However, Dracaena massangeane shows a single yield of 55,300 in year 4 representing a 4:1 ratio.

2.4 Livestock

2.4.1 Dairy

Improved feeding and management practices for dairy maybe divided as care of: the dairy cow, the new born calf; housing for dairy calves; the heifer from weaning and of bulls and, introduction of milking equipment on some dairy farms.

In caring for the dairy cow, good quality pasture or other nutritious forage crops such as legume species usually forms the bulk of feed. Grain feed, containing a high percentage of energy and protein matter in readily digestible form should be included in the diet of dairy cows especially during lactation. However, the amount of such feed given will largely be determined by their cost relative to the value of additional milk yield that can be expected from their ingestion. A standard of 1 kg feed to 3.4 lit milk produced maybe used as a guide.

Generally, dairy cows should be dried off 6 to 8 weeks before calving in order to rest the milk secreting organs. In this way, the cow can build up its body reserves to meet the demand of the next lactation while the unborn calf becomes more developed. When a cow is dried off and is in poor condition, she should be given the same ration as while she was in milk to assist weight gain. This will produce a stronger calf, and influence larger and more consistent milk yield later.

For the newborn calf, navel treatment with tincture of iodine to prevent entry of germs and its receiving of the first milk or colostrum from its mother are vital. This vital fluid will nourish, strengthen, induce bowel movements and build up its body resistance to certain infections.

The calf should be left with the cow for 2 to 3 days, depending on the condition of the udder of the dam. Free feeding during those days will have beneficial effects on the function of the udder.

The siting and construction of housing for dairy calves should allow maximum ventilation and good exposure to sunlight. It should not at any time suffer from dampness. Stalls should be 1 m wide, 2 m long with solid partitions 1.3 m high to prevent contact with neighbouring calves.

Proper care after weaning for female calves is an important consideration if the replacement heifer is to realise its potential. Feeding of concentrates up to 12 months is advised to develop the digestive system. After this she should be placed on pasture until 2 months before calving when she might be given 0.23 to 0.45 kg of concentrates daily. Also a good supply of fresh, clean water (about 45 lit daily) should be provided and placed where calves can reach it at all times. Mineral lick for pasture supplement is also recommended. This extra care can be compensated by breeding heifers 6 to 9 months

earlier than one not given similar consideration and attention. Generally, for Jamaica Hope heifers weight at first breeding is 273 kg at 16 to 18 months old.

During the first six months of pregnancy, the cow should only be given good pastures or fodder, after then she should be placed with the milking herd to gain familiarity with the milking parlour.

It takes 5.5 to 6 years to ascertain whether a bull will have a good record of siring highly productive daughters. However, when young, they should be separated from heifers at about 6 months, at which time he should also be trained to lead. Bulls should receive a little more ration than females of the herd as they grow faster. They should be kept in a confined space about 0.2 ha, located with a view of farm activities with a suitable shed. One or two pregnant cows can be allowed with him to prevent ill-tempered and dangerous behaviour caused by loneliness.

Within the project area, a number of dairy farmers practise hand milking. It is recommended that milking machines suited to their operations be used to obtain Grade A milk which attracts a Government subsidy of 30 cents per quart (1.14 lit) and also to improve efficiency.

2.4.2 Beef

In order to improve beef quality, annual production and the feed conversion ratio, several rearing practices are proposed for beef production. These include rearing systems, feed rations, use of hormones and improved management of pasture.

A combination of two rearing systems of production are recommended. They are the cow and calf system with a feed lot fattening operation and the weaner feedlot system. In the former, all young animals not required for replacement purposes are fattened for sale. This involves intensive rotational grazing on highly stocked, highly fertilized pastures and, the feeding of concentrates in a covered lot. In the latter system, weaners and thin cattle from other farms outside the project area are bought for feeding to slaughter weight (455 kg) in feedlots (allowing 7 m^2/animal) combining intensive pasture and concentrate feeding. The combination of systems is recommended because invariably there will be a shortage of weaners for purchase by all farmers. However, the weaner to market system is preferred.

It is preferred that commercial concentrates be fed, however, at the rates necessary (2 to 2.4 kg/100 kg bodyweight) to gain 1 kg body weight per day, costs will be prohibitive. Therefore it is more economical to apply the appropriate fertilizer dressings to pastures and/or partially substitute with a well-balanced blended feed made from local by-products. Several combinations of blended feeds are made by farmers. However, it is necessary that they be well balanced if used as a concentrate substitute.

Weaning calves placed directly unto the feedlot should be placed on a warm-up programme for about 120 days followed by a finishing ration for about 100 days. Roughage consumption is usually limited to about one-fourth to one-third of total grain intake after cattle are on full feed. Grain allowance for fattening cattle should be increased

gradually. Feeding too much grain early in the period can lead to severe scouring and cattle that go "off feed". Four to six weeks should be allowed before the full grain ration. Mineral salt can also be incorporated into the diet.

The use of hormones in injectable implants or feed supplement form maybe easily administered to fattening cattle whether heifers or steers. The use of these, diethylstilbestrol for example, can increase gains in finishing cattle by 10 to 20%. Others are specific to heifers and steers but the benefit is similar, that of increased weight gain.

Water is important in the animals' diets. At least 45 lit of water should be provided for yearlings and 36 lit for fattening calves on feedlot. Provision of water is especially important as mineral salt is fed with protein concentrate which requires water to aid in excreting the excess salt. Anticipated duration for weaners on feedlot is 9 months and, calf to market system is expected to be 17 months.

2.4.3 Pasture

For the establishment of new pastures, cuttings of improved species (African Stargrass and Guinea grass) are spread over the land and harrowed into the soil. Application of fertilizer begins as soon as the grass has begun to grow which should be at least 125.4 kg/ha (1 cwt/acre) of a complete NPK mixture. This should be followed by 251 kg/ha (2 cwt/acre) of sulphate of ammonia 4 months later and again after 8 months as there will be adequate water supply to make this appropriate.

High protein legumes may also be planted with young or established pastures. Examples of these are Quickstick (Gliricidia spps) which is a fast growing woody legume easily established from cuttings. It may be planted to form a fence providing an abundance of nutritious fodder. Another legume of excellent rating is Leucaena leucocephala which is a fast growing hardy perennial legume. It recovers quickly and persistently despite heavy grazing. These legumes along with the above fertilizer rates will give a carrying capacity of 2 or more animal units per acre.

Dairy farmers in general, should provide 6 to 7 grazing paddocks for the milking herd followed by the dry herd and 6 to 7 paddocks for rearing replacement heifers. In respect of the calf to market system of beef cattle production, about 14 paddock, 6 paddocks for the breeding herd and 8 for weaners should be provided. For all paddocks, it is necessary that mineral licks, adequate water (about 27 to 48 lit) for each fattener and shade (whether by a tree or shed) should be provided.

Proper rotational grazing, is designed to put animals on pasture when the stage of growth provides optimum nutrition while the power of recovery is not reduced and that paddocks get adequate rest (about 5 weeks for African Stargrass).

Weed control should include mowing pastures once or twice per year to control weeds such as devil's horsewhip (Achyantes aspera), broom weed (Sida acuta) and many others.

Use of selective chemical weed killers, such as 2-4-5T is effective against broad leaf weeds. Application is most effective when the weeds are in vigorous growth. However, for some persistent and noxious weeds such as Nightshade (Echites sp) and Guinea hen weed (Petivera albacea), manual removal is more effective.

Due to improved management practices set out above, carrying capacity of pastures per acre is 2 animal units. However, the economic optimum stocking rate will be determined by (among other parameters) the type of animal product produced, that is, milk or beef. In making this assessment, milk producers should be aware that dairy cows require a lighter stocking rate than their equivalent in beef animals on the same pasture as milk flow is very sensitive to pasture quality.

2.4.4 Production

Under project condition, proposed gross area in pasture is 1,330 ha which is distributed in St. Dorothy (631 ha) and Rio Cobre West area (699 ha). As mentioned above, most of beef cattle farms within the project area are concentrated at Bush Park in Rio Cobre West area. Depending on the results of field survey, pasture areas for dairy and beef in without and with project condition are set out in the table below:

(Unit: ha)

	Pasture Area					
	Beef		Dairy		Total	
	Without	With	Without	With	Without	With
St. Dorothy	58	40	473	591	531	631
Rio Cobre West	216	200	437	499	653	699
Total (Gross area)	274	240	910	1,090	1,184	1,330
Total (Net area)	247	216	819	981	1,066	1,197

If all pastures will be improved and adequately managed having sufficient water supply, carrying capacity of pasture may be up-graded to 2 animal units (AU) per acre from 0.85 AU/acre at present. The best milk producer within the project area produces 17.8 kg (15 qts) of milk per cow per day with pastures of 0.82 AU/acre and concentrates 8.2 kg/cow/day. Assuming that 17.8 kg of milk per cow per day will be received, pasture with 2 AU carrying capacity would produce 6,506 kg of milk per acre (16,069 kg/ha). Then, total milk production in the project area will be 15,764 ton from net pasture area of 981 ha.

Assuming a stocking rate of 4.3/ha (based on a semi-intensive system of 50 fatteners on 12 ha of pasture) and finished weight of 450 kg; duration of fattening as 6 months,then liveweight production per ha per year is calculated as 3,780 kg per ha/year. Net area of pasture is 216 ha. Therefore total annual production in the project area is approximately 816 ton.

2.5 Post Harvest Facilities

Production of farm produce after implementation of the irrigation works should rapidly increase. Based on production targeted for the project area under anticipated yield and production section, present processing and other post-harvest facilities are examined here.

With respect to sugarcane, despite uncertainty about production of sugar at Bernard Lodge, Monymusk and New Yarmouth Sugar Factories, they are capable of milling the additional production under project conditions. Moreover, sugarcane from Innswood and Old Harbour Estates have been milled at these two factories during past years.

Planned expansion for the Spanish Town Rice Mill in 1987 is, 2 sets mills with capacity of 4.5 ton/hr. If improved milling operations are as at present, that is, 16 hours/day for 325 days per year, these mills will be able of producing 46,800 ton of finished rice per year. Annual production of paddy after project implementation will be approximately 25,200 ton (15,120 ton finished rice) or 32% of the mills output. It has been indicated that the mill can operate for 24 hours each day, giving maximum capacity of 70,000 ton of finished rice per year.

The Spanish Town Rice Mill also has the facilities and plans for drying corn. Dryer bin capacity for grain is 18 ton. Therefore, adequate facilities are already in place to dry the 23,000 ton of corn to be produced under project conditions.

Soybean will be sent to the Jamaica Soya Products Ltd. for processing. The crushing capacity of the mill is 90,000 ton/year. So far, 58,000 ton and 46,000 ton were crushed in 1984 and 1985 respectively. It is hoped that for 1987, 70,000 ton will be crushed. However, the supply of soybean is dubious for 1987. Projected production is approximately 3,000 ton or 3.3% of the mill's capacity. It is therefore reasonable to say that sufficient milling capacity is available for additional soybean produced.

The capacity of the packaging plant for St. Catherine Vegetable Producers Association was not ascertained. Nevertheless, it is anticipated that at 25,000 ton of vegetable per year, the plant will still be operating below full capacity. However, grading machine and cold storage with precooling equipment should be introduced for export and more beneficial domestic market.

Increase in production of beef can be adequately handled by the present slaughtering facilities with some improvements. There is need for specially constructed abattoirs and meat storage facilities.

In respect of milk, the two processors serving the area, Cremo Ltd. and Century Farm, as already indicated, are operating considerably below potential. Production of milk is anticipated to be 15,764 ton which can be adequately processed by the expanded facilities at Century Farms and/or Cremo Ltd.

At present, there are no established facilities for the processing of inland Tilapia. Proposed production of 3,400 ton/year may be sold fresh or, if evisceration is done, farmers will need to provide simply designed buildings, equipment and, storage facilities.

2.6 Aquaculture

Proposed improved rearing practices for fish include; decreasing turn around time between pond stockings: inclusion of brood ponds on small farms; increased stocking rate and, revised procedure for hand-sexing fingerlings.

The prolonged period between restocking ponds (7.5 weeks) is attributed to piece-meal harvesting in accordance with market demand. Ponds should be harvested in a single operation on 2 to 3 weeks period. The pond should be completely drained, and any remaining puddles treated with rotenone to eliminate all fish before refilling and beginning the next production cycle 3 to 5 weeks later. Sometimes when ponds have several generations of fish due to improper sexing, fingerlings or larger fish which have not attained required market weight should also be harvested, hand-sexed and redistributed to other ponds containing fish of similar size. The use of rotenone to terminate ponds prevents further contamination of the subsequent production cycle.

All small farms with at least 0.4 ha of production pond should have a brood pond which is stocked at a density of 7,500 to 10,000 per ha. The sex ratio of the brood stock is approximately 3 females per male. Frequent partial harvesting of fry once per week should begin 5 to 7 weeks after stocking brood fish which is essential for the success of this management practice. If partial harvests are discontinued for an extended period, the average size of fingerlings increases, resulting in increased cannibalism on small fry and a great reduction in the total number of fry. With an uninterrupted programme of frequent harvests, brood ponds can remain productive for more than 8 months although more usually for 4 to 6 months.

Purchases of the red Tilapia hybrid which are not previously hand-sexed by the vendor, should be done by the farmer. This maybe somewhat time consuming but if number of male fish is known at the onset, the duration of the crop can be decreased by 1 to 2 weeks despite the added time needed to rear this species.

The stocking rate used for nursery ponds should be raised from 150,000/ha of fry to 180,000/ha. Suggested feeding schedule should begin at a daily rate of 11 kg/ha during the first week and gradually increased to 40 kg/ha by the fourth week and 60 kg/ha by the sixth week. Total feed consumption should range from 1,400 to 1,900 kg/ha/crop.

With particular reference to small-scale farmers, hand-sexing techniques needs improvement. Instead of sexing on the pond banks using small water-filled barrels to keep densely packed fingerlings for several minutes, stressing of fish could be lessened if cages submerged in the nursery ponds are used. This lessens double handling of fish from barrels to ponds and visa versa.

Proper use of poultry manure can decrease feed consumed to produced a ton of marketable fish from 1.5 ton in well-managed unfertilized ponds to 1 ton. However, care should be taken not to over manure ponds which results in very dense plankton, decreased oxygen levels and, if at harvest time, produces off-flavour of fish.

Proposed land use indicates the increased gross area for aquaculture to be 580 ha (net area in ponds is 70% of gross that is, 406 ha). However, Production from all areas should increase owing to improved rearing practices. It is anticipated that 2.5 crops per year is attainable with a yield of 2,800 kg/ha per crop. The table below sets out anticipated production by area.

	Gross Area	Net Area	Production/ Crop	Production/ Year
	(ha)	(ha)	(ton)	(ton)
St. Dorothy	81	56.7	158.9	397.3
Rio Cobre West	165	115.5	323.6	809.0
Rio Cobre East	295	206.5	578.6	1,446.5
Small Farmers Area	3	27.3	76.5	191.3
Total	580	406	1,137.6	2,844.1
Average Yield	2,800 kg/ha			

Annual production of fresh water fish from the project area is calculated to be 2,840 ton per year.

2.7 Intensification of Agricultural Research and Extension

2.7.1 Present condition of the research activities

For achievement of the successful agricultural production in the project area, improvement and development of farming technologies by means of research activities and extension services are indispensable. Present research condition of agricultural production in relation to this project is summarized as follows:

(1) Upland crops and livestock

As described in the section of Agricultural Institution, sugarcane research and extension are done by Sugar Industry Research Institute cooperating with sugar estates in the conduct of field trials. Major research includes varietal improvement, soils and fertility, plant protection, cultural practices and irrigation. Researches on cattle breeding/husbandry and pasture management are carried out at Bodles Research Station (dairy) and Grove Place Research Station (beef-cattle). Bodles Research Station also conducts researches on vegetables, grains (corn, soybean, red pea, etc.) and other crops, including mainly variety and fertilizer trials. Major constraints of these researches generally are the deficit of budget and/or the lack of research personnel.

Export Crop Project with support funding through the World Bank has been implemented since 1983 with the broad objectives of expanding production and marketing of export crops. This Project provides funding for undertaking research, with other components, of major export crops viz. sugarcane, vegetables, ornamental horticulture and others (citrus, coffee, etc.). Research of ornamentals includes the performance of varieties of Leatherleaf Fern and exotic flowers and foliage under different ecological conditions. As for

vegetables, research has five (5) trials with the introduction of new varieties for export and use of agronomic and plant protection technologies for their production. Vegetable crops which have been identified are sweet/hot pepper, pumpkin/squash, musk melon, cucumber, Chinese cabbage, etc.

(2) Rice

Rice Research Programme had been implemented with technical cooperation of Japanese Government through JICA in 1976-1981. The research included varieties, fertilizers and chemicals was conducted both at Elim (St. Elizabeth) and Bodles Research Station. In 1982, Rice Research Programme was handed over to BRUMDEC (Black River Upper Morass Development Company) which produced rice under large-scale farming. BRUMDEC continued rice research and carried out a number of trials of varieties and cultural practices especially adaptable for peat soils. However, rice research had terminated when BRUMDEC was turned over to Jamculture Ltd. in 1985 (January). Then, there is no rice research in the island except for local trials in rice producing area. Research and extension are indispensable for improved rice production in the proposed paddy land of 3,900 ha (9,600 acres) as well as in the other area.

(3) Water usage at on-farm level

It is very important for water economy in proposed irrigable area of 14,620 ha (36,120 acres) to use effectively irrigation water. However, many examples of ineffective and inefficient water usage at on-farm level are found in the project area owing to the lack of technology for which no research and extension service have been conducted. Research and training are necessary for establishment and extension of on-farm level irrigation technology.

