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Democratic Socialist Republic of Sri Lanka

Ministry of Mahaweli Development

Maduru Oya Project

Feasibility Report

Main Report

ACRES Acres International Limited, Niagara Falls, Canada

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ACRES

August 20, 1980

Mr. N.G.P. Panditharatne
Director-General
Mahaweli Authority of Sri Lanka
500 T.B. Jaya Mawatha
Colombo 10, Sri Lanka

Dear Sir: Maduru Oya Project

We have pleasure in transmitting herewith our Feasibility Report on the Maduru Oya Project. This is the final issue of the report and follows closely the format of the initial issue of November 1979 which is now superseded.

Our recently completed studies of the irrigation development in System B take account of the additional soils and topographic mapping which became available in April 1980. At the same time we have been able to include the more definitive costs of the headworks based on the selected contractor's tender.

Parallel with our technical studies we have had constructive discussions on the government's developing plans for the management of the project during the construction, settlement and operation phases. Our commentary on these subjects has now been incorporated in the report.

We would like finally to express our great appreciation of the cooperation we have received from the Authority and other government agencies, as well as the cordial relations which have developed with the many individual Sri Lankans with whom we have been working.

We will be very pleased to answer any queries you may have on this report.

Yours very truly

W. G. Lockett
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FOREWORD

The Feasibility Report on the Maduru Oya Project is made up as follows:

Main Report - contained in this volume

Annex A - The Project Area

Annex B - Soils and Land Classification

Annex C - Hydrology and Water Balance

Annex D - Engineering Works

Annex E - Agronomic Studies

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GLOSSARY OF TERMS AND ABBREVIATIONS

ADB	Asian Development Bank
Acres	Acres International Limited
Anicut	diversion weir
Asweddumized	prepared by surrounding with bunds
CECB	Central Engineering Consultancy Bureau
CIDA	Canadian International Development Agency
Chena	shifting cultivation slash and burn
FAO	Food and Agriculture Organization of the United Nations
Ganga	a river with significant flows throughout the year
GOSL	Government of Sri Lanka
IBRD	International Bank for Reconstruction and Development (the "World Bank")
IRR	Internal Rate of Return
LUD	Land Use Division of the Irrigation Department
lakh	one hundred thousand (100,000)
MASL	Mahaweli Authority of Sri Lanka
MDB	Mahaweli Development Board
MEA	Mahaweli Economic Agency
Maha	the season of the northeast monsoon (approximately December to February)
O & M	Operation and Maintenance
Oya	a river with little or no flow during the dry season
PMB	Paddy Marketing Board

Glossary of Terms and Abbreviations - 2

Rs	Sri Lanka Rupees (Rs 16.00 = US $1.00 Rs 13.00 = Can $ 1.00 approximately)
UNDP	United Nations Development Programme
USAID	United States Agency of International Development
Yala	the season of the southwest monsoon (approximately May to September)

SUMMARY AND CONCLUSIONS

1 - INTRODUCTION

The Maduru Oya project, a component of the Mahaweli Development Scheme, is located in the basin of the Maduru Oya, which lies to the east and is separate from that of the Mahaweli Ganga itself.

The purpose of the project is to provide irrigation water to the System B area, so as to facilitate the ultimate settlement of some 35 000 farming families.

2 - THE PROJECT AREA AND EXISTING LAND USE

The total area of System B is approximately 135 000 ha. The present population is 26 000.

The climate is typical of the "Dry Zone" of Sri Lanka, with 75 percent of the average annual rainfall occurring in the Maha season.

About 54 percent of the total area is forest covered, 27 percent is under shifting cultivation and 11 percent is committed to paddy farming.

3 - THE PROJECT

The main physical components of the project are:

- Headworks

  Dam and reservoir - gross storage 555 $10^6 m^3$

  Link tunnel from Mahaweli - capacity - 34 m^3/s

  Share (with System C) of the Minipe Right Bank Transbasin Canal in the Mahaweli Valley

- Main and Branch Canal Systems - 248 km

  Left Bank Canal - capacity at headworks - 56.2 m^3/s

  Right Bank Canal - capacity at headworks - 32.5 m^3/s

- Tertiary systems, drainage, land leveling, etc

- Homesteads and settlements

- Nonirrigation infrastructure.

4 - PROPOSED LAND USE

Land classification based on soils and topographic mapping indicates that irrigable soils under command of the proposed canal system amount to some 62 100 ha. Of these about 79 percent have been found suitable for paddy cultivation, while the remaining 21 percent are suitable for upland crops; upland areas are considerably dispersed, however.

To obtain a water balance, it was found necessary to reduce the irrigable area by some 8 percent. This can be achieved by conditionally deferring the development of an area at the eastern end of the Left Bank Canal system.

The upland areas include certain soil types (Noncalcic Brown soils), the performance of which needs to be examined in a program of applied research on a pilot farm. For present purposes a representative cropping pattern (groundnuts rotated with soybeans) has been assumed.

The proposed allocation of land, not including the deferred area mentioned above, is as follows.

(a) Lowlands

Irrigable soils within command	48 800 ha
Net area allotted to farms	34 300 ha
Farm size	1.0 ha
Cropping pattern (Maha/Yala)	paddy/paddy
Number of paddy farmers	34 300

(b) Uplands

Irrigable soils within command	13 300 ha
Net area allotted to farms	1 800 ha
Farm size (including homestead)	1.8 ha
Representative cropping pattern	groundnuts/ soybeans
Number of upland farmers	1 000

Homesteads for the paddy farmers (0.4 ha each) will be located on the uplands, generally on nonirrigable land. In addition, a holding of 0.2 ha/family has been proposed for an estimated 11 800 nonfarm settlers.

The approximate gross land use is estimated to be

Irrigated agriculture	48 000 ha
Homestead and settlement	20 000 ha
	68 000 ha

The total number of settler families (farm and nonfarm) is estimated to be 47 000.

After development, the population of the area will be about 250 000.

5 - ANTICIPATED YIELDS

Government crop-cutting surveys carried out from 1973 to 1978, and more detailed surveys carried out in September 1979 and April to June 1980 in the project area, indicate mean paddy yields in the Maha season of 5.4 and 5.0 t/ha on soil series representative of Land Classes 1R and 2R respectively.

The following yields have been adopted in the present studies.

Paddy yields by land classes (applicable to 0.95 of farm area)

	Maha (t/ha)		Yala (t/ha)	
Land Class	1R	2R	1R	2R
Base Case	4.6	4.1	4.6	4.1
Higher	5.1	4.5	5.1	4.5
Lower	4.1	3.7	4.1	3.7

Cropping intensity: Maha 0.98 Yala 0.90

Representative upland crops:

Groundnuts	1.5 t/ha
Soybeans	1.6 t/ha

6 - RATE OF DEVELOPMENT

Provided construction of the dam is completed by the end of July 1983, and provided water is available for diversion from the Mahaweli by early August 1983, it should be possible to deliver adequate water supplies to the newly developed hectarage in the 1983/84 Maha season. Thereafter two scenarios for the completion of this project have been studied.

Area of new land harvested (total of 35 830 ha, which includes paddy land and uplands) is as follows:

Year	Scenario A	Scenario B
1984	9 020	5,540
1985	11,293	5,315
1986	9,209	5,669
1987	6,308	5,764
1988	-	5,819
1989	-	5,763
1990	-	1,960

7 - RATE OF SETTLEMENT

Settlers will be engaged on the land preparation of their allotments. They will be brought into the area about one and a half years before their first harvest on irrigated land. Settler arrivals for lowlands are as follows.

Year	Scenario A	Scenario B
1982	4 900	2 300
1983	9 000	5 800
1984	9 800	5 900
1985	8 900	6 300
1986	1 700	5 100
1987		4 600
1988		4 300

More than 31 000 settler families will come from outside the project area.

8 - PROJECT COSTS

The estimated cost (mid 1979 economic prices) of the project is summarized below.

	Sri Lankan (million Rs)	Foreign	Totals
Headworks	406.7	1,296.2	1,702.9
Main and Branch Canals	552.0	1,160.1	1,712.1
Tertiary system	665.6	74.0	739.6
Subtotal, irrigation works	1,624.3	2,530.3	4,154.6
Nonirrigation infrastructure	627.0	157.0	784.0
TOTALS	2,251.3	2,687.3	4,938.6
	(45.6 percent)	(54.4 percent)	(100.0 percent)

Allocated Right Bank Transbasin Canal cost Rs 150 million
Annual operation and maintenance cost Rs 61 million

9 - PROJECT BENEFITS

Based on economic prices the following tabulation shows the benefits estimated for the Base Case (see Item 10) after full development has been achieved.

	Without Project (million Rs)	With Project	Net	Percent of Total
Paddy and uplands	79	692	613	82.2
Homesteads	-	64	64	8.6
Livestock	-	39	39	5.2
Fisheries	-	2	2	0.3
Forestry (average annual)	-	9	9	1.2
Power	-	19	19	2.5
TOTALS	79	825	746	100.0

With the exception of paddy, all benefits have been expressed as incremental benefits beyond those realized at present in the project area.

10 - INTERNAL RATE OF RETURN

The discounted cash flow method has been used to determine the internal rate of return for a number of different cases.

The Base Case is

- Base Case paddy yields

- build-up of net benefits from paddy - 60 percent to 100 percent in 5 years has been assumed

- allocation of Right Bank Transbasin Canal costs - 25 percent of canal costs.

The Base Case has been applied to Scenarios A and B.

Sensitivity tests have been performed for variations of paddy yields in both scenarios. Other sensitivity tests have been performed against the Base Case in Scenario A.

Case	Internal Rate of Return Scenario A (percent)	Internal Rate of Return Scenario B (percent)
Base case	10.1	9.8
Sensitivity tests:		
- higher paddy yields	11.6	11.2
- lower paddy yields	8.6	8.4
- paddy net benefit build-up over 8 yr	9.8	9.4
- Right Bank Transbasin Canal cost allocation - 50 percent of total cost	9.4	9.0
- capital costs up 10 percent	9.4	9.1
- net benefits down 10 percent	9.1	8.8
- Scenario A planned and built, Scenario B benefits realized	9.1	-
- full development (no deferred area)	10.6	
- allocation of Nelugala Corridor to wildlife	10.3	

11 - SECONDARY BENEFITS

Certain other benefits have not been included in the above analyses. The spin-off effect due to construction and other activity during the development period, the redistribution of income, and other social benefits are estimated to add 4 to 6 percentage points to the Base Case IRR.

12 - FARM INCOME

Financial farm incomes (based on 1979 price levels) are estimated to be about Rs 11,000 to 12,000/yr for both paddy and upland farmers, including income-in-kind from domestic food production.

13 - FINANCIAL COST

The financial terms, the cost of the project and associated agricultural and social infrastructure are as follows

	Million Rupees	Percent of Total
Headworks	1,677	29
Main and Branch Canals	1,636	29
Tertiary irrigation system	697	12
Roads	427	8
Settlement	165	3
Project management infrastructure	145	3
Agriculture processing and services	684	12
Social infrastructure	243	4
Total (1979 cost)	5,674	100

Of the total, Rs 2,711 million would be local currency and Rs 2,963 would be foreign currency.

14 - CONCLUSIONS

(a) The proposed irrigation project is technically feasible, and, without external constraints, can be completed in time for agricultural production to commence in Maha 1983/84.

(b) Based on direct economic costs and benefits the indicated internal rate of return is 10.1 percent. A range of 8.4 percent to 11.6 percent is indicated by the sensitivity tests carried out.

(c) The adoption of the Nelugala Jungle Corridor as a means to achieve a water balance results in a minor change in the internal rate of return. The decision on whether to allocate this area to wildlife should, therefore, focus on land-use policy and potential farmer/wildlife conflicts, rather than on economic considerations.

(d) Significant social benefits are also attributable to the project.

(e) Two rates of development have been considered. The rate to be adopted should consider that simultaneous activities on other major projects (not only those within the Mahaweli complex) could impose constraints on the availability of manpower. This should be taken into account in the detailed planning of the development of the downstream area.

15 - SPECIAL RECOMMENDATIONS

Certain of the recommendations contained in this Report and its Annexes require special mention in view of their importance to the project. These recommendations are discussed under the following headings.

- Land Classification
- Hydrology
- Engineering

- Agriculture
- Settlement
- Environment
- Project Management.

Further details under all subject headings can be found in the related annexes.

15.1 - Land Classification

The land classification maps which have been produced to date are adequate at the feasibility study level only. A major effort will be required to improve the detail and to integrate the land classification work into the engineering design of the tertiary systems and the selection of homestead areas.

15.2 - Hydrology

(a) A fully equipped meteorological station should be set up at Welikanda, augmented by 5 to 6 daily rainfall gauges located throughout the project area.

(b) Observations of flood depths and durations should be made on the lower Maduru Oya floodplain, and the results related to observations at the Welikanda gauging station. This will assist in the further evaluation of development potential in the floodplains.

(c) It is strongly recommended that computer simulation studies of the overall Mahaweli system be reviewed and updated to reflect the new information obtained from the feasibility studies of Systems A, B and C. This will allow confirmation of headworks dimensions and evaluation of operating policies.

15.3 - Engineering

(a) A survey of, and a construction program for, remedial measures required in existing major and minor tank schemes is needed to ensure that benefits in these areas are realized.

(b) The land classification team should coordinate their work closely with that of the design team. Similarly, the Survey Department's program of intensification of mapping should be closely coordinated with planning work.

(c) Early consideration should be given to the question of installing hydroelectric plants on the Left Bank Main Canal. The objective would be to examine the merit of modifying the fall structures at the present stage, so as to minimize "retrofit" costs in the future if and when a power installation is justified.

15.4 - Agriculture

(a) A comprehensive livestock program, focusing as a minimum on the breeding of draft buffalo, should be developed as soon as possible.

(b) A large tractor-hire service will be needed to bridge the gap between livestock availability and farm power needs in the early years of the project

15.5 - Settlement Planning

(a) An overall regional plan is needed for the area covering Polonnaruwa to Batticaloa and Trincomalee to Mahiyangana, so that development of the project area proceeds within a defined broader context.

(b) The detailed planning of homestead areas should incorporate a soils-oriented assessment of suitability for rainfed cropping. Work should start on assembling the necessary information.

(c) The settler selection procedures should take into account

- the average labor requirement of 2.8 persons per paddy farmer

- the eligibility of all families now resident in the project area

- the need for nonfarmer settlers.

(d) Experience with the worker-settler program elsewhere should be closely monitored to determine its impacts.

15.6 - Environment

(a) The appointment of a full-time environmental coordinator to work with the design and implementation team is recommended.

(b) Allocation of "green belts", forest and firewood reserves, and wildlife corridors should be made at an

early stage and the boundaries surveyed to minimize inadvertent clearing and/or encroachment.

(c) The recommended fisheries program in the major reservoirs and tanks should be developed.

15.7 - Project Management

(a) It is recommended that a Mahaweli System Water Management Center be established without delay within MEA under the direction of a Manager, Water Resources, with its own hierarchy within the MEA organization.

1 - INTRODUCTION

1.1 - The Context of the Maduru Oya Project

The Mahaweli Ganga is the largest river in Sri Lanka. The Maduru Oya project is part of a comprehensive scheme for the utilization of the Mahaweli Ganga for purposes of irrigation and hydroelectric power generation.

As conceived in the Master Plan prepared by UNDP/FAO in 1968, the Mahaweli Scheme envisages the ultimate formation of a series of storage reservoirs in the Mahaweli basin itself. Diversions fanning out from the mainstream would deliver water to an array of widespread systems throughout the northern part of the island. A total of some 13 main systems have been identified by the letters "A" through "M". A number of component irrigation projects, some of considerable magnitude, are thus required to complete the Mahaweli development as a whole. The location of the scheme in Sri Lanka is shown in Figure 1, while Figure 2 shows the layout of the scheme and the relationships of its individual projects.

The first of the component projects to be undertaken were the Polgolla Diversion and the Bowatenna Reservoir, which, with other associated works, feed System H. This system has already commenced operation and settlement is scheduled for completion in 1980.

In 1978 the Government of Sri Lanka approved the Accelerated Mahaweli Programme, included in which is the construction, as a matter of priority, of the Kotmale and Victoria reservoirs and the development of Systems B and C, together amounting to some 85 000 ha.

The Government agencies which are most actively involved in the Accelerated Programme are

- The Ministry of Mahaweli Development

- The Mahaweli Authority of Sri Lanka (having overall coordinating responsibility)

- The Mahaweli Development Board, referred to as "MDB"

- The Irrigation Department

- The Central Engineering Consultancy Bureau, referred to as "CECB".

An additional agency, to be known as the "Mahaweli Economic Agency", is in the process of being formed, and will be concerned with all aspects of the operation of the developments.

System B, covering an area of some 135 000 ha, will be served by the Maduru Oya project, comprising a 550-million m^3 storage reservoir in the Maduru Oya basin (to the east of the Mahaweli) which will receive substantial supplementary flows from the Mahaweli Ganga itself via a link tunnel.

The feasibility of the Maduru Oya project, including intensive settlement and irrigation development in System B, is the subject of this report. An earlier version of the feasibility report, based on incomplete soils and topographic information, was submitted in November 1979 and is referred to as the "Initial Issue" of the Feasibility Report. The purpose of that report was to provide sufficient information for financing decisions to be made pending the final conclusions reported herein.

1.2 - Objective of the Project

The Maduru Oya project reflects to a marked degree the Government's long-term objectives in promoting the Mahaweli Scheme. The principal aim is the establishment of an integrated rural society, which is able to sustain, through the medium of irrigated agriculture and associated activities, an acceptable standard of living, while contributing to the economic well-being of the country as a whole.

It will be appreciated that, in principle, accomplishment of this objective is not necessarily the same as maximizing the return on investment in the area, which might in theory be achieved with a lower concentration of settlement. However, the social benefits associated with the settlement aspects of the project, while difficult to quantify, are considered to be of prime importance by the Government. The productive settlement of 45 000 or more families in the project area is accepted as a major objective of the Maduru Oya project.

1.3 - Logic and Format of the Report

The format of any feasibility report should reflect the logic of the associated studies. In a typical irrigation project these studies start from a data base and follow three main paths

(a) Engineering - to determine the available water resources and define the physical works required to exploit these resources

(b) Agricultural - to determine and evaluate the agricultural production which can be achieved, and the irrigation water required to sustain this production

(c) Human - to determine the human resources and social infrastructure required for the agricultural development and to relate the impact of future settlement on existing communities.

