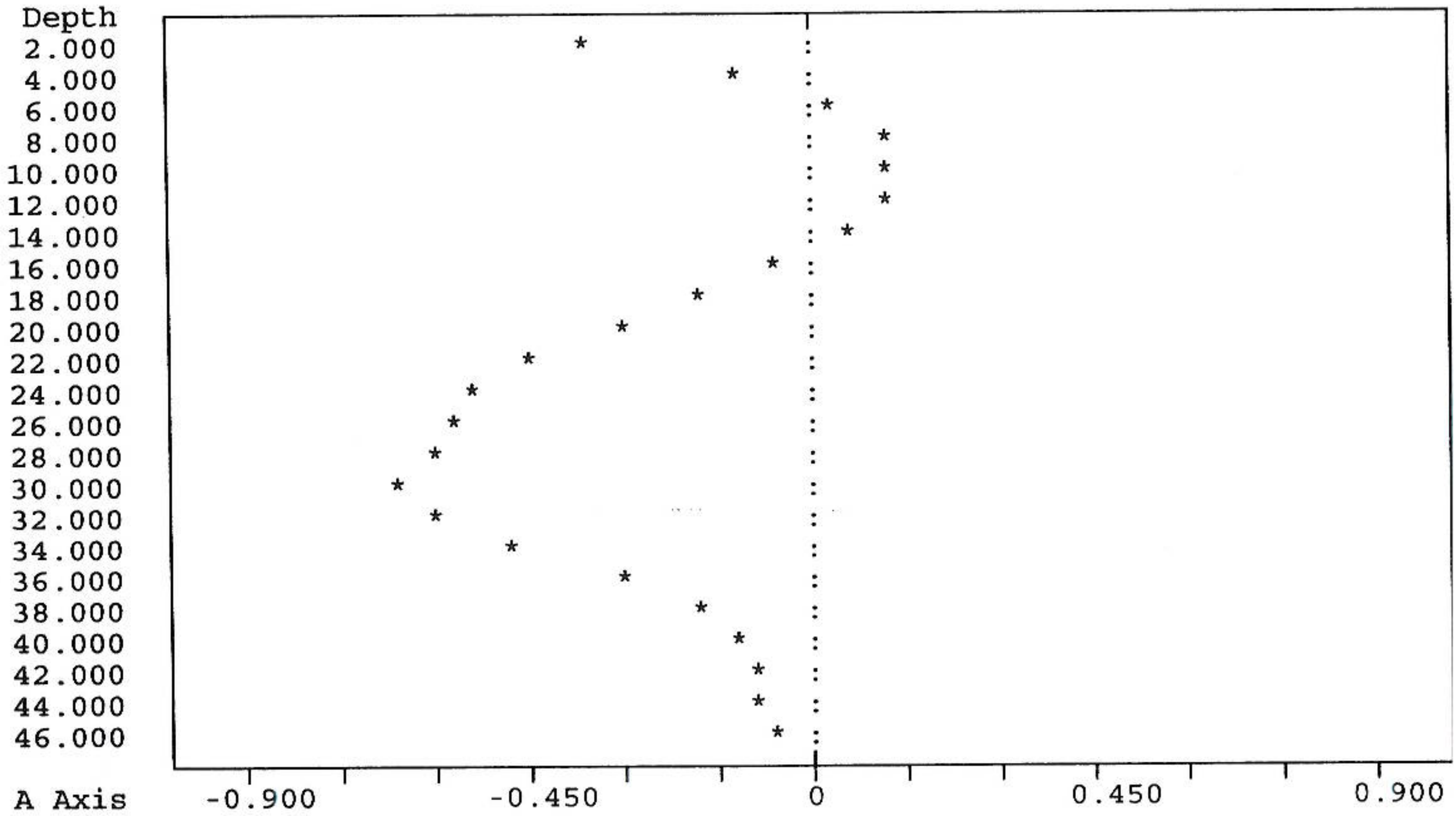
	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP
DEPTH	A0	A180	INCR.DEV	A0	A180	INCR.DEV	IN.	IN.
2.000	-163		-0.1956	-203		-0.2436	-0.0480	-0.0504
4.000	-98		-0.1176	-128		-0.1536	-0.0360	-0.0024
6.000	-35		-0.0420	-68		-0.0816	-0.0396	0.0336
8.000	-14		-0.0168	-15		-0.0180	-0.0012	0.0732
10.000	31		0.0372	3		0.0036	-0.0336	0.0744
12.000	83		0.0996	63		0.0756	-0.0240	0.1080
14.000	96		0.1152	95		0.1140	-0.0012	0.1320
16.000	83		0.0996	95		0.1140	0.0144	0.1332
18.000	111		0.1332	90		0.1080	-0.0252	0.1188
20.000	100		0.1200	129		0.1548	0.0348	0.1440
22.000	40		0.0480	68		0.0816	0.0336	0.1092
24.000	23		0.0276	27		0.0324	0.0048	0.0756
26.000	55		0.0660	44		0.0528	-0.0132	0.0708
28.000	-18		-0.0216	49		0.0588	0.0804	0.0840
30.000	-78		-0.0936	-60		-0.0720	0.0216	0.0036
32.000	-130		-0.1560	-98		-0.1176	0.0384	-0.0180
34.000	-133		-0.1596	-149		-0.1788	-0.0192	-0.0564
36.000	-66		-0.0792	-103		-0.1236	-0.0444	-0.0372
38.000	-38		-0.0456	-46		-0.0552	-0.0096	0.0072
40.000	-17		-0.0204	-19		-0.0228	-0.0024	0.0168
42.000	-12		-0.0144	-14		-0.0168	-0.0024	0.0192
44.000	-27		-0.0324	-15		-0.0180	0.0144	0.0216
46.000	-49		-0.0588	-43		-0.0516	0.0072	0.0072

END OF RECORDS

Data for: 97-01

Page
CUM.DEV. IN.