2.7.2 Recommendation

(1) The main rice research station

Rice research should be under the full control of Research and Development Division of MOA. Bodles Research Station which has 2 ha (5 acres) paddy field should be continuously the main rice research station with fundamental and overall research item in the island as follows:

- introduction and primary selection of new varieties on a continuous basis (eg. International Observation Rice Nursery for Latin America, International Rice Yield Nursery for Latin America),
- nutritious and physio-ecological experiment for high yielding technology of rice, and
- plant protection against diseases, insect pest and weeds (including varietal resistance, cultural control, pesticide and herbicide trial).

(2) Test farm

Satellite stations in other location research corresponding to the specific local conditions; Black river for pear soils, Amity Hall for saline soils, etc. For the project, as most of soils on the proposed paddy land are saline heavy clay (Class II-IV). Bodles will establish a test farm as sub-station of rice research for trials of variety, fertilization, cropping system and soil management in relation to soil salinity.

(3) Pilot farm

Proposed paddy land will include both large-scale farm with fully mechanized farming as in Amity Hall and small-scale farm with semi-mechanized cultivation in Little Hartland and Small Farmers Area. Pilot farm is necessary for the reason as follows:

- identification and demonstration of research finding both for small and large-scale farms,
- training of small farmers with respect to management and technology of rice farming, and
- establishment of mother farm's managing and supporting procedure for small farmers.

(4) Location

Item	Location
Fundamental rice research	Boddles Research Station
Irrigation research at on-farm level	Boddles Research Station
Test farm	Central part of Amity Hall area (or west part of Hartlands)
Pilot farm	Central part of Amity Hall area (or west part of Hartlands)

The site of test and pilot farm will establish at the same location in II or III grade of soil salinity area, as distributed in paddy area, for trials and training. The site where above conditions are satisfied may be central part of Amity Hall or west part of Hartlands.

Table H-1 PRESENT LAND USE

Land Use	Area (ha)	Percent of Arable Land
1. Arable Land		
Sugar cane	8,900	42.4
Vegetable/crop	920	4.4
Orchard	320	1.5
Paddy	390	1.8
Pasture	2,700	12.9
Ruinate	6,690	31.9
Woodland	530	2.5
Aquaculture	210	1.0
Swamp	340	1.6
Sub-total	21,000	100.0
2. Non arable Land		
Urban Land	4,240	-
Wet land	190	-
Limestone	60	-
Salinas	620	-
Mangrove	910	-
Others	340	-
Sub-total	6,360	-
3. Total Land	27,360	-

Table H-2 PRESENT LAND USE OF ARABLE LAND

(Unit: ha)

	North St. Dorothy		Bodles Research Stat.		Spring Garden and Thetford		Salt Island		North of Spanish Town		Outside of RCE*		Sub-total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Sugar cane	18	1.8	-	-	262	22.0	-	-	154	8.8	379	23	813	12.5
Vegetable/crop	62	6.2	24	5.3	141	11.8	-	-	24	1.4	14	0.8	265	4.0
Tobacco/Horticul.	190	18.9	-	-	-	-	-	-	-	-	21	1.3	211	3.2
Orchard	23	2.3	31	6.9	182	13	-	-	-	-	-	-	236	3.6
Paddy	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasture	437	43.5	295	65.8	219	18.4	-	-	157	9.0	405	24.3	1,513	23.3
Grassland	10	1	46	10.3	15	1.1	-	-	587	33.5	291	16.8	949	14.6
Bush/grass	67	6.7	9	2	22	1.1	-	-	354	20.2	126	7.6	578	8.9
Bush	105	10.4	16	3.6	234	19.6	363	86.2	393	22.4	167	10	1,278	19.7
Woodland	93	9.2	27	6	116	9.3	-	-	59	3.4	87	5.2	382	5.9
Aquaculture	-	-	-	-	-	-	58	13.8	240.4	-	-	-	82	1.3
Swamp	-	-	-	-	-	-	-	-	-	-	175	11	175	2.7
Total	1,005	100.0	448	100.0	1,191	100.0	421	100.0	1,752	100.0	1,665	100.0	6,482	100.0

	South St. Dorothy		Bushy Park West		Rio Cobre West		Small Farmer		Rio Cobre East		Sub-total		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Sugar cane	644	43.2	96	11.6	2,456	48.2	114	12.1	4,775	77.6	8,085	55.7	8,898	42.4
Vegetable/crop	22	1.5	118	14.3	213	4.2	95	10.1	-	-	448	3.1	713	3.4
Tobacco/Horticul.	-	-	-	-	-	-	-	-	-	-	-	-	211	1.0
Orchard	3	0.2	83	10.0	-	-	-	-	-	-	86	0.6	322	1.5
Paddy	-	-	-	-	386	7.6	-	-	-	-	386	2.7	386	1.8
Pasture	531	35.7	244	29.5	409	8.0	-	-	-	-	1,184	8.1	2,697	12.9
Grassland	41	2.8	32	3.9	204	4.0	297	31.5	1,166	19.0	1,740	12.0	2,689	12.8
Bush/grass	133	8.9	113	13.6	535	10.5	106	11.2	66	1.1	953	6.6	1,534	7.3
Bush	102	6.8	126	15.2	592	11.6	285	30.2	83	1.3	1,188	8.3	2,466	11.8
Woodland	-	-	-	-	76	1.5	8	0.8	61	1.0	145	1.0	527	2.5
Aquaculture	14	0.9	16	1.9	62	1.2	39	4.1	-	-	126	0.8	208	1.0
Swamp	-	-	-	-	162	3.2	-	-	-	-	162	1.1	337	1.6
Total	1,490	100.0	828	100.0	5,095	100.0	944	100.0	6,151	100.0	14,508	100.0	20,990	100.0

Remarks : *RCE --Rio Cobre East

Numbers in parenthesis express percentage of total for each column

Table H-3 DOMESTIC CROP PRODUCTION AND AREA

Item	Area					Production (ton)		
	1983		1984		Percentage Change	1983	1984	Percentage Change
	(ha)	(%)	(ha)	(%)				
Legume	940	18.9	982	18.2	-0.9	941	941	0.0
Vegetable	1,223	24.6	1,347	2.51	10.1	13,398	14,269	6.5
Condiment	161	3.2	225	4.2	39.9	732	1,250	70.8
Fruit	103	2.1	93	1.7	-9.4	1,317	1,196	-9.2
Cereal	280	5.6	292	5.4	4.2	416	327	-21.4
Plantain	277	5.6	297	5.5	7.2	3,063	3,297	7.6
Potato	248	5.0	266	4.9	47.6	2,476	3,750	51.5
Yam	1,105	22.2	1,123	20.9	1.6	12,557	13,188	5.0
Other tuber	531	10.7	588	10.9	10.7	5,760	6,431	11.7
Sorrel	108	2.2	105	1.9	0.0	122	92	-25.2
Total	4,978	100.0	5,373	100.0	7.9	40,778	44,742	9.7

Table H-4 NUMBER SLAUGHTERED AND WEIGHT OF LIVESTOCK IN ST. CATHERINE, 1981-1984

Item	Year	Number	Weight (ton)	
			Total	Dressed
Cattle	1981	12,657	2,708	2,257
	1982	12,180	2,603	2,169
	1983	14,511	3,052	2,543
	1984	14,502	3,305	2,754
	All island	70,403	14,485	12,071
	% of all	20.6	22.8	22.8
Goat	1981	8,538	114	95
	1982	7,448	89	74
	1983	9,260	104	87
	1984	10,817	130	109
	All island	56,726	716	597
	% of all	19.0	18.2	18.2
Sheep	1981	271	4.4	3.7
	1982	231	3.5	2.9
	1983	206	2.9	2.4
	1984	190	3.4	2.8
	All island	823	15.8	13.2
	% of all	23.1	21.6	21.6

Table H-5 PRODUCTION OF SUGARCANE 1985/86

	Area Cropped (ha)	Production (ton)	Average Yield (ton/ha)
Innswood Estate	1,594	87,469	54.8
Bernard Lodge Estate	1,624	96,114	59.2
Caymanas Estate	381	30,917	81.1
Old Harbour Estate	425	32,217	75.8
Total	4,024	246,716	61.3

Table H-6 OPERATION AND LABOUR COSTS OF SUGARCANE PER HA

Item		Mechanical/ Manual or Material	No. of Time or Rate of Input	Cost per Hectare (J$) Replants	Ratoons
(1) Operation and Labour					
Land preparation					
Ploughing		Disk plough	2	203.8	-
Harvesting		Disk harrow	1	180.0	-
Ridging		Ridger	1	127.0	-
Planting		Manual	1	243.8	-
Covering (moulding)		Ridger	1	127.0	127.0
Fertilizing		Manual	3	55.5	55.5
Herbicide Appl.		Manual	3	49.2	49.2
		Boom sprayer	1	21.0	21.0
Weeding		Manual	1	98.8	98.8
Moulding		Ridger	1	108.3	108.3
Harvesting		Manual	1	547.3	396.6
Loading		Cane loader	1	217.2	158.0
Transportation		Truck	1	217.2	602.9
Water Management		Manual	-	75.4	75.4
Sub-total (1)				2,881.3	1,692.7
(2) Input Materials					
Fertilizer	1	23.10.20	1,106 kg	557.5	557.5
	2	16.9.18	1,106 kg	499.6	499.6
	3	Sulphate/ammo	1,106 kg	380.2	380.2
Herbicide	1	Gexapax combi Actril DS		237.5	237.5
	2	Citowett		2.0	2.0
Planting Materials		Cane seeds	8.8 ton	605.2	-
Sub-total (2)				2,282.0	1,676.8
(3) Total (1)+(2)				516,321.0	3,369.5

Source: Innswood Estates

Table H-7 PERCENTAGE CHANGE IN HECTARE REAPED BY CROP 1981-1985

(Unit: ha)

Crop	1981	1982	% 81-82 change	1983	% 82-83 change	1984	% 83-84 change	1985	% 84-85 change
Calaloo	101	119	18.0	119	0.3	132	11.0	67	-49.0
Pumpkin	88	68	-23.0	81	18.0	68	-16.0	33	-52.0
Tomato	42	38	-9.0	31	-20.0	42	36.0	23	-44.0
Cucumber	51	46	-8.0	46	0.0	51	21.0	63	13.0
Okra	46	113	155.0	113	-0.7	123	9.0	58	-53.0
String bean	3	8	178.0	1	-84.0	2	67.0	1	-60.0
Onion	20	26	30.0	16	-38.0	22	35.0	6	-74.0
Hot pepper	8	7	-15.0	14	100.0	42	206.0	5	-87.0
Sweet pepper	6	11	65.0	12	12.0	47	300.0	15	-67.0
Watermelon	3	2	-12.0	2	20.0	2	-33.0	1	-100.0
Corn	102	34	-66.0	41	20.0	26	-36.0	21	-22.0
Totals	468	472	1.8	476	0.6	557	18.0	293	-48.0

Source: Data Bank, Ministry of Agriculture

Table H-8 PERCENTAGE CHANGE IN PRODUCTION BY CROP 1981-85

(Unit: ton)

Crop	1981	1982	% 81-82 change	1983	% 82-83 change	1984	% 83-84 change	1985	% 84-85 change
Calaloo	1,009	1,323	31.0	1,327	0.3	1,325	-0.1	746	-44.0
Pumpkin	1,373	833	-39.0	983	18.0	756	-23.0	364	-52.0
Tomato	421	428	2.0	341	-20.0	416	22.0	235	-44.0
Cucumber	504	410	19.0	516	26.0	436	15.0	771	77.0
Okra	246	378	53.0	500	33.0	626	25.0	321	-49.0
String bean	13	42	223.0	5	-87.0	6	20.0	3	-50.0
Onion	203	264	30.0	127	-52.0	145	14.0	42	-14.0
Hot pepper	27	31	15.0	46	48.0	140	204.0	18	-87.0
Sweet pepper	22	58	164.0	104	79.0	365	252.0	171	-53.0
Watermelon	31	25	-19.0	27	9.0	16	-40.0	6	-61.0
Corn	226	31	-87.0	46	48.0	29	-37.0	23	-22.0
Totals	4,075	3,823	-6.0	4,022	5.0	4,260	1.0	2,700	-37.0

Source: Data Bank, MOA

Table H-9 AVERAGE YIELD PER HECTARE OF SELECTED CROPS IN THE STUDY AREA 1981-85

(Unit: ton)

Crop	1981	1982	1983	1984	1985	Average
Calaloo	11.3	12.5	12.5	11.3	12.5	12.5
Pumpkin	17.5	13.8	13.8	12.5	12.5	13.8
Tomato	11.3	12.5	12.5	11.3	11.3	11.3
Cucumber	11.3	10.0	2.5	8.8	13.8	11.3
Okra	6.3	3.8	5.0	5.0	6.3	5.5
String bean	5.0	6.3	5.0	3.8	5.0	5.0
Corn	2.5	1.0	1.3	1.3	1.3	1.8
Onion	11.3	11.3	8.8	8.8	8.8	9.5
Hot pepper	3.8	5.0	3.8	3.8	3.8	4.0
Sweet pepper	3.8	6.3	10.0	8.8	12.5	8.3
Watermelon	12.5	12.5	12.5	11.3	10.0	12.5

Source: Data Bank, MOA

Table H-10 COMPARISON OF AVERAGE YIELD PER HECTARE OF SELECTED CROPS BY SOURCE

(Unit: ton)

Crop	JDB	Association	Data Bank	MOA	Survey
Calaloo	25.0	60.0	12.5	12.5	25.0
Pumpkin	17.5	15.0	13.8	10.0	15.0
Tomato	12.5	8.8	11.3	12.5	8.8
Cucumber	15.0	11.3	11.3	11.3	11.3
Okra	5.0	22.5	5.5	6.3	10.0
String bean	N/A	N/A	5.0	N/A	4.4
Pak choi	12.5	12.5	N/A	N/A	12.5
Onion	10.0	31.3	9.5	10.0	11.3
Hot pepper	10.0	8.8	4.0	7.5	7.5
Sweet pepper	18.8	8.8	8.3	12.5	8.8
Watermelon	20.0	N/A	12.5	12.5	12.5
Red peas/beans	1.0	0.6	N/A	1.1	1.0
Corn	2.5	1.8	1.5	3.8	3.8

Remarks: JDB - Reference book for Agricultural Credit Officers
Association - Representative from St. Catherine Vegetable Producers Association
Data Bank - Of the Ministry of Agriculture (MOA)
MOA - Economic and Planning Unit

Table H-11 LABOUR REQUIREMENT AND INPUT MATERIAL PER HECTARE FOR SOME CROPS

	Calaloo	Onion	Sweet Pepper	Okra	Pumpkin
A. Labour					
Land clearing (tractor hrs)	2.5	2.5	2.5	2.5	2.5
Plough & harrow & furrow (tractor hrs)	5.0	5.0	5.0	5.0	5.0
Nursery bed (man-day)	12.0	-	12.0	-	-
Transplanting (man-day)	15.0	-	10.0	-	-
Planting (man-day)	-	5.0	-	12.0	5.0
Weeding (man-day)	62.0		37.0	25.0	7.5
		}200.0			
Weeding & thining (man-day)	-		-	-	12.0
Fertilizer appl. (man-day)	10.0	10.0	2.5	2.5	2.5
Pesticide appl. (man-day)	31.0	25.0	20.0	25.0	15.0
Reaping & Grading (man-day)	79.0	37.0	66.0	180.0	30.0
Total number of man-days	216.5	284.5	155.0	252.0	79.5
B. Materials					
Seed (kg/ha)	0.07	8.5	0.7	6.7	4.5
Fertilizer (Kg/ha) S/A	753.0	753.0	753.0	627.0	494.0
Pesticide (Kg/ha)	28.0	28.0	27.0	20.0	33.0
Growing season (days)	90.0	740.0	180.0	90.0	150.0

Source: St. Catherine Vegetable Association

Table H-12 FIELD OPERATION AND LABOUR REQUIREMENT OF RICE

	Time of Operation	Machinery Used	Efficiency (hr/ha)
Land Preparation			
Ploughing	2	Disc Plough	0.5 (0.1 hr/ac x 2)
Harrowing	1	Disc Harrow	0.25 (0.1 /ac)
Seeding	1	Aerial	-
Fertilizer Appl.	3	Aerial	-
Herbicide Appl.	2	Aerial	-
Insecticide Appl.	2	Aerial	-
Harvesting	1	Combine Havester	2.5 (1hr/ac)
Water control, others	-	Manpower	17.8 MD (7.2 MD/ac)

Note: Tractor (Versatile 300 HP) and combine harvester
(John Deer 4.5m) are hired from Jamaica Soya Products.