The equalizing of water demands with available supply is evidently an essential feature of these studies and forms the link between the engineering and agricultural aspects. Once this water balance is satisfied, an economic appraisal of the project can be made.

It is evident that a choice must be made as to the appropriate order in which parallel series of studies should be treated. In the present case the format favored by the IBRD and FAO has been used as a guideline. After presentation of the general background factors, the report describes the physical features of the project and then proceeds to consider what the project will achieve. Treatment of the environmental aspects is followed by a description of the economic studies carried out to assess the project's feasibility. Conclusions and recommendations have been included with the summary which precedes the main text of the report.

The main text of the report is envisaged as a presentation of the feasibility studies as a whole, while detailed analyses and other supporting material are assembled in a series of annexes.

2 - BACKGROUND

2.1 - Sri Lanka - Physical Geography

The island of Sri Lanka is located off the southern tip of India between latitude 6°00'N and latitude 7°50'N. Roughly oval in shape, having a length in a north-south direction of 430 km and a width of 180 km, its area is 65 000 km^2. A general map is presented in Figure 1.

The central and southern part of the island is quite mountainous, with peaks rising to 2,500 m above sea level. The northern region is an undulating plain with occasional prominent rock outcrops.

The climate is dominated by the two monsoons characteristic of the South Asian region. The northeast monsoon affects Sri Lanka from December to February. This season is known as the "Maha". The southwest monsoon season lasts from May to September and is known as the "Yala".

Due to land configuration and other factors, the southwestern part of the island receives abundant rainfall from both the monsoons and is known as the Wet Zone. In contrast, the northern areas experience rainfall only during the Maha season and are known as the Dry Zone. An intermediate belt may be distinguished from the Dry Zone, in which a limited amount of rainfall occurs during the Yala season.

Consolidated rainfall data for typical location in these climatic zones are shown in the following tabulation.

Zone	Location	Average Rainfall (mm) Oct-Mar (Maha)	Apr-Sept (Yala)	Totals
Wet	Ratnapura	1 641	2 247	3 888
Dry	Anuradhapura	999	448	1 447
Intermediate	Kurunegala	1 116	959	2 075

The abundant rainfall occurring in both seasons in the mountainous areas of the Wet Zone gives rise to a number of important rivers, known for their relatively regular discharge patterns as "Gangas". Smaller rivers (especially in the Dry Zone) tend virtually to dry up in the dry season and are known as "Oyas". The largest river in the country is the Mahaweli Ganga, which rises in the mountains south of Kandy and, having traversed the northeastern part of the Dry Zone, discharges into the Bay of Bengal near Trincomalee.

In its natural state, Sri Lanka was substantially covered by forest. However, while in the Wet Zone this included extensive areas of equatorial rain forest (of which the Sinharaja Forest is but a remnant), the vegetation in the Dry Zone can be better described as "scrub jungle". Much of the forest cover in the mountainous areas has been lost to tea cultivation, while in the Dry Zone and the coastal plains the natural cover has been affected extensively by slash and burn ("chena") cultivation, followed in some areas by more permanent settlement.

2.2 - Sri Lanka - General Economic Geography

The climatic zones and physical features of Sri Lanka have had a dominant effect on the development of the country.

The original colonization of the island - in a series of invasions from India - took place essentially from north to south, with settlement for the most part in the Dry Zone. The desirability of irrigation development was recognized and some remarkable schemes, involving long diversion canals delivering water to storage tanks, were developed over the course of several centuries up to about the 14th century.

Since the 16th century, trading and commercial ventures by Portuguese, Dutch and, more recently, British interests have given rise to specific agrarian activities which survive as the mainstays of the Sri Lankan economy. Of these the more important are the tea, rubber and copra industries, development of which has taken place mainly in the central and southern parts of the country. These commodities account for 70 percent of Sri Lanka's export trade, and additional earnings result from minor export crops such as cocoa and various spices.

Rice is the major nonplantation crop, although a large variety of minor food crops is also grown for domestic consumption. In total, agricultural activities account for 30 percent of the national income. In terms of employment, over 50 percent of the work force is engaged in agriculture. The country's total labor force is estimated at 7 million; of this labor force over 1 million are unemployed.

Despite this emphasis on agriculture, Sri Lanka finds it necessary to import a number of basic foodstuffs. These include rice, flour, sugar, dried fish, and milk and milk products. One of the objectives of the Accelerated Mahaweli Programme is to reduce the nation's dependence on imported foodstuffs, particularly rice and sugar.

The present population of Sri Lanka is about 14 million. Table 2.1 gives the distribution of the population by district. The locations of the Districts of Polonnaruwa, Batticaloa, and Amparai are shown in Figure 3, which also indicates the principal towns, roads and railways in the region of the Maduru Oya project.

2.3 - Other Studies of Maduru Oya Project

The FAO studies of the late 1960's, which culminated in 1968 in a comprehensive set of reports and Master Plan for the Mahaweli Scheme(1), constituted the first detailed assessment of the potential of the Maduru Oya basin with its water supply augmented by diversion from the Mahaweli. These studies, which were conducted at a reconnaissance level, involved the following basic components specific to the project area, known as "System B".

- A reconnaissance-level soils map, which formed the basis for the estimation of lands of various categories which are available for irrigation.

- Irrigation system layouts (unpublished) based on the above plus existing 1:31 680 (20-ft contour) topographic maps.

- System operation studies, incorporating relevant elements of the main system, to allow sizing of the principal components of the Maduru Oya project.

- Cost studies and economic analyses based on the above.

In 1977, with the decision by the new government of Sri Lanka to accelerate the implementation of the Mahaweli Scheme, the Maduru Oya project took on new importance and more detailed

TABLE 2.1

SRI LANKA POPULATION BY DISTRICT - 1978

District	Population ('000)	Percent
Colombo	2 972	20.95
Kalutara	808	5.69
Kandy	1 285	9.06
Matale	354	2.50
Nuwara Eliya	468	3.30
Galle	814	5.74
Matara	660	4.65
Hambantota	388	2.74
Jaffna	801	5.65
Mannar	90	0.63
Vavuniya	111	0.78
Batticaloa	300	2.12
Amparai	316	2.23
Trincomalee	223	1.57
Kurunegala	1 159	1.87
Puttalam	437	3.08
Anuradhapura	458	3.23
Polonnaruwa	190	1.34
Badulla	665	4.69
Monaragala	228	1.61
Ratnapura	739	5.21
Kegalle	718	1.06
TOTALS	14 184	100.00

Source: Registrar General's Department

studies began. These were undertaken almost simultaneously in early 1978 by the Dutch firm of NEDECO and the Sri Lanka Government's CECB. These studies continued into mid-1979, and thus overlapped the feasibility studies which are the subject of this report.

NEDECO's studies covered all the component projects of the Mahaweli Scheme, with emphasis on the projects selected for early development, known as the Accelerated Mahaweli Programme. The data base was essentially unchanged from that developed for the FAO studies, and studies were conducted to evaluate the physical interaction among the projects, reassess the sizing of major system components, perform economic analyses, and conduct studies on feasible implementation rates.

Studies carried out by CECB focused on the headworks for the proposed project--the tunnel which is needed to divert water from the Mahaweli basin and the dam and associated power-houses. By late 1978, the studies had been carried into the feasibility stage, with reconnaissance-level assessments of agricultural benefits, again based on FAO data. In November 1978, the government decided to proceed directly to the Tender Document stage for the tunnel and the dam. Acres was assigned responsibility for the preparation of the documents for the tunnel, while CECB proceeded with their work on the dam. In February 1979, draft Tender Documents were presented to a CIDA-appointed Engineering Review Board. At this point three types of dam were under consideration--earth fill, rock fill and concrete gravity. The decision was made to drop the earth-fill alternative from further consideration, and to issue Tender Documents for both the rock-fill and concrete alternatives. The finalized documents were issued in August 1979, and bids were received in late November.

The following table summarizes the key elements of the project, as derived during the above studies.

	FAO(1)	NEDECO(3)	CECB(4)**
Minipe Right Bank Canal Capacity (m^3/s)	28.3	61	62
Means of Diversion	Tunnel	Tunnel*	Tunnel
Diversion Capacity (m^3/s)	24	24	34
Reservoir Full Supply Level (m)	97.5	97.5	95.5***
Live Storage Capacity ($10^6 m^3$)	344	429	467
Irrigated Area (ha)	44 000	50 500	50 500

The conclusions of these studies, along with Acres' Terms of Reference, defined the starting point and framework for the execution of the feasibility study of the Maduru Oya project.

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* As of late 1978. In March 1979, NEDECO suggested that a canal diversion alternative be assessed, but by then the preparation of Tender Documents for the tunnel had progressed so far as to make this impractical.

** As of February 1979.

***Earlier CECB and NEDECO studies set the FSL at 97.5 m but new reservoir surveys indicate that the dam could be lowered by 2.0 m with no loss of live storage.

3 - PROJECT AREA

The general layout of the Mahaweli Scheme, including the component projects already completed as well as those comprising the Accelerated Programme, is shown in Figure 2. System B occupies the Maduru Oya basin which lies to the east and is separate and distinct from that of the Mahaweli Ganga.

Figure 3 shows the location of System B itself in relation to the important centers of Trincomalee, Polonnaruwa and Batticaloa. The area is bounded in the north and west by Systems A and C respectively.

3.1 - Physical Features

The southern part of the project area, occupied by that portion of the Maduru Oya basin which drains to the proposed reservoir, is separated from the Mahaweli Ganga valley by a north-south line of hills of height up to about 670 m above sea level. These hills are Precambrian in origin, in common with the underlying formations throughout the project area. The link tunnel planned to divert water from the Mahaweli Ganga into the Maduru Oya reservoir will penetrate this line of hills. A spur from the northern end of this range traverses the Maduru Oya valley in a generally southeasterly direction. The gap through which the Maduru Oya flows in its northerly course forms the site of the proposed dam. At this point the river is about 67 m above sea level.

The irrigation area lies along either side of the Maduru Oya downstream from the Maduru Oya damsite. It is bounded on the southwest by the Hungamala Ela and System C, on the northwest

by the floodplain of the Mahaweli Ganga, on the north by System A, on the east by the lagoon lying inland from the Bay of Bengal, and on the southeast by the Meeyankolla Ela.

The geology of the area is characterized by Precambrian rocks. They have given rise to a mature, mantled and undulating peneplain which merges imperceptibly to the north and northeast into the Pleistocene and Miocene sediments of the coastal plain. Large, prominent and isolated erosional remnants and prominent ridges rise to heights of over 400 m (Gunner's Quoin) above the general level of the surrounding plain. The elevation of the latter varies from about 80 m above sea level in the south to under 30 m in the extreme north. The mantle covering the peneplain rock is generally thin and sometimes nonexistent, as in areas of rock knob plain and outcropping flat rock.

Two very different soils have developed on the Precambrian rocks. On those rich in ferromagnesian minerals, moderately deep to shallow (<100 cm), reddish to brown, sandy clay loam soils have developed, on slopes which often exceed 2 percent and sometimes 4 percent. These soils normally occur in association with prominent rock outcrops. On the rocks relatively poor in ferromagnesian minerals but rich in quartz, moderately deep to shallow, grey brown, loamy sand and sandy loam soils occur. These overlie impermeable rocks and usually occur on slopes not exceeding 4 percent. The soils of the upper slopes tend to be "moderately well" to "well drained" while those of the lower slopes tend to be "imperfectly drained".

Associated with these soils are "imperfectly" to "poorly drained" bottomland and old alluvial soils of variable but

usually sandy texture. These old alluvial soils are not necessarily associated with the present-day drainage. A relatively wide band of "imperfectly" to "very poorly drained" recent alluvium (with the exception of a low, narrow, moderately freely draining levee soil) occurs along the Maduru Oya and the Mahaweli Ganga.

3.2 - Climate and Hydrology

The Maduru Oya basin experiences a tropical climate, falling under the influence of the northeast (December to February) and southwest (May to September) monsoons. The northeast monsoon (Maha) brings most of the annual rainfall, and therefore runoff, in the catchment area (see Figure 4). The southwest monsoon (Yala) is typically dry due to the orographic effect of the Central Highlands of Sri Lanka. Rainfall in the intermonsoon periods can be caused by either convective or cyclonic storms. Relatively minor temperature fluctuations are normally experienced, compared with wider fluctuations in precipitation and streamflow. The latter fluctuations have important implications for the development of rainfed and irrigated agriculture.

3.2.1 - Rainfall Data

Daily rainfall data for long periods (over 100 yr in two cases) are available for several stations near the project area. There are six stations with reliable records covering the period of 1950 through 1977.*

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*This period was chosen by NEDECO for analysis of the hydrologic records in the entire Mahaweli Development area. It has been used in this study to produce results which are comparable to those computed by NEDECO.

Observations at two of the most useful stations from an agricultural point of view (Welikanda and Vakaneri) have unfortunately been discontinued in recent years.

The Meteorological Department has indicated, however, that these two stations could be reactivated shortly. The Welikanda station should be upgraded to allow measurements of key climatic parameters - temperature, wind velocities, sunshine etc to aid in the operation of the project and to provide basic data for agricultural research workers.

3.2.2 - Streamflow Data

Two stream gauges have been in operation on the Maduru Oya in the recent past (see Table 3.1). The long period over which no flow measurements were made (1960 to 1978) was a source of concern when the hydrological studies were undertaken. Results from the flow measurement program conducted in 1979 at Welikanda indicate, however, that only a minor shift in the rating curve (about .15 m) has occurred since flow measurements were discontinued in 1960. No adjustments to the flows estimated from the old rating curve are justified. Further checking of the reliability of the rating curve would require provision to be made for the safe measurement of flood flows, combined with the establishment of supplementary staff gauges to allow water surface profile calculations to be performed.

Flows at the Maduru Oya damsite have been estimated by NEDECO for the ungauged period using a regression equation developed with the flows at Welikanda as the independent variable. The correlation coefficient is high (R = .93), indicating a reliable relationship. In view of the reassuring results of the 1979 check on the Welikanda rating curve, the accuracy of the estimated monthly flows at the damsite should be adequate for use in reservoir operation studies.

TABLE 3.1

SUMMARY OF CHARACTERISTICS OF
MADURU OYA STREAMFLOW GAUGING STATIONS

Location	Drainage Area (km^2)[1]	Stage Observations			Maximum Estimated Flow (m^3/s)[2]	Flow Measurements			
		Begin	End	Missing		Begin	End	Maximum Stage (ft)	Maximum Flow (m^3/s)
Maduru Oya at Damsite	452	Feb 1951	Sept 1957	2 months	416	Nov 1951	Mar 1957	9.50	156
Maduru Oya below Damsite	459	Jan 1978	present	-	27	Oct 1978	present	N.A.[3]	N.A.[3]
Maduru Oya at Welikanda	966	Feb 1946	present	15 months	1 800	Nov 1953 Dec 1978	June 1960 present	11.0	202

Notes:

[1] Measured from 1 in. = 1 mile maps.

[2] Estimated by extending rating curve beyond the measured range and using the observed stage.

[3] N.A. - Not Available.

3.3 - Present Land Use

The availability of high quality aerial photographs taken in March 1979, coupled with field investigations, has facilitated the preparation of a map of existing land use. This map is presented in Figure 5. Table 3.2 summarizes the distribution of seven main land-use categories. It is interesting to note that of the total of 123 800 ha mapped in System B, some 66 700 ha are still forest covered. This forest cover is actively being encroached upon, as evidenced by the considerable area - 32 800 ha - affected by recent chena or slash and burn activity. Not including the 3,900 ha of rock outcrop, the remaining 20 400 ha are variously committed to permanent settlement, small paddy farming, homesteads, large farms and reservoirs.

It may be concluded from an examination of present land use that existing human commitment to the area does not constitute more than a modest constraint to development. However, a major impact on the natural environment is already making itself felt in the form of chena activity.

3.4 - Communications and Access

The project area is traversed by a main highway and rail connection between Polonnaruwa and Batticaloa on the east coast. The principal point of entry to the area in the west is at Manampitiya where the road and railway cross the Mahaweli Ganga on a common bridge.

An all-weather road runs south from Manampitiya, via the Pimburettewa Scheme, to the Maduru Oya damsite. Another road leads north from Welikanda to Kandakadu. On the right bank,

TABLE 3.2

SUMMARY OF PRESENT LAND USE IN SYSTEM B[1]

Land Use Category	Left Bank	Right Bank	Total	Percent of Total
	(areas - ha)			
Paddy				
- major schemes[2]	4 900	-	4 900	4.0
- minor schemes + rainfed	4 300	4 500	8 800	7.1
Subtotal	9 200	4 500	13 700	11.1
Chena	22 700	10 100	32 800	26.5
Forest				
- dense forest	1 000	300	1 300	1.1
- medium forest	31 800	18 000	49 800	40.2
- light forest (parkland)	9 200	2 000	11 200	9.0
- plantation	4 200	200	4 400	3.6
Subtotal	46 200	20 500	66 700	53.9
Homesteads, settlements	2 600	300	2 900	2.3
Tanks, standing water	2 800	400	3 200	2.6
Rock outcrops	2 800	1 100	3 900	3.2
Large farms[3]	600	-	600	0.4
TOTAL	86 900	36 900	123 800[4]	100.0

Source: Interpretation of 1979 aerial photographs

[1] The project area excludes the Mahaweli floodplain, but includes Pimburettewa, Vakaneri and Punanai schemes.

[2] Pimburettewa, Vakaneri and Punanai schemes. Note that Figure 5 does not include all of the Vakaneri scheme. The tabulated figures have been adjusted to include its entire area.

[3] Includes coconut plantation, Cashew Corporation Farm, Livestock Board Farm, Paper Corporation "Illuk Farm"--cultivated areas only.

[4] The gross area shown here differs slightly from that quoted elsewhere for the project. This is due to the airphoto coverage being limited to about 90 percent of the project area.

another all-weather road crosses the area from east to west, reaching a point opposite Welikanda. The ford across the Maduru Oya at this location is only passable in the dry season. No permanent bridge over the Maduru Oya yet exists upstream from Valaichchenai.