Using Reading Set # 21



SLOPE INDICATOR DATA REDUCTION

Printed by DMM on 10/26/1997 Page
Site: RAP-SI Installation: 97-01
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	5	21
SENSOR:	28051	28051
DATE	05/30/199712:40	10/23/199709:50
READINGS PER DIRECTION	23	23

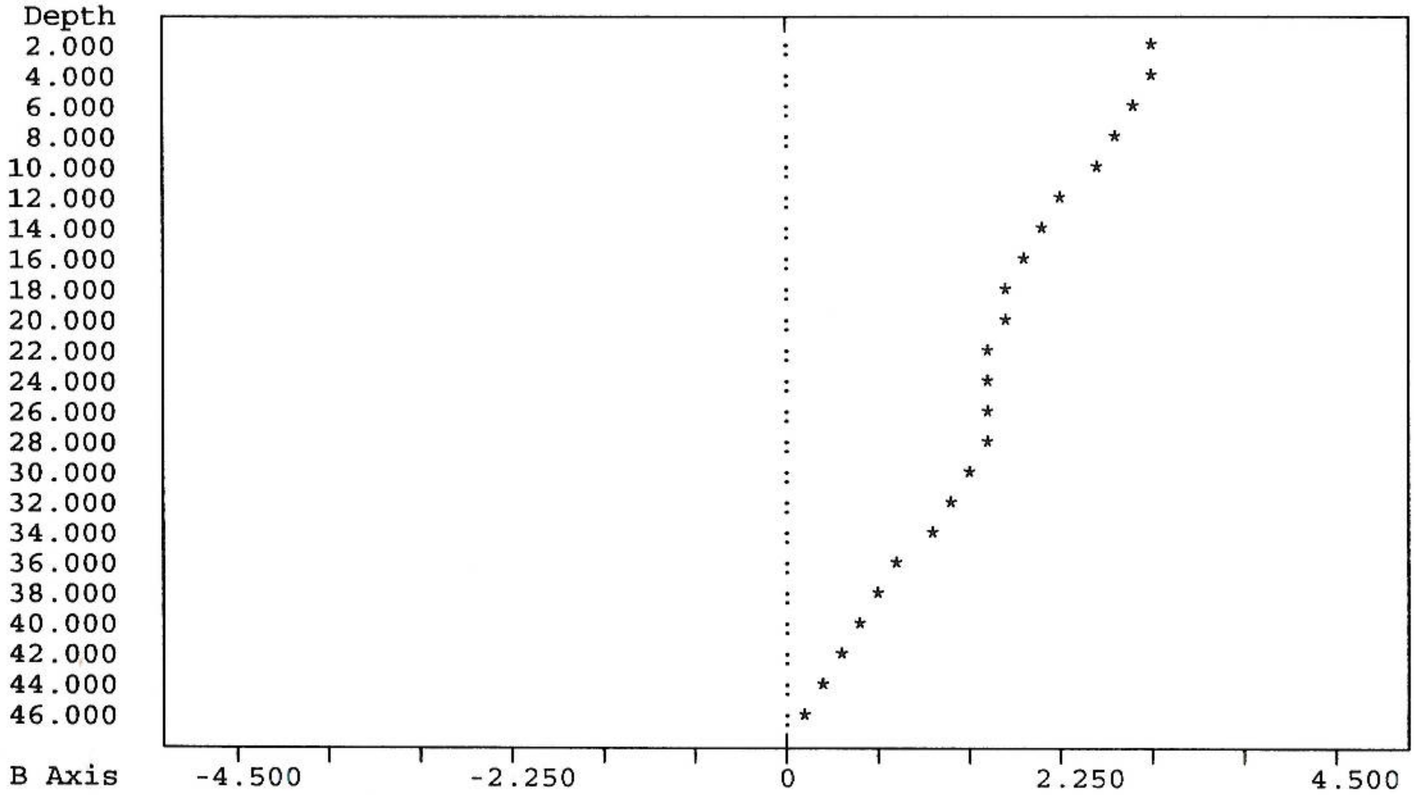
SENSOR: 28051

DEPTH	PREVIOUS DATA B0	B180	INCR.DEV	CURRENT DATA B0	B180	INCR.DEV	INCR DISP IN.	CUM.DISP. IN.
2.000	35		0.0420	0		0.0000	-0.0420	0.0444
4.000	81		0.0972	57		0.0684	-0.0288	0.0864
6.000	153		0.1836	112		0.1344	-0.0492	0.1152
8.000	154		0.1848	169		0.2028	0.0180	0.1644
10.000	157		0.1884	166		0.1992	0.0108	0.1464
12.000	134		0.1608	153		0.1836	0.0228	0.1356
14.000	120		0.1440	131		0.1572	0.0132	0.1128
16.000	103		0.1236	117		0.1404	0.0168	0.0996
18.000	45		0.0540	91		0.1092	0.0552	0.0828
20.000	29		0.0348	49		0.0588	0.0240	0.0276
22.000	26		0.0312	30		0.0360	0.0048	0.0036
24.000	-11		-0.0132	2		0.0024	0.0156	-0.0012
26.000	42		0.0504	33		0.0396	-0.0108	-0.0168
28.000	148		0.1776	96		0.1152	-0.0624	-0.0060
30.000	146		0.1752	166		0.1992	0.0240	0.0564
32.000	117		0.1404	129		0.1548	0.0144	0.0324
34.000	134		0.1608	127		0.1524	-0.0084	0.0180
36.000	151		0.1812	153		0.1836	0.0024	0.0264
38.000	130		0.1560	150		0.1800	0.0240	0.0240
40.000	128		0.1536	133		0.1596	0.0060	0.0000
42.000	143		0.1716	151		0.1812	0.0096	-0.0060
44.000	154		0.1848	139		0.1668	-0.0180	-0.0156
46.000	145		0.1740	147		0.1764	0.0024	0.0024

END OF RECORDS

Data for: 97-01 Page

Using Reading Set # 21 CUM.DEV. IN.



SLOPE INDICATOR DATA REDUCTION

Page

Printed by DMM on 11/14/1997
Site: RAP SI   Installation: 97-02
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	5	18
SENSOR:	28051	28051
DATE	05/30/199712:05	10/23/199708:33
READINGS PER DIRECTION	23	23