Table H-13 MANGO PRODUCTION IN THE STUDY AREA

Extension	Harvested Area (ha)	Production in 1985 (dz)
Nightingale Grove	5.7	N/A
Bushy Park	0.8	2,100
Old Harbour	3.2	8,400
Spring Garden	0.4	1,050
Hartlands	0.4	1,050
Spanish Town E	5.3	13,650
Spanish Town S	2.4	6,300
Bellview	1.2	3,150
Total	19.4	35,700

Source: Data Bank

Table H-14 PRESENT CONDITION OF SOME DAIRY CATTLE FARMS

	Particulars	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
1	Land use:						
	Gross area (ha)	42	61	10	86	38	121
	Improved pasture	39	61	4	73	34	89
	Unimproved pasture	-	-	6	12	-	32
	Other	2	-	-	1	4	-
2	Herd size:						
	Total	91 - (70)	379 - (230)	60 - (54)	215 - (136)	200 - (186)	280 - (181)
	Milking cows	45	120	48	57	110	120
	Bulls	3	19	-	1	3	2
	Calves					18	80
	Heifers	}43	}85	}12	}157	33	50
	Dry cows					36	28
3	Local Feed Ration	yes	no	yes	yes	no	no
4	Commercial Feed:						
	Total herd (kg/day)	680	777	254	353	1386	1402
	kg/milking cow/day	N/A	3.6	5	6.3	8.2	8.2
5	Pasture Fertilization (kg/Ha/year)	Poultry manure only	690 (SA)	502 (SA) with some cattle manure	251 (SA)	753 (SA) & 51 (MP)	376 (SA) & 627 (7-14-14)
6	Water source	Owen Well	St. Dorothy Irr.	St. Dorothy Irr.	St. Dorothy Irr.	St. Dorothy Irr. and Own Well	River
7	Duration of Lactation	305 days	305 days	335 days	210 days	305 days	305 days
	#Lactation/cow	8	10	10	4	7	6
8	Average Milk production (kg/day/cow)	8.3	10.7	10.4	8.3	11.8	17.8
9	Total Milk Production (kg/year)	113,849	390,339	166,730	99,291	397,568	650,565

Remarks: SA = Sulphate Ammonia
MP = Muriate of Potash
Figures in parenthesis denote Animal Unit (AU) of total herd size.

Table H-15 MILK PRODUCTION IN THE STUDY AREA

Extension Area	Milk Production (Kg) 1985	1986 Oct.
Nightingale Grove	270,328	197,207
Bushy Park	216,262	138,882
Old Harbour	3,299,074	2,361,136
Spring Garden	34,602	27,729
Hartlands	-	-
Spanish Town	59,250	31,066
Bellview	-	-
Total	3879517	2,755,960

Table H-16 PRESENT CONDITION OF SOME BEEF CATTLE FARMS

	Case 1	Case 2	Case 3	Case 4
Land use: Gross Area (ha)	2	2.4	15	60
Improved pasture (ha)	1	1.8	-	-
Unimproved pasture (ha)	-	0.4	14	20
Others*	1	0.2	1	40
Herd size: Total	21	25	50	60
Cows	-	10	18	30
Bulls	-	1	2	1
Fatteners	21	8	30	25
Calves	-	6	-	4
Commercial feed (kg/day)				
per Total herd	136	Infrequent	181	11
per Fattener	6.3	-	5.4	0.5
Rearing system	Weaner to market	Calf to market	Calf to market	Calf to market
Pasture fertilizaiton: Type	Sulphate of Ammonia	Sulphate of Ammonia	None	None
Rate kg/ha/year	627	94	N/A	N/A
Water source	Spring Garden Well	Old Harbour Branch	Own well	St.Dorothy Irrigation Scheme
Irrigation Cycle	3 days	7 days	rainfed	rainfed
Age at weaning (months)	9	9	9	9
Weight at weaning (kg)	226	158	234	154
Duration of fattening (months)	6	12	13	24
Daily liveweight gain (kg/day)	1	0.7	0.6	0.4
Finished weight (liveweight, kg)	407	430	453	453
Total production (kg/year)	17123	3443	7425	9090

Note: * Others in land use
Case 1: Vegetables, Case 2: Residence,Case 3: Orchard, Case 4: Sugarcane

Table H-17 POST HARVEST FACILITIES SERVING THE STUDY AREA

Name	Location	Raw material from Project Area	Operating Efficiency	Comments
Spanish Town Rice Mill	Spanish Town	Rice	Medium	Expansion underway
Century Farm Milk Process.	Lodge	Milk	Low	Expansion underway 100% fresh milk product
Cremo Ltd.	Three Miles	Milk	Medium	Uses reconstituted milk
St. Catherine Veg. Prod. Ass.	Gutters	Vegetable/ Condiments/fruits	Low	Water is most limiting constraint
Thetford Seed Farm	Church Pen	Field crops	Low	Emphases on vegetable crops
Bernard Lodge Sugar Factory	Bernard Lodge	Sugarcane	Low	Closed

Note: High denotes over 70%, medium:- 51-70% and low: less than or equal to 50%

Table H-18 PROPOSED LAND USE

(Unit: ha)

	St. Dorothy		Rio Cobre West						Rio Cobre East		Small Farmers		Total	
			Bushy Park West		Rio Cobre West		Sub-total							
	Without	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without	With
Sugar cane	644	712	96	0	2,456	1,873	2,552	1,873	876	676	114	0	4,186	3,261
Vegetable/crop	22	63	118	156	213	424	331	580	4,049	3,472	95	106	4,497	4,221
Grains	0	0	0	0	0	0	0	0	765	0	0	0	765	0
Ornamentals	0	0	0	0	0	0	0	0	166	166	0	0	166	166
Orchards	3	3	83	192	0	14	83	206	0	577	0	0	86	786
Paddy (rice-rice)	0	0	0	0	714	1,716	714	1,716	0	0	0	0	714	1,716
(rice-grain)	0	0	0	0	0	604	0	604	0	765	0	799	0	2,168
Pasture	531	631	244	464	409	235	653	699	0	0	0	0	1,184	1,330
Grassland	41	0	32	0	89	0	121	0	0	0	297	0	459	0
Bush/grass	133	0	113	0	322	0	435	0	0	0	106	0	674	0
Bush	102	0	126	0	592	0	718	0	0	0	285	0	1,105	0
Woodland	0	0	0	0	76	0	76	0	0	0	8	0	84	0
Aquaculture	14	81	16	16	62	149	78	165	295	295	39	39	426	580
Swamp	0	0	0	0	162	0	162	0	0	0	0	0	162	0
Reservoir	0	0	0	0	107	187	107	187	0	200	0	0	107	387
Total	1,490	1,490	828	828	5,202	5,202	6,030	6,030	6,151	6,151	944	944	14,615	14,615

Note:- Without: Without project condition, With : with project condition

Table H-19 LAND USE PLAN OF CROP DIVERSIFICATION PROJECT (AGRO 21)

	Location	Crops	Area (acre)	Area (ha)	Comments
A	Bernard Lodge		880	356	
B	Caymanas	Vegetables	870	352	
C1	Caymanas	Orn. Hort.	210	85	
C2	Caymanas	Orn. Hort.	200	81	Tentative
D1	Bernard Lodge	Grains	1,888	765	
D2	Bernard Lodge	Aquaculture	280	113	Tentative
E1	Bernard Lodge	Vegetables	1,640	664	
E2	Bernard Lodge	Orchard crop	580	235	Tentative
F	Caymanas	Vegetables	1,145	464	
G1	Bernard Lodge	Sugarcane	2,162	876	
G2	Bernard Lodge	Aqauaculture	450	182	Tentative
H	Caymanas	Vegetables	1,425	577	
I	Bernard Lodge	Vegetables	3,460	1,401	
Total			15,190	6,151	

Table H-20 FIELD OPERATION OF SUGARCANE

	Machinery or Manual	*No. of Times*	*Tractor hour (hr/ha)*	*Man Day (md/ha)*
1. Land Preparation				
Furrowing	*Ridger*	1	2	-
Ploughing	Disc plough	2	6	-
Harrowing	Disc harrow	2	4	-
Levelling	Leveller	1	2.5	-
Ridging	Ridger	1	2	-
Subsoiling	Subsoiler	1	2	-
2. Planting				
Dropping	Manual	1	-	2.8
Covering	Ridger	1	2	-
3. Moulding for ratoon	Ridger	1	2	-
4. Fertilizing	Manual	1	-	1.5
	Broadcaster	1	0.5	-
5. Cultivating	Spring tyne	1	1	-
6. Herbicide application	Manual	2	-	1.7
7. Harvesting	Manual	1	-	32.0
8. Loading, Scraping	Cane loader	1	-	-
9. Water management	Manual	8	-	-

Table H-21 INPUT MATERIALS OF SUGARCANE

Materials	Application (Kg/ha)	(cwt)
1. Fertilizer		
Sulphate Ammonia (21%)	625	5.0
	600	4.8
	250	2.0
2. Herbicide	(lit/ha)	
Gesapax Combi 500	2.8	-
2-4, D	2.8	-
Actril DS	1.1	-
3. Planting Materials	(ton/ha)	
setts	10	-

Table H-22 PROPOSED FIELD OPERATION, INPUT MATERIALS PER HECTARE OF PADDY

		Unit	Requirement
1. Field Operations			
Ploughing (Tractor)		hr	0.5x2
Harrowing & levelling (Tractor)		hr	0.4x3
Water Management		md	4
Seeding		md	1
Herbicide app.		md	1x2
Fertilizer app.		md	0.6x3
Pest control		md	0.5x2
Supplemental		md	0.4
Planting			
Harvesting (Combine)		hr	1x1
Transportation		100 kg	45
2. Materials			
Seeds		kg	90
Herbicide:	Bentiocarb	lit	3.4
	Propanil	lit	1.6
	24-D Amine	lit	2.0
Pesticide:	Fenitrothion	lit	1.5x2
Fertilizer:	(12-24-12)	kg	177
	(17-0-17)	kg	125
	Urea	kg	63
Irrigation water			

Table H-23 FIELD OPERATION AND INPUT MATERIALS PER HECTARE OF SOYBEAN

		Unit	Requirement
1. Operation			
Harrowing	Disc harrow	hr	0.4
Rotavating	Rotovator	hr	0.6
Land levelling	Leveller	hr	2.5
Ridging	Ridger	hr	1.2
Planting	seed planter		
		} hr	0.6
Fertilizing	fertilizer dist.		
Moulding	Bed shaper	hr	1.2
Herbicide app.	Manual (knapsack)	md	2.5
Pesticide app.	Boom sprayer	hr	0.6x4
Reaping	Combine	hr	2.5
Transportation	Truck		
Irrigation		md	7
2. Materials			
Planting materials	seed with inoculant	kg	56
Fertilizer	T.S. Phosphate (45%)	kg	250
	Murate of potash (60%)	kg	125
Herbicide	Diphenamid (Dymid)	kg	5
	Bentazon (Basagran)	kg	2.5
Pesticide	Monocrotophos (Nuvacron)	lit	2.5x4

Table H-24 FIELD OPERATION AND INPUT MATERIALS PER HECTARE OF CORN

		Unit	Requirement
1. Operation			
Harrowing (2 times)	Recline harrow	hr	0.4
	Harrow	hr	0.4
Rotavating	Rotovator	hr	0.6
Land levelling	Leveller	hr	2.5
Furrowing & bedding	Bed shaper	hr	1.2
Planting	Seed planter	hr	0.6
Fertilizing	Fertilizer dist.		
Spraying	Boom sprayer	hr	0.6
Weeding	Manual (knapsack)	md	2.5
Fertilizing	Manual	md	1.2
Spraying (6 times)	Boom sprayer	hr	0.6x6
Reaping	Combine	hr	2.5
Transportation	Truck	hr	-
Irrigation	Manual	hr	7
2. Materials			
Seeds		kg	17
Fertilizer	Urea	kg	250
	T.S. Phosphate (45%)	kg	250
	Muriate Potash (60%)	kg	500
	Sulphate Ammonium (21%)	kg	500
Chemicals	Pesticide, Herbicide	lit	

Table H-25 INPUT MATERIALS, LABOUR AND MACHINERY INPUT PER HECTARE BY CROP (VEGETABLES - LARGE SCALE)

Items	Cucumber	Sweet Pepper	Zucchini squash	Cantaloupe
1. Fertilizer (kg)				
(7-21-21)	784	560	784	784
(46-0-0)	112	56	112	224
(22-0-22)	112	235	112	336
(21-0-0)	224	112	112	336
2. Seed (kg)	2.2	2.2	2.2	2.2
3. Fungicides				
Ridomil (kg)	4.9	7.4	2.5	7.4
Bravo (lit)	5.6	11.2	2.8	8.4
Manzate (kg)	13.4	22.4	11.2	15.7
Benlate (kg)	1.1	2.2	2.2	5.6
4. Herbicides				
Prefar (lit)	11.2	11.2	11.2	11.2
Alanap (lit)	11.2	-	11.2	11.2
Treflan (lit)	2.8	-	2.8	2.8
Dactal (kg)	-	11.2	-	-
5. Insecticide				
Furadan (kg)	11.2	11.2	11.2	11.2
Basudin (lit)	4.2	6.7	8.4	8.4
Lannate (kg)	2.2	6.7	2.2	4.5
6. Tractor labour (hr)	14.7	21.7 kg	13.2	17.8
7. Cultural labour				
Weed and thin (hr)	31	44	22	31
Irrigation	11	11	11	11
Other labour (man days)	42	55	33	42

Table H-26 RECOMMENDATIONS FOR PESTICIDE USAGE

Crop	Product	Mode of Action	Pests or Diseases Controlled	Rate of Application	Waiting Period before Harvesting	Comments
Vegetables/ legumes	Basudin 40 WP (I)	Conduct	Aphids, Mealy Bugs, Scales, Leaf hoppers, White Fly	1.68-2.24 kg/ha	7 days	
Vegetables esp. corn, red peas	Chlorodane 80% (I)	Contact/stomach	Army worms, caterpillars, beetles crickets	1.4-2.8 L/ha	-	Avoid contamination of edible portion
	Nuvarcon 40 SCW	Systemic	Suckling, mining and chewing insects e.g. leaf hoppers	1.05 L/ha	21 days	Medium - large farm
Vegetables especially onions	Maneb/Dithane (F)	Contact	Purple blotch Downing mildew	2.24 kg/ha	10 days	
Tomato/cucumber pumpkin	Ridomill MZ 58 (F)	Systemic contact	Late and early blight, phytopthora, downing mildew	2.24 kg/ha	7 days	Medium - large farm
All vegetables	Gramoxone Super (H)	Contact	Grasses and broad leaf weeds	1.4-2.8 L/ha in 180 l. water		
Vegetables except corn and other grass related crops	Fusilade (H)	Systemic Post emergence	Grass weeds	1.4 - 2.8 L/ha		

Key: I = insecticides; F = fungicides; H = herbicides

Table H-27 PROPOSED LABOUR INPUT MATERIAL REQUIREMENT FOR SOME MAIN CROPS (VEGETABLES - SMALL SCALE)

Labour md/ha	Calaloo	Onion	Okra	Pumpkin	Corn	Tomato	Red peas
1. Operation							
Land clearing (tractor hr)	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Plough/harrow (tractor hr)	5	5	5	5	5	5	5
Nursery bed	12	-	-	-	-	12	-
Transplanting	15	-	-	-	-	15	-
Planting	-	5	12	5	12	-	12
Staking/tying	-	-	-	-	-	15	-
Weeding	36	}120	18	-	-	18	18
Weeding/thinning or moulding	-			12	30	-	-
Fertilizer application	10	10	5	5	5	5	5
Pesticide application	31	25	25	15	7.5	15	7.5
Herbicide application	4	4	2.5	2.5	2.5	4	2.5
Reaping and grading	79	37	180	30	15	30	
Reaping/windrowing	-	-	-	-	-	-	12.5
Drying/picking pods and bagging	-	-	-	-	-	-	15
Total Labour	194.5	208.5	250	77	79.5	121.5	80
2. Materials							
Seeds (kg/ha)	0.14	4.5	6.7	4	-	-	-
Stakes	-	-	-	-	-	9680	-
Fertilizer S/A (kg/ha)	753	251	494	494	251	251	125
12-24-12 NPK	-	494	251	251	376	645	251
Pesticide (kg/ha)	28	18	20	33	16	20	12
Fusilade (lit/ha)	2.8	2.8	2.8	1.4	-	2.8	1.4

Table H-28 SOME CHARACTERISTICS OF MANGO CULTIVARS IN THE STUDY AREA

Cultivar	Season of maturity	Aveage weight (kg)	Regularity of bearing	Anthracnose susceptibility	Comments
Tommy Atkins	June- July	0.5-0.75	Fairly good	MS	Good resistance to fruit fly. Very attractive in appearance. Large mango, good texture, flavour and shelf life.
Keitt	Aug. Sept.	0.55 - 0.8	Good	MS	Very large heavy fruit, fresh juicy with some fibre near the seed. Not as attractive as Tommy Atkins.
St. Julian		0.2 - 0.3	Somewhat irregular	R	Smooth, sweet. good flavour little fibre, soft flesh. Bruises easily. Usually gives two per year.
East Indian	May - June	0.3 -0.4	-	S	Stringy and very sweet. Very popular on local market
Hayden	May - June	0.5 - 0.75	Poor		Rather large fruit, can be used for processing