With a view to development activity in System B the general condition of these lines of communication must be regarded as below average. Upgrading of the Habarana - Polonnaruwa - Batticaloa road will be required and a new road traffic bridge across the Mahaweli at Manampitiya would be desirable. The railway connection is, basically, well suited to serve the project area, provided that sidings and terminal facilities at Manampitiya and Welikanda are improved. Apart from this, investment in railway system improvements should be concentrated on upgrading of the signaling system, rolling stock, traffic management and existing stretches of roadbed.

Within the project area, a basic network of rudimentary road exists which will require a major upgrading effort and further development. The interior of the project area is relatively inaccessible.

3.5 - Existing Development

The greater part of System B area lies within the administrative districts of Polonnaruwa and Batticaloa. A very small part of the area near the damsite falls within Amparai District. The boundaries between these districts are shown in Figure 3.

The population of the area is approximately 25 000; its density of 20 persons/km^2 is very low compared to the national average of 225 persons/km^2. Most of the economic activity is taken up by agriculture. Two major tank schemes dominate: Vakaneri in the east, which dates from the turn of the century; and Pimburettewa toward the southwest, which has been developed within the past 10 years. Limited commercial activity is apparent along the road between Polonnaruwa and Batticaloa. Social services in the area are below the national average.

Other aspects of the existing situation are discussed in succeeding sections.

4 - THE PROJECT

4.1 - General Description

The layout of the physical features of the Maduru Oya project is shown on Figure 6. The irrigation works are considered under the following headings.

- Headworks, comprising the dam and reservoir, plus the link tunnel through which water is diverted from the Mahaweli Ganga valley to the reservoir

- Main Canals

- Tertiary Systems and Drainage

- On-farm works.

It is evident that a share of the Minipe Right Bank Trans-basin Canal in the Mahaweli valley must also be considered as part of the Maduru Oya project.

The social infrastructure required in connection with the settlement of some 40 000 families is described in Section 5. The following paragraphs provide a concise description of the irrigation works and studies related thereto. Further details may be found in Annexes B (Soils and Land Classification), C (Hydrology and Water Balance), and D (Engineering Works).

As already discussed in Section 2.3, the magnitude of the irrigation works has been the subject of a series of interrelated studies by CECB/SOGREAH[2,4] and NEDECO[3]. Thus, the following key dimensions were indicated on the basis of irrigation water demands assumed prior to the current, more definitive, land use studies.

Maduru Oya Reservoir Full Supply Level	- 95.50 m
Maduru Oya Reservoir Gross Storage	- 555 $10^6 m^3$
Maduru Oya Reservoir Live Storage	- 467 $10^6 m^3$
Link Tunnel Design Capacity	- 34 m^3/s
Left Bank Canal Design Capacity	- 48 m^3/s (now revised to 56.2 m^3/s)
Right Bank Canal Design Capacity	- 35 m^3/s (now revised to 32.5 m^3/s)

The present feasibility studies, based on updated water requirements, serve to demonstrate the adequacy of a project having the above dimensions.

4.2 - Land Classification

Reliable land classification is a prerequisite for all other studies related to the planning of an irrigation project. The characterization and delineation of lands to be developed allows the agricultural, engineering and socioeconomic studies to proceed on a strong factual base. The following paragraphs describe the data base and methodology employed in the land classification work carried out for this study, and present an overall assessment of the land resources of the project area. Further details are presented in Annex B.

4.2.1 - Mapping

Semidetailed soils mapping, with overlapping topographic mapping at scales of 1:5,000 or 1:3,168*, is available from the Land Use Division (LUD) of the Irrigation Department for all of the project area.** Earlier assessments of the project's viability were based on a reconnaissance-level soils map prepared by the FAO in the course of earlier studies,(1) with overlapping topographic mapping at a scale of 1:31 680.

4.2.2 - Soils

Fifteen great soil groups have been identified in Sri Lanka, six of which occur in the project area.

(a) The Reddish Brown Earths (RBE)
(b) The Noncalcic Brown Soils (NCB)
(c) The Low Humic Gley Soils (LHG)
(d) The Recent Alluvial Soils (RAL) of the Maduru Oya and Mahaweli Ganga
(e) The Old Alluvial Soils (OAL)
(f) The Solodized Solonetz Soils (SS)

The great soil groups have been divided for this study into upland and lowland categories, on the basis of natural internal drainage.

*The existence of these two scales reflects the fact that Sri Lanka is in the process of adopting metric standards. It will be some time before mapping originally processed to Imperial Scales is transformed to metric scales.
**The Initial Issue of this report was based on semidetailed mapping for about 67 percent of the project area.

Upland Soils

The Upland category consists of well to moderately well drained RBE, NCB and upper levee bank soils. This group is never waterlogged for any appreciable time during the year. Large areas of shallow, steeply sloping (slopes exceeding 4 percent), gravelly or high (and therefore uncommandable), Reddish Brown Earth soils occur. The shallow and moderately shallow phases are unsuitable for irrigated agriculture. The freely to moderately freely drained Reddish Brown Earth soil series are the Wilayaya, Manampitiya, Ulhitiya and Muthugala series. Well drained RBE's occupy 16 percent of the project area.

The well to moderately well drained Noncalcic Brown soils identified by LUD are the Maduru and Welikanda Series. The Maduru Series consists of moderately deep, dark grayish brown to pale yellowish brown, loamy sand to sandy loam with some manganese concretions and gravel over impermeable, quartz-rich, acid rock. A high percentage of the sand is coarse. A second series, the Welikanda Series, occurs where the clay content in the subsoil exceeds 15 percent. This soil is darker in color and may represent a transition zone to the brown phase of the Reddish Brown Earths. Well drained NCB's occupy 12 percent of the project area.

Also included in the category of Upland soils, but of alluvial origin, is the moderately well drained, narrow Maduru Oya levee soil. It is known as the Bulatiebbe Series, and occurs over less than 1 percent of the project area.

Lowland Soils

The imperfectly drained soils are naturally waterlogged throughout the rainy season and well into the dry season. Some of the soils mapped in this group will be unusable for agriculture during some parts of the year unless flooding can be controlled.

The imperfectly drained Reddish Brown Earths occur as part of the catenary sequence of which the freely drained Wilayaya, Muthugala, Manampitiya and Ulhitiya Series form the upper members. Four series, the Alawakumbura, Mawakulam, Horaborawewa and Padamundakulam, have been identified. Together they occupy 7 percent of the project area.

The imperfectly drained Noncalcic Brown soils are represented by the Maduru variant, known as the Galwewa Series. A second series, the Boattewewa, is a variant of the Welikanda Series and has a slightly higher clay content. Together, these two series occupy 23 percent of the project area.

The lowest lying group of soils consists of imperfectly to very poorly drained Recent Alluvial, Old Alluvial, Low Humic Gley and Solodized Solonetz soils. Recent Alluvials associated with the Maduru Oya are the Timbiri Aru, Odigar Villu and Beliannewala series, which together account for 6 percent of the project area.

The Old Alluvial soils in old tributary valleys vary in texture and drainage. Whereas the Ulpothawewa Series is typically imperfectly drained, pale brown to grayish brown, sandy loam underlain at about 60 cm by gleyed sandy clay loam,

the Moogamana Ela Series is a poorly drained, gleyed gray to dark gray sandy clay loam with a thin sandy loam layer on the surface. The Kumarapuragama and Arasanagar Series are deep, medium to coarse sands, the first being well drained and the second imperfectly drained. The Old Alluvials occupy 20 percent of the project area.

The Solodized Solonetz soils, which occur on nearly level land, consist of light brownish to white sand, overlying gray to olive gray, mottled alkaline clay which sometimes shows a columnar structure. The Pochchakadu Series is considered to be slightly better drained than the poorly drained Vakaneri Series. These soils occupy under 1 percent of the project area.

The remaining Lowland soils are the Low Humic Gleys that occupy the valley bottoms. Three poorly drained series have been identified: Mailadeniya, a deep loamy sand over sandy clay loam, and the Kuda Oya and Damminewala Series, both sandy clay loam over sandy clay in texture. The LHG's occupy 3 percent of the project area.

4.2.3 - Land Classification

The approach to land classification used in this study follows the general principles laid down by the United States Bureau of Reclamation (USBR), with modifications where necessary to meet local requirements and maintain consistency with studies of other projects in the Mahaweli Scheme. In formulating the criteria for land classification, the following assumptions were made.

- Most of the area and irrigation water would be given to annual crops.

- Surface methods of irrigation (furrow or basin) would be used.

- Where drainage is not restricting, a variety of upland crops would be grown (i.e. on the soils of the upper slopes); where drainage is restricting, paddy would be the main crop (i.e. on the soils of the lower slopes and bottom-lands).

- Perennial crops, and homesteads, would preferably be located on land classed as unsuitable for annuals.

- While deviation from these assumptions might be considered, such deviations would be occasional and thus warrant special attention at the detailed project planning stage.

Thus, the land classification is based on two broad groups

(a) Upland (designated "U") for moderately well to well drained soils of the upper slopes, and

(b) Lowland (designated "R") for the imperfectly, poorly and very poorly drained soils of the lower slopes and bottom lands.

Within each group there are three land classes.

Class 1 - Soils with no or minor limitations to annual cultivation, capable of producing good yields with minimum expenditure.

Class 2 - Soils with moderate to moderately severe limitations to annual cultivation, but capable of producing reasonable yields with acceptable levels of expenditure. These soils will require higher

land development costs and/or inputs of fertilizer and water than those of Class 1, and returns may be appreciably lower. Limitations imposed by soil type or depth are designated by the subscript "s", while topographic limitations (the most important of which is slope) are designated by the subscript "t".

Class 6 - All soils that do not meet the criteria for Classes 1 and 2. This includes both arable and nonarable land. Nonarable land is designated "6N" and includes rock, roads, tank bunds, tanks and water-courses. Potentially arable land is designated "6U" or "6R", and includes land that may or may not have agricultural potential, depending on the severity of the limitations.

The freely draining Reddish Brown Earth soils have been assigned a basic land class of "1U"* when soil depth or topography are not limiting. The higher clay content series of the Noncalcic Brown soils have been assigned basic "$2U_s$" (the Welikanda Series) and "$2R_s$" (the Boattewewa Series) land classes, while the low clay content series have been assigned to Class 6. The lowland soil series having physical and chemical characteristics which render them suitable for lowland paddy cultivation have been assigned basic land classes of "1R" or "$2R_s$".

*Except for Wilayaya Series, which has been assigned to Class "$2U_s$".

The sandier series which have unsuitable physical and/or chemical characteristics have been assigned to Class "6R", due to their much higher water requirements and lower potential productivity.

Table 4.1 summarizes the distribution of the Upland and Lowland land classes, according to map areas outlined in Annex B. The boundaries of the Pimburettewa and Punanai schemes, as well as the limits of gravity command of the proposed irrigation system are accounted for in this table. The areas in the Upland "1U" and "2U") and Lowland ("1R" and "2R") land classes represent the gross areas available for gravity irrigation by the proposed system.

The areas of irrigable land shown in Figures 6 and 7, and summarized in Table 4.1, indicate that the project area is dominated by land suitable for lowland paddy cultivation. Land classed as "1U" and "2U" occupies only 25 percent of the total irrigable area under command. Furthermore, these upland areas occur in small, scattered blocks throughout the project area. The largest contiguous block is only 430 ha in extent, and only 5,610 ha of the 13 300 ha area classed as "1U" or "2U" occurs in blocks of over 35 to 40 ha. This will have important implications in selecting cropping and land holding patterns in the uplands.

4.3 - Water

The influence of the hydrological cycle on the Maduru Oya project can be considered under two main headings--water requirements and availability for irrigation, and flood hydrology. The first topic relates to the assured provision of irrigation water to allow full agricultural potential to be reached, whereas the second relates to the evaluation and accommodation of the effects of storm events on cropping potential and engineering design.

4.3.1 - Irrigation Water Requirements

The computation of monthly crop water requirements for the 1950 to 1977 simulation period adopted by NEDECO(3) was based on the following generalized equation

$$\text{Water Requirements (mm)} = \frac{ET_c + LP + P - ER}{e} \qquad (1)$$

here ET_c* = Crop evapotranspiration (mm)
LP* = Land preparation requirement (mm)
P* = Deep percolation losses (mm)
ER = Effective rainfall (mm)
e = Overall efficiency factor

This equation was solved for four different land class types--one Upland, two Lowland (Classes "1R" and "2R") and one Floodplain (Class "1R"). Effective rainfall for the 28-yr simulation period was calculated for paddy lands using a formula developed by the LUD, and for the uplands using the approach outlined in FAO Paper 24.(6) The key assumptions underlying the calculation of the project water requirements are summarized in Table 4.2, and the total** monthly water requirements for System B are shown in Table 4.3.

* The derivation of these parameters is explained in Section 6.2.4.
**For the "full development" case. As discussed in Section 4.3.3, there is a need to reduce these demands to achieve a water balance.

TABLE 4.1

SUMMARY OF LAND CLASSES WITHIN GRAVITY COMMAND ('000 ha)

Sector	Map Area	New Development Area												Major Schemes - Existing									Total Area							
		Within Gravity Command								Above Gravity Command				Irrigable									Irrigable							
		Uplands			Lowlands			Non-Irrig	Total	Irrigable		Non-Irrig	Total	Uplands			Lowlands			Non-Irrig	Total	Scheme Name	Uplands			Lowlands			Non-Irrig	Grand Total
		(1U)	(2U)	(1U+2U)	(1R)	(2R)	(1R+2R)			(1U+2U)	(1R+2R)			(1U)	(2U)	(1U+2U)	(1R)	(2R)	(1R+2R)				(1U)	(2U)	(1U+2U)	(1R)	(2R)	(1R+2R)		
1	1	1.61	2.09	3.70	6.76	5.10	11.86	10.67	26.23	0.70	0.01	6.22	6.93	0.19	0.19	0.38	1.28	0.55	1.83	1.90	4.11	Pimburettewa	1.33	3.45	4.78	8.04	5.66	13.70	18.79	37.27
2	2	1.63	0.22	1.85	2.02	2.53	4.55	3.55	9.95	0.75	0.23	1.33	2.31										1.03	1.57	2.60	2.11	2.67	4.78	4.88	12.26
	3	0.91	2.76	3.67	7.15	7.79	14.94	14.79	33.40	1.01	0.51	3.39	4.91										1.03	3.65	4.68	7.32	8.13	15.45	18.18	38.31
	Sector 2	2.54	2.98	5.52	9.17	10.32	19.49	18.34	43.35	1.76	0.74	4.72	7.22										2.06	5.22	7.28	9.43	10.80	20.23	23.06	50.57
3	4	0.07	1.66	1.73	1.82	4.68	6.50	5.69	13.92	0.48	0.33	3.81	4.62										0.06	2.15	2.21	1.82	5.01	6.83	9.50	18.54
	5	0.32	2.03	2.35	5.73	5.24	10.97	12.74	26.06	0.69	0.24	0.42	1.35		0.07	0.07	1.74	0.01	1.75	0.18	2.00	Punanai	0.34	2.77	3.11	7.49	5.47	12.96	13.34	29.41
	Sector 3	0.39	3.69	4.08	7.55	9.92	17.47	18.43	39.98	1.17	0.57	4.23	5.97		0.07	0.07	1.74	0.01	1.75	0.18	2.00		0.40	4.92	5.32	9.31	10.48	19.79	22.84	47.95
GRAND TOTAL		4.54	8.76	13.30	23.48	25.34	48.82	47.44	109.56	3.63	1.32	15.17	20.12	0.19	0.26	0.45	3.02	0.56	3.58	2.08	6.11		3.79	13.59	17.38	26.78	26.94	53.72	64.69	135.79

TABLE 4.2

SUMMARY OF KEY ASSUMPTIONS USED IN COMPUTING WATER REQUIREMENTS

	Land Class Grouping			
	Lowlands		Flood Plain	Uplands
	1R	2R	1R	1U + 2U
Areas (ha)*	14 400	20 350	2 430	2 580
Land preparation (mm)	180	180	180	75
Percolation rate (mm/d)	3	6	3	-
Calculation of effective rainfall	LUD Formula**	LUD Formula**	LUD Formula**	FAO Paper 25[16]
Farm/distribution efficiency	0.70	0.70	0.70	0.50
Main canal efficiency	0.90	0.90	0.90	0.90
Overall efficiency	0.63	0.63	0.63	0.45

* Areas corresponding to "full development" case. See Section 4.3.3 for a discussion of the need to eliminate an area to achieve a water balance.

** LUD Formula: ER (mm) = 0.67 (MR-25) Max ER = 225 mm.

TABLE 4.3

SYSTEM B - IRRIGATION WATER REQUIREMENTS - FULL DEVELOPMENT
(10^6 m^3/month)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1950	95	114	14	194	188	227	180	11	5	132	100	79	1339
1	37	101	77	140	180	227	179	40	34	145	29	64	1253
2	37	117	81	162	189	227	163	46	52	144	64	66	1348
3	67	134	88	168	206	214	109	9	16	89	45	26	1171
4	37	101	44	159	197	227	178	37	52	109	103	26	1270
5	49	74	88	131	203	227	178	22	1	143	126	68	1310
6	85	118	88	193	206	189	164	18	45	94	29	40	1269
7	113	13	89	194	169	227	171	46	49	121	29	26	1247
8	107	112	55	145	146	227	147	9	47	139	117	26	1277
9	50	138	88	184	196	226	179	28	36	94	49	47	1315
1960	37	13	82	144	181	227	115	46	44	154	29	96	1168
1	37	23	46	193	177	227	150	46	23	135	29	26	1112
2	118	137	74	189	184	227	143	46	26	69	62	32	1307
3	37	13	50	153	206	227	179	45	7	95	29	26	1067
4	93	61	38	194	167	227	118	11	52	119	140	110	1330
5	138	13	88	159	202	227	180	9	52	146	29	26	1269
6	80	137	37	180	201	224	178	6	20	52	29	66	1210
7	141	72	73	170	202	226	179	43	47	94	29	26	1292
8	123	138	47	192	206	227	179	46	52	163	58	52	1483
9	142	108	88	85	203	227	177	10	37	73	116	26	1347
1970	111	46	79	165	166	217	180	33	29	151	49	61	1287
1	68	133	77	152	200	227	155	24	44	133	108	26	1347
2	166	137	86	189	168	209	178	46	3	52	74	39	1347
3	169	118	55	163	168	188	99	34	1	120	88	26	1229
4	170	124	85	143	190	224	177	43	20	181	93	73	1523
5	118	79	15	125	179	224	65	23	50	110	61	26	1075
6	88	137	89	179	204	214	174	27	29	142	29	26	1338
7	115	127	37	125	177	223	140	26	19	92	29	26	1136
AVG	94	94	66	163	188	222	158	30	32	118	63	45	1273

Note: These water demands are computed for the "full development" case. See Section 4.3.3 for discussion of the need to reduce these demands to achieve a water balance.