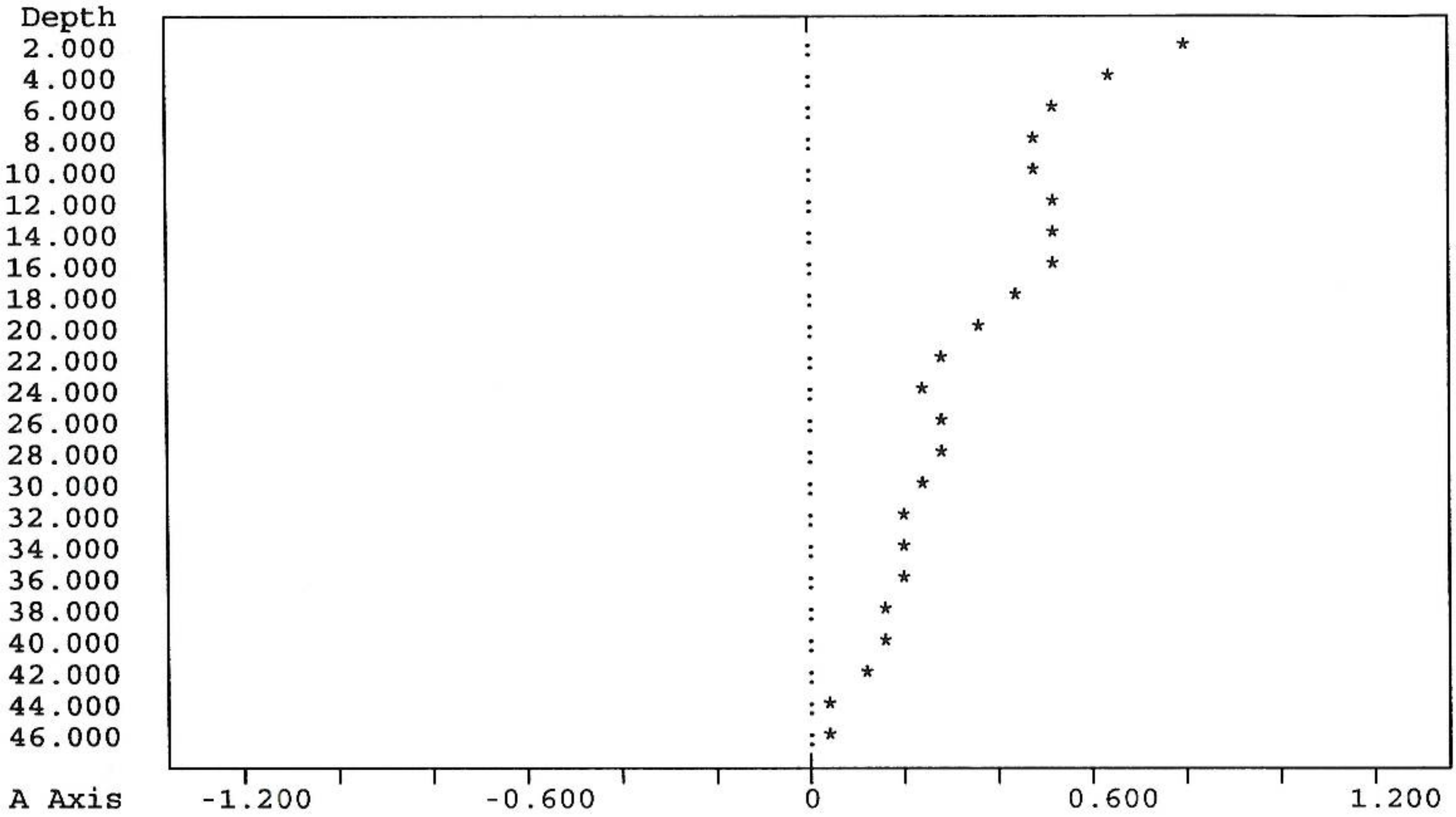
SENSOR: 28051

	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP.
DEPTH	A0	A180	INCR.DEV	A0	A180	INCR.DEV	IN.	IN.
2.000	94	-85	0.1074	171	-115	0.1716	0.0642	0.1122
4.000	57	-52	0.0654	96	-83	0.1074	0.0420	0.0480
6.000	-10	17	-0.0162	65	-58	0.0738	0.0900	0.0060
8.000	-26	37	-0.0378	-13	21	-0.0204	0.0174	-0.0840
10.000	-2	4	-0.0036	-25	37	-0.0372	-0.0336	-0.1014
12.000	21	-17	0.0228	-4	9	-0.0078	-0.0306	-0.0678
14.000	57	-49	0.0636	22	-14	0.0216	-0.0420	-0.0372
16.000	64	-58	0.0732	55	-48	0.0618	-0.0114	0.0048
18.000	86	-79	0.0990	65	-58	0.0738	-0.0252	0.0162
20.000	15	-11	0.0156	86	-75	0.0966	0.0810	0.0414
22.000	-11	17	-0.0168	15	-10	0.0150	0.0318	-0.0396
24.000	2	2	0.0000	-11	20	-0.0186	-0.0186	-0.0714
26.000	45	-39	0.0504	4	3	0.0006	-0.0498	-0.0528
28.000	24	-17	0.0246	47	-38	0.0510	0.0264	-0.0030
30.000	18	-13	0.0186	23	-13	0.0216	0.0030	-0.0294
32.000	6	1	0.0030	20	-10	0.0180	0.0150	-0.0324
34.000	17	-11	0.0168	5	4	0.0006	-0.0162	-0.0474
36.000	22	-14	0.0216	19	-10	0.0174	-0.0042	-0.0312
38.000	18	-11	0.0174	24	-13	0.0222	0.0048	-0.0270
40.000	63	-58	0.0726	21	-11	0.0192	-0.0534	-0.0318
42.000	26	-19	0.0270	63	-54	0.0702	0.0432	0.0216
44.000	45	-41	0.0516	28	-17	0.0270	-0.0246	-0.0216
46.000	43	-35	0.0468	45	-38	0.0498	0.0030	0.0030

END OF RECORDS

Data for: 97-02 ~~Page~~

Using Reading Set # 18 CUM.DEV. IN.



SLOPE INDICATOR DATA REDUCTION

Page

Printed by DMM on 10/26/1997
Site: RAP SI Installation: 97-02