Remarks: R = resistant; S = susceptible; MS = moderately susceptible

Table H-29 TOTAL MONTHLY LABOUR REQUIREMENT IN THE PROJECT AREA

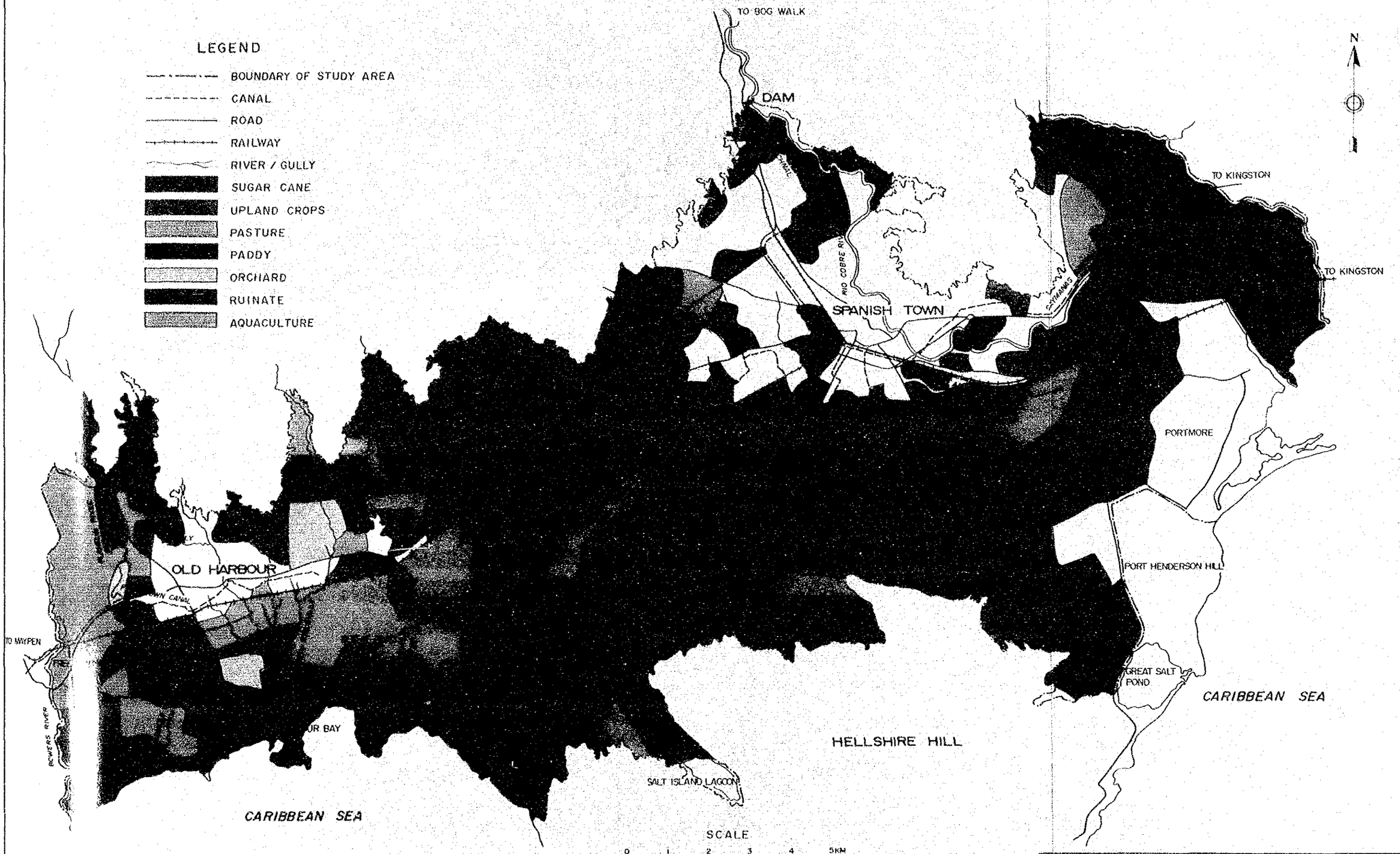
Cropping Pattern	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
Sugarcane	15,700	16,900	17,600	17,600	17,100	17,100	17,100	3,300	2,600	2,600	2,000	2,000	11,000
Vegetable													
vege./(vege.)	21,900	19,100	12,200	0	0	0	0	0	1,500	6,100	8,200	12,200	6,800
(vege.)/vege.	0	0	1,150	1,490	1,040	1,600	2,160	900	0	0	0	0	700
vege./grain	67,200	67,200	50,600	1,900	6,000	6,200	2,100	1,400	11,900	11,900	30,800	30,800	24,000
Rice													
rice/rice	24,800	0	5,000	4,500	4,600	4,200	15,400	13,900	6,600	3,700	4,200	3,700	7,600
rice/grain	33,000	11,800	15,200	9,000	21,900	19,400	600	3,100	6,200	3,400	5,300	3,500	13,100
Orchard	17,800	20,600	20,400	21,300	17,800	22,300	24,400	11,500	9,200	5,600	2,000	2,000	14,600
Ornamental	8,430	7,150	8,430	5,650	8,430	7,150	8,430	5,650	8,430	7,150	8,430	5,650	7,400
Dairy	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900
Beef	280	280	280	280	280	280	280	280	280	280	280	280	300
Aquaculture	21,940	21,940	21,940	21,940	21,940	21,940	21,940	21,940	21,940	21,940	21,940	21,940	21,900
Total per month	213,950	167,870	155,700	86,560	101,990	103,070	95,310	64,870	71,550	65,570	86,050	84,970	108,100
	7,130	5,600	5,190	2,890	3,400	3,440	3,810	2,160	2,390	2,190	2,870	2,830	3,660

Table H-30 PROJECTED YIELD AND PRODUCTION FOR MANGO AND PAPAYA

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
1. Mango										
Average yield/tree (kg)	-	-	-	5	15	30	50	75	75	75
125 trees/ha										
Average yield/ha (ton)	-	-	-	0.6	1.9	3.8	6.3	9.4	9.4	9.4
Projected production										
from 595 ha (ton)	-	-	-	357	1,131	2,261	3,749	5,593	5,593	5,593
2. Papaya										
Average yield/tree (kg)	23.0	17.0	16.5	20.0	13.5	16.5	20.0	13.5	16.5	20.0
1,500 trees/ha										
Average yield/ha (ton)	35	25	25	30	20	25	30	20	25	30
Projected production										
from 105 ha (ton)	1,837.5	1,312.5	2,625.0	3,150.0	2,100.0	2,625.0	3,150.0	2,100.0	2,625.0	3,150.0
in 2 phases of 52.5 (ha)										

Table H-31 PROJECTED YIELDS OF ORNAMENTAL CROPS

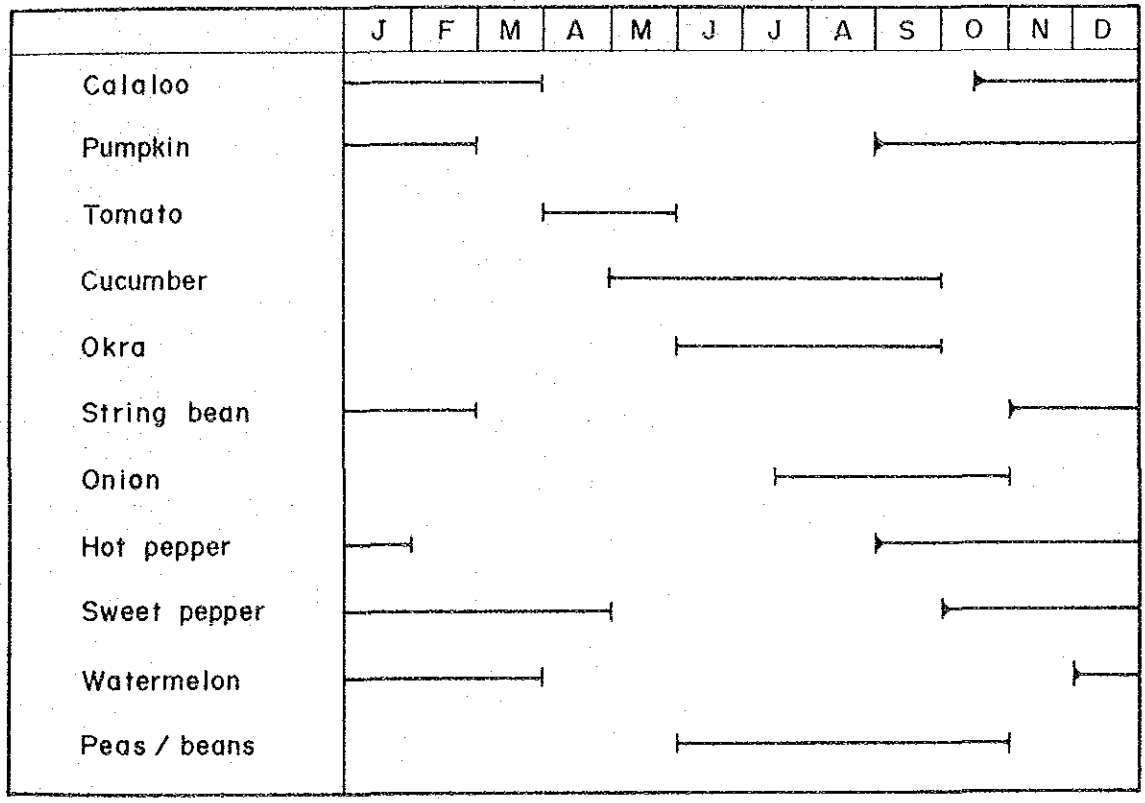
	Yield(plants/ha)				
Crop	Year 1	Year 2	Year 3	Year 4	Year 5
Leatherleaf Fern	0	1,156,000	1,927,000	1,927,000	1,927,000
Dracaena massangeane	0	0	0	55,300	55,300
Croton	79,000	178,000	178,000	198,000	198,000
Golden Pothos	5,928,000	11,856,000	11,856,000	11,856,000	11,856,000
Aglonema (silver queen)	158,000	316,000	474,000	474,000	474,000
Yucca (tips)	41,500	83,000	100,700	110,700	110,700
Dracaena Janet Craig (tips)	166,700	233,400	333,400	400,100	400,100
Philodendron	5,335,000	10,670,400	10,670,400	10,670,400	10,670,400



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. H-1 PRESENT LAND USE MAP

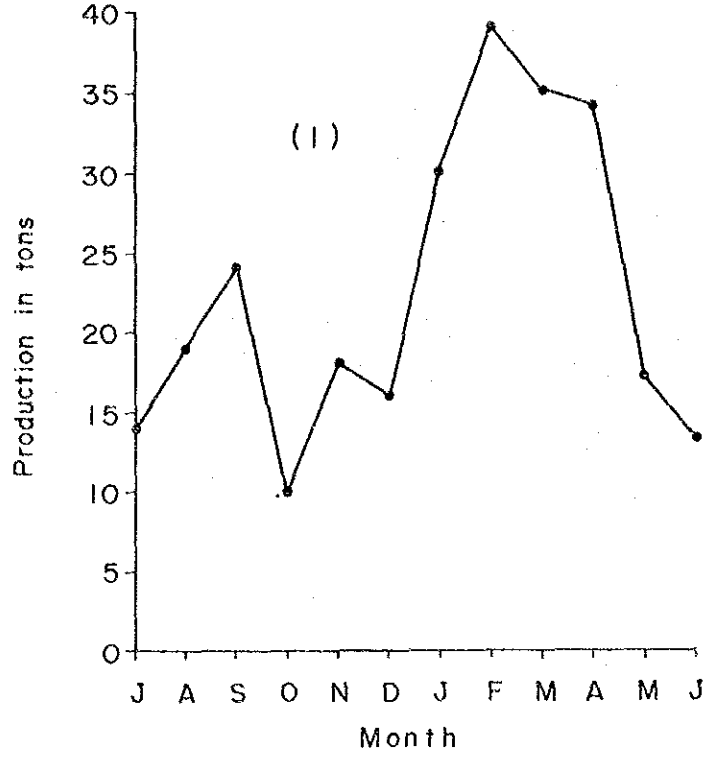
JAPAN INTERNATIONAL COOPERATION AGENCY

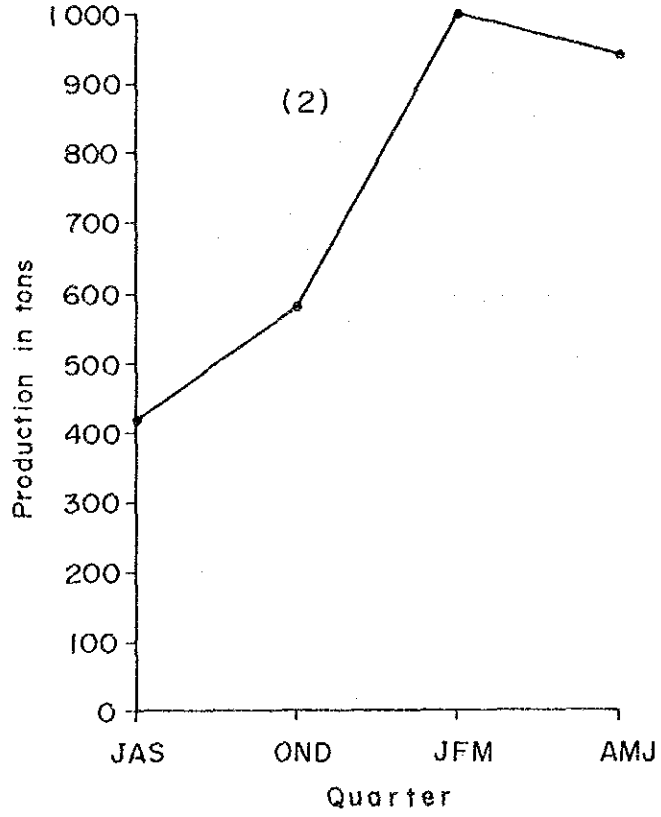


THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. H-2
PLANTING SEASON OF SELECTED CROPS

JAPAN INTERNATIONAL COOPERATION AGENCY

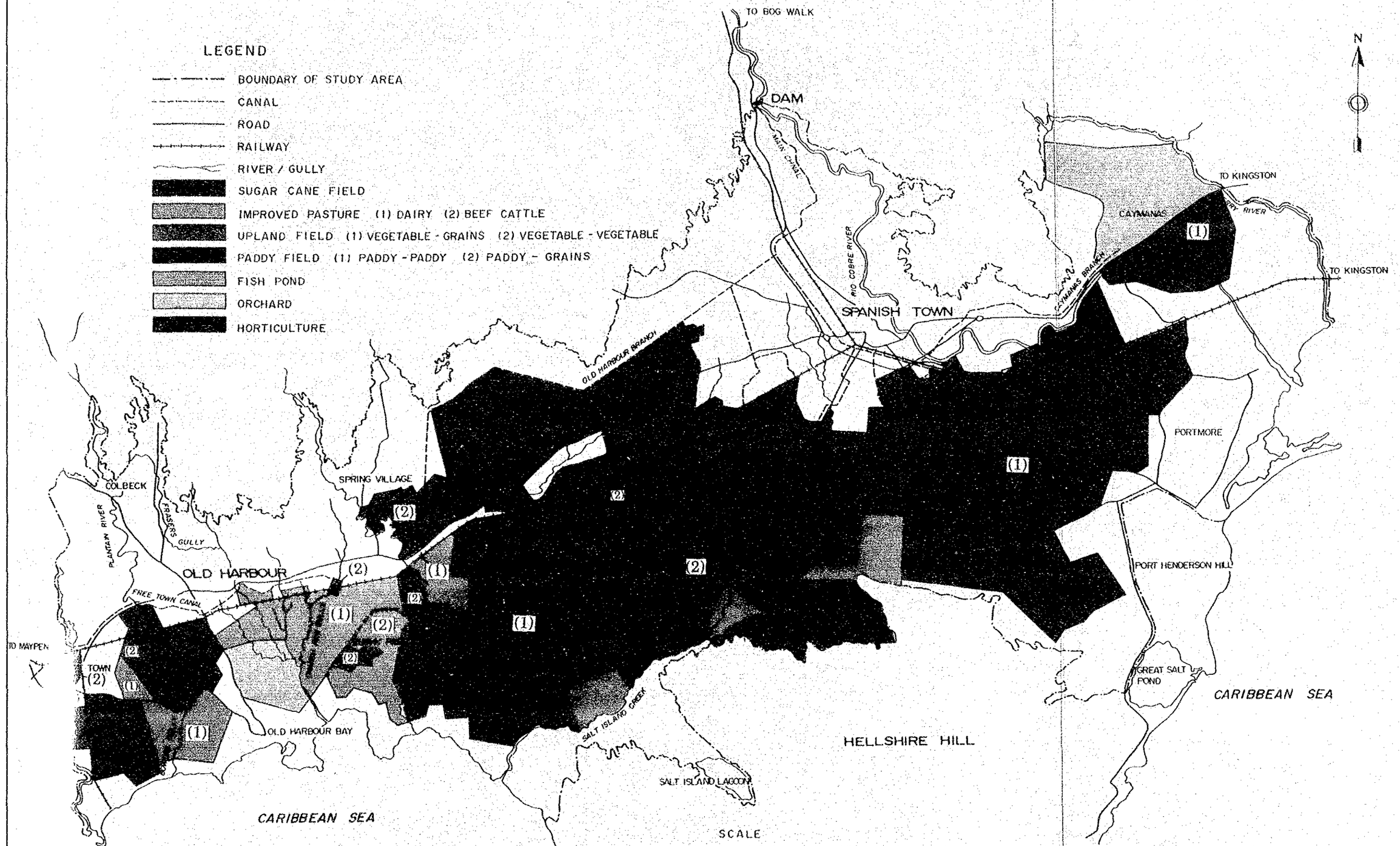




THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. H-3
PRODUCTION OF SELECTED VEGETABLES
(1) ST. CATHERINE VEGETABLE ASSOCIATION-1985
(2) DATA BANK-1985