M.C.D.

4.3.2 - The Water Supply

Quantity

The irrigation water demands presented in Section 4.3.1 are much larger than the available natural water supply in the Maduru Oya basin. The approach taken for this and preceding studies is to provide for the diversion of sufficient water into the Maduru Oya reservoir via the link tunnel to supplement the natural flows. The combined inflows will be reregulated, using the storage provided by the Maduru Oya reservoir, to supply the irrigation water requirements. The recent NEDECO studies have confirmed that there is sufficient surplus water available in the Mahaweli basin to permit the diversion of the quantity of water likely to be needed for the Maduru Oya project.

Quality

Limited water quality data are available for the Maduru Oya and Mahaweli basins. Additional testing of water samples is being carried out as part of the USAID-sponsored environmental study of the Mahaweli Scheme. Initial results from the latter program and the analyses available from other sources indicate that the potential water supply is of good quality. Electrical conductivity levels are below 170 μmhos/cm in the Mahaweli and below 30 μmhos/cm in the Maduru Oya. The maximum computed Sodium Adsorption Ratio (SAR) is 2.25. According to the standards published by the U.S. Department of Agriculture (USDA)[7] and the Food and Agriculture Organization of the United Nations (FAO)[8], the combination of Mahaweli and Maduru Oya water which will irrigate the project area should fall into the "no problem" category for both salinity and sodium

hazards. This, combined with the heavy Maha rainfall and basic drainage provisions to be incorporated into the project design, will render water quality problems unlikely.

4.3.3 - Water Balance

In a development project which is as complex as the Mahaweli Scheme, the first objective should be to ensure that limited water resources are being used to the best advantage. Thus the decision as to whether System B should receive Mahaweli water should be made in the context of other opportunities to use it. The NEDECO and CECB/SOGREAH studies have addressed this question and confirmed that water use in System B at the proposed level of development constitutes an economical use of the resource. These studies also led to the decision to fix the headworks design parameters at the levels quoted in Section 4.1.

The water requirements which are presented in Table 4.3 are greater than those computed by NEDECO, due to changed unit water requirements, cropping patterns and estimated irrigable areas. They are also greater than those computed for the Initial Issue of this report.(5) The limited number of computer runs reported herein are intended to assess the performance of the delivery system (the Minipe Right Bank Canal, link tunnel and Maduru Oya reservoir) which was sized by NEDECO in cooperation with the Irrigation Department and CECB. No changes to the headworks design parameters are assumed to be possible, but tests of the effects of increasing the size of each of them individually are shown for illustrative purposes.

4.3.3.1 - Simulation Results

Table 4.4 summarizes the results of six computer runs which were executed by MDB staff in June 1980 using the NEDECO computer program. The program considers the interaction of Systems B and C*, given a set of upstream regulation conditions. Shortage frequency and total shortage volume over the 28-yr simulation period are shown in the table as indicators of system performance. Since it is not normally practical to design for a "zero shortage" condition for an irrigation project, a frequency of serious shortage of about 1 in 10 yr (2 or 3 occurrences in 28 yr) is regarded as acceptable; this was the condition reached for full irrigation demands in the studies leading to the Initial Issue of the Feasibility Report.(5)

The first set of runs (Runs 1 - 3) show how the system performs under 100, 95 and 90 percent of full irrigation demands respectively. Run 1 indicates an unacceptably high frequency and volume of shortages for full irrigation demands; almost 50 percent of the simulated years had some shortages, most of them serious. Run 2 shows a reduction in shortages, and Run 3 shows an almost complete elimination of shortages. Interpolating between the results of Runs 2 and 3 indicates that about 92 percent of full demand could be supplied with the acceptable volume and frequency of shortage described above.

A further set of runs (Runs 4, 5 and 6) was also executed to assess the effects on System B's shortages of individually increasing the capacity of the three major headworks elements which affect the project. The results in Table 4.4 indicate

*The most recently computed demands for System C were used, based on assumptions contained in Hunting Technical Services Limited's 1979 report(9), combined with cropped areas revised in 1980.

TABLE 4.4

SUMMARY OF SIMULATION RESULTS[1]

Irrigation Demand Level		Minipe R.B. Canal Capacity	Link Tunnel Capacity	Upstream Regulation	Shortages In System B	
System B	System C	(m^3/s)	(m^3/s)		Years[2]	Volume[3] ($10^6 m^3$)
Full Demands	Full Demands	62.0	34	Victoria, Kotmale	6	285
Full Demands	Full Demands	55.8	34	Victoria, Kotmale	10	744
Full Demands	Full Demands	68.2	34	Victoria, Kotmale	0	0
50% Demand	50% Demand	62.0	34	Kotmale only	0	0

Notes: [1]Basic Conditions:
- Maduru Oya Reservoir FSL = 95.5 m Live Storage = 467 x $10^6 m^3$
- System C demands - the "Sugar Option"

[2]Of a possible total of 28 years in the simulation period

[3]Total shortage volume over the 28 year simulation period

that increasing by a modest amount the capacity of any one of the headworks elements would be insufficient to satisfy 100 percent of irrigation demands. A combination of increased capacity dam height, link tunnel capacity and Minipe Right Bank Canal capacity would be required.

In preparing the Initial Issue of this report, a computer run was executed which assessed the ability of the Maduru Oya reservoir to satisfy irrigation water demands before the completion of the Victoria dam, with partial development of Systems B and C. This run indicated that over 50 percent of the full demands (as computed at that time) could be met with no shortages. It can be inferred from this run that the Yala 1985 cropped area (for Scenario A) of 2 300 ha of paddy land can be irrigated with a low probability of shortage. This will be the last Yala crop grown before the Victoria dam provides regulated flows to the Minipe Anicut.

It should be noted that the water demands of System C during the peak usage months of May, June and July have a significant influence on the behavior of the Maduru Oya reservoir. During these months, the quantity of water available for diversion through the link tunnel is reduced to a level below its hydraulic capacity. Since these are months of low natural reservoir inflows and high System B irrigation demands, the quantity of water diverted through the tunnel will directly affect the minimum reservoir level, which is normally reached at the end of July. A 20 percent increase in May to July water demand in System C would, therefore, deprive System B of the same amount of water--an average of 59 million m^3/yr. The frequency and magnitude of shortages in System B would increase as a result.

4.3.3.2 - Implications for Project Development

It is clear from the simulation studies reported herein that the combination of diversion and storage works committed in the Mahaweli and Maduru Oya basins is not capable of delivering the water requirements now estimated for the full potential development area. It is estimated that about 92 percent of these demands can be reliably met. Since the irrigation water requirements are theoretical values which will undoubtedly prove inaccurate under actual project conditions, it is recommended that the following project development sequence be followed.

(a) Develop about 92 percent (i.e. eliminate some 3 200 ha of paddy land and 200 ha of uplands) of the total project area, postponing development of a relatively expensive* "tail-end" area of the project to achieve a water balance. Allow for the later development of the area by providing adequate upstream canal capacities, turnout structures, etc.

(b) Implement a water use monitoring program as the project is developed, so that projections of ultimate water demand levels can be revised to reflect actual project conditions. This program should be combined with a concerted effort to deliver water efficiently and equitably.

*Annex L contains a discussion of the economics of choosing among three potential "drop off" areas, the locations of which are indicated on Figure 6.
(a) The area commanded by Branch Canals LB-L7 and LB-R8
(b) The area commanded by Branch Canals LB-L10 and LB-R8
(c) The area commanded by Branch Canal RB-R1.

(c) Using new information on the operating policies to be followed at Polgolla diversion, Victoria dam and Minipe Anicut, along with revised estimates of System C demands, perform new simulation studies to assess the level of water demand which can be met within System B.

(d) If the simulation studies indicate that it is feasible, proceed with the development of the postponed area. This would involve the constructon of the necessary lined branch canals and the construction of the tertiary irrigation and drainage systems, socal infrastructure, etc. No modifications to the headworks or main canals would be involved.

Section 4.4.4 contains calculations related to the estimation of the "base case" net irrigable area. This incorporates a reduction of the irrigated area through the deferral of development of the area commanded by Branch Canals LB-L10 and LB-R8, and a discussion of the rationale for choosing this area over other potential "drop off" areas.

4.3.4 - Flood Hydrology

The Maduru Oya

The Maduru Oya floodplain, in its current, unregulated state, experiences short duration flooding during the Maha season. For example, the cyclone of November 23/24, 1978 caused widespread flooding, the maximum extent of which is shown on Figure 6 for the lower floodplain area.

The Maduru Oya dam will control the runoff from some 47 percent of the drainage area at Welikanda. It can be expected to provide substantial flood control benefits in the floodplain area, particularly in the reduction of the magnitude and duration of persistent flooding during the Maha season. More intense flood peaks will be affected less, since the effects of an intense storm event on the smaller watershed area downstream from the dam will be to cause a larger peak flow per unit area than would have resulted from the same storm over the entire catchment.

Hydrological studies were conducted, using the unit hydrograph approach, to determine the influence of the dam on flood peaks of sufficiently high probability of exceedence to be used in agricultural planning. In these studies, it was assumed that spill from the dam would make no contribution to the flood peak, due to the probability of a low initial reservoir level and to the delay in peak occurrence to be expected by routing the flood through the reservoir. An examination of reservoir operation simulation runs confirmed the practicability of operating the reservoir to allow full attenuation of minor (up to 10-yr average recurrence interval) floods. The unit hydrograph analyses indicated the following effects on flood peaks at Welikanda.

Average Recurrence Interval	Before Dam (m^3/s)	After Dam (m^3/s)
5 yr	907	677
10 yr	1,190	875
25 yr	1,590	1,130

Topographic and rating curve information indicates that the reduced 5- and 10-yr peaks would still cause significant damage to crops, particularly in the area close to Welikanda, where the narrow floodplain will result in greater flood depths, more rapid rates of water level increase and higher flow velocities. Flood records at Welikanda were therefore examined to determine whether late transplanting of the Maha paddy crop, combined with the flood control benefits from the reservoir, would allow productive cultivation of the lower floodplain area. These studies indicate that the flood peak which can be expected to occur on the average once in 5 years after January 15 is only 300 m^3/s, versus the "pre-dam, whole season" 5-yr peak of 967 m^3/s. The former flow would probably* result in very minor flooding in the lower floodplain.

The Mahaweli Ganga

Flow records for the Mahaweli Ganga at Manampitiya indicate that inundation of the floodplain under present conditions lasts for as long as 3 months in the Maha season. Widespread inundation typically begins in late October, and often lasts until late January.

The ultimate potential of the Mahaweli floodplain would depend on the following important factors, none of which can be accurately determined at this time.

*This should be confirmed by hydraulic analyses or by observations of flood stages in the lower floodplain area.

(a) The location of the System A weir. If the originally envisaged site near Kandakadu is chosen, backwater effects from the weir will modify the flood regime. The extent of this modification will be intimately related to the configuration of headpond dikes. If an alternative site at Kalinga Nuwara is chosen, the System A Main Canal will run along the edge of the floodplain, isolating it completely from System B.

(b) The degree of flood regulation to be achieved by the main stem reservoirs to be constructed upstream. This will depend on reservoir sizes and flood operating policies, neither of which have been finalized for most of the reservoirs.

(c) The floodplain is now an important grazing and wildlife area. A strong case can be made for preserving it as such.

The Mahaweli floodplain was excluded from the irrigation development area for purposes of this study because of these factors. Future activities in the area are assumed to be compatible with annual long duration flooding.

Small Catchments

Frequency analysis of storm events was conducted for several nearby rainfall stations and the results compared with a regional storm rainfall frequency study.(10) Rainfall intensity-duration-frequency curves are presented in Annex C for use with unit hydrograph or similar methods in the design of major drainage conveyance works. Minor drainage channels can be sized in accordance with locally established unit storm water duties, which are documented in Annex D.

4.4 - Irrigation Works

4.4.1 - Headworks

Right Bank Transbasin Canal and Link Tunnel (Figures 8 and 9).

In the Mahaweli Ganga valley the existing anicut at Minipe serves a centuries-old irrigation system (called System E) on the left bank of the river. It is planned to replace this anicut with a new diversion structure which will serve not only the Mahaweli left bank but also, via the Right Bank Transbasin Canal, Systems B and C of the Accelerated Programme. The Minipe Right Bank Transbasin Canal leads to the Ulhitiya and Ratkinda reservoirs which are interconnected, and to this point the canal is a common feature of the irrigation works for these systems. The Ratkinda reservoir forms the headworks for the northern part of System C and also for the link tunnel leading to the Maduru Oya reservoir.

The link tunnel has a length of 5.7 km between portals. It has a modified "D" type horseshoe section, 5 m by 5 m, and is unlined except for the concrete-paved invert. The tunnel is designed to operate under low pressure with the control gate at the downstream end.

The tunnel is approached through an inlet channel 900 m in length, designed so that the planned maximum flow of 34 m^3/s can be passed when the Ratkinda reservoir is drawn down to its minimum working elevation of 104.42 m. The intake structure incorporates trashracks and provision for stoplogs.

Exploratory drillings have indicated that the rock, principally granite gneiss, is sound throughout the length of the tunnel, with the exception of the portal areas where the diminished cover introduces the likelihood of some weakness due to weathering. This situation is normal and the effects are minimized by locating the tunnel so that deep cover is reached as soon as possible after entry. The only other area of some concern is near the downstream end of the tunnel where it passes through two dolerite dikes. Provision has been made for fully lining the tunnel in this area.

The downstream portal structure houses a control gate with electrically operated hoist. A short open channel, paved to resist erosion, conveys the tunnel discharge to the Vila Oya, a tributary of the Maduru Oya. Provision has been made for the improvement of the natural channel of the Vila Oya to take the tunnel flow.

Dam and Reservoir (Figure 10)

The site of the Maduru Oya dam is clearly dictated by topography. The range of hills striking in a southeasterly direction across the valley, referred to in Section 3.2, is pierced by the river at a point 33 km south of Welikanda. This creates a narrow gap which, superficially, forms an attractive damsite.

The main rock types observed at the damsite are quartzo-felspathic gneiss, calc-gneiss and hornblende biotite gneiss. Geological exploration has been carried out, by means of trenching and core drilling. These investigations indicate overburden ranging in depth from 2 to 10 m, below which the bedrock may be affected by weathering to depths generally in the range of 2 to 8 m. Weathering occurs to a depth of over 20 m on the left flank where the bedrock consists of calc-gneiss.

Three types of dams have been considered during the course of the studies: earth-fill, rock-fill and concrete gravity. It was concluded that the earth-fill option was less favorable than the other two, but comparative cost studies failed to show a clear advantage between the rock-fill and concrete gravity dams. It was therefore decided to prepare tender designs and specifications for both these alternatives so that a final choice could be made on the basis of firm tendered prices. It has been decided, on the basis of tenders received in late 1979, to proceed with construction of the rock-fill dam. For the purpose of this report, therefore, the following description and cost estimate are based on the tenders for the rock-fill dam.

The proposed rock-fill dam incorporates a central impervious core protected on each side by filter zones of appropriately graded material. The main shell of the dam comprises rock fill obtained from an adjacent quarry and compacted in layers. The maximum height of the dam is 40 m and the crest length 1,008 m. The crest of the dam is set at El 101.0 to allow for a flood rise of 1.9 m plus a 1.6-m margin for wind set-up and wave action.

On the downstream face, a 10-m wide berm is formed to carry the future public road leading from the right bank to Manampitiya. If more detailed location studies indicate that the road should preferably be carried on the crest of the dam, the design can be readily adapted with insignificant changes in overall cost.

The spillway is designed to pass the "Maximum Probable Flood", under which conditions the estimated surcharge is 1.9 m, as noted above. The spillway takes the form of a simple

ungated overflow weir located on the left abutment of the dam. This weir discharges into a chute which returns the flow to the river channel immediately downstream from the dam.

Minor saddle dams are required to ensure closure of the reservoir rim at El 101.0 m. These embankments are formed of compacted homogenous fill protected on the upstream face by riprap.

Irrigation Outlets and Power Plants

On the right bank a reinforced concrete intake structure is founded on bedrock at the upstream toe of the dam embankment. This structure incorporates trashracks and a closure gate. From the bottom of the intake structure a reinforced concrete pressure conduit 4 m in diameter and founded on bedrock leads to a powerhouse structure located at the downstream toe of the dam. Immediately upstream from the powerhouse the pressure conduit bifurcates, one branch feeding a conventional 2.4-MW Kaplan turbine generating unit and the other branch forming the irrigation outlet controlled by a 2.6 m by 3.5 m steel gate. In normal circumstances, irrigation deliveries will be passed through the generating unit. The separate irrigation outlet acts as a bypass when irrigation requirements exceed the capacity of the generating unit or when it is shut down for any reason. The tailrace from the powerhouse and irrigation outlet leads directly into the Right Bank Main Canal, where a side spillway permits the return of surplus water to the river. The maximum irrigation flow at the headworks is estimated to be 32.5 m^3/s.

On the left bank, a natural depression is deepened to form a channel capable of passing the maximum left bank irrigation demand (56.2 m^3/s), when the reservoir is drawn down to El 83.0 m. At a point some 2.7 km from the left abutment of the main dam, this channel is blocked by a closure dam having a wide central impervious core with rock-fill shell. This dam incorporates a reinforced concrete intake structure from which a 4.5-m diameter pressure conduit feeds the left bank powerhouse. The powerhouse incorporates an irrigation bypass similar in function to that on the right bank. The power installation comprises two Kaplan units, each of 2.4-MW capacity.

The output of each power plant is stepped up from 6.6 kV (generation voltage) to 33 kV. The right bank power output is transmitted at 33 kV to a switching station adjacent to the left bank plant, from which 33-kV lines lead to Manampitiya (there connecting with the existing 33 kV system) and to Mahiyangana at the southern end of System C.