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	5	18
SENSOR:	28051	28051
DATE	05/30/199712:05	10/23/199708:33
READINGS PER DIRECTION	23	23

SENSOR: 28051

	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP
DEPTH	B0	B180	INCR.DEV	B0	B180	INCR.DEV	IN.	IN.
2.000	433	-409	0.5052	475	-431	0.5436	0.0384	0.1122
4.000	401	-365	0.4596	422	-392	0.4884	0.0288	0.0738
6.000	309	-289	0.3588	403	-363	0.4596	0.1008	0.0450
8.000	318	-288	0.3636	307	-290	0.3582	-0.0054	-0.0558
10.000	370	-343	0.4278	326	-290	0.3696	-0.0582	-0.0504
12.000	372	-340	0.4272	374	-346	0.4320	0.0048	0.0078
14.000	369	-340	0.4254	378	-342	0.4320	0.0066	0.0030
16.000	361	-338	0.4194	368	-337	0.4230	0.0036	-0.0036
18.000	383	-350	0.4398	370	-337	0.4242	-0.0156	-0.0072
20.000	312	-289	0.3606	386	-350	0.4416	0.0810	0.0084
22.000	317	-286	0.3618	312	-288	0.3600	-0.0018	-0.0726
24.000	362	-327	0.4134	321	-286	0.3642	-0.0492	-0.0708
26.000	414	-386	0.4800	367	-326	0.4158	-0.0642	-0.0216
28.000	435	-401	0.5016	422	-389	0.4866	-0.0150	0.0426
30.000	337	-312	0.3894	441	-398	0.5034	0.1140	0.0576
32.000	325	-310	0.3810	337	-309	0.3876	0.0066	-0.0564
34.000	332	-310	0.3852	329	-308	0.3822	-0.0030	-0.0630
36.000	343	-320	0.3978	330	-307	0.3822	-0.0156	-0.0600
38.000	370	-340	0.4260	343	-319	0.3972	-0.0288	-0.0444
40.000	373	-353	0.4356	366	-340	0.4236	-0.0120	-0.0156
42.000	363	-351	0.4284	370	-349	0.4314	0.0030	-0.0036
44.000	374	-345	0.4314	370	-350	0.4320	0.0006	-0.0066
46.000	401	-335	0.4416	380	-344	0.4344	-0.0072	-0.0072