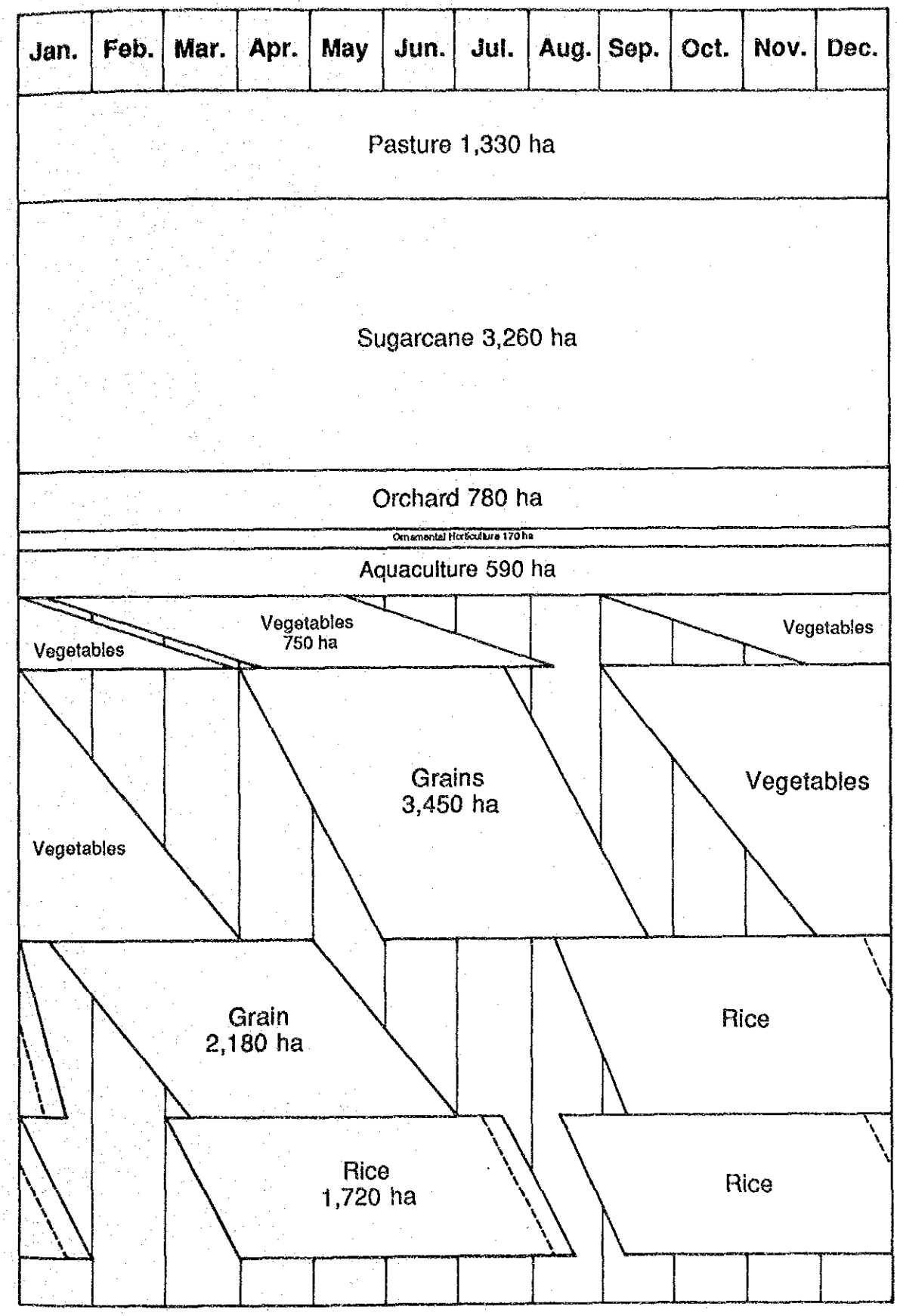
JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. H-4 PROPOSED LAND USE MAP

JAPAN INTERNATIONAL COOPERATION AGENCY



THE MODERNIZATION AND EXPANSION OF THE RIO COBRE IRRIGATION SCHEME

Fig. H-5
PROPOSED CROPPING PATTERN

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX - I

IRRIGATION AND DRAINAGE

ANNEX-I

IRRIGATION AND DRAINAGE

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1. INTRODUCTION

1.1 Rio Cobre System

Rio Cobre water is diverted into the main canal with a maximum water level of El. 42.4 m (140 ft.) at intake. Most of the irrigated land lies between elevations of 3 m (10 ft.) and 30 m (100 ft.), so that irrigation is possible mostly by gravitation. The main canal was designed for a conveyance capacity of 8.8 m^3/sec (23 million m^3/month); however its present capacity has been reduced to approximately 3.2 m^3/sec (8 million m^3/month) due to deterioration of the system. Some of the manually operated gates provided at the headworks enable control of the diversion.others, and the gates on the scouring sluice are out of order.

The canal is blocked with vegetation and siltation. A drop structure with weir is located in the main canal to divert water to the municipal water supply of Spanish Town. This weir causes a considerable decrease in the canal conveyance capacity. Near Spanish Town the main canal bifurcates to the east and to the west.

The system with a total length of 54 km (33.8 miles) is mostly unlined. The condition of the canals is rather poor due to insufficient maintenance. The sides of the canals are damaged, causing water losses and this condition is further aggravated by the farmers breaking banks to divert water.

The water is supplied 24 hours a day with few measuring devices and distribution is based on rough estimation. This results in considerable waste of water due to under and/or over supply to the users.

1.2 Groundwater System

1.2.1 The limestone aquifer

About 80 wells of varying depths of 30 m to 100 m have been drilled to pump water from the limestone aquifer. Some of these wells are out of use due to blockage and deterioration of equipment.

Their discharges vary between several tens to several hundreds of cubic meters per hour. These wells are generally not equipped with flow recorders and their water levels are not being observed. Some of the wells supply water to urban and industrial users. Annual production from the limestone aquifer was approximately 90 million m^3 (24 billion USG) per year in 1980.

1.2.2 The alluvial aquifer

There are about 60 wells located in alluvium which are in more or less the same condition of deterioration as those located in the limestone aquifer. Annual production from the alluvial aquifer was approximately 40 million m^3 (11 billion USG) per year in 1972.

1.3 Drainage System

At present drainage of the plains, mostly irrigated, is primarily by man-made channels which act as tributaries of the main streams crossing the plains. The eastern plains area is drained by the Rio Cobre and the Ferry River while the Coleburns Gully and Plantain River drain the west. The central area is drained by Salt Island creek and its tributary, the Black River. It has been noted that, apart from the Salt Island Creek, the plains are drained well by through-flowing streams and flood drainage channels originating in the hills to the north. There are, however, minor drainage systems originating on the plains, primarily in the west, where the deposits are very clayey. The very permeable nature of the alluvium in the east prevents the natural development of this kind of drainage, as most applications of water, natural or artificial, rapidly infiltrate into the ground.

2. EXISTING IRRIGATION SYSTEM

2.1 Headworks Dam

It is understood that the present Headworks Dam was built in 1874. An old drawing and recent investigations carried out by the study team indicate that it is probably a masonry and concrete in-filled gravity floating dam some 12 m (40 ft.) high from the base, with a crest level some 9.6 m (32 ft.) from the dam foundation. The top width appears to be 4.5 m (15 ft.) and the bottom width 11 m (36 ft.). A stone filled buttress and apron with concrete surface is indicated across the river downstream to form a water cushion. The width of the dam overflow section is some 90 m (300 ft.).

There is some evidence that the dam was originally designed to be some 45 m (150 ft.) wide and that an earthen extension was added following experience of an early flood, the construction of this having later been somewhat altered as proved by drilling carried out by the study team.

The dam is equipped with 0.75 m (2.5 ft.) high flashboards consisting of vertical steel rods at approximately 0.90 m (3 ft.) interval which support horizontal planks. When the river rises in flood without warning most of the boards are lost together with some of the vertical steel rods.

The condition of the intake gates is poor. The main problem is the headstocks. These need to be replaced and some attention given to the slide gates.

Two scouring sluice gates were provided for flushing sediment from upstream of the dam. These have not been used and are now inoperable. In theory these gates have a valuable function in reducing the amount of silt entering the canal and it is noted that Agro 21 has started to replace these gates with new ones.

2.2 Rio Cobre Irrigation Scheme

2.2.1 Main canal

(1) Headworks to bifurcation

The main canal from the Headworks Dam to the bifurcation, where the Old Harbour Branch takes off, is generally an unlined channel of approximately 4.7 km (2.9 miles) long. The first 300 m (1,000 ft.) below the dam has a lined section generally 7.6 m (25 ft.) wide and 1.7 m (5.5 ft.) deep with a concrete invert. The main part of the canal is generally trapezoidal 10.7 to 12.2 m (35 to 40 ft.) wide at the top and 6.1 to 7.6 m (20 to 25 ft.) bed width with an average existing depth of 2.0 m (6.5 ft.). It is possible that there is an average 0.5 m (1.5 ft.) of silt in the bottom of the canal so the original depth may have been 2.5 m (8 ft.).

In places where the canal widens out to 15 m (50 ft.) or more and through a gorge section some 300 m (1,000 ft.) long the section reduces to a width of 4.5 m (15 ft.) and the depth reduces to 1.5 m (5 ft.).

A longitudinal section and cross sections at 100 m intervals shows an uneven invert of the canal section which might be due to past cleaning by excavation machine. The average slope of the main canal is 1 in 4,500.

A short length - 12.2 m (40 ft.) - of the canal passes over a gully as an aqueduct of 10.7 m (35 ft.) width and 0.9 m (3 ft.) depth. There are seven bridges over the canal: five for minor roads; one for the main road from Spanish Town to the north, and one for the railway main line. A large Parshall Flume and a partially destroyed weir just above the main road crossing is occasionally used for flow measurements.

The level at the downstream end of the canal is controlled by a drop structure with wooden stoplogs and the flow is restricted by improvised means to maintain levels sufficiently high to supply a side intake of the Spanish Town Water Works.

(2) Bifurcation to Caymanas branch

The main canal continues from the bifurcation, where the Old Harbour branch takes off, to the southeast and parallel to the Spanish Town By-pass. This is an unlined canal approximately 4.7 km (2.0 miles) long varying in section from 3.6 to 7.2 m (12 to 24 ft.) in width and from 6.0 to 1.2 m (20 to 4 ft.) in depth with side slopes about 1:1.

For half the length of this canal, the bed is made of hard material and for the rest is filled with one to two feet of silt. There are nine road bridges, three railway bridges, and one culvert under the main Spanish Town By-pass. The size of the culvert is about 1.5 m (5 ft.) dia. A large Parshall Flume exists at approximately 300 m (1,000 ft.) below the bifurcation but has not been used for measurements. There are many turnouts to deliver water to irrigation canals and also inlets for factories, and various check structures to control water level.

The general condition of the canal is rather poor. Considerable attention is required to clean the channel and form the invert to uniform grades, to re-shape the banks and to reconstruct most of the check structures.

2.2.2 Branch canal

(1) Turners Pen

The Turners Pen canal branches off from the main canal near the main fork of the railway track from Kingston to Old Harbour.

Water enters this canal through a single steel gate of 0.7 m (2.5 ft.) in width. The condition of this gate seems to be reasonable. However, some repairs and maintenance will be required. Immediately below the branch outlet on the main canal, several lengths

of rail track have been placed across the canal to raise the water level. A small length of this canal is lined with concrete whereas the remainder is unlined and is in poor condition.

A culvert of 0.76 m (2.5 ft.) diameter under the By-pass road appears to be of inadequate size to carry the required discharge. An aqueduct of 0.6 m (2 ft.) width and 0.83 m (2.75 ft.) depth carries canal water across Town gully. Further down the canal, the gradient steepens and the desired discharge capacity seems to be attained.

Overall, for the required capacity to be carried in the canal, significant improvement works need to be carried out, particularly in the upper section of the branch.

(2) Port Henderson

The Port Henderson canal branches off from the main Rio Cobre irrigation canal at the south of Spanish Town Railway Station. The canal serves a large tract of land in the Bernard Lodge east area and as far as south as the Great Salt Pond.

The turnout structure to the canal is in reasonable condition with two independently operated gates which are operated by screw threaded shafts. A permanent check structure across the main canal would be necessary to control the water level of this branch. The trapezoidal concrete lined section of the canal up to the culvert under the Spanish Town By-pass seems to be in good condition and is able to carry its designed discharge. The size of the pipe culvert is not known, but it may have been designed to carry the designed discharge. After passing through the culvert, the canal is unlined and has a relatively steep gradient, but due to the poor condition of the bank, its carrying capacity is limited. The canal gradually slackens in gradient and potential capacity. At this point the canal is situated on the top of an earth bank to maintain as much elevation as possible.

(3) Cumberland Pen

The Cumberland Pen branch and Caymanas branch leave the main Rio Cobre irrigation canal just to the south of the Spanish Town By-pass. The Cumberland Pen branch continues in a westerly direction to the south of the railway to serve that portion of Caymanas Estates. A subsidiary branch, the Lawrencefield branch, serves the area between the Rio Cobre and the South Dyke road.

Since the flow into the Cumberland Pen branch is over a fixed weir, control of this flow is by increasing or decreasing the flow down the Caymanas branch by the operation of a control gate at the head of the latter.

In 1985, the canal was completely lined, partly with concrete but mostly with wet stone masonry from the beginning of the canal to its end where it is linked to the International Agro Management farm. The wet stone masonry having rectangular section varied from 2.8 to 1.5 m in top width and from 1.0 to 0.9 m in depth, while the trapezoidal section has 2.9 m in top width, 1.3 m in bottom width and 0.8 m depth with 1:1.0 side slope. For much of its length the canal runs alongside the railway.

(4) Caymanas

At the end of the main canal, the Cumberland Pen branch and Caymanas branch take off. The water enters the branch through a single control gate which was recently replaced. The water level at the gate is maintained by the fixed weir at the head of the Cumberland Pen branch.

The capacity of the canal is limited in the first 100 m (330 ft.) before it passes under the Port Henderson road. Below the Port Henderson road the canal has a rectangular concrete channel. At the end of this section the canal passes into a 0.9 m (3 ft.) dia. riveted steel inverted syphon pipe to carry water across the Rio Cobre. At the mouth of this pipe, a screen of vertical bars is provided to prevent weed and other debris entering the syphon. Originally the pipe crossing the river was below the river bed, but due to erosion of the sandy bed, the river has 0.3 to 0.4 m (1 to 1.25 ft.) underneath the pipe. This has made the pipe vulnerable to damage during floods.

The syphon emerges on the left bank of the river and connects with a concrete lined canal. The canal, which runs on the southern side of the road is generally above the adjacent ground level and many illegal syphon pipes have been installed to irrigate small plots for cultivation. It passes under the Spanish Town By-pass in a culvert between two concrete chambers. The size of this pipe is not known. The section of the canal adjacent to FIDCO is virtually flat and as such, significant ponding and poor flow occurs in the canal up to the weir located at the north of the Twickenham Park roundabout. The gradient increases significantly until the canal reaches Central Village where the lined section alongside the main road is very flat.

(5) Old Harbour: First Bifurcation to Innswood Factory

The Old Harbour branch takes off at the first bifurcation of the main canal. This canal effectively irrigates most of the western area of the system through its subsidiary branches; the Sydenham and Hartlands Canals. Flow into this branch is controlled by two large steel gates located immediately below the diversion of the main channel. The gates are becoming loosened by unauthorized use. There are two blockwork stilling screens and silt and heavy debris get trapped immediately below the gates. Flow entering the branch canal can be measured in a 3.7 m (12 ft.) wide square notch weir which is in good condition.

The canal passes by concrete culvert under the Spanish Town By-pass road and a short distance downstream is a concrete lined canal. Below this portion, the left bank is built of wire gabions to prevent erosion of the bank. There are several weirs in the canal from 0.3 to 0.9 km (1,000 to 3,000 ft.) from the bifurcation. These weirs were constructed basically to maintain water at such a level that the adjacent land could be irrigated.

There are five bridges and eighteen turnouts on the canal. Among these turnouts two turnouts which branch off the Sydenham canal and Hartlands canal are located at 1.3 and 2.9 km downstream from the bifurcation, respectively. The canal in this section is heavily choked with weeds. Below the turnout to the Sydenham branch the canal bed gradient increases towards the Hartland branch; the capacity thus increases. At this section, the

canal banks are lined with rough masonry. Below the turnout to the Hartland branch the canal is unlined with a steep gradient and considerable weed growth has encroached on the canal. A new sink hole has recently been formed near the Innswood Factory so that a by-pass canal has had to be constructed.

(6) Sydenham

The Sydenham canal branches off the Old Harbour canal near the junction of St. Johns Road and the Spanish Town Road at Friendship Village. The canal serves the Bernard Lodge west land.

Water entering the canal at the turnout form the Old Harbour canal is controlled by a gate raised by a screw thread and handle. The level of water entering the head of the canal can be controlled by placing stop-logs in the Old Harbour canal. The channel runs into a chamber. From the chamber, water flows over a 1.2 m (4 ft.) square notch weir, and discharge into a short length of masonry channel before the channel becomes unlined. The canal passes through several residential areas. The canal, in some sections is lined generally above the adjacent ground level and in other sections the canal is unlined. There are several road and one railway crossing along the entire length of the canal. Below the railway crossing the canal is wholly in unlined earth sections.

(7) Hartlands

The Hartlands canal branches off to the south from the Old Harbour canal. It irrigates the Bernard Lodge and Innswood Estates lands.

Water enters the Hartlands branch through two steel gates supported by a concrete frame. These gates are in satisfactory condition and the canal's existing gradient permits good flow except from change 1,600 to 3,000 where the gradient is flatter to facilitate supply water to the fields. The canal is wholly unlined. There are two major crossings: under the Old Harbour main road where the canal passes through two right angled bends before passing into the culvert; and under the railway after which the canal again turns through a right angle and runs parallel to the truck until reaching the Hartlands road.

(8) Old Harbour: Innswood Factory to Amity Hall

The Old Harbour branch continues beyond the Innswood Factory to serve its western lands and to carry water to the south for the main Spanish Town - Old Harbour Road to serve Amity Hall.