Status of Headworks Design

The design of both the link tunnel and the dam has been carried to the tender stage.* The designs, technical specifications, and tender documents have been scrutinized by an Engineering Review Board appointed by CIDA. Modifications mutually agreed upon by the Board and the consulting engineers have been incorporated. On the basis of tenders submitted in late 1979, a Canadian contractor was selected in

*The Central Engineering Consultancy Bureay (CECB) has been responsible for the completion of designs and tender documents for the dam, and Acres International Limited has had similar responsibilities for the link tunnel.

mid 1980. A consulting firm has also been selected in preparation of detailed designs and the supervision of construction.

4.4.2 - Main and Branch Canal Systems

The location of the main and branch canals on the left and right banks is shown on Figure 6. The command level at the upstream end of each system is El 77.70 m, and the maximum rate of delivery into each system is

Left Bank System - 56.2 m^3/s
Right Bank System - 32.5 m^3/s

The project area has been divided into three approximately equal sectors. Sectors 1 and 2 are located on the left bank and are expected to be developed in sequence. Sector 3, the right bank area, is expected to be developed last due to its poorer access conditions.

Consideration was given to the question of whether or not the canals should be lined in order to minimize leakage. For a given set of conditions lined canals will cost more than unlined canals. The amount of this additional cost is, to a certain extent, mitigated by various hydraulic conditions such as limiting velocity, shape of cross section, etc.* However, these same factors lead to the conclusion that it is

*Studies comparing the cost of a lined vs unlined canal over a 10-km reach of the Left Bank Main Canal indicated that a lined canal would not incur a large cost penalty. See Annex D for further information.

virtually impracticable and certainly undesirable to design an unlined system with a view to lining it in the future if leakage proves excessive. Available data indicate that the materials in which the canals would be located are quite pervious and erodible, and that leakage from unlined channels would be excessive. For the purpose of the feasibility study, therefore, it was decided that the design should be based on canals lined with concrete.

Summaries of the particulars of the main and branch canals are given in Table 4.5. The general design of the main and branch canal system follows well-established practice. In overburden, the trapezoidal sections have sideslopes of 1V to 2H. In rock cuts, the rock excavations are battered at 6V to 1H. Cross regulators are located at 2- to 10-km intervals along the line of the main canal. The canal structures are of conventional design. For reasons of safety, the maximum velocity is limited to 1.5 m/s.

4.4.3 - Tertiary Irrigation and Drainage Systems

Sample Areas

Designs of tertiary irrigation delivery and drainage systems have been developed for five sample areas which are representative of conditions encountered in various parts of the project area. Layout features, system costs, settlement patterns and infrastructure requirements determined from the sample areas were used as a basis for extrapolation to the remainder of the project. The locations of these sample areas are indicated on Figure 6. Annex D contains discussions of the important features of each, along with cost and infrastructure area loss calculations.

TABLE 4.5

DESIGN FEATURES OF MAIN AND BRANCH CANALS

Description	Branch Offtake Location Along MC (km)	Branch Offtake Location Along Br (km)	Length (km)	Upstream Design Flow (m^3/s)	Hydraulic Structures: Control Structure No. MC	Control Structure No. Br	Offtake Structure No. Br	Offtake Structure No. Disty (direct)	Other Structures No.: Chutes and Falls	Siphon Cross-ings	Bridges	Spillway Siphons	Escapes
	2	3	4	5	6	7	8	9	10	11	12	13	14
Sector 1													
Tailrace canal	-	-	1.80	56.2	-	-							
Kuda Oya Crossing	-	-	-	-	-	-	-	-	-	-	-	1 (29mx8m)	1
Main Canal (LBMC)			31.69	51.4	7	-	6	17	3(C)	-	5	6	2
- Br LBR1		-	17.90	5.7	-	7	-	16	2(C)	-	-	-	1
- Br LBL1	12.25	-	13.40	7.3	-	6	-	16	2(C)	-	-	-	1
- Br LBL2	14.00	-	5.00	1.9	-	3	-	7	1(C)	-	-	-	1
- Br LBL2	22.45	-	2.40	2.3	-	3	-	3	1(C)	-	-	-	1
- Br LBL3	23.80	-	6.65	2.3	-	2	-	3	1(C)	-	-	-	1
- Br LBL4	24.80	-	3.93	1.3	-	2	-	3	1(C)	-	-	-	1
Subtotal (Sector 1)			82.77		7	23	6	65	11	-	5	7	9
Sector 2													
Main Canal (LBMC)	-	-	25.65	37.2	7	-	12	6	1(C)	1(RR)	5	-	1
- LBL5	33.06	-	2.40	2.6	-	3	-	6	2(C)	-	-	-	1
- LBR3	35.14	-	2.00	1.4	-	2	-	5	-	1(RR)	-	-	1
- LBR4	38.13	-	0.30	1.0	-	1	-	2	-	-	-	-	1
- LBL6	39.20	-	4.70	2.8	-	3	-	6	-	-	-	-	1
- LBL7	41.43	-	8.70	6.6	-	5	3	5	1(C) 1(F)	-	2	-	1
- LBL7A	-	4.0	2.10	2.8	-	2	-	5	-	-	-	-	1
- LBL7B	-	8.7	1.50	1.0	-	2	-	4	-	-	-	-	1
- LBL7C	-	8.7	3.90	1.6	-	2	-	3	1(F)	-	-	-	1
- Br LBR5	46.82	-	2.00	2.1	-	2	-	4	-	-	-	-	1
- Br LBL8	46.82	-	3.90	1.4	-	2	-	4	-	-	-	-	1
- Br LBR6	49.31	-	4.30	3.2	-	2	-	7	1(C)	1(RR)	-	-	1
- Br LBR7	53.40	-	5.10 2.0(PL)	2.5	-	4	-	6	1(C)	1(RR)	-	-	1
- Br LBL9	53.90	-	5.91	7.0	-	4	-	8	1(F) 2(C)	-	-	-	1
- Br LBL10	57.34	-	4.04	5.0	-	3	-	7	1(C)	-	-	-	1
- Br LBR8	57.34	-	6.00	4.1	-	3	2	4	-	-	-	-	1
- Br LBR8A	-	6.0	1.60	1.6	-	1	-	2	1(C)	-	-	-	1
- Br LBR8B	-	6.0	4.10 1.35(PL)	2.1	-	3	-	5	1(C)	-	-	-	1
Subtotal (Sector 2)			91.45		7	44	17	89	13	4	7	-	18
Total (LBMC System)			174.22		15	67	23	154	24	4	12	7	27
Sector 3													
Main Canal (RBMC)	-	-	40.70	32.5	10	-	6	27	2(C)	1 (600m)	5	11	4
- Br RBL1	17.94	-	2.40	1.5	-	2	-	4	-	-	-	-	1
- Br RBL2	22.49	-	5.70	3.9	-	4	-	9	2(C) 1(F)	-	-	-	1
- Br RBR1	23.47	-	21.1	10.8	-	12	2	18	-	-	-	-	3
- Br RBR1	-	9.4	4.0	1.5	-	3	-	6	-	-	-	-	1
- Br RBR1B	-	13.0	6.15	2.6	-	3	-	7	-	-	-	-	1
- Br RBL3	26.92	-	5.90	3.6	-	4	-	8	1(C)	-	-	-	1
- Br RBL4	33.00	-	4.70 2.25(PL)	3.2	-	3	-	4	1(C)	-	-	-	1
- Br RBL5	40.70 (RBMC end)	-	3.92	4.7	-	4	-	5	-	-	-	-	1
Total (RBMC System)			96.90		10	35	8	88	7	1	5	11	14
TOTALS (RB + LB)			271.12		25	102	31	242	31	5	17	18	41

Notes: 1 - Costs of distributary offtakes are included in ter[illegible]ry system cost estimates

2 - Abbreviations: C - Chute
F - Fall
PL - Pipeline
RR - Railroad
MC - Main canal
Br - Branch
RB - Right bank
LB - Left bank

Design Features

Separate delivery systems are recommended for upland and lowland areas. This separation can be achieved at the distributary channel, the subdistributary channel or the field channel level, depending on the placement of upland areas. With respect to the lowland area, the following design features have been adopted, based on analysis of the sample areas, laboratory and field tests of soil characteristics, and past experience by the Irrigation Department and MDB.

(a) Distributary Channels (Capacity 0.28 - 1.0 m^3/s)

The channels aré unlined, except at bends which are protected by mortared precast slabs to minimize erosion.

The minimum bed width is 0.30 m, with side slopes of 1H:1V in cut and 1.5H:1V in fill.

The land reservation of 20 m now used by MDB is adequate for the canal and maintenance road.

Control structures are spaced to allow Full Supply Level (FSL) to be reached in the offtake at the farthest turnout when the Distributary Channel is operating at two-thirds of the design flow depth.

Typical designs used by MDB for minor structures are adequate. The quality of construction of small structures in System H has been poor, however. Improved construction supervision will be required, particularly if small contractors are used.

Flow measurement at each structure is made possible by the installation of gate scales and staff gauges.

At the end of each channel a tail fall with a connection to the nearest drainage is provided.

(b) Subdistributary Channels
(Capacity up to 0.28 m^3/s)

The channels are unlined.

The MDB land reservation of 20 m, adopted in this study, is probably excessive. Some additional lands could be made available for irrigation by reducing the reservation to 14 m.

Other design features as for Distributary Channels.

(c) Field Channels
(Serving Areas of 12 to 20 ha)

Turnout areas are bounded on the downslope side by drainage channels, either natural or artificial.

A cart track is provided along each field channel to provide road access to each farm.

The land reservation of 10 m, now used by MDB and adopted in this study, is probably excessive. Reduction to 7.5 m should be possible.

The practice (now used by the Irrigation Department) of providing equal diameter field turnouts for all channels, needs to be modified to suit probable water requirements in the interests of economical water management.

At the end of each field channel a tail fall with a connection to the nearest drainage is provided.

(d) Drains - Lowlands

The objective of drain design in paddy areas is to prevent flooding damage, permit annual flushing of the fields, and ensure a water table level that is high enough to permit economical water use.

The layout is such that every 1-ha plot can drain into either a natural or artificial field drain.

Field drains are designed for a discharge of at least 9.3 L/s/ha.

A minimum drain depth of 0.60 m is assumed.

(e) Drains - Uplands

The objectives of drain design in the upland areas are to prevent flood damage and to allow control of the water table level.

Field drains having a minimum depth of 1.2 m and spacing of 100 m have been assumed for cost estimating purposes. Studies of soil characteristics indicate that a wide range of field drain spacings may, in fact, be required, depending on soil conditions. Where soil and decomposed bedrock permeabilities are relatively low, subsurface drainage may be justified. Field drains discharge into a 1.2-m deep contour drain which runs along the bottom of the upland area. This drain discharges at key points into the delivery system for the lower paddy areas.

The discharge capacity of the drains should be computed using recognized soil drainage formulae, and checked against a storm drainage flow of 11 L/s/ha.

(f) Secondary and Major Drains

These drains will be formed out of existing water-courses.

Where these drains run through paddy land they are to be cleared, realigned, and deepened to improve their hydraulic characteristics and to enable reclamation of valuable land for cultivation.

4.4.4 - Estimation of Net Irrigable Area

Table 4.1 presents a summary of total irrigable land available under gravity command. To estimate the net irrigable land--that land which can be allocated to farmers-- the following losses must be taken into account

- paddy areas prone to serious flooding but suitable for grazing
- forest and other reserves, and existing government farms
- existing settlements
- small isolated areas which will not be served with water
- upland areas which are either too small in extent to be served by a separate irrigation system, or which are required for nonirrigated homestead sites
- irrigation and other infrastructure.

Tables 4.6 and 4.7 summarize the calculations performed to estimate net irrigable area for paddy and upland areas respectively. For the paddy areas, the estimate of losses due to persistent flooding was based on hydrological analysis and analysis and examination of Sample Area 3. Reserve areas are shown on Figure 6. Isolated area losses were taken as 2 percent, while irrigation and other infrastructure losses ranged from 14 to 18 percent, depending on soil type, as derived from studies of the sample areas.

For the upland areas, only those blocks having areas exceeding 35 to 40 ha were considered to be manageable as independent irrigation units. Losses for irrigation and other infrastructure were taken as 18 percent, based on analysis of sample Areas 2, 3, 4 and 5.

As discussed in Section 4.3, the water requirements calculated for the net irrigable areas shown in Tables 4.6 and 4.7 cannot be met by the delivery system as constrained by the Minipe Right Bank Canal, link tunnel, and Maduru Oya reservoir capacities now committed. A satisfactory water balance was indicated, however, for a net irrigable area of about 92 percent of the areas shown in Tables 4.6 and 4.7. An assessment was therefore made of the areas on the periphery of the project for which development could be deferred pending verification that lower water usage rates than those assumed in Section 4.3 can be achieved. This would mean that development could proceed in the deferred area without depriving other parts of the project area of water during the Yala season.

Consideration was given to the conditional deferral of areas which met the following criteria.

- served by one or more well-defined and preferably relatively expensive branch canal or canals

TABLE 4.6

DERIVATION OF NET IRRIGABLE AREA OF PADDY LAND (000's ha)

Sector and Map Area	Basic Land Class	Subdiv.	Gross Area in Command	Losses - Alternative Land Uses: Floodplain Pasture[1]	Forest Reserves[2]	Misc. Reserves[3]	Govt. Farms[4]	Existing Settlements	Total Losses	Avail. Irrig. Area	Irrig. Infra. Losses[5]	Net Irrig. Area
SECTOR 1												
1	1R	LOW-NON ME	4.86	0.68	-	-	-	0.10	0.78	4.08	0.65	3.43
		ME	1.90	-	-	-	-	-	-	1.90	0.38	1.52
	2R	LOW	5.10	-	-	-	-	0.26	0.26	4.84	0.77	4.07
SECTOR 2												
2	1R	LOW-NON ME	1.09	-	-	-	-	0.01	0.01	1.08	0.17	0.91
		ME	0.93	-	-	-	0.03	-	0.03	0.90	0.18	0.72
	2R	LOW	2.53	-	-	-	0.24	-	0.24	2.29	0.37	1.92
3	1R	LOW-NON ME	1.52	-	-	0.28	-	0.01	0.29	1.23	0.20	1.03
		ME	4.59	-	0.07	0.65	0.34	-	1.06	3.53	0.71	2.82
		FP	1.04	0.21	-	-	-	-	0.21	0.83	0.15	0.68
	2R	LOW	7.79	-	0.08	0.35	0.06	0.10	0.59	7.20	1.15	6.05
SECTOR 2	1R	LOW-NON ME	2.61	-	-	0.28	-	0.02	0.30	2.31	0.37	1.94
		ME	5.52	-	0.07	0.65	0.37	-	1.09	4.43	0.89	3.54
		FP	1.04	0.21	-	-	-	-	0.21	0.83	0.15	0.68
	2R	LOW	10.32	-	0.08	0.35	0.30	0.10	0.83	9.49	1.52	7.97
SECTOR 3												
4	1R	LOW-NON ME	0.42	-	-	-	-	-	-	0.42	0.07	0.35
		ME	0.21	-	-	-	-	-	-	0.21	0.04	0.17
		FP	1.19	0.24	-	-	-	-	0.24	0.95	0.17	0.78
	2R	LOW	4.68	-	-	-	-	-	-	4.68	0.75	3.93
5	1R	LOW-NON ME	2.32	-	-	-	-	-	-	2.32	0.37	1.95
		ME	1.87	-	-	-	-	-	-	1.87	0.37	1.50
		FP	1.54	0.36	-	-	-	-	0.36	1.18	0.21	0.97
	2R	LOW	5.24	-	-	-	-	0.02	0.02	5.22	0.84	4.38
SECTOR 3	1R	LOW-NON ME	2.74	-	-	-	-	-	-	2.74	0.44	2.30
		ME	2.08	-	-	-	-	-	-	2.08	0.41	1.67
		FP	2.73	0.60	-	-	-	-	0.60	2.13	0.38	1.75
	2R	LOW	9.92	-	-	-	-	0.02	0.02	9.90	1.59	8.31
TOTAL	1R	LOW-NON ME	10.21	0.68	-	0.28	-	0.12	1.08	9.13	1.46	7.67
		ME	9.50	-	0.07	0.65	0.37	-	1.09	8.41	1.68	6.73
		FP	3.77	0.81	-	-	-	-	0.81	2.96	0.53	2.43
	2R	LOW	25.34	-	0.08	0.35	0.30	0.38	1.11	24.23	3.88	20.35
	1R	LOW	19.71	0.68	0.07	0.93	0.37	0.12	2.17	17.54	3.14	14.40
		FP	3.77	0.81	-	-	-	-	0.81	2.96	0.53	2.43
	1R		23.48	1.49	0.07	0.93	0.37	0.12	2.98	20.50	3.67	16.83
	2R		25.34	-	0.08	0.35	0.30	0.38	1.11	24.23	3.88	20.35
	1R+2R		48.82	1.49	0.15	1.28	0.67	0.50	4.09	44.73	7.55	37.18

Notes: 1 Floodplain pasture - in Sector 1 - lower Kuda Oya area lost estimated from hydrological analysis.
Other areas - 20 percent of floodplain soils.
2 Forest reserves - map area 3 - portion of former Korale Reserve.
3 Misc. reserves - map area 3 - area between railroad and main E-W road, area between road and Vakaneri Tank.
4 Map area 2 - NLDB Livestock Farm; Map area 3 - NPC Fiber Farm.
5 Irrigated infrastructure losses - 1R - Moogamana Ela soils - 0.18 + 0.02 = 0.20 of available irrigable area
1R - Lowlands - non ME soils - 0.14 + 0.02 = 0.16 of available irrigable area
1R - Floodplains - 0.18 of available irrigable area
2R - all areas - 0.14 + 0.02 = 0.16 of available irrigable area.

TABLE 4.7

DERIVATION OF NET IRRIGABLE AREA OF UPLANDS ('000 ha)

Sector and Map Area	Gross Area in Command	Area in Small Blocks[1]	Area in Large Blocks[2]	Block Numbers[3]	Large Blocks to Homesteads	Large Blocks to Irrigation	Irrigation Infra-structure Losses[4]	Net Irrigation Area
1-1	3.70	2.01	1.69	1-16	0.77	0.92	0.17	0.75
2-2	1.85	0.84	1.01	17-26	0.53	0.48	0.09	0.39
3	3.67	2.18	1.49	27-40	0.09	1.40	0.25	1.15
Subtotal	5.52	3.02	2.50		0.62	1.88	0.34	1.54
3-4	1.73	1.12	0.61	47-51	0.61	-	-	-
5	2.35	1.54	0.81	41-46	0.46	0.35	0.06	0.29
Subtotal	4.08	2.66	1.42		1.07	0.35	0.06	0.29
Grand Total	13.30	7.69	5.61		2.46	3.15	0.57	2.58

Notes:

[1]Areas less than 35 ha.
[2]Areas exceeding 35 ha.
[3]Refer to Figure D-3.
[4]18 percent of gross area available for irrigation.