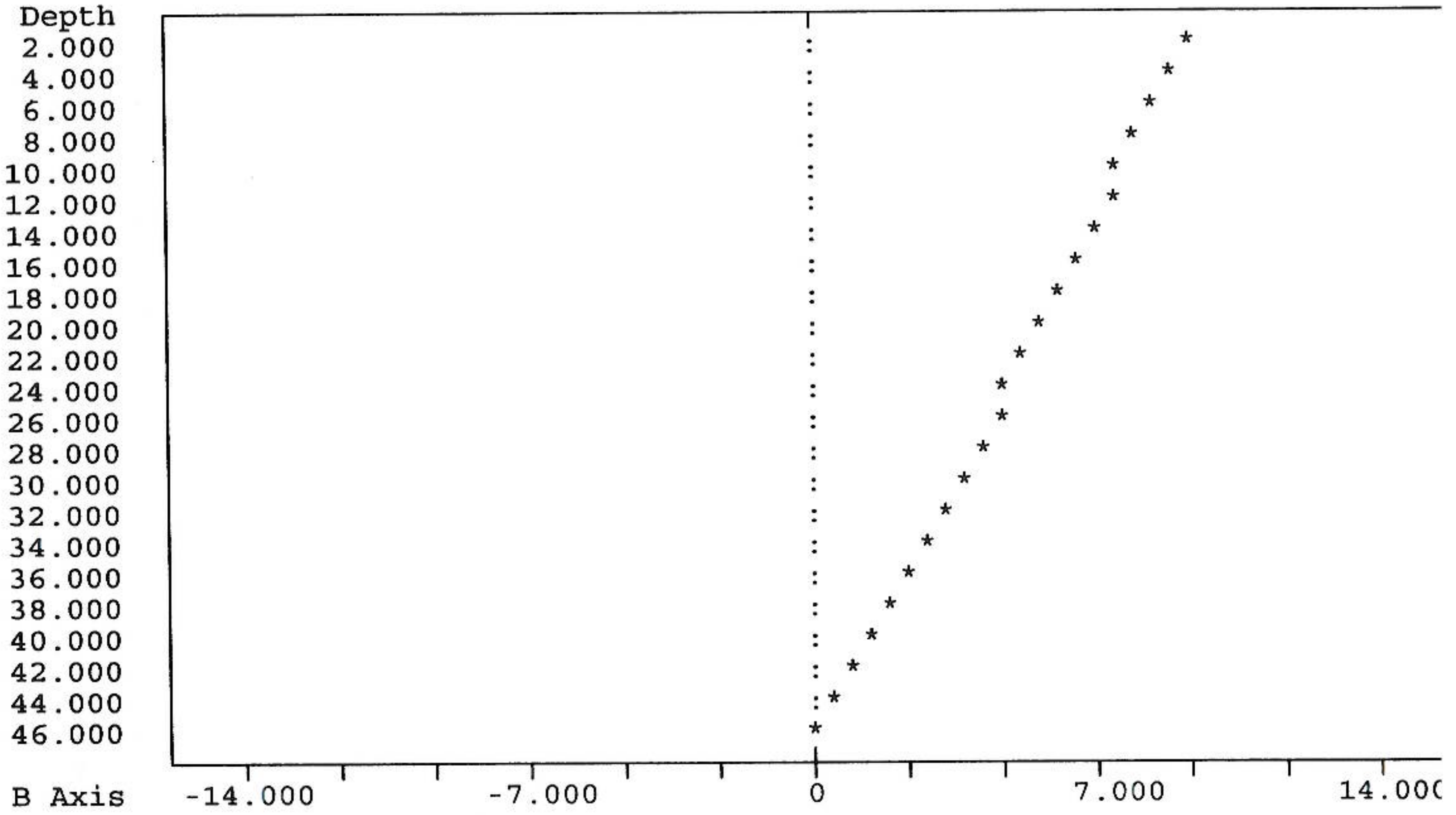
END OF RECORDS

Data for: 97-02

Page

Using Reading Set # 18

CUM.DEV. IN



SLOPE INDICATOR DATA REDUCTION

Printed by DMM on 10/26/1997
Site: RAP SI   Installation: 97-03
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	4	15
SENSOR:	28051	28051
DATE	05/30/199710:56	10/23/199706:43
READINGS PER DIRECTION	15	15