The canal is generally unlined but a section about 800 m (2,600 ft.) long has recently been lined with masonry where considerable leakage was noted. This section is located about 760 m (2,500 ft.) downstream of the Innswood factory. The length of canal from the Innswood factory to the main Spanish Town - Old Harbour Road crossing is about 6,800 m (4.2 miles). Immediately before the crossings, a pond has been created on the canal due to construction of a check structure with two gates.

Below the main road the canal continues to the south, crosses under the railway line, and continues south to Amity Hall. The general cross section of the unlined portions of the canal varies between 2.5 to 4.5 m (8 to 15 ft.) in width and 0.8 to 1.1 m (2.5 to 3.5 ft.) in depth. Some sections are badly silted and some sections have weed problems. In some where blockwork walls have been constructed to protect the banks, the walls have been damaged by tree roots.

2.3 St. Dorothy Water Supply System

2.3.1 St. Dorothy Plain Irrigation Authority (SDPIA)

SDPIA was established by the St. Dorothy Plain Irrigation (Establishment) Order 1961. The Authority is run by a Board which is appointed by the Minister (MOA).

The area over which SDPIA has jurisdiction is approximately 8,000 ha (20,000 acres). However, a large portion of this area is too hilly and rugged for irrigation and consequently, irrigation at present is confined to the Plains. The potentially irrigable land is confined to an area of approximately 4,800 ha (12,000 acres) subject to availability of irrigation water.

It is noted that at present there is no source of surface water for irrigation and therefore irrigation in this area has to depend on underground water. The area which is capable of being economically irrigated seems to be no more than 2,200 ha (5,000 acres). The total acreage under cultivation which is served by this System is approximately 1,870 ha (4,620 acres).

2.3.2 Flood irrigation system

The flood irrigation system consists of four deep wells which have been drilled to pump water from the limestone aquifer.

The system commences from the two deep wells situated at Free Town in the Parish of Clarendon. The principal features of wells and pumps as well as discharge are as follows:

Name of Wells	Free Town No.1	Free Town No. 2
Depth	30.5 m (100 ft.)	30.5 m (100 ft.)
Diameter of casing	610 mm (24 in.)	610 mm (24 in.)
Output of pump	150 HP	125 HP
Rating of power	128.5 kw/hr	91.3 kw/hr
Discharge capacity	1,115 m^3/hr (1,467 cy/hr)	863 m^3/hr (1,135 cy/hr)

Water pumped up from the above two deep wells is conveyed through the main canal up to Bushy Park. The water carrier system of the main canal consists of three different types with a total length of 14,100 m (46,226 ft.) as follows:

Woodstave pipe	:	2,808 m	(9,200 ft.), 860 mm (34 in. diameter)
Concrete flume	:	362 m	(1,188 ft.)
Lined canal	:	10,931 m	(35,838 ft.)

Another flood irrigation system is supplied by deep well which has been drilled in the limestone aquifer at Bodles. Water pumped up from this well is conveyed by a 16 inch diameter pipeline 0.8 km in length. After this, the water is conveyed to the field by open canal.

The principal features of well and pump as well as discharge are as follows:

Name of well	Bodles	
Depth	53.4 m	(175 ft.)
Diameter of casing	406 mm	(16 in.)
Output of pump	50 HP	
Rating of power	33.4 kw/hr	
Discharge of capacity	373 m^3/hr	(446 cy/hr)

The canal (Distributary E) consists of two different types of channels with total length of 2,182 m (7,154 ft.). The length of each channel is as follows:

Pipeline	:	793 m (2,600 ft.) , 860 mm (34 in.) diameter
Lined canal	:	1,389 m (4,554 ft.)

A fourth deep well flood irrigation system is supplied by a deep well which has been drilled in the limestone aquifer at the Marine Terminal. The water pumped up from this deep well boosts the discharge of Distributary (A) which branches off from the main canal at the flume section. The principal features of well and pump as well as discharge are as follows:

Name of well	Marine Terminal	
Depth	36.6 m	(120 ft.)
Diameter of casing	406 mm	(16 in.)
Output of pum	50 HP	
Rating of power	27.6 kw/hr	
Discharge capacity	282 m^3/hr	(337 cy/hr)

The canal (Distributary A) consists of two different types of conveyance with a total length of 4,682 m (15,351 ft.). The length of each is as follows:

Concrete pipeline	:	440 m (1,443 ft.), 860 mm (34 in.) diameter
Lined canal	:	4,242 m (13,908 ft.)

Other than the above main canal and distributaries, there are another nine distributaries. The name, type and length of each distributary are as follows:

Name of Distributary	Type of Canal	Length
A2	Lined	1,567 m (5,137 ft.)
A3	Lined	604 m (1,980 ft.)
B	Lined	621 m (2,037 ft.)
C	Lined	373 m (1,237 ft.)
F	Lined	1,610 m (5,280 ft.)
F1	Lined	231 m (759 ft.)
F2	Lined	1,127 m (3,696 ft.)
G	Lined	835 m (2,739 ft.)
H	Earthen	483 m (1,584 ft.)

2.3.3 Sprinkler irrigation system

The sprinkler irrigation system consists of three deep wells which have been drilled to pump up water from the limestone aquifer. These are independently operated and another pump is used as booster for one of the above. The area under irrigation is, according to the Authority, 170 ha (420 acres).

The principal features of wells and pumps as well as discharge are as follows:

Name of Wells	Sandy Bay	Bowers	Kilbys	Kilbys (Boster)
Depth	-	(154 ft.)	(150 ft.)	-
Diameter of casing	406 mm (16 in.)	610 mm (24 in.)	406 mm (16 in.)	305 m (12 in.)
Output of pump	150 HP	60 HP	20 HP	20 HP
Rating power	121.6 kw/hr	48.5 kw/hr	12 kw/hr	12 kw/hr
Discharge capacity	721 m^3/hr (863 cy/hr)	136 m^3/hr (163 cy/hr)	84 m^3/hr (101 cy/hr)	- (-)

3. DEVELOPMENT PLAN FORMULATED BY AGRO 21

3.1 General

Agro 21 Corporation Limited is currently engaged in a Crop Diversification and Irrigation Programme on the St. Catherine Plains, which involves basically redundant banana and cane lands covering approximately 6,100 ha (14,990 acres) in the two estates, Caymanas and Bernard Lodge. A project loan and grant agreement for the above programme was signed on September 25, 1985 between the Government of Jamaica and the United States of America.

The purpose of the project is (1) to rehabilitate the existing irrigation infrastructures (off site) of the Rio Cobre Irrigation Works, (2) to reinforce the institutional capacity of Agro 21 to promote and develop private commercial agricultural investment, (3) to upgrade the Government ability to efficiently operate and maintain the rehabilitated system, and (4) to establish a small farmer linkage programme at Agro 21 to help small producers gain.

3.2 Area to be Developed

This project area has been divided into nine, Blocks A to I in order to promote and develop private commercial agricultural investment. Area and irrigation system for each block are summarized as stated below:

Unit: ha (acres)

Description	Area by System					
	Ditch		Pipeline		Total	
"A" Bernard Lodge	-	(-)	356	(880)	356	(880)
"B" Caymanas	-	(-)	352	(870)	352	(870)
"C" Hort. Park	-	(-)	85	(210)	85	(210)
"D" Bernard Lodge	877	(2,168)	-	(-)	877	(2,168)
"E" Bernard Lodge	-	(-)	898	(2,220)	898	(2,220)
"F" Caymanas	-	(-)	463	(1,145)	463	(1,145)
"G" Bernald Lodge	1,057	(2,612)	-	(-)	1,057	(2,612)
"H" Caymanas	-	(-)	577	(1,425)	577	(1,425)
"I" Bernard Lodge	475	(1,175)	925	(2,285)	1,400	(3,460)
Total	2,409	(5,955)	3,656	(9,035)	6,065	(14,990)

In addition to the above, small structure rehabilitation will be carried out for the areas utilized by small farmers.

3.3 Design Philosophy Related to Project

(1) Water supply

A survey was made of the existing wells to determine if they should be used in the new scheme. Wells in an advanced state of deterioration or those pumping excessive amounts

of sand would be abandoned. New wells are located to suit hydrogeologic conditions and system logistical considerations. All new wells will be in the alluvium with depth ranging from about 18 to 34 m (60 to 110 ft.) Water is taken generally from two strata at about 15 and 30 m (50 and 100 ft.) The wells are all 0.6 m (14 in.) diameter cased, gravel packed and with stainless steel wedge-wire screens. Design capacities are estimated to be approximately 1.9 m^3/min. (500 USG/min.) with actual yields ranging from 0.9 to 2.3 m^3/min. (250 to 600 USG/min.). Canals will be sized to supply a base flow to the areas that can generally meet summer crop consumptive use take into account effective rainfall. Sufficient well capacity will be developed to augment canal flows as required to meet peak winter dry season consumptive use. All main canals will be rubble concrete lined with permanent control structures and gates. Consideration was given to using large diameter concrete pipes to permit burying the system in residential areas but the cost was prohibitive. At the end of lined canals operational storage reservoirs with a capacity store about two (2) days equivalent ditch flow will be installed. These reservoirs will assist RCIW. Canal pumping plants will be located at the terminal reservoirs. These plants will be designed to introduce the canal water into the pressurized distribution piping. All pumping equipment will be electrically powered by the Jamaica Public Service Corporation.

(2) Infield distribution

Pressurized infield mainline piping systems will be installed to connect the canal pumping plant and wells and provide a water source within about 370 to 460 m (1,300 to 1,500 ft.) of all fields within this project area. The actual piping materials will be PVC or asbestos cement with take-off hydrant valves spaced 100 to 200 m (330 to 660 ft.) apart hydrant pressures will be 4.2 to 4.9 kg/cm^2 (60 to 70 lb/square in.) which will be adequate to operate most drip and overhead systems. The decision to use pressurized main pipelines instead of ditches reflects the concern for improved water management practices essential for the success of the farming enterprises.

(3) Fencing

Securing this project area against theft of equipment and crops was felt to be essential. Further it is necessary to fence out the animals normally found grazing in the local communities. The fence will be constructed of 1.2 m (4 ft.) high hog wire topped with three strands of barbed wire to an overall height of 1.8 m (6 ft.) Treated hardwood posts will be set in concrete. Gates will be fabricated from hog and barbed wire mounted on a galvanized iron pipe frame.

(4) Roads and drains

Roads and drains will be realigned as required and reshaped. In critical traffic areas a marl surface layer will be installed to facilitate all-weather use.

3.4 Rehabilitation and Improvement

(1) Rio Cobre pumping plant

This facility will withdraw water from the Rio Cobre at a location below Spanish Town and lift it into a main junction in the canal system. This will provide supplemental water to the Caymanas and Bernard Lodge fields in the eastern portions of the project.

(2) Main canal weed cleaning

A major problem of weed growth exists in the 4.6 km (2.9 miles) of main canal from the intake to the first bifurcation. Use is proposed of an aquatic weed harvesting machine that has been designed for use in this type of application. This is a preliminary recommendation to frame the general approach and costs involved.

(3) Bridge and gate repair

The main canal is crossed by seven bridges in varying stages of deterioration. Expenditure is proposed for repair of the bridges. Such repair would consist primarily of concrete and masonry patching and clearing of trees and bush.

(4) River deweeding and cleaning

A general deweeding and cleaning of the river would probably not contribute significantly toward improving the flows through the RCIW main intake. It is expected to use the aquatic weed harvester to periodically remove plant growth from the area around the intake and along the bank for some distance upstream.

(5) Desilting gate R and M

In regard to the scouring sluice, two gates were originally provided to allow for dumping of large flows with consequent flushing of silt accumulation in the area immediately upstream of the intake gates. Such gates also are useful in regulating river flows so as to minimize damage to the flash boards. The gates have fallen into a state of disrepair and are no longer operable. It is proposed that these gates be rebuilt.

(6) Main canal blockage removal

Early in the 1950's the Spanish Town Domestic Water Works installed a weir crest and wooden gate structure to provide for raising the water surface in the main canal by 0.9 to 1.2 m (3 to 4 ft.) so as to allow gravity flow to a newly constructed sand filter. This activity started a process that ultimately contributed to serious reductions in the main canal flow capacity. Raising the water surface caused the canal to spread beyond its original banks and reduce the velocity. This aggravated weed control problems, caused flooding and increased water loss. A pump is proposed to provide flows to the water works thereby permitting the removal of the weir and wooden gate structure. A set of control gates would be installed that would allow for a raising of the water surface to provide gravity flow into the facility should the pumps fail.

With the blockage removed the main canal gradient will be increased. This will increase average velocities, return the canal to its original banks and increase delivery capacity. Further the higher canal velocities should help reduce the weed growth problem.

(7) Remove weir and flume

Towards the lower end of the main canal a weir and Parshall flume were installed for flow measuring purposes. Both installations are no longer operable and represent a needless impedance to flow. Their removal will increase the main canal gradient and increase its carrying capacity.

(8) River desilting

A general removal of silt in the river bed is probably not justified as it would redeposit after several large storm flows. However, some periodic general cleaning in the area immediately upstream of the main intake would probably be justified to increase diversion capabilities. A tentative proposal is a small Horizontal Auger Dredge. This unit could be used to keep a channel to the intake gates open.

4. BASIC CONCEPT OF DEVELOPMENT

The Government of Jamaica has placed great emphasis on increasing food production through Agro 21. The plan aims to reverse the decline in agricultural exports, to develop non-traditional crops and create new employment opportunities, and for substitution of agricultural products imports.

In line with the above objective, the Rio Cobre Irrigation Scheme has been formulated to maximize the potential agricultural benefits through efficient use of land and water resources. The main concepts of the projects are:

- to modernize and expand the present irrigation scheme by reconstructing and improving existing infrastructures of the Rio Cobre irrigation system together with Free Town irrigation system,
- to introduce diversified cropping patterns including non-traditional crops into the annual rotation of cropping,
- to increase and stabilize yields and production of crops by means of proper management of irrigation and drainage,
- to achieve the successful small scale farmer linkage through proper training and agricultural support services, and
- to promote the levelling up of living standards and more equitable distribution of income to the people.

Despite the fact that the project area is favourably located near Kingston the capital of Jamaica, and has high potential in agricultural development, agricultural productivity in this area remains low due to the limitation of the present water supply system and deterioration of structures. In order to achieve successful agricultural development in the project area, the following undertakings need to be realized:

- reconstruction and rehabilitation of the irrigation network consisting of a diversion headworks, main and branch canals, a bifurcation with a pump station as well as a pipeline and concrete flume,
- construction of reservoirs, pump stations, facilities for return flow utilization, etc.,
- rehabilitation of the drainage network consisting of main and branch drains,
- on-farm development including irrigation and drainage systems and road networks,
- construction of a road network,
- operation and maintenance of irrigation and drainage works,
- improvement and strengthening of the agricultural support services, and
- improvement of socio-economic infrastructures.

5. DEMARCATION OF AREA FOR IRRIGATION DEVELOPMENT

5.1 Demarcation of the Project Area

5.1.1 Potential arable land

The study area covers approximately 27,400 ha (68,500 acres) including farmland, grass land, bush land, urban land, swampy land, rocky land, etc. In order to demarcate the potential arable land from the study area, the following factors were taken into consideration:

(1) Land capability classification

Based on the evaluation of land capability both for upland crops and rice, land classified in Grades I, II, III and IV were proposed for agricultural development. In this evaluation, the relevant factors in the demarcation were soil texture, topography, soil depth, fertility, drainability, soil salinity and acidity, and soil physical properties.

(2) Present land use

Present land use and vegetation were also taken into account in the selection of the potential arable land. In the study area, there are a number of towns and villages. Spanish Town is situated in the northern part of the Rio Cobre area and Old Harbour in the centre of the St. Dorothy area. These towns, residential and commercial areas were excluded from the potential arable land. The eastern and southern seashores of the study area are covered by mangrove forest. In addition, there are considerable miscellaneous areas such as gullied land, beaches, sand mining, etc. These areas are also excluded from the potential arable land.

In due consideration of the above, the potential arable land within the study area was confined to approximately 21,000 ha consisting of 16,200 ha in the Rio Cobre area and 4,800 ha in the St. Dorothy area as summarized below:

(Unit: ha)

Category of lands	Rio Cobre Area	St. Dorothy Area	Total
Study area	21,600	5,800	27,400
Non-arable land	5,400	1,000	6,400
- Urban land	(3,600)	(600)	(4,200)
- Swampy land	(1,400)	(300)	(1,700)
- Rock land	(100)	(-)	(100)
- Other land	(300)	(100)	(400)
Potential arable land	16,200	4,800	21,000

5.1.2 Selection of area to be developed

In selecting the area to be developed, it is necessary to conduct a water balance study, which will be discussed in a later section. For this, a provisional delineation of the project area had to be made including the area to be developed by Agro 21.

The arable land within the study area is approximately 21,000 ha in the St. Catherine Plains. In the following paragraphs the advantages and disadvantages in formulating the project in the study area are discussed.

(1) Rio Cobre East

The development plan for Rio Cobre East was formulated by Agro 21. The land covers 6,150 ha and for the most part is covered with sugarcane, although a part has been developed for non-traditional crops and is covered with winter vegetables and grain crops. In terms of land capability, it is mostly classed as Grade I consisting of recent alluvium. There is no limitation in regard to upland crops. Topographically it is fairly flat and suitable for any kind of irrigation method. Its elevation ranges from El. 4 m to El. 32 m, and hence the entire area could be irrigated by gravity flow from the Rio Cobre irrigation system. Drainage is excellent owing to the pervious nature of the soils. Therefore, this area is proposed to be taken up for development.