- located on the periphery of the project area

- involving the reduction of the net irrigable area of the project by about 3,000 ha of paddy.

Four areas (see Figure 6) were subjected to detailed analysis.

(a) The areas commanded by Branch Canals LB-L7 and LB-R8. Net irrigable area lost: paddy 3,060 ha, uplands 940 ha.

(b) The areas commanded by Branch Canals LB-L10 and LB-R8. Net irrigable area lost: paddy 2,850 ha, uplands 780 ha.

(c) The area commanded by Branch Canal RB-R1. Net irrigable area lost: paddy 4,600 ha, uplands 190 ha.

(d) The area contained within the Nelugala Jungle Corridor. Net irrigable area lost: paddy 2,270 ha, uplands 140 ha.

Consideration was given to economic (Annex L) and planning and implementation factors (Annex I) before deciding to adopt the second alternative as the "base case" for the economic analysis presented in this report. Alternative (d) (the Nelugala Corridor case) and the full development case were retained for sensitivity analyses. Table 4.8 presents a summary of the calculations performed to estimate the net irrigable areas associated with the base case and Nelugala Corridor case. Table 4.9 summarizes the net irrigable areas by sector for all three cases.

BLE 4.8

CULATION OF NET IRRIGABLE AREAS -
L AND PARTIAL DEVELOPMENT

ctor	Map Area	Gross Areas (1) 1R	2R	1R+2R	1U+2U	Reserve Losses (2) 1R	2R	Irrigable Infras. Losses: No. "Drop Off" (3) 1R	2R	1U+2U	Net Irrigable Area: No. "Drop Off" (4) 1R	2R	1R+2R	1U+2U
	1	6.76	5.10	11.86	0.92	0.78	0.26	1.03	0.77	0.17	4.95	4.07	9.02	0.75
	2	2.02	2.53	4.55	0.48	0.04	0.24	0.35	0.37	0.09	1.63	1.92	3.55	0.39
	3	7.15	7.79	14.94	1.40	1.56	0.59	1.06	1.15	0.25	4.53	6.05	10.58	1.15
	Total	9.17	10.32	19.49	1.88	1.60	0.83	1.41	1.52	0.34	6.16	7.97	14.13	1.54
	4	1.82	4.68	6.50	-	0.24	-	0.28	0.75	-	1.30	3.93	5.23	-
	5	5.73	5.24	10.97	0.35	0.36	0.02	0.95	0.84	0.06	4.42	4.38	8.80	0.29
	Total	7.55	9.92	17.47	0.35	0.60	0.02	1.23	1.59	0.06	5.72	8.31	14.03	0.29
Grand	Total	23.48	25.34	48.82	3.15	2.98	1.11	3.67	3.88	0.57	16.83	20.35	37.18	2.58

Drop Off LB L10 and LB R8, RHA, R8B

Map Area	Gross Area Losses (5) 1R	2R	1U+2U	Revised Gross Area (6) 1R	2R	1U+2U	Reserve Areas Lost (7) 1R	2R	Revised Reserve Areas (8) 1R	2R	Change in Irrig. Infras. Losses (9) 1R	2R	1U+2U	Revised Irrig. Infras. Losses (10) 1R	2R	1U+2U	Net Irrigable Area (11) 1R	2R	1R+2R	1U+2U
1	-	-	-	6.76	5.10	0.92	-	-	0.78	0.26	-	-	-	1.03	0.77	0.17	4.95	4.07	9.02	0.75
2	-	-	-	2.02	2.53	0.48	-	-	0.04	0.24	-	-	-	0.35	0.37	0.09	1.63	1.92	3.55	0.39
3	3.30	1.60	0.95	3.85	6.19	0.45	1.00	0.43	0.56	0.16	0.43	0.19	0.17	0.63	0.96	0.08	2.66	5.07	7.73	0.37
Total	3.30	1.60	0.95	5.87	8.72	0.93	1.00	0.43	0.60	0.40	0.43	0.19	0.17	0.98	1.33	0.17	4.29	6.99	11.28	0.76
4	-	-	-	1.82	4.68	-	-	-	0.24	-	-	-	-	0.28	0.75	-	1.30	3.93	5.23	-
5	-	-	-	5.73	5.24	0.35	-	-	0.36	0.02	-	-	-	0.95	0.84	0.06	4.41	4.38	8.80	0.29
Total	-	-	-	7.55	9.92	0.35	-	-	0.60	0.02	-	-	-	1.23	1.59	0.06	5.72	8.31	14.03	0.29
Grand Total	3.30	1.60	0.95	20.18	23.74	2.20	1.00	0.43	1.98	0.68	0.43	0.19	0.17	3.24	3.69	0.40	14.96	19.37	34.33	1.80

Drop Off Melugala Corridor (Sector 2 - Portions of LB L7B, LB L7C, LB L8; Sector 3 - RB L4, RB DA 3-6)

Map Area	Gross Area Losses (5) 1R	2R	1U+2U	Revised Gross Area (6) 1R	2R	1U+2U	Reserve Areas Lost (7) 1R	2R	Revised Reserve Areas (8) 1R	2R	Change in Irrig. Infras. Losses (9) 1R	2R	1U+2U	Revised Irrig. Infras. Losses (10) 1R	2R	1U+2U	Net Irrigable Area (11) 1R	2R	1R+2R	1U+2U
1	-	-	-	6.76	5.10	0.92	-	-	0.78	0.26	-	-	-	1.03	0.77	0.17	4.95	4.07	9.02	0.75
2	-	-	-	2.02	2.53	0.48	-	-	0.04	0.24	-	-	-	0.35	0.37	0.09	1.63	1.92	3.55	0.39
3	0.61	1.79	0.17	6.54	6.00	1.23	0.09	0.10	1.47	0.49	0.09	0.27	0.03	0.97	0.88	0.22	4.10	4.63	8.73	.01
Total	0.61	1.79	0.17	8.56	8.53	1.71	0.09	0.10	1.51	0.73	0.09	0.27	0.03	1.32	1.25	0.31	5.73	6.55	12.28	1.40
4	-	-	-	1.82	4.68	-	-	-	0.24	-	-	-	-	0.28	0.75	-	1.30	3.93	5.23	-
5	3.32	0.25	-	5.41	4.99	0.35	0.06	-	0.30	0.02	0.05	0.04	-	0.90	0.80	0.06	4.21	4.17	8.38	0.29
Total	0.32	0.25	-	7.23	9.67	0.35	0.06	-	0.54	0.02	0.05	0.04	-	1.18	1.55	0.06	5.51	8.10	13.61	0.29
Grand Total	0.93	2.04	0.17	22.55	23.30	2.98	0.15	0.10	2.83	1.01	0.14	0.31	0.03	3.53	3.57	0.54	16.19	18.72	34.91	2.44

AS ABOVE

otes: (4)=(1)-(2)-(3); (6)=(1)-(5); (8)=(2)-(7); (10)=(3)-(9); (11)=(6)-(8)-(10); 1U and 2U areas in large, usable blocks only.

TABLE 4.9

NET IRRIGABLE AREAS FOR
ALTERNATIVE DEVELOPMENT CASES
('000 ha)

Sector	Case: Base Use 1R	Base Use 2R	Base Use 1U+2U	Nelugala Corridor 1R	Nelugala Corridor 2R	Nelugala Corridor 1U+2U	Full Development 1R	Full Development 2R	Full Development 1U+2U
1	4.95	4.07	0.75	4.95	4.07	0.75	4.95	4.07	0.75
2	4.29	6.99	0.76	5.73	6.55	1.40	6.16	7.97	1.54
3	5.72	8.31	0.29	5.51	8.10	0.29	5.72	8.31	0.29
Grand Total	14.96	19.37	1.80	16.19	18.72	2.44	16.83	20.35	2.58
- Paddy		34.33			34.91			37.18	
- Uplands		1.80			2.44			2.58	
- Paddy and Uplands		36.13			37.35			39.76	

4.5 - Schedule and Cost Estimates

It is envisaged that construction of the various main components of the irrigation project will be undertaken as follows.

Project Area	Principal Construction Agency	Supervision
Headworks	Expatriate Contractor	Expatriate Consultants
Main and Branch Canals	Expatriate Contractor	Expatriate Consultants
Tertiary Systems and On-Farm Works	Local Forces	M.D.B.

The above arrangement forms the basis of the scheduling and cost studies outlined in the following paragraphs and presented in greater detail in Annex D.

4.5.1 - Schedule

A number of development scenarios have been and continue to be considered under the Accelerated Mahaweli Programme. Among these is a schedule for System B proposed by the government which envisages the initial delivery of water in time to irrigate the Maha crop of 1983/84. Assuming a 3-yr development period for downstream works, this schedule would indicate completion of the irrigation system in 1987.

Commencement of irrigation deliveries in October 1983 calls for the completion of the Maduru Oya dam in time to impound water diverted from the Mahaweli via the link tunnel by early August 1983. Provided that upstream diversion works (the Minipe Right Bank Transbasin Canal, Ulhitiya and Ratkinda reservoirs) are also operational at that time, there should be no problem in delivering sufficient water via the tunnel to fill the dead storage zone and supply water for the 1983/84 Maha crop in Sector 1.

A contractor and a supervising consulting firm have been selected for the headworks. Discussions with their representatives and with government officials have confirmed that, barring unforeseen events, the headworks can be completed in time to meet the above schedule.

In the present studies two scenarios have been considered for the development of the downstream area. Both of these scenarios are based on the premise that irrigation of some hectarage in Maha 1983/84 is a prime objective. The first, referred to as "Scenario A", approximates the government schedule referred to above. In this scenario land is brought under irrigation in the course of eight growing seasons--Maha 1983/84 to Yala 1987.

To facilitate proper examination of the important issue of settlement rates, an alternative schedule, referred to as Scenario B, has been considered. In this scenario the build-up of land brought under irrigation is spread over 13 growing seasons--Maha 1983/84 to Maha 1989/90.

A consolidated bar chart showing the construction schedules discussed above is presented in Figure 11. Figures 12 and 13 present the associated phasing of settlement and agricultural activities.

4.5.2 - Cost Estimates

Capital cost estimates for the irrigation works have been prepared at different levels of detail, depending on the stage reached in the engineering design.

In the case of the headworks, as already mentioned, the engineering has been taken effectively to the "final design" stage, thereby facilitating the preparation of tender documents, including drawings, technical specifications and schedules of quantities. A contractor has been selected by the government and it is this contractor's tender which forms the basis for the mid 1979 economic cost estimate used in this report.

The layouts of the main and branch canals have been based on mapping to scales appropriate for feasibility studies. Test pits at 1 to 5 km intervals have provided indications of the depth of overburden and thus enabled approximate quantities of rock and earth excavation and earth fill to be estimated. Based on these quantities, unit rates have been developed on the assumption that construction would be by an expatriate contractor, generally using equipment-intensive methods.

In the case of the tertiary system, including drainage and on-farm development, "per hectare" costs have been evolved on the basis of the five sample areas referred to in Section 4.4.3. Construction by local forces using labor-intensive methods has been assumed. Unit costs have been based on standard rates developed by the Ministry of Mahaweli Development, subject to careful scrutiny and, where indicated, appropriate adjustment.

The following tables summarize the cost estimates of the irrigation works, as discussed above.

Table 4.10 - Headworks - Summary of Capital Costs

Table 4.11 - Main and Branch Canals - Estimated Capital Costs

Table 4.12 - Tertiary Systems, Drainage and Land Development Summary of Capital Costs - Base Case

Table 4.13 - Tertiary Systems, Drainage and Development - Summary of Capital Costs - Nelugala Corridor Case

Table 4.14 - Tertiary Systems, Drainage and Development - Summary of Capital Costs - Full Development Case

Table 4.15 - Schedule of Capital Costs - Base Case

TABLE 4.10

HEADWORKS - CAPITAL COST ESTIMATE SUMMARY

	Sri Lanka ($Rs x 10^6$)	Foreign ($Can\$ x 10^6$)	Total ($Rs x 10^6$)
Economic Costs			
Headworks	349.2	90.6	1,526.6
Contingency	17.5	4.5	76.3
Engineering	40.0	4.6	100.0
Total economic cost	406.7	99.7	1,702.9
Financial Costs			
Headworks	374.4	86.8	1,502.5
Contingency	18.7	4.3	75.1
Engineering	40.0	4.6	100.0
Total financial cost	433.1	95.7	1,677.6

TABLE 4.11

MAIN AND BRANCH CANALS ESTIMATED
CAPITAL COST - CONSOLIDATED SUMMARY

(in 10^6 Sri Lanka Rupees)

	Development Case	Financial Costs						Economic Costs					
		Local	Foreign	Subtotal	Contingencies at 15%	Engineering costs	Total	Local	Foreign	Subtotal	Contingencies at 15%	Engineering Costs	Total
SECTOR 1	A	173.00	287.92	460.92	69.14	57.00	587.06	164.02	319.59	483.61	72.54	57.00	613.15
	B	173.00	287.92	460.92	69.14	57.00	587.06	164.02	319.59	483.61	72.54	57.00	613.15
	C	173.00	287.92	460.92	69.14	57.00	587.06	164.02	319.59	483.61	72.54	57.00	613.15
SECTOR 2	A	104.16	192.18	296.34	44.45	31.00	371.79	98.00	213.86	311.86	46.78	31.00	389.64
	B	112.96	212.80	325.76	48.86	31.00	405.62	106.24	236.49	342.73	51.41	31.00	425.14
	C	121.73	230.11	351.84	52.78	31.00	435.62	114.37	256.02	370.39	55.56	31.00	456.95
SECTOR 3	A	194.16	340.74	534.90	80.23	62.00	677.13	183.14	379.71	562.85	84.43	62.00	709.28
	B	189.38	325.47	514.85	77.23	62.00	654.08	178.69	363.28	541.97	81.29	62.00	685.26
	C	194.16	340.74	534.90	80.23	62.00	677.13	183.14	379.71	562.85	84.43	62.00	709.28
TOTAL PROJECT	A	471.32	820.84	1,292.16	193.82	150.00	1,635.98	445.16	913.16	1,358.32	203.74	150.00	1,712.07
	B	475.34	826.19	1,301.53	195.23	150.00	1,646.76	448.95	919.36	1,368.31	205.24	150.00	1,723.55
	C	488.89	858.77	1,347.66	202.15	150.00	1,699.81	461.53	955.32	1,416.85	212.53	150.00	1,779.38

A = Base Case
B = Nelugala Jungle Corridor Case
C = Full Development Case

TABLE 4.12

TERTIARY SYSTEM, DRAINAGE
AND LAND DEVELOPMENT
SUMMARY OF CAPITAL COST - BASE CASE*
(in million Rupees)

Sector and Land Class	Sri Lanka	Foreign	Total
Sector 1			
Pimburettewa, Vakaneri,** Punanai,** small tanks, rainfed	27.5	3.1	30.6
New lands (Lowlands 1R, 2R) including main drains	126.8	14.1	140.9
Subtotal	154.3	17.2	171.5
Contingencies	23.1	2.6	25.7
TOTAL FOR SECTOR 1 (LOWLANDS, ETC)	177.4	19.8	197.2
New lands (Uplands 1U, 2U)	15.3	1.7	17.0
Contingencies	2.3	0.3	2.6
TOTAL FOR SECTOR 1 (UPLANDS)	17.6	2.0	19.6
TOTAL FOR SECTOR 1	195.0	21.8	216.8
Sector 2			
Small tanks, rainfed	11.5	1.3	12.8
New lands (Lowlands 1R, 2R), including main drains	163.2	18.1	181.4
Subtotal	174.7	19.4	194.1
Contingencies	26.2	2.9	29.1
TOTAL FOR SECTOR 2 (LOWLANDS, ETC)	200.9	22.3	223.2
New lands (Uplands 1U, 2U)	15.5	1.7	17.2
Contingencies	2.3	0.3	2.6
TOTAL FOR SECTOR 2 (UPLANDS)	17.8	2.0	19.8
TOTAL FOR SECTOR 2	218.7	24.3	243.0

Table 4.12 - 2

Sector and Land Class	Sri Lanka	Foreign	Total
Sector 3			
Small tanks, rainfed	33.4	3.7	37.1
New lands (Lowlands 1R, 2R) including main drains	179.7	20.0	199.7
Subtotal	213.1	23.7	236.8
Contingencies	32.0	3.5	35.5
TOTAL FOR SECTOR 3 (LOWLANDS, ETC)	245.1	27.2	272.3
New lands (Uplands 1U, 2U)	5.9	0.6	6.5
Contingencies	0.9	0.1	1.0
TOTAL FOR SECTOR 3 (UPLANDS)	6.8	0.7	7.5
TOTAL FOR SECTOR 3	251.9	27.9	279.8
GRAND TOTAL - SECTORS 1, 2 AND 3	665.6	74.0	739.6

* All costs are "economic".

**Vakaneri and Punanai schemes, although located outside the area, are included in Sector 1 as improvement works will be carried out at same time as development of Sector 1 (lowlands).