SENSOR: 28051

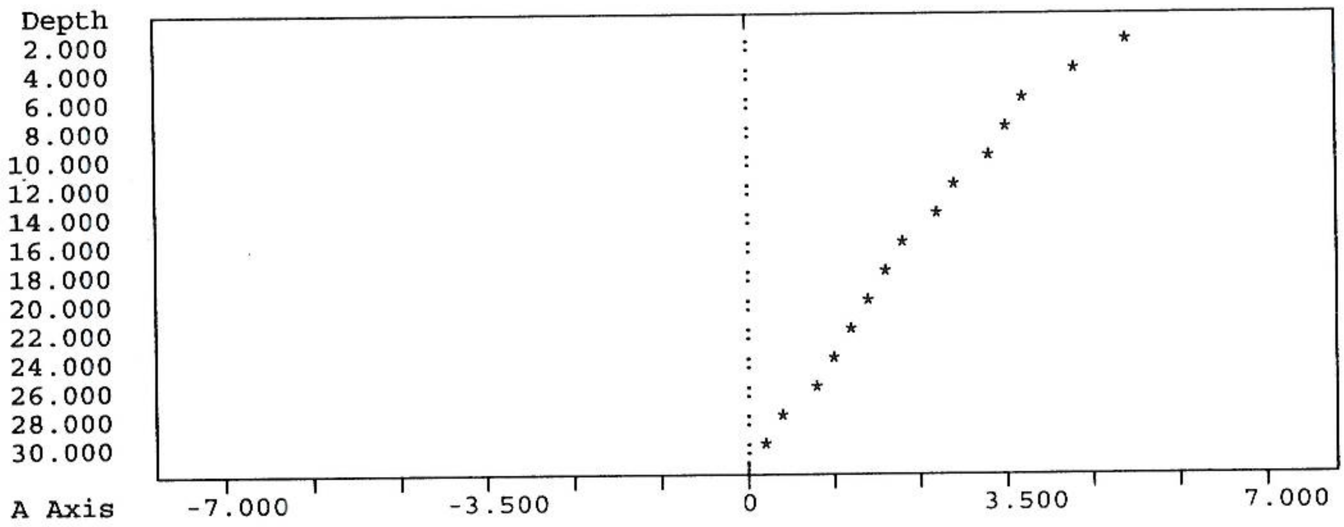
	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP.
DEPTH	A0	A180	INCR.DEV	A0	A180	INCR.DEV	IN.	IN.
2.000	423	-418	0.5046	576	-516	0.6552	0.1506	0.4032
4.000	324	-320	0.3864	523	-514	0.6222	0.2358	0.2526
6.000	229	-227	0.2736	344	-333	0.4062	0.1326	0.0168
8.000	221	-220	0.2646	228	-221	0.2694	0.0048	-0.1158
10.000	299	-297	0.3576	221	-215	0.2616	-0.0960	-0.1206
12.000	339	-337	0.4056	301	-296	0.3582	-0.0474	-0.0246
14.000	286	-285	0.3426	341	-335	0.4056	0.0630	0.0228
16.000	188	-186	0.2244	287	-282	0.3414	0.1170	-0.0402
18.000	148	-146	0.1764	189	-183	0.2232	0.0468	-0.1572
20.000	222	-217	0.2634	151	-143	0.1764	-0.0870	-0.2040
22.000	254	-250	0.3024	223	-215	0.2628	-0.0396	-0.1170
24.000	257	-252	0.3054	256	-250	0.3036	-0.0018	-0.0774
26.000	281	-277	0.3348	259	-252	0.3066	-0.0282	-0.0756
28.000	261	-259	0.3120	282	-274	0.3336	0.0216	-0.0474
30.000	322	-312	0.3804	262	-257	0.3114	-0.0690	-0.0690

END OF RECORDS

Data for: 97-03

Using Reading Set # 15

Page
CUM.DEV. IN.



SLOPE INDICATOR DATA REDUCTION

Page

Printed by DMM on 10/26/1997
Site: RAP SI   Installation: 97-03
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	4	15
SENSOR:	28051	28051
DATE	05/30/199710:56	10/23/199706:43
READINGS PER DIRECTION	15	15

SENSOR: 28051

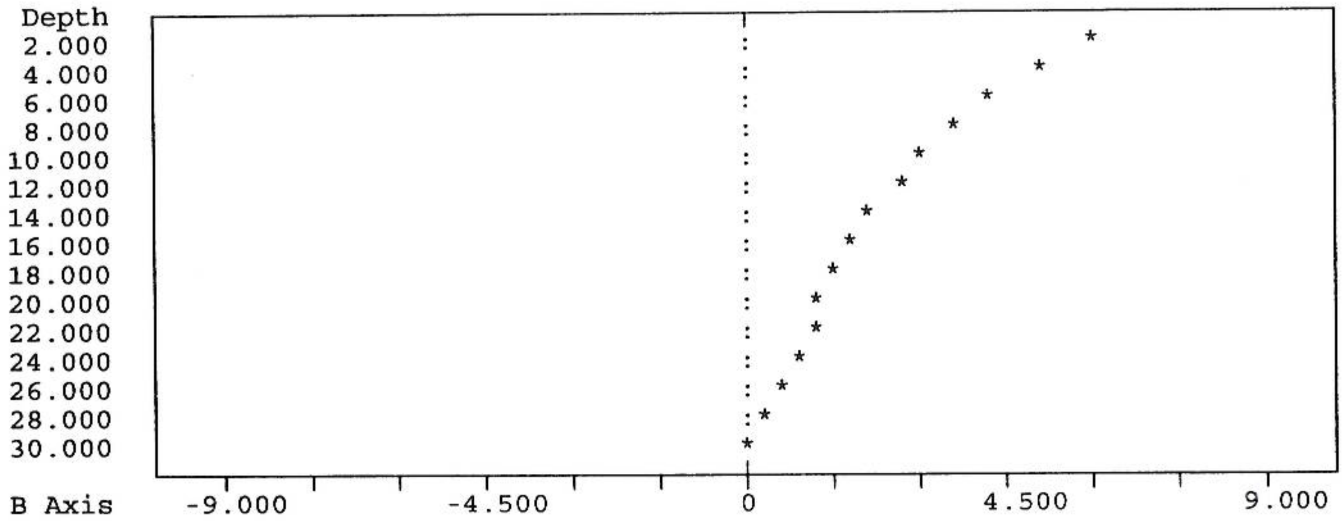
	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP.
DEPTH	B0	B180	INCR.DEV	B0	B180	INCR.DEV	IN.	IN.
2.000	720	-678	0.8388	771	-753	0.9144	0.0756	0.7104
4.000	509	-479	0.5928	697	-654	0.8106	0.2178	0.6348
6.000	438	-410	0.5088	509	-472	0.5886	0.0798	0.4170
8.000	398	-363	0.4566	439	-408	0.5082	0.0516	0.3372
10.000	343	-328	0.4026	399	-362	0.4566	0.0540	0.2856
12.000	304	-280	0.3504	343	-322	0.3990	0.0486	0.2316
14.000	262	-243	0.3030	307	-281	0.3528	0.0498	0.1830
16.000	223	-201	0.2544	266	-243	0.3054	0.0510	0.1332
18.000	185	-170	0.2130	223	-200	0.2538	0.0408	0.0822
20.000	217	-184	0.2406	185	-169	0.2124	-0.0282	0.0414
22.000	229	-211	0.2640	219	-187	0.2436	-0.0204	0.0696
24.000	223	-207	0.2580	231	-210	0.2646	0.0066	0.0900
26.000	210	-190	0.2400	225	-206	0.2586	0.0186	0.0834
28.000	181	-163	0.2064	211	-191	0.2412	0.0348	0.0648
30.000	167	-130	0.1782	189	-158	0.2082	0.0300	0.0300