(2) Small Farms

Small farms in the Rio Cobre irrigation system occupy 950 ha. At present, farmers are growing sugarcane and vegetables. In terms of land capability, most of the land is categorized as Grade II and partly as Grades III and IV. The land slope of the northern area is gentle with micro relief, whereas the southern area is flat. Drainage of the northern area is good and of the southern area is moderate. The elevation ranges from El.5 m to El. 30 m, and hence the entire area can be irrigated by gravity flow from the Rio Cobre irrigation system. The above discussion indicates that this area is to be included in the project area.

(3) Rio Cobre West

Rio Cobre West covers 5,180 ha. The land is broadly divided into two, the northern area and the southern area. Most of the former area is covered with sugarcane, whereas part of the latter is paddy fields. In terms of land capability, the former is classed as Grades II and III in terms of upland crop, whereas the latter is Grades I and II in terms of paddy. Land slopes in the northern area are gentle with micro relief, whereas the southern area is flat. Drainage of the northern area is favourable and the southern area is moderate. The elevation ranges from El. 4 m to El. 32 m, and hence the entire arable area could be irrigated by gravity from the Rio Cobre irrigation system. For these reasons, this area is supposed to be developed for agriculture.

(4) St. Dorothy South

The area covered by the St. Dorothy irrigation system at present is 2,340 ha. The irrigated land is used for cropping of sugarcane, pasture, orchard and vegetables, but considerable areas, which are not irrigated are covered with bush and grass. In terms of land capability, the land is mostly classed as Grade II and partly as Grade III. There is no limitation to growing crops. Topographically the land is fairly flat and suitable for any kind of irrigation method. The elevation ranges from El. 4 m to 20 m, and hence the entire area could be irrigated by gravity flow either from the St. Dorothy Irrigation system or from the Rio Cobre Irrigation system by extending its canal system. The fact stated above suggests that this area is to be taken up for development.

(5) Spring Garden and Thetford

Arable land in Spring Garden and Thetford amounts to 1,190 ha, part of which is presently used for crops such as sugarcane, vegetables, orchards, pasture, etc. with sprinkler irrigation. The remaining area is mostly covered by bush and grass. In terms of land capability, the land is classed as Grades II and III. In terms of topography, the land is fairly flat with minor undulation. Drainage is favourable because the Coleburns gully passes through the centre of the area. Provided that surface water can be made available, it would be possible to develop the whole area. Since the land elevation ranges from El. 18 m to El. 34 m and the proposed water level of the Old Harbour branch canal is El. 19 m, the land is not able to be irrigated by gravitation. It is noted that approximately 710 ha can be put into irrigation by lifting water. It is therefore proposed to be taken up for irrigation development.

(6) St. Dorothy North

1,010 ha of arable land to the north of St. Dorothy is irrigated by sprinkler directly from wells. Pasture, tobacco and vegetables predominate but grass, bush and woodlands occupy 25%. In terms of land capability, the land is classed as Grade II. In terms of topography, the land is fairly flat with minor undulation. Drainage is favourable because the Plantain river flows in the area. If surface water could be made available, it would be possible to develop the whole area. Since the elevation ranges between El. 90 m and El. 35 m, and located far from the present surface water sources, it is very difficult to irrigate this land. Therefore, this land is not proposed to be taken up for development.

(7) North of Spanish Town

1,750 ha of arable land are located to the north of Spanish Town which is mostly covered with pasture, grass and bush includes approximately 150 ha of sugarcane. In terms of land capability, the land is classed as partly Grade II but mostly Grade IV. Its topography is rather elevated ranging from El. 35 m to El. 60 m, and fairly undulating. Since the water elevation of the main canal is approximately El. 40 m, it would be difficult to irrigate by gravity. As the land has fairly steep slopes, drainage would present no problem. It is noted that this area is being urbanized rapidly, it seems very difficult to put this land into irrigation systematically. The discussion made above indicates that this area should be reserved for housing.

(8) North of the Rio Cobre East

Agro 21 formulated its development plan excluding 1,670 ha of land located to the north of Caymanas. The land is wet and mostly covered by grass and bush. In terms of land capability, this land is classed as Grade VI due to poor drainage and hence is not suitable for cultivation. Artificial drainage would be indispensable for developing the land for agricultural purposes. For these reasons, this land is not proposed to be included in the project area.

(9) Salt Island

The potential arable land in Salt Island is 420 ha. The land is at present covered with grass and bush, and no farming is practiced. In terms of land capability it is classed as Grade VI due to salinity and poor drainage. Its topography is very flat and low, and natural drainage is difficult.For these reasons, the land is not suitable for cultivation.

From the considerations discussed above, the potential development area was selected to be 15,330 ha as summarized below:

Potential Development Area	Area (ha)
Rio Cobre East	6,150
Small Farms	950
Rio Cobre West	5,180
St. Dorothy South	2,340
Part of Spring Garden and Thetford	710
Total	15,330

5.1.3 Demarcation of the project area

Land irrigable by groundwater (Free Town irrigation system) in the St. Dorothy area was estimated at 1,490 ha on the basis of availability of groundwater. Since the total St. Dorothy area is 2,340 ha, the balance of 850 ha has to be excluded from the groundwater based system. It is possible nevertheless to include this area in the Rio Cobre area by expanding its system. The table below shows the possible development area in the respective irrigation systems.

Possible Development Area	Area (ha)
1. Rio Cobre Irrigation System	
Gravity Irrigation System	
Rio Cobre East (including Small Farms)	7,100
Rio Cobre West (including 850 ha from St. Dorothy)	6,030
Lift Irrigation System	
Spring Garden and Thetford	710
2. Free Town Irrigation System	
St. Dorothy South	1,490
Total	15,330

For more detailed demarcation of the project area, four (4) alternatives were further examined.

(1) Alternative 1: area to be developed by rehabilitating the Rio Cobre gravity irrigation system;

(2) Alternative 2: area to be developed by rehabilitating the Rio Cobre gravity and Free Town irrigation systems;

(3) Alternative 3: area to be developed by rehabilitating and expanding the Rio Cobre gravity irrigation system and rehabilitating the Free Town irrigation system; and

(4) Alternative 4: area to be developed by lift irrigation in addition to Alternative 3.

To compare and evaluate the above alternatives, a water balance study was made on the basis of water availability and requirements. The irrigable area both in rainy and dry seasons for each alternative were worked out as shown in Fig. I-1 and summarized as shown below:

	Area to be Irrigated (ha)	
	Rainy Season	Dry Season
Alternative 1 (9,950 ha)		
Rio Cobre East	5,000	3,580
Rio Cobre West	4,950	1,900
Total	9,950	5,480
Alternative 2 (12,370 ha)		
Rio Cobre East	5,800	5,750
Rio Cobre West	5,180	4,250
St. Dorothy	1,490	1,490
Total	12,370	11,490
Alternative 3 (14,620 ha)*		
Rio Cobre East	7,100	7,100
Rio Cobre West	6,030	6,030
St. Dorothy	1,490	1,490
Total	14,620	14,620
Alternative 4 (15,330 ha)**		
Rio Cobre East	7,100	7,100
Rio Cobre West	6,030	6,030
St. Dorothy	1,490	1,490
Part of Spring Garden	710	710
Total	15,330	15,330

Remarks: *; Reservoirs with 15 million m^3 capacity required.
**; Reservoirs with 20 million m^3 capacity and a 300 kw pump required.

After this, a general economic comparison was made in terms of IRR, B/C ratio and B-C for each alternative. The results are shown in the table below:

Alternative	IRR (%)	B/C*	B-C*
1	1.6	0.43	-123
2	22.8	2.57	397
3	23.5	2.49	489
4	19.4	1.99	416

Remark: *; Discount rate: 10%

All the indices of Alternative 1 have very low values, which are attributable to the fact that the irrigable area is very limited and that most of the area proposed would be covered with sugarcane of which benefit is fairly low.

A comparison between Alternatives 2 and 3 shows that the IRR and B-C of Alternative 3 are higher than those of Alternative 2, although B/C of Alternative 2 is slightly higher than that of Alternative 3. This means that the larger area is more beneficial because the

ruinate lands, due to lack of irrigation water could be converted to productive farm lands which would result in a higher benefit in relation to the construction costs of the reservoirs.

The indices of Alternative 4 by contrast show rather lower values than Alternatives 2 and 3, due to the higher construction costs of larger reservoirs and the pumping facility compared with the attendant benefits.

As a result, it can be said that Alternative 3 is the most desirable for development. Therefore it is proposed that the project area should be bounded by the Caymanas branch, Old Harbour branch and Free Town canals on the north, by the marshy land along the seashore and Hellshire on the south, by Portmore residential area on the east and by the Bowers river on the west as shown below:

(Unit: ha)

Project Area	Gross	Net
Rio Cobre East	7,100	6,220
Rio Cobre West	6,030	5,210
St. Dorothy	1,490	1,330
Total	14,620	12,760

5.2 Water Resources

The main water resources available in the study area are surface water and groundwater. The volume that can be obtained from these water resources has been assessed as follows:

(1) Surface water

Though several rivers and gullies are found in the study area, the Rio Cobre is only river which has water available for irrigation throughout the year. Other rivers such as the Plantain river, Coleburns gully and Black river have negligibly small discharges especially in the dry season.

The annual mean discharge of the Rio Cobre at the dam site is approximately 315 million m^3 (10.0 m^3/sec on average) and the annual discharge of the drought year with a return period of 5–years is estimated at 202 million m^3 (6.5 m^3/sec on average).

(2) Groundwater

In order to evaluate the groundwater potential in the Lower Rio Cobre Basin, use was made of a simulation model on the basis of the hydrogeological investigations. For calibration of the model the observed groundwater data in 1972 were used. Optimal yield was analysed as annual abstraction such that the groundwater level after one year's discharge would be almost the same as the primary water level, and that the groundwater level during discharge would always be above sea level in the limestone aquifer. After

several trials using the probable rainfall data in 1975. The annual permissible volumes of extraction in the Lower Rio Cobre were estimated as follows:

(Unit: million m^3/year)

Source	Agriculture	Industrial	Domestic*	Total
Limestone basin	60.7	5.9	37.2	103.8
Alluvial basin	31.0	2.6	2.5	36.1
Total	91.7	8.5	39.7	139.9

Remark: *; includes requirement for supply outside the study area.

The table below shows the water resources available in the study area under drought year conditions.

(Unit: million m^3/year)

Source		Volume
Surface water	(Rio Cobre)	202
Groundwater	(Limestone aquifer)	104
	(Alluvial aquifer)	36
Total		342

Annual available groundwater from both limestone and alluvial aquifers in the study area were assessed at approximately 140 million m^3 based on the results of the groundwater simulation analysis. It is noted that the annual permissible abstraction of groundwater within the project area was assessed to be approximately 79 million m^3 based on the same procedure. The results are summarized as follows:

(Unit: million m^3/year)

Area	Limestone	Alluvial	Total
Rio Cobre	28	28	56
St. Dorothy	22*	1	23
Total	50	29	79

Notes: *; Includes volume pumped up from Free Town wells. Figures above do not include the water pumped for industrial and domestic use.

5.3 Determination of Capacities of the Reservoirs and the Main Canal

5.3.1 Selection of optimum scale of reservoir

In order to determine the optimum scale of reservoir, a water balance study between the demand (water requirement) and supply (surface water and groundwater) for irrigation of 14,620 ha gross was made for the period of 29 years from 1955 to 1983 as shown in

Fig. I-2. As will be seen from Table I-1 there are large differences in the magnitude of deficit from year to year. The maximum deficit is estimated at approximately 110 million m^3 in 1976 whereas the minimum is nil. It is noted that the deficit of the dry year with a return period of 5-year occurs in 1975.

In order to fulfill the requirement of the dry year of once in five years, it is necessary either to develop surface water by creating new reservoirs or to develop groundwater by drilling new wells. An alternative water supply study for economic comparison was made in Table I-2. The first three lines show the demand (total water requirements for 14,620 ha gross) and supply (surface water and return flow only). After the fourth line, the balance demand to be supplied by either surface water from the reservoirs, groundwater from the wells or combination of the both are shown for the respective scale of the reservoirs.

Construction costs and operation and maintenance costs for new reservoirs and wells are estimated as shown in Table I-3 depending on the seven different size of reservoirs. Assumption here is that the operation of the pumps is 12 hours a day.

Based on the above table, an economic comparison was made in terms of the net present values which were calculated for combination of costs of reservoirs and wells. The results are given in Table I-4. It may be seen from the table that the optimum scale of reservoirs is approximately 15 million m^3.

5.3.2 Selection of location of the reservoirs

Location of the reservoir storage was determined with due consideration to the followings:

(1) Low permeability of the reservoir area,
(2) Embankment materials to be available within the area,
(3) Favourable location to receive and to distribute water, and
(4) Suitable foundation.

In selecting the site for Reservoir No. 1, land consisting of recent alluvium of high permeability, is avoided. In this regard, the reservoir should be west of Port Henderson Branch. In order to distribute water to the southern irrigable areas, the reservoir should be located at the northernmost. Soil mechanics testing shows that permeability is very low and that embankment material can be obtained within the proposed reservoir area. The foundations were also proved to be sound by these tests. The area to be occupied by the reservoir is proposed to be approximately 200 ha.

In selecting the site for Reservoir No. 2, the low head of the canal had to be taken into account in considering the storage capacity. The site selected is a depression in the upper basin of the Black river where soil tests have indicated that permeability is very low and that embankment materials can be obtained within the proposed reservoir area. The foundation were also proved to be sound by these tests. The area to be occupied by the reservoir is proposed to be approximately 80 ha.

In addition to these two, there are a further two small reservoir groups. One group is under construction or under planning with a total area of 107 ha, and located at Amity Hall in the Rio Cobre west area, whereas the other group comprises some existing reservoirs with an area of 15 ha situated at Brampton Farm in the St. Dorothy. The latter are expected to be included in the Rio Cobre west area by extending a canal from Old Harbour branch.

Table I-4 shows the results of a water distribution study for the relevant canals and reservoirs. As shown in the table, it is expected that the reservoirs will have storage capacities summarized below:

(Unit:million m^3)

Reservoir	Implementation stage	Capacity
No.1 (Towns Gully)	To be constructed	9.6
No.2 (Black River)	To be constructed	3.8
No.3 (Amity Hall)	Under construction/planning	1.2
No.4 (Mendes Pen)	Existing	0.4
Total		15.0

5.3.3 Design capacity of the main canal

The intake capacity of the main canal at the intake structure was estimated from a study of the daily river discharge. Fig. I-4 illustrates the discharge of the river, and intake at capacities of 8 m^3/sec, 10 m^3/sec and 12 m^3/sec of the main canal, respectively. It may be seen from the figure that there is little difference in intake during the low flow season irrespective of the capacity of the main canal, whilst there is a considerable difference in the high flow season. Therefore, the design intake discharge was determined taking into account requirements for irrigation water as well as requirements for the reservoirs, artificial recharge for groundwater and municipal and industrial uses during the high flow season. It is expected that the maximum water demand is approximately 10 m^3/sec.

6. DEVELOPMENT PLAN

6.1 Constraints in the Existing Irrigation System

Present conditions in the irrigation system of the Rio Cobre Irrigation Works and the St. Dorothy Irrigation system have been described in the previous section of this annex. This section reviews the constraints in the existing irrigation system.

According to information obtained from the two operation organizations, the schemes irrigate approximately 12,000 ha (30,000 ac) of land in the study area. However, it is important to note that much of the land in the study area receives insufficient water for farming especially in the dry season. The reason for this is thought to be that many of the facilities have deteriorated and the canals are blocked with vegetation and sediment.

The headworks dam which is equipped with flash boards cannot maintain the required water level throughout the year since the boards have deteriorated or been lost together with some of the vertical steel rods. The condition of intake gates is poor. The main problem is the headstocks. As these gates are not functioning, it is impossible to regulate the water entering the canal. Despite the valuable function of the scoring sluice gates in reducing the amount of silt entering the canal, these have not been used and are now inoperable.

The main canal (from the headworks dam to the bifurcation) is generally an unlined channel of approximately 4.7 km in length. The level at the downstream end of the canal is controlled by a weir with wooden stoplogs and the flow is restricted by improvised means to maintain water level for the intake of the Spanish Town Water Works. This is the biggest obstacle for satisfactory operation of the canal which, in turn, not only restricts the flow but also encourages silting and weeding due to low velocity of flow.

The east main canal (from the bifurcation to the Caymanas branch) is an unlined channel approximately 4.7 km long. the general condition of the canal is rather poor. The flow is restricted due to the irregular slopes of the canal section and grades of the canal bed. The banks of the canal are eroded, and hence silting is observed.

The west main canal (from the bifurcation to the Hartlands branch) is approximately 2.9 km long. The canal in this section is heavily choked with weeds. Below the turnout to the Sydenham branch the canal bed gradient increases towards the Hartlands branch, the capacity thus increases. At this section, the canal banks are lined with rough masonry. It is noted that gravity irrigation in this section is difficult due to the low level of the canal.

6.2 Irrigation and Drainage Development Plan

6.2.1 Development plan formulated by Agro 21

The development plan formulated by Agro 21 is presented in Chapter 3. Generally speaking, it is expected that Agro 21 will provide for off-site improvements and that

private investors will finance on-site improvements such as land levelling, drip and sprinkler irrigation, shade houses and the like.

The area to be developed by Agro 21 is 6,151 ha situated in Bernard Lodge Estate and Caymanas Estate which are bounded by the Caymanas branch to the north, by the Hellshire Hill to the south, by the Portmore residential area to the east and by the Hartlands branch to the west.

It is expected that the project will finance the following in the first year (1985), for which engineering plans and cost estimates have been prepared by Agro 21 and approved by US AID.