TABLE 4.13

TERTIARY SYSTEMS, DRAINAGE AND LAND DEVELOPMENT - SUMMARY OF CAPITAL COSTS - NELUGALA CORRIDOR CASE
(in million Rupees)

Sector and Land Class	Sri Lanka	Foreign	Total
Sector 1	27.5	3.1	30.6
Pimburettewa, Vakaneri, Pananai, small tanks, rainfed	27.5	3.1	30.6
New lands - paddy, including main drains	126.8	14.1	140.9
Subtotal	154.3	17.2	171.5
Contingencies at 15 percent	23.1	2.6	25.7
TOTAL FOR SECTOR 1 (PADDY LAND)	177.4	19.8	197.2
New lands - Uplands (1V+2V)	15.3	1.7	17.0
Contingencies at 15 percent	2.3	0.3	2.6
TOTAL FOR SECTOR 1 (UPLANDS)	17.6	2.0	19.6
TOTAL FOR SECTOR 1	195.0	21.8	216.8
Sector 2			
Small tanks, rainfed	11.5	1.3	12.8
New lands - paddy, including main drains	179.5	19.9	199.4
Subtotal	191.0	21.2	212.2
Contingencies at 15 percent	28.7	3.2	[illegible]
TOTAL FOR SECTOR 2 (PADDY LAND)	219.7	24.4	244.1
New lands - Uplands (1V+2V)	28.4	3.2	31.6
Contingencies at 15 percent	4.3	0.5	4.8
TOTAL FOR SECTOR 2 (UPLANDS)	32.7	3.7	36.4
TOTAL FOR SECTOR 2	252.4	28.1	280.5

Table 4.13 - 2

Sector and Land Class	Sri Lanka	Foreign	Total
Sector 3			
Small tanks, rainfed	33.4	3.7	37.1
New lands - paddy, including main drains	172.3	19.2	191.5
Subtotal	205.7	22.9	228.6
Contingencies at 15 percent	30.9	3.4	34.3
TOTAL FOR SECTOR 3 (PADDY LAND)	236.6	26.3	262.9
New lands - Uplands (1V+2V)	5.9	0.6	6.5
Contingencies at 15 percent	0.9	0.1	1.0
TOTAL FOR SECTOR 3 (UPLANDS)	6.8	0.7	7.5
TOTAL FOR SECTOR 3	243.4	27.0	270.4
GRAND TOTAL - SECTORS 1, 2, 3	690.8	76.9	767.7

Note: All costs are "Economic".

TABLE 4.14

TERTIARY SYSTEMS, DRAINAGE AND LAND DEVELOPMENT - SUMMARY OF CAPITAL COSTS - COMPLETE DEVELOPMENT CASE*
(in million Rupees)

Sector 1	Sri Lanka	Foreign	Total
Pimburettewa, Vakaneri, Punanai, small tanks, rainfed	27.5	3.1	30.6
New lands - paddy, including main drains	126.8	14.1	140.9
Subtotal	154.3	17.2	171.5
Contingencies at 15 percent	23.1	2.6	25.7
TOTAL FOR SECTOR 1 (PADDY LAND)	177.4	19.8	197.2
New lands - Uplands (1U + 2U)	15.3	1.7	17.0
Contingencies at 15 percent	2.3	0.3	2.6
TOTAL FOR SECTOR 1 (UPLANDS)	17.6	2.0	19.6
TOTAL FOR SECTOR 1	195.0	21.8	216.8
Sector 2			
Small tanks, rainfed	11.5	1.3	12.8
New lands - paddy, including main drains	210.7	23.4	234.1
Subtotal	222.2	24.7	246.9
Contingencies at 15 percent	33.3	3.7	37.0
TOTAL FOR SECTOR 2 (PADDY LAND)	255.5	28.4	283.9
New lands - Uplands (1U + 2U)	31.3	3.5	34.8
Contingencies at 15 percent	4.7	0.5	5.2
TOTAL FOR SECTOR 2 (UPLANDS)	36.0	4.0	40.0
TOTAL FOR SECTOR 2	291.5	32.4	323.9

Table 4.14 - 2

Sector and Land Class	Sri Lanka	Foreign	Total
Sector 3			
Small tanks, rainfed	33.4	3.7	37.1
New lands - paddy, including main drains	179.7	20.0	199.7
Subtotal	213.1	23.7	236.8
Contingencies at 15 percent	32.0	3.5	35.5
TOTAL FOR SECTOR 3 (PADDY LAND)	245.1	27.2	272.3
New lands - Uplands (1U + 2U)	5.9	0.6	6.5
Contingencies at 15 percent	0.9	0.1	1.0
TOTAL FOR SECTOR 3 (UPLANDS)	6.6	0.7	7.5
TOTAL FOR SECTOR 3	251.9	27.9	279.8
GRAND TOTAL - SECTORS 1, 2 AND 3	738.4	82.1	820.5

*All prices are "economic".

TABLE 4.15

SCHEDULE OF CAPITAL COSTS - BASE CASE*
(in million rupees)

Year	Headworks		Main and Branch Canals		Tertiary System	
	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
1981	204.3	204.3				
1982	561.0	562.0	122.6	92.0	49.3	39.4
1983	596.0	596.0	292.4	153.3	124.8	60.5
1984	340.6	340.6	457.4	250.7	206.4	105.1
1985			410.6	250.7	171.8	118.6
1986			251.8	300.5	96.1	124.1
1987			177.3	239.2	75.7	112.9
1988				141.9	15.5	70.3
1989				141.9		64.9
1990				141.9		43.8
TOTAL	1,702.9	1,702.9	1,712.1	1,712.1	739.6	739.6

*All costs are "economic".

5 - SETTLEMENT PLANNING

The settlement process, as discussed under Section 5.2, deals with what should be considered in a government-sponsored migration program. The number of settlers and the rate of settlement are indicated.

Section 5.2 discusses the planning of settlements. It deals with the regional context of the project area, the indicated future land use for the area, and the settlements and road networks.

Social infrastructure aspects are discussed under Section 5.3. Matters that require commitment if the project area is to accommodate the settlers successfully are noted.

5.1 - The Settlement Process

5.1.1 - Number of Settlers

The number of settler families that can be accommodated in System B is directly related to the amount of land that will be brought into production under irrigation. A major planning parameter of this study, and the Accelerated Mahaweli Programme in general, is that it is the intention of the Government of Sri Lanka to allocate 1 ha of paddy land to Mahaweli settlers. The estimated net irrigable area suitable for paddy cultivation is 34 300 ha. This is the amount of land that can be allocated in 1-ha parcels to settlers. It excludes the area for which development should be conditionally deferred to achieve a project-wide water balance, as discussed in Section 4.3.

The estimate excludes paddy land in the major tank schemes in the adjacent to System B - Pimburettewa, Vakaneri and Punanai. However, it does include areas currently under small tanks and rainfed paddy lands.

The assumption is made that ultimately all 34 300 ha of net irrigable paddy land identified by the study can be allocated to the same number of farmers in 1-ha parcels. Proper integration of all small tanks within the overall irrigation system is assumed.

On the uplands the situation is not quite as clear, due to the limited experience with these types of soil under irrigated conditions. Land classification has identified a total irrigable area of 5,600ha in 55 blocks of 35 or more hectares. Smaller blocks cannot be effectively served by separate irrigation systems. A number of upland blocks will be required to allow for the homesteads of paddy farmers, reducing the irrigable upland area to 2,200 ha. After allowing for irrigation infrastructure, this would leave 1,800 ha for allocation.

For the purposes of this study, it has been assumed that "pure" upland farmers can be induced to settle, when allocated 1.8 ha, which would include 0.3 ha of homestead. This would allow 1,000 farmers to be settled. The total of upland and lowland settlers would then be 35 300.

However, the results of a special study on upland farm size and experimentation with upland soils at the proposed System B demonstration farm could indicate that larger upland farm units might be more appropriate.

Considering that some 4,000 Mahaweli land allocations can be made to those presently residing in System B, an additional

31 300 settler families would be selected from outside the project area. The latter number would include those who work or have certain claims to land in the area but who do not live within the project area.

A minimum of 25 percent nonfarm employment and population is necessary for the basic functioning of a rural society. This nonfarm component would include services to farmers, commercial and farm industry activities, social and personal services, and government. It does not include hired farm labor for seasonal peaks, which could be satisifed through migrant labor movement. The nonfarm settlers who will make a permanent home in the area would total some 11 800 families. The total number of settler families, both farm and nonfarm and including those now in the area, should number 48 800 by the end of the 1980's.

As a result of the development of System B, the population of the area will increase tenfold, from about 25 000 to close to 250 000 in the next 10 years. The influx of such a larger number of people into relatively virgin territory over a brief period of time will require a planning effort commensurate with the size of this monumental migration.

The movement of people into System B will be in sharp contrast to the experience in System H, where only one-quarter of the farm settlers are from "outside" as shown on the following table.

	System H	System B
Farm families from area	18 000	4 000
Farm families from "outside"	6 000	31 000
TOTALS	24 000	35 000

Table 5.1 shows a summary of the settler population estimates. While by no means precise, the figures serve to indicate the overall dimensions of the future population structure of the area.

5.1.2 - Selection of Settlers

There is ample experience in Sri Lanka with colonization schemes and hence with settler selection. However, the size of the anticipated program is such that extraordinary settlement planning measures will be required.

There is without question a large reservoir of potential settlers. The response to invitations to apply for settlement in System H, extended to selected villages in selected electorates, indicates many more prospective settlers than settler places. This excess of supply makes it possible to insist that basic selection criteria are met. While one can be confident that sufficient settlers can be selected for System B, the willingness of potential settlers to come forward for subsequent phases of the Mahaweli Development Programme will to some extent depend on how well the aspirations of early settlers are fulfilled.

The selection criteria to be developed for System B should take into account the following.

- Those now living in the area should have the first priority for settlement. In the near future it should be made known to project area residents what residency requirements the government intends to employ. Deferring the residency cut-off date may be advisable.

TABLE 5.1

SUMMARY OF SETTLER FAMILIES AND POPULATION FOR SYSTEM B

		Families	Population at 5 pers/family
A.	Paddy Settlers	34 300	171 500
	Upland Settlers	1 000	5 000
	Farmer Settlers	35 300	176 500
	Nonfarm Settlers	11 800	59 000
	Total Settlers	47 100	235 500
B.	Farmer Settlers Required	35 300	176 500
	Present in Area	4 000	20 000
	Settlers from "Outside"	31 300	156 500
C.	Nonfarm Settlers Required	11 800	59 000
	Present in Area	1 800	9 000
	Settlers from "Outside"	10 000	50 000
D.	By late eighties:		
	Farm Population	35 300	176 500
	Nonfarm Population	11 800	59 000
	Existing Schemes Population	1 800	9 000
	Total	48 900	244 500
E.	By year 2000:		
	Farm Population	37 100	185 500
	Nonfarm Population	18 550	92 750
	Total	55 650	278 250

Note: Pimburettewa, Vakanéri and Punani Schemes excluded under A, B, C. (Estimated 1979 resident population of 9,000 or 1,800 families.) This population shown separately under D and included with farm population under E.

- Areas adjacent to System B (the districts of Trincomalee, Polonnaruwa, Batticaloa and Amparai) should receive preference for settler selection.

- Preferably, the settlers to be attracted from districts further away from the project area should have Dry or Intermediate Zone living and farming experience.

- The ultimate ethnic composition of System B should be viewed in the context of the overall Accelerated Mahaweli Programme.

- The settlers should not have land elsewhere or other major assets, nor should they now have incomes that exceed the projected family income for System B farmers.

- The settlers should be young (in their 20's or 30's) and energetic. While most farmer settlers will be married, selection of related but unmarried settlers (brothers, sisters, cousins) should be considered.

- A specific program should be developed for nonfarm settlers.

Once settlers have been selected in their area of origin, groups of them and their families should be brought together for several orientation sessions. In the preparation workshops, a realistic picture should be painted of the conditions that await the family and what they can hope to achieve. If the settler is to be separated from his family for a number of months, the financial provisions for the family left behind should be discussed. In the case where the settler is expected to work on the tertiary system for a period of time, the physical and contractual working conditions under which his labor is to be provided should be communicated clearly.

5.1.3 - Rate of Settlement

Some of the key aspects of the settlement phase are

- the male head of the settler household is expected to arrive some period in advance of his family in order to work on the tertiary irrigation system and on his allotment

- he will be housed in temporary camps and organized with fellow settlers into contract work groups

- he will be allocated his paddy plot and somewhat later his homestead; since it takes about 1 man-year to prepare an allotment from rough ploughing, the bulk of the settler's effort would go into the preparation of his own land

- the settler would be paid the current labor rate for any work performed, thus allowing him to maintain his family prior to agricultural production

- settler arrivals would be spread over months, taking into account the rainy season, the proposed first season of production and the period required to prepare allotments.

For purposes of this report, the settlers have been grouped according to the schedules of land production indicated in the two development scenarios. For Scenario A this entails eight groups, the first comprising 4,900 settlers, corresponding to the 4,900 ha projected for first production in Maha 1983/84. This group is divided into seven subgroups of 700 settlers each. The first such subgroup would arrive in April 1982 and the last seven in October 1982. No arrivals would take place in the November-January wet season. The settlers would work on land and field channel preparation for

part of 1982 and throughout 1983, and with the start of the 1983/84 Maha season, they would commence production on their allotment. Their first harvest would be in February 1984. From the arrival of the first subgroup of 700 to the first harvest, a period of 23 months would have elapsed (16 months from the arrival of the last subgroup). This is a considerable length of time; for the sake of morale and productivity every effort should be made to ensure that the preproduction period does not lengthen beyond this time period, considering also that for part of this period the settler is separated from his family. The advantages and disadvantages of bringing in settlers much before they can be productively employed on their allocated paddy lands should be carefully weighed.

For Scenario A the total settlement period is 5 years and for Scenario B it is 7 years (see Table 5.2).

It should be noted that while the settlers in total are intended to provide some 45 000 man-years of work on the tertiary system and land preparation, this is only about one-third of the total work effort required. The balance would have to come from hired construction labor.

For Scenario A the number of months during which settlement takes place is 39, corresponding to an average of 880 settlers per month. With 22 working days per month a daily arrival rate of 40 families (200 persons) is implied. Settler families and their belongings are transported by lorries, allowing two families and effects per lorry. To bring 40 families per day would require 20 lorry trips. In general, Scenario A calls for the daily arrival of some 20 lorries, each carrying two families, from early 1982 to mid 1986, exclusive of the wet season.

TABLE 5.2

SUMMARY OF PADDY FARM SETTLER ARRIVALS

	Scenario A		Scenario B	
1982	4 900	(7)	2 300	(4)
1983	9 000	(8)	5 800	(8)
1984	9 800	(8)	5 900	(8)
1985	8 900	(8)	6 300	(8)
1986	1 700	(8)	5 100	(8)
1987	-		4 600	(8)
1988	-		4 300	(8)
TOTAL	34 300		34 300	

Note: Figures in brackets refer to the number of months over which actual paddy farmer arrivals take place.

For Scenario B the daily quota of lorry loads of families would be 15 (based on a monthly settlement of 660 families), for the period mid 1982 to the end of 1988. The intensity of settlement activity under Scenario B is about 75 percent of that required by Scenario A.

The rates of settlement discussed above have as their basis the earliest date the irrigation system and land can be physically developed. To attain the rate of settlement called for under Scenario A will require a supreme logistic, organizational and administrative effort in line with the overall thrust of the Accelerated Mahaweli Programme. Under Scenario B the effort would be somewhat less intense.

5.1.4 - Assistance to Settlers

Assistance to settlers will have to be provided, if only to ensure that the investment, approaching Rs 140,000 in each hectare of irrigated land, is being utilized with economic efficiency.

For the estimates of settlement cost, a base of 35 000 families has been used. The families now living in the project area who will be allocated Mahaweli land will also fall into most of the categories of assistance. Total settlement costs amount to Rs 165 million or Rs 4,730/family, as shown in Table 5.3.

Settlers will be paid for work they perform on the irrigation system, on jungle clearing and on leveling and bunding of their farm area. Since this is included as part of the cost of the tertiary system it is not considered a settlement cost. If settlers are paid current rates for precultivation work, this would remove the need for including World Food Aid as a cost to the project.

TABLE 5.3

SUMMARY OF SETTLEMENT COSTS
(mid 1979 prices)

	million Rupees
Selection, Orientation and Training	7
Transportation	10
Temporary Camps	35
Tools	7
Housing Materials	53
Wells	28
Physical Planning and Surveying	10
Overhead	15
TOTAL	165

5.1.5 - Organizing for Settlements

The task of organizing settlement will fall to the Mahaweli Economic Agency. For each family the settlement process may take a number of years, from selection in the home village, to full production on Mahaweli land. Throughout this period, staff is required to assist along each step of the way. A number of organizations will be involved.

The actual selection of settlers will be carried out by the Government Agent, under the direction of the MA or the MEA (see Annex I, Appendix II).

The orientation and preparation of settler families in the home village should be carried out by MEA staff. Special teams should be set up to organize, in cooperation with the Government Agent, groups of selected settlers. The MEA teams would take stock of particular settler group characteristics in order that the best fit with the new environment can be aimed for.

The management of the temporary camps and the settler work groups would also be carried out by MDB. Settlers would receive MDB staff assistance in the preparation of their allotments. The laying out of farm plans and homesteads would be undertaken by MDB but their allocation would be carried out by MEA staff in cooperation with the Lands Department.

Once situated on the homestead, the MEA team that brought the settlers to the area would hand over ongoing duties to the Settlement Service Team and the Field Officers. The Field Officer would apply his range of guidance skills to settler problems as they arise and refer settlers to the Settler Service Team if he is not in a position to satisfy a specific concern.

Typical settlement matters that would arise in the early period include

- land administration matters (boundary disputes, allocation of land and suitability of the land for the family)

- food and subsistence problems (where food and other aid may not be timely or sufficient)

- health problems (to advise on basic preventative public health measures and where to seek competent help)

- credit problems (to assist the settler in obtaining an appropriate level of credit)

- community development matters (to assist the settlement in attracting key items of social infrastructure)

- housing problems (to assist in securing supplies of building materials) and,

- general problems of adjustment to a new environment.

The Field Officer should be allowed to operate with a reasonable degree of independence, within a properly organized and communicated framework of settler assistance measures.

5.2 - Planning of Settlements

5.2.1 - Regional Context

The context in which System B is considered in this report takes as the region the area bounded by the centers of

Trincomalee, Dambulla, Matale, Kandy, Mahiyangana, Batticalos and Valaichchenai.

The rate of growth in the Dry Zone districts over the last few years has been considerably higher than the national rate (see Table 5.4). This reflects in part the introduction of some colonization schemes and the influx of chena cultivators. With the Mahaweli projects, the population of the region could double over the next 20 years. The population growth of the region will precipitate the redrawing of municipal, electoral, district and administrative boundaries.

The internal road network of the region is underdeveloped at present. However, the Mahaweli Programme will generate road improvements. One such improvement will be a primary road from Manampitiya to the south, across the Maduru Oya dam, then linking with Highway 5, thus serving the Gal Oya population. Another important road will be from Mahiyangana to Manampitiya.

One of the key elements in the transportation network of the Maduru Oya region is the shared road/railway bridge across the Mahaweli Ganga, at the westerly entrance to System B. A new bridge will be required once the population east of the river increases significantly.