END OF RECORDS

Data for: 97-03

Using Reading Set # 15

Page
CUM.DEV. IN.



SLOPE INDICATOR DATA REDUCTION

Printed by DMM on 10/26/1997
Site: RAP SI Installation: 97-05
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	7	18
SENSOR:	28051	28051
DATE	07/11/199710:29	10/23/199711:14
READINGS PER DIRECTION	28	28

SENSOR: 28051

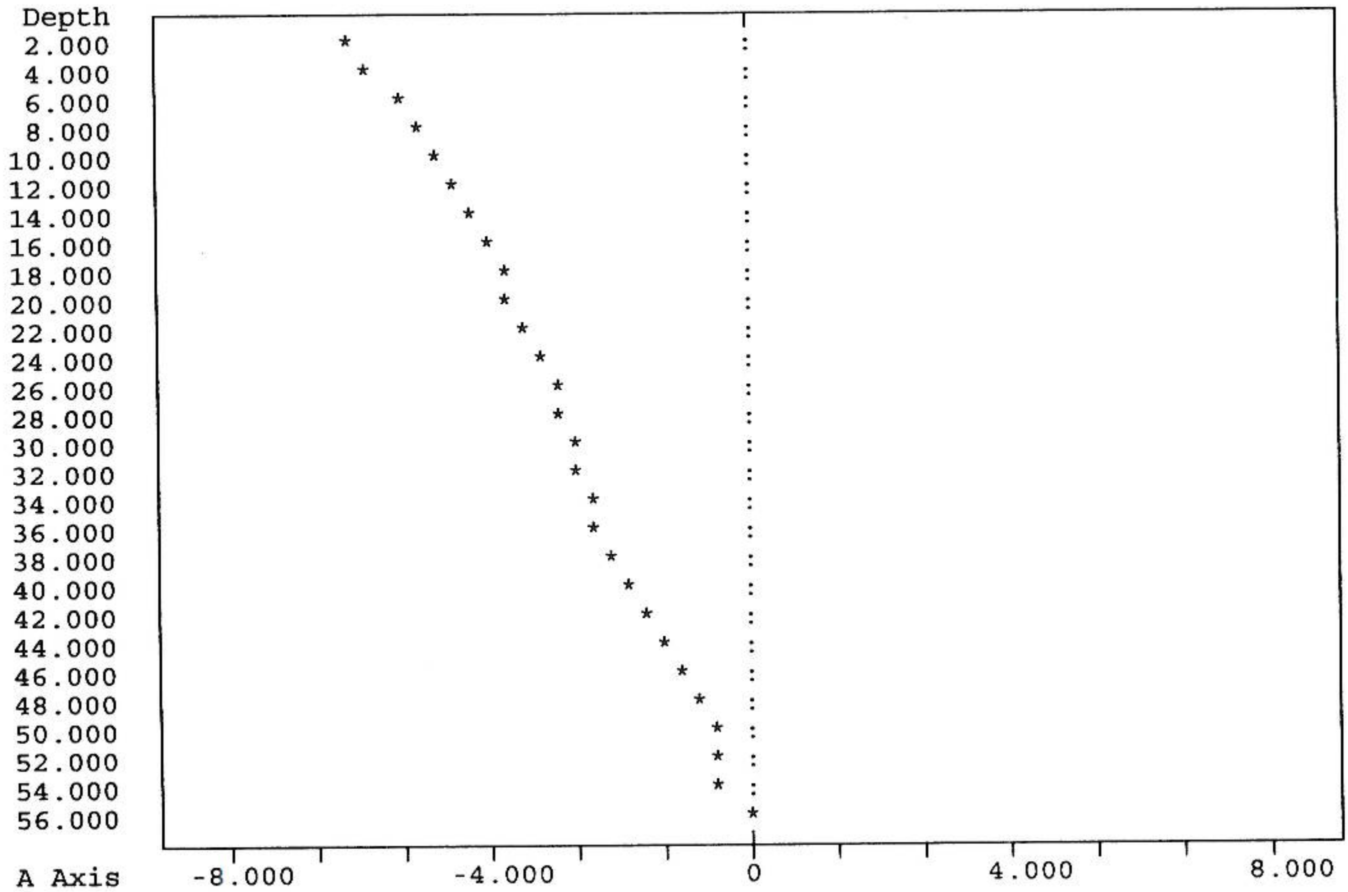
	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP.
DEPTH	A0	A180	INCR.DEV	A0	A180	INCR.DEV	IN.	IN.
2.000	-254		-0.3048	-289		-0.3468	-0.0420	-0.4932
4.000	-232		-0.2784	-280		-0.3360	-0.0576	-0.4512
6.000	-237		-0.2844	-249		-0.2988	-0.0144	-0.3936
8.000	-243		-0.2916	-225		-0.2700	0.0216	-0.3792
10.000	-236		-0.2832	-237		-0.2844	-0.0012	-0.4008
12.000	-185		-0.2220	-242		-0.2904	-0.0684	-0.3996
14.000	-117		-0.1404	-232		-0.2784	-0.1380	-0.3312
16.000	-162		-0.1944	-189		-0.2268	-0.0324	-0.1932
18.000	-207		-0.2484	-116		-0.1392	0.1092	-0.1608
20.000	-146		-0.1752	-150		-0.1800	-0.0048	-0.2700
22.000	-75		-0.0900	-205		-0.2460	-0.1560	-0.2652
24.000	-135		-0.1620	-146		-0.1752	-0.0132	-0.1092
26.000	-195		-0.2340	-74		-0.0888	0.1452	-0.0960
28.000	-109		-0.1308	-128		-0.1536	-0.0228	-0.2412
30.000	-110		-0.1320	-191		-0.2292	-0.0972	-0.2184
32.000	-158		-0.1896	-109		-0.1308	0.0588	-0.1212
34.000	-183		-0.2196	-102		-0.1224	0.0972	-0.1800
36.000	-275		-0.3300	-151		-0.1812	0.1488	-0.2772
38.000	-221		-0.2652	-179		-0.2148	0.0504	-0.4260
40.000	-297		-0.3564	-272		-0.3264	0.0300	-0.4764
42.000	-222		-0.2664	-218		-0.2616	0.0048	-0.5064
44.000	-163		-0.1956	-285		-0.3420	-0.1464	-0.5112
46.000	33		0.0396	-227		-0.2724	-0.3120	-0.3648
48.000	33		0.0396	-171		-0.2052	-0.2448	-0.0528
50.000	-91		-0.1092	37		0.0444	0.1536	0.1920
52.000	-153		-0.1836	-79		-0.0948	0.0888	0.0384
54.000	-110		-0.1320	-149		-0.1788	-0.0468	-0.0504
56.000	-107		-0.1284	-110		-0.1320	-0.0036	-0.0036