- Rehabilitation of 7 wells, construction of 12 new wells including electrical service
- Construction of new pumping station on the Rio Cobre (capacity 45 cfs)
- Construction of 2 small pump stations on the canal
- Reshaping and lining of branch canals
- Underground piping and hydrants
- Roads and drainage rehabilitation
- Canal cleaning, bridge repair & gates
- Removal of obstructions in the canal
- Fencing

Additional infrastructure work in the subsequent two years (1986, '87) of the project, for which preliminary engineering planning has been completed is contemplated to include:

- Rehabilitation or replacement of sluice gates of the Rio Cobre dam, (under replacement work) including clearing of upstream approaches
- Drilling and equipping of some 31 new wells
- Rehabilitation of conveyance canals and dams; (under construction)
- Rehabilitation of service roads
- Installation of piping and water control structures
- Fencing

6.2.2 Overall development plan

Agro 21 will not develop the gravitational water source by rehabilitating the headworks dam or the main canal, although minor works on the dam and removal of obstruction in the canal would be performed. Rather, it intends to develop the water source by constructing a new pumping station on the Rio Cobre as well as by rehabilitating and constructing wells in the alluvial aquifer. As far as the extent of the area to be developed by Agro 21 is concerned, its development concept seems to be reasonable.

However, it is important to note that substantial rehabilitation of the headworks dam and the main canal is indispensable for overall development in the St. Catherine Plains. Eventually it will be necessary to include the area (to be developed by Agro 21) in the overall development plan by modifying the development plan formulated by Agro 21. Accordingly, the following works are proposed under this project.

(1) Rio Cobre common water infrastructure

(a) Rehabilitation of the headworks and intake structure

Though the flow discharge to be diverted to the main canal is planned at 9.63 m^3/sec, raising of the dam crest elevation would be required so as to ensure this discharge to improve performance. The height to be raised with mass concrete on the existing dam crest is 0.6 m (2 ft.) over the whole length of the crest. Rehabilitation of the apron and retaining wall downstream of the dam should also be included. As far as the intake structure is concerned, the structure itself is still durable and has enough capacity to divert the design discharge. The eight sluice gates installed at the intake structure have deteriorated and require replacement with new ones. In order to reduce seepage through dam foundation, it is proposed to carry out certain grouting.

(b) Rehabilitation of the main canal (from the intake structure to No. 1 bifurcation)

The main canal, approximately 4.7 km long with a design capacity of 9.63 m^3/sec, will require lining with concrete. Eight bridges and one aquaduct also require reconstruction. The bifurcation will also be reconstructed and a pumping station will be established to supply water to the Spanish Town Water Works.

(2) Rio Cobre East (Agro 21)

(a) Rehabilitation of the east main canal
(from No. 1 bifurcation to No. 2 bifurcation)

The east main canal which is generally in unlined canal would be lined with concrete. The total length of the canal lining is 4.7 km and all the related structures such as turnouts, drops and checks as well as bridges would be reconstructed.

(b) Reconstruction of the Rio Cobre syphon

The existing syphon crossing of the Rio Cobre by the Caymanas branch canal is exposed on the river bed and faces serious damage by flood. It is proposed to replace it by a new syphon of ductile iron pipe.

The total length of pipe required is 134 m and 900 mm in diameter.

(c) Construction of Town gully reservoir

One reservoir is planned at Corletts Pen along Town gully. The storage capacity of this reservoir will be 9.6 million m^3 in an area of 200 ha. Water would be supplied to the reservoir through Turners Pen branch canal and delivered to both Port Henderson and downstream of Turners Pen branch canals. The height of the dike would vary from a maximum of 10.0 m to a minimum of 4.2 m.

(3) Rio Cobre West

(a) Rehabilitation of the west main canal
(from No. 1 bifurcation to No. 3 bifurcation)

Total length of the west main canal (2.8 km) would be lined with concrete and all related structures would be reconstructed. The design capacity of the canal is planned to meet the irrigation water requirement, necessary discharge to the reservoir (Black river reservoir) and discharge to the sinkhole for artificial recharge.

(b) Rehabilitation of Hartlands branch

The Hartlands Canal branches off to the south from the west main canal, and forms the boundary between the Rio Cobre East (Agro 21) and the Rio Cobre West. However, it irrigates both Bernard Lodge and Innswood Estates lands. It is proposed that the canal be lined with concrete. The canal is 7.1 km long with a design discharge of 2.77 m^3/sec. All the related structures will be reconstructed.

(c) Rehabilitation of Old Harbour branch

The Old Harbour canal branches off to the west from the west main canal. There are three notable features along this branch. One is a sinkhole which facilitate groundwater recharge located on the right bank; the second is a reservoir proposed to be created on the left bank; and the third is the extension canal towards the St. Dorothy area. In order to supply the design discharge, the canal must be raised considerably.

(d) Construction of the Old Harbour branch extension canal

In order to irrigate an area of about 850 ha located in the St. Dorothy area, it is proposed to extend the Old Harbour branch canal into the area. The total length of the canal to be extended with concrete lining canal is 5.1 km. Structures necessary such as syphons, turnouts, checks and culverts would be newly constructed.

(e) Construction of Black river reservoir

This reservoir would be located about 1 km west of the Innswood sugar factory. Storage capacity of the reservoir would be 3.8 million m^3 in an area of 80 ha.

The reservoir would receive water through the Old Harbour branch canal and would deliver to downstream by the Old Harbour branch canal and by the Black river to Amity Hall. The height of dike will vary from a maximum of 8.8 m to a minimum of 4.8 m.

(4) St. Dorothy

(a) Rehabilitation of the Free Town pipeline

Water from the Free Town pump station is carried by a woodstave pipeline constructed in 1963. The pipeline has deteriorated considerably and plenty of water is wasted by leakage. Consequently it is proposed to replace the pipeline with a new one. A ductile iron pipe with a diameter of 700 mm would be proposed for new pipeline. The length of the pipeline is 2.8 km and design discharge is 0.55 m^3/sec.

(b) Rehabilitation of the Free Town pump station

Two pump sets are installed at the Free Town pump station. The total discharge from the two pump is 0.34 m^3/sec at present. In order to increase the discharge from the two wells, two pumps would be replaced by new ones. In addition three pumps would be newly installed at wells which would be newly constructed at Free Town pump station to reach a total discharge of 0.55 m^3/sec.

(c) Rehabilitation of the Free Town canals

The existing open canal system delivers pumped water from Free Town, Marine Terminal, and Bodles pumping stations to farming land. The main canal commences at the outlet point of the Free Town pipeline and several distributory canals branch off from the main canal. Both main and distributory canals would be lined with concrete.

The total lengths of the main and distributory canals were computed to be 7.9 km and 10.3 km respectively.

6.2.3 Drainage plan

(1) Category and function of drains

Drainage canals are classified by function as follows:

(a) Field ditches are provided to drain excessive water and to control the subsurface water level at each farm plot.

(b) Function of collector drains is to drain excessive water and surface water collected by the field ditches to secondary or main drains.

These drains are categorized as on-farm level development, of which preliminary design is made in Annex-J. The design discharges of these two drains were determined as shown below based on the assumption that the rain water can be drained within 24 hours.

Condition of Ground Surface	Design Discharge
Rice field (flat)	10.7 lit/sec/ha
Upland crop field (flat)	8.2 lit/sec/ha

(c) Secondary drain transport water from collector drains to natural gullies or rivers which form the main drains. Preliminary design of the secondary drain is presented in this section.

(d) Main drains carries water from the secondary drains to the sea. Natural gullies and rivers act as the main drains.

(2) Development plan of the secondary drain

Unit design discharge under different field conditions may be summarized as follows:

	Drainage Area	T	C	Design Discharge
	(ha)	(hr)		(lit/sec)
Rice field	100	24	0.65	10.7
Upland crop field	100	48	0.5	4.1
Rice field	500	48	0.65	5.3
Upland crop field	500	60	0.5	3.3
Upland crop field	1,000	72	0.5	2.7

The layout of the secondary drains is planned on the topographical maps at a scale of 1:12,500.

Fig. I-6 shows the layout of the secondary drains.

(3) Main drain

Drainage of the plains, at present, is primarily through man-made channels which act as tributaries of the main streams crossing the plains. The eastern plains area is drained by the Rio Cobre and the Ferry river while the Coleburns gully and Plantain river drain the west. The central area is drained by Salt Island gully and its tributary, the Black river. It has been noted that, apart from the Salt Island creek, the plains are drained well by through-following streams and flood drainage channels originating on the plains. Because of the very permeable nature of the alluvium in the east, most applications of water, natural or artificial, rapidly infiltrate into the ground. As far as the Salt Island creek is concerned, it flows in the mangrove forest, and flooding does not seriously affect agriculture in the study area. Thus no river training will be required at an in the project area.

The respective rivers and gullies command the following drainage areas:

Ferry river	:	Block H
Rio Cobre	:	Block C, Block F and Small farms
Nago Head Spring	:	Block B
Natural channel to Great Salt Pond	:	Block A and Block E
Campeachy gully	:	Block I
Town Gull	:	Part of Block G
Tributary of Salt Island creek	:	Block D and part of Block G
Spring Garden river	:	Part of Bernard Lodge
Black river	:	Part of Bernard and Amity Hall
Coleburns gully	:	Spring Village and Bushy Park
Frasers gully	:	Brampton Farm
Bowers gully (Plantain river)	:	Colbeck, Lodge and Kellys Pen

7. IRRIGATION WATER DISTRIBUTION SCHEDULE

The water distribution schedule for each branch is shown in Table I-4.

7.1 Caymanas Branch

The Caymanas branch irrigates 901 ha (811 ha net) covering Block H and part of Block F. The peak water demands occur in July amounting 574 lit/sec. This branch is designed to convey surface water of 134 lit/sec and groundwater 440 lit/sec.

7.2 Cumberland Branch

The Cumberland branch serves 1,238 ha (1,114 ha net) covering Black A, Block B, Block C, part of Block F and small farms. Water requirement in June will be the highest. Out of the total water supply of 898 lit/sec, 348 lit/sec will be supplied by surface water and 550 lit/sec by groundwater.

7.3 Port Henderson Branch

The benefited area of the Port Henderson branch is 2,105 ha (1,890 ha net) This branch serves water to Block E and Block I. The peak water requirements take place in June. Since the total demands exceed supply from surface and subsurface water, supplemental water will be required from the reservoir (Towns gully reservoir). Out of the total demand of 1,712 lit/sec, 552 lit/sec will be supplied by surface water, 400 lit/sec from the wells and 760 lit/sec from the reservoir.

7.4 Turners Pen Branch

The Turners Pen branch irrigates part of Block D, Block G, Block I and small farms covering 1,556 ha (1,236 ha net). The peak water demands occur in April. Since, in this month, the water supply from surface and subsurface sources is not sufficient to meet demand, it is necessary to obtain additional water from the reservoir (Town gully reservoir). Of the total demand of 1,416 lit/sec, surface flow supplies 349 lit/sec, wells 200 lit/sec, return flow 142 lit/sec and the reservoir 725 lit/sec.

7.5 Water Balance of Reservoir No.1

The capacity of reservoir No.1 is designed to be 9.6 million m^3. The water is supplied from the Turners Pen branch. Inflow to the reservoir lasts from October to February when the river flow exceeds the demand. The reservoir distributes the water to the Port Henderson branch and Turners Pen branch during March and July.

7.6 Sydenham Branch

The Sydenham branch irrigates 663 ha (597 ha net) covering part of Block D and Block G. The peak water demand occurs in August and is 612 lit/sec. This branch is designed to convey surface water of 512 lit/sec and groundwater of 100 lit/sec.

7.7 Hartland Branch

The benefited area of the Hartland branch is 2,871 ha (2,484 ha net) covering part of Block G and Block D, part of Innswood Estate, Hartland small farms and Amity Hall. Water requirements in March will be the highest. Out of the total supply of 2,286 lit/sec, 1,937 lit/sec will be supplied by surface water, 100 lit/sec by groundwater and 229 by return flow. However, it is noted that the surface flow in April decreases, and thus it is necessary to supply water from a reservoir (reservoir No. 3) located at Amity Hall. The amount of the supply from the reservoir is 20 lit/sec.

7.8 Old Harbour Branch

The Old Harbour branch serves 2,944 ha (2,543 ha net) covering most of Innswood Estate, part of Amity Hall and Bushy Park. The peak water requirements take place in July. Since the total demands exceed supply from surface and subsurface water, supplemental water will be required from the reservoir (Black river reservoir). Out of the total demand of 2,714 lit/sec, 753 lit/sec will be supplied by surface, 900 lit/sec from the wells, 271 lit/sec by return flow and 790 lit/sec from the reservoir.

7.9 Old Harbour Extension Canal

The Old Harbour Extension canal commands 846 ha (746 ha net) covering Brampton Farm, Lloyds Pen and part of Bushy Park. Peak water demands occur in April amounting to 550 lit/sec. This extension canal is therefore designed to convey surface water of 360 lit/sec and water from the two reservoirs, 100 lit/sec from reservoir No. 2 and 90 lit/sec from reservoir No. 4. No groundwater supply is expected for this area.

7.10 Water Balance of Reservoir No. 2

The capacity of reservoir No. 2 is designed to be 3.80 million m^3. The water will be supplied from the Old Harbour branch. There will be inflow to the reservoir from November to February and again in May when the river flow exceeds demand. The reservoir will supply water to the Old Harbour branch during March, May, June and July.

7.11 Water Balance of Reservoir No. 3

The capacity of reservoir No. 3 is designed to be 1.20 million m^3. The water will be supplied from both the Hartlands branch and the Old Harbour branch. There will be inflow to the reservoir from November to February as long as the river flow exceeds demand. The water from the reservoir will be used for irrigation of Amity Hall during March and April.

7.12 Water Balance of Reservoir No. 4

The capacity of reservoir No. 4 is designed to be 0.40 million m^3. The water will be supplied from the Old Harbour Extension canal. Inflow to the reservoir will last from

January to February as long as the river flow exceeds the demand. The reservoir will supply water to Brampton Farm during March and April.

7.13 Main Canals

Design discharges of the main canals were determined as seen in Fig. I-6 and Table I-4. From the table, the design discharge of the three main canals will be:

East Main canal	:	4.10 lit/sec (July)
West Main canal	:	6.35 lit/sec (April)
Main canal (Intake to Bifurcation)	:	9.63 lit/sec (July)

Table I-1 LIST OF ANNUAL DEFICIT

Year	Deficit
1955	0.00
1956	0.00
1957	1.64
1958	0.00
1959	26.44
1960	0.00
1961	1.24
1962	0.00
1963	0.00
1964	0.00
1965	5.62
1966	0.00
1967	30.42
1968	34.91
1969	0.00
1970	2.31
1971	5.82
1972	0.58
1973	1.37
1974	0.00
1975	8.34
1976	110.86
1977	28.55
1978	0.00
1979	0.00
1980	0.30
1981	1.01
1982	0.55
1983	52.18

Table I-2 ALTERNATIVE WATER SUPPLY STUDY FOR ECONOMIC COMPARISON

(Unit: m3/sec)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total m3/sec	Total MCM
I. Total Water Requirement	7.03	7.63	8.76	10.20	7.42	8.74	10.66	8.91	6.76	4.81	6.54	8.25	95.71	248.08
II. Water Supply														
1. Surface water	4.22	4.31	4.56	3.76	3.55	4.58	4.42	5.34	5.73	4.12	5.51	5.45	55.55	143.99
2. Return flow	0.37	0.41	0.57	0.66	0.48	0.45	0.49	0.55	0.49	0.37	0.43	0.50	5.77	14.96
3. Alternative case for remaining water supply														
Reservoir volume = 0 million m3														
Groundwater	2.44	2.91	3.63	5.78	3.39	3.71	5.75	3.02	0.54	0.32	0.60	2.30	34.39	89.13
Reservoir water	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reservoir volume = 2 million m3														
Groundwater	2.44	2.91	3.55	5.50	3.33	3.68	5.53	3.02	0.54	0.32	0.60	2.30	33.72	87.40
Reservoir water	-	-	0.08	0.28	0.06	0.03	0.22	-	-	-	-	-	0.67	1.73
Reservoir volume = 5 million m3														
Groundwater	2.44	2.91	3.43	5.07	3.23	3.65	5.20	3.02	0.54	0.32	0.60	2.30	32.71	84.78
Reservoir water	-	-	0.20	0.71	0.16	0.06	0.55	-	-	-	-	-	1.68	4.35
Reservoir volume = 10 million m3														
Groundwater	2.44	2.91	3.22	4.37	3.08	3.58	4.66	3.02	0.54	0.32	0.60	2.30	31.04	80.46
Reservoir water	-	-	0.41	1.41	0.31	0.13	1.09	-	-	-	-	-	3.35	8.67
Reservoir volume = 12 million m3														
Groundwater	2.44	2.91	3.14	4.09	3.02	3.56	4.43	3.02	0.54	0.32	0.60	2.30	30.37	78.72
Reservoir water	-	-	0.49	1.69	0.37	0.15	1.32	-	-	-	-	-	4.02	10.41
Reservoir volume = 15 million m3														
Groundwater	2.44	2.91	3.02	3.66	2.92	3.52	4.10	3.02	0.54	0.32	0.60	2.30	29.35	76.08
Reservoir water	-	-	0.61	2.12	0.47	0.19	1.65	-	-	-	-	-	5.04	13.05
Reservoir volume = 20 million m3														
Groundwater	2.44	2.91	2.82	2.96	2.77	3.45	3.55	3.02	0.54	0.32	0.60	2.30	27.68	71.75
Reservoir water	-	-	0.81	2.82	0.62	0.26	2.20	-	-	-	-	-	6.71	17.38