END OF RECORDS

Data for: 97-05

Using Reading Set # 18

Page
CUM.DEV. IN.



SLOPE INDICATOR DATA REDUCTION

Page

Printed by DMM on 10/26/1997
Site: RAP SI Installation: 97-05
Description: LANDSLIDE HAZARD WARNING SYSTEM

	PREVIOUS	CURRENT
DATA SET	7	18
SENSOR:	28051	28051
DATE	07/11/199710:29	10/23/199711:14
READINGS PER DIRECTION	28	28

SENSOR: 28051

	PREVIOUS DATA			CURRENT DATA			INCR DISP	CUM.DISP.
DEPTH	B0	B180	INCR.DEV	B0	B180	INCR.DEV	IN.	IN.
2.000	-328		-0.3936	-357		-0.4284	-0.0348	-0.1464
4.000	-346		-0.4152	-349		-0.4188	-0.0036	-0.1116
6.000	-412		-0.4944	-337		-0.4044	0.0900	-0.1080
8.000	-444		-0.5328	-335		-0.4020	0.1308	-0.1980
10.000	-439		-0.5268	-414		-0.4968	0.0300	-0.3288
12.000	-423		-0.5076	-447		-0.5364	-0.0288	-0.3588
14.000	-405		-0.4860	-444		-0.5328	-0.0468	-0.3300
16.000	-349		-0.4188	-429		-0.5148	-0.0960	-0.2832
18.000	-342		-0.4104	-412		-0.4944	-0.0840	-0.1872
20.000	-365		-0.4380	-346		-0.4152	0.0228	-0.1032
22.000	-327		-0.3924	-344		-0.4128	-0.0204	-0.1260
24.000	-302		-0.3624	-365		-0.4380	-0.0756	-0.1056
26.000	-317		-0.3804	-329		-0.3948	-0.0144	-0.0300
28.000	-331		-0.3972	-309		-0.3708	0.0264	-0.0156
30.000	-333		-0.3996	-306		-0.3672	0.0324	-0.0420
32.000	-303		-0.3636	-333		-0.3996	-0.0360	-0.0744
34.000	-264		-0.3168	-335		-0.4020	-0.0852	-0.0384
36.000	-249		-0.2988	-299		-0.3588	-0.0600	0.0468
38.000	-297		-0.3564	-264		-0.3168	0.0396	0.1068
40.000	-435		-0.5220	-243		-0.2916	0.2304	0.0672
42.000	-465		-0.5580	-293		-0.3516	0.2064	-0.1632
44.000	-386		-0.4632	-425		-0.5100	-0.0468	-0.3696
46.000	-294		-0.3528	-471		-0.5652	-0.2124	-0.3228
48.000	-294		-0.3528	-391		-0.4692	-0.1164	-0.1104
50.000	-251		-0.3012	-306		-0.3672	-0.0660	0.0060
52.000	-285		-0.3420	-250		-0.3000	0.0420	0.0720
54.000	-321		-0.3852	-281		-0.3372	0.0480	0.0300
56.000	-307		-0.3684	-322		-0.3864	-0.0180	-0.0180

END OF RECORDS

Data for: 97-05

Using Reading Set # 18