While detailed attention is being paid to the planning of the component systems, the overall regional framework and inter-system linkage are so far not being examined. This could result in opportunities being lost and a reduction in the region's potential. A plan for the region should, therefore, be developed as a matter of priority. In the planning exercise, attention should be paid to, among other things

TABLE 5.4

POPULATION OF MADURU OYA REGION (IN THOUSANDS)

District	1968	1978	Increases 1968 to 1978 No.	Increases 1968 to 1978 Percent	Persons per km^2 - 1978
Trincomalee	165	223	58	35	85
Polonnaruwa	134	190	56	42	56
Batticaloa	233	300	67	29	122
Amparai	251	316	65	26	106
TOTALS	783	1,029	246	31	90
Sri Lanka	11,992	14,184	2,198	18	219
Madura Oya Region as a Percentage of Sri Lanka	6.5	7.3			

Source: Table A-4.1

- principal transportation facilities (road, rail, air, water)
- relationships among the Mahaweli systems
- functions and locations of major centers
- demographic and cultural aspects
- potential of farm and nonfarm sectors
- incentives and organization required to meet development objectives for farm and nonfarm sectors, and
- administrative boundary matters.

5.2.2 - The Project Area

Development Plan

Central to the physical planning for System B is the change in land use that will result from the introduction of irrigated agriculture. Table 5.5 shows the elements of major change. Agricultural lands will increase from 14 000 ha to 48 000 ha; land for homesteads and settlements will increase from 3,000 to 23 000 ha; and chena and forest land will decrease from 100 000 ha to 46 000 ha. About 54 000 ha, or 44 percent of the overall area, will undergo a complete change in land use, while indirect effects will be felt on the remaining area.

The physical impact on the existing project area population (indicated in Table 5.6) will be modest; the existing population of 26 000 will for the most part be able to continue to live in or near their present locations. However, the present settlement pattern already favors the uplands. Any moving will be over a short distance and should not entail great expense to families since most existing homes are not of a permanent nature.

The main criteria for the location of settlements are the distance between the paddy field and the homestead and,

TABLE 5.5

PRESENT AND FUTURE (YEAR 2000)
LAND USE IN PROJECT AREA

	1980*		2000	
	(ha)	(percent)	(ha)	(percent)
Paddy Farms	13 700	11	45 500	37
Upland Farms	-	-	2 200	2
Chena	32 800	27	12 800	10
Forest	66 700	54	32 900	27
Homesteads				
Settlements	2 900	2	22 700	18
Standing Water	3 200	3	3 200	3
Rock Outcrops	3 900	3	3 900	3
Large Farms	600	-	600	-
TOTAL	123 800	100	123 800	100

Notes: A modest land area for future livestock will also be required; this will affect the chena and forest categories.

Total area shown based on airphoto coverage which is about 90 percent of the total project area.

*From Table A-3.1.

TABLE 5.6

POPULATION OF THE PROJECT AREA - 1979

District	No. of Persons	Percent	Persons Per km^2
Polonnaruwa	20 930	81	29
Batticaloa	4 255	17	8
Amparai	572	2	22
TOTAL	25 757	100	20

Sector	No. of Persons	Percent
1	17 304	67
2	5 849	23
3	2 604	10
TOTAL	25 757	100

Source: Tables A-4.2 and A-4.3

perhaps of similar importance, the distance between the homestead and the nearest elementary school.

Figure 6 presents a general map of System B. Land suitable for irrigated agriculture is indicated. With one notable adjustment, the paddy area shown is proposed for development. Development of the Nelugala Corridor for irrigated agriculture is included in the proposed plan, while the northeastern area is conditionally deferred to achieve a project-wide water balance.

Alternatively, a water balance could be achieved with the corridor excluded from agricultural development and the northeastern area developed. However, this would be less attractive because the corridor would divide the project area in two; it would be crossed by a railway, roads and canals and would present significant wildlife/farmer/settlement conflicts.

Figure 6 also shows the irrigable upland soils, in blocks exceeding approximately 40 ha. These lands are widely scattered and in many cases are surrounded by large tracts of potential paddy land. In order to provide homesteads for paddy farmers within reasonable walking distance, certain upland blocks will be required for unirrigated homestead development. The land suitability of these sites will not be wasted as homestead crop cultivation will take place on them. Annex I contains an assessment of the needs for homestead sites for each of the blocks. Section 4.4.3 of the Main Report summarizes the areas remaining for use under irrigation.

The future land use for System B is indicated in Figure 7. This figure shows future paddy lands mostly concentrated along the Maduru Oya and remaining paddy lands rather

scattered. There are significant areas that can be retained and further developed as forest, thus helping to meet the large firewood demand of the future population. Major settlement concentrations are indicated, subject to further planning. The basic road network as shown is discussed in Section 5.2.4, below.

5.2.3 - Settlements

Much of the settlement area will be part of the economic base of the area, providing homestead crops and accommodating livestock. The proposals call for the allotment of plots to nonfarm settlers and therefore land use provisions should be made to allow for a measure of spontaneous nonfarm settlement. Such settlement would be an indication of the attraction of the area; it should therefore not be hampered by lack of sites.

The land currently in use for homestead and settlement is about 3,000 ha. If the proposed 0.4-ha homestead concept is accepted, the total land requirement for farmers' homesteads would total some 17 000 ha. Nonfarm settlers on 0.2-ha plots would increase the requirement to 20 000 ha. To accommodate future increases in the nonfarm population a further 3,000 ha should be identified. For homesteads and settlements of all types an eventual requirement of some 23 000 ha should be anticipated.

The detailed planning of settlements for the area has yet to be undertaken, as it must build on the indicated future agricultural land use information only recently completed. As a basis for discussion, the following organization of settlements (summarized in Table 5.7) for System B is postulated.

TABLE 5.7

INDICATED RANGE OF SETTLEMENTS*

			Population
Regional Center - Welikanda		(5 000 families)	25 000
Towns (or Townships) -			
Manampitiya	15 000	(3 000 families)	
Aralaganwila	15 000	(3 000 families)	
Meeyankolla	7 500	(1 500 families)	
Punanai	7 500	(1 500 families)	
Trikonamadu	5 000	(1 000 families)	
Other	5 000	(1 000 families)	
Total			55 000
Villages - 15 at 3 000 population (600 families)			45 000
Small Villages - 25 at 1 500 population (300 families)			37 500
Hamlets - 50 at 750 population (150 families)			37 500
Subhamlets - 100 at 250 population (50 families)			25 000
Scattered Settlements of less than 50 families			25 000
Total Population (50 000 families)			250 000

*Based on project area population of 250 000.

Regional Centers

Whether the area should have its own regional center or whether it should rely on Polonnaruwa to serve this function is still a matter to be determined. With a projected population for System B of some 250 000, a district administrative regional center could well develop at Welikanda, especially if district administrative functions are located there.

Towns

Area settlements of significance include Aralaganwila (resulting from the development of the Pimburettewa Scheme), Manampitiya and Welikanda. While Welikanda is more centrally located within System B and with respect to the ultimate population, Manampitiya is at the gateway of the system and of Sector 1. It would appropriate to stimulate development at Manampitiya in the early years of implementation.

For the Right Bank area, a new community, known as Meeyankolla, could develop to serve the needs of the population. To provide full access to Sector 3, two bridges across the Maduru Oya will be required; one to the east of Aralaganwila and another to the south of Welikanda. The upgrading of the existing causeway at Kiran will also be required.

Table 5.7 shows the indicated towns and the population sizes they might attain. On a combined basis, the towns and the regional center would account for some 32 percent of the area population.

Villages

The village would be 600 families or 3,000 persons. This is about the same as the village size currently used by MDB for

planning purposes. Villages would include centers like Ellawewa and Wadamunne.

Small Villages

With 300 families to 1,500 population, small villages would be able to offer a basic range of services, such as commerce, education, health, etc. Forty villages and small villages would, with a total population of 83 000, account for 30 percent of the total population.

Hamlets

Slightly larger than the MDB hamlet, this community of 750 persons (150 families) could provide a school, a cooperative store, some boutiques and mobile health service.

Subhamlets

These communities, with sizes of 50 families or 250 persons each, would be the smallest grouping of dwellings to which a social service could be allocated. A subhamlet could support a small elementary school with two teachers.

Educational facilities in settlements of this size would increase the enrolment ratio. A typical subhamlet would have 65 elementary students.

Below the subhamlet level there will still be a requirement to settle families in smaller clusters or strips. Many of the present settlements in System B fall within the "scattered" category.

The concept of this wide range of settlement sizes should be reviewed in concert with the 0.4-ha homestead paddy lands within the project area indicated by Figure 7.

5.2.4 - Roads

Five categories of roads are identified: access roads, the primary road network, irrigation system roads, link roads and roads within settlements. Their costs are summarized in Table 5.8.

Access Roads

These jeep type roads are to be constructed in advance of main and branch canal construction, for use by engineers and surveyors. The network will cover the 248-km canal network, but after canal construction, these roads will be of limited use. The total estimated cost is Rs 200,000/km, resulting in a total estimated cost of Rs 49 million.

Primary Road Network

Highway A11 through System B is a "national" road; the bridge across the Mahaweli is a "national" bridge. Therefore, the upgrading cost of A11 and the eventual construction of a separate road bridge (leaving the existing bridge for rail) are not considered as project costs.

Consultants sponsored by the Asian Development Bank have estimated costs (about Rs 1.5 million/km) for primary roads in the project area. The estimated costs include full road formation (including structures) and 24-ft pavement with gravel surface.

The primary road network consists of some 10 roads, all of which should be required for the development of System B. The network, shown in Figure 7, is compatible with regional needs and the location of existing and proposed communities. Many of the roads now exist in basic form or as tracks; the

TABLE 5.8

SUMMARY OF ROAD COSTS
(mid 1979 prices)

Type	Length (km)	Rs per km	Total Cost (million Rs)
Access Roads	245	200 000	49
Primary Roads	155	1 500 000	233
Irrigation System Roads Upgrading	80	200 000	16
Link Roads	250	300 000	75
Roads Within Settlements	450	125 000	54
TOTAL			427

Note: Of the total cost, Rs 311 million was used in the economic analysis.

indicated cost is to bring them to standard or replace them with roads of primary standard. The length of the roads within System B is 155 km, and the construction cost is estimated to be Rs 233 million.

Irrigation System Roads

These roads will be on the banks of the main and branch canals. As such they will make a major contribution to the internal road network of System B. This basic road network will be constructed as part of the irrigation system, and the costs are included in estimates for the irrigation works. For surfacing and widening, a cost of Rs 200,000 has been allocated to one-third of the network. The total cost is estimated to be Rs 16 million.

Link Roads

These would link settlements to other parts of the road network, and would complete the road network, except for roads within settlements. Some link roads already exist but many more would still be required. An estimated 250 km of link roads will be required, at a total cost of Rs 75 million.

Roads Within Settlements

These do not sustain heavy volumes of motorized traffic; most need not be more than 12 ft in width. Allowing for existing settlements, some 30 000 new homesteads will be added to the area. Each would have some 15 m of road, for a total length of 450 km. At a cost of Rs 120 000/km, this would total Rs 54 million.

5.3 - Social Infrastructure

A significant amount of social infrastructure will be required for the project population. The cost of providing schools, hospitals, post offices and police stations is not considered an economic project cost as these services should be available to Sri Lankans, wherever they choose to live on the island. However, the financial cost of constructing social infrastructure facilities exceeds Rs 6,600/family.* Detailed social infrastructure and operations planning has already been commenced by MEA and MDB but more work on standards and benchmarks is required. Table 5.9 summarizes the component costs, which are discussed below.

Schools

It has been recommended that small, one-block schools be used extensively in order to reach subhamlet populations.

Larger schools are required in the larger centers. For a mix of schools, the cost of school building, teacher accommodation and school furnishings has been estimated to cost Rs 2,500/student. Considering the 35 000 farm settler families and the existing inventory of area schools, an additional 40 000 student spaces will be required, at a total cost of Rs 100 million.

Health

The project area will need a 90 bed District Hospital, four 48-bed Peripheral Units, 12 Central Dispensaries and village accommodation for 60 health workers/midwives. These

*Added to settlement cost of Rs 4,700/family, the total comes to Rs 11,300/family.

TABLE 5.9

SUMMARY OF SOCIAL INFRASTRUCTURE COSTS
(million Rs [1979])

Schools	100
Health	40
Police and Post Offices	12
Electricity and Telecommunications	35
Development Centers, Town Centers, Community Meeting Facilities, GSD Buildings	21
Markets, Banks, Coop Stores	17
Urban Water Supplies	6
Miscellaneous Infrastructure	12
TOTAL	243

facilities, which are a minimum to serve a farm population of 35 000 families, are estimated to cost Rs 40 million.

Police and Post Offices

A large police complex is already being planned for Welikanda. The cost of this complex, together with the cost of four smaller police stations, is estimated to be Rs 6 million. The Rs 6 million estimate for postal services includes 3 post offices, 20 subpost offices, post boxes, transportation and equipment.

Electricity and Telecommunications

While most of the project area households will not have electrical service, public, community and commercial buildings and paddy processing plant should be served. This will require a distribution network that will reach all settlements of any size. The estimated cost for electrical service is Rs 30 million. Basic telephone service can be provided to the area's main centers for an estimated Rs 5 million.

Development Centers

This category includes a major community development center for the project area, similar to the center being developed for System C at Giranduru Kotte, smaller centers in other towns, community meeting facilities in villages and Grama Seveka buildings. A total requirement of some 1,700 m^2 of buildings is indicated, for a total cost of Rs 21 million.

Markets, Banks, Coop Stores

Five markets, 1 for each major urban center, 14 banks, a large central cooperative depot and 20 cooperative centers are indicated at an estimated total cost of Rs 17 million.

Urban Water Supplies

A number of towns will require some form of piped water system. For Welikanda such a system is already being implemented. Other towns would in time also require piped water. The estimated cost of Rs 6 million does not include water treatment facilities.

Social infrastructure costs are estimated to be Rs 243 million. While this is a significant amount, it represents only 4 percent of the overall financial Maduru Oya project cost. The certain and timely expenditure of these monies would aid materially in helping the settlers achieve the project's social and economic objectives.

6 - AGRICULTURAL DEVELOPMENT AND PRODUCTION

6.1 - Present Situation

Traditionally the 1,900-mm (75-in.) isohyet separates Sri Lanka's Wet and Dry Zones. Rainfall at Welikanda has a mean annual value of 1,765 mm, and places the center of System B within the Dry Zone. The amount of rainfall increases toward the east--Vakaneri, with an annual rainfall of 1,926 mm, lies on the fringe of the Dry Zone.

Agriculture in System B follows the centuries-old Dry Zone pattern. Paddy is grown on all 7,000 ha of the irrigated land, while the slash-and-burn (chena) cultivation method is used for annuals, mainly cereals and root crops. Perennials and vegetables are grown in homestead plots. Because of limited input requirements, this agricultural system is relatively satisfactory, but the shifting cultivation does result in permanent damage to forest and soil resources.

6.1.1 - Rainfed Cropping

Precipitation patterns in all parts of System B are typical of those in Agroecological Zone DL 2, which is characterized by heavy rainfall in the Maha and very little in the Yala. The Maha rainfall is high, even for the Dry Zone. Thus successful unirrigated cropping during the Maha is possible.

The area under rainfed upland crops in Maha 1977 - 1978 is indicated in Table 6.1. Figures for the considerable areas under tobacco and coconut, and for the two kenaf/sunnhemp

TABLE 6.1

RAINFED UPLAND CROPPING AREA
IN SYSTEM B - MAHA 1977/78

Crop	Polonnaruwa District (ha)	Batticaloa District (ha)	Total (ha)
Cereals			
- Maize	134	344	478
- Millet	17	15	32
Pulses	22	17	39
Oil Seeds			
- Sesame	34	6	40
- Groundnuts	10	20	30
Root Crops			
- Cassava	114	264	378
- Sweet Potato	25	16	41
Vegetables			
-Chillies and Onions	67	61	137
Perennials	80	520	600
Others	94	43	137
TOTALS	597	1 306	1 903

Note: Reference to the Polonnaruwa and Batticaloa Districts means those parts within System B.

Source: Department of Census and Statistics

farms established at Welikanda and Punanai by the Cashew Corporation and the National Paper Corporation respectively are not included.

There is a larger rainfed paddy area in the Batticaloa District than in the Polonnaruwa District. In both districts, maize and cassava are dominant crops. Perennials (coconuts) are also a significant part of rainfed agriculture in the Batticaloa District.*

Cultivation of rainfed rice on bunded fields falls into a different category than the rainfed cultivation of upland rice. The former method, apart from reducing water stress, achieves low soil redox potentials that contribute to nutrient availability. The area which is officially recorded as being under rainfed rice cultivation in the project area is shown in Table 6.2. The growing of rainfed paddy is rarely attempted in Yala.

6.1.2 - Irrigated Cropping

The total extent of asweddumized land developed under existing irrigation schemes in the project area is officially estimated to be 7,321 ha. Two of the major schemes, Pimburettewa and Vakaneri, cover 1,232 ha and 3,279 ha respectively. Pimburettewa is a colonization scheme, as is Wadamunne (150 ha). The numerous minor irrigation schemes account for about one-third of the total irrigated area. Many of these minor schemes are fed by small village tanks associated with "purana"** villages.

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* The rainfed category in the Batticaloa District is dominated by the lands in the flood plain of the Maduru Oya. This accounts for much of the difference in distribution of rainfed and small tank scheme lands.

**Traditional.

TABLE 6.2

AREA AND CROPPING INTENSITY OF
PADDY PRODUCTION IN SYSTEM B - 1973-1979

District	Major Irrigation Schemes			Minor Irrigation Schemes			Rainfed		
	Asweddumized Area (ha)	Cropping Intensity Maha (%)	Cropping Intensity Yala (%)	Asweddumized Area (ha)	Cropping Intensity Maha (%)	Cropping Intensity Yala (%)	Asweddumized Area (ha)	Cropping Intensity Maha (%)	Cropping Intensity Yala (%)
Polonnaruwa*	1 232**	94	41	1 895	86	26	674	92	2
Batticaloa*	3 789	76	30	399	72	13	5 615	73	2
Amparai*	-	-	-	6	67	50	66	39	0
Total	5 021	81	32	2 300	83	24	6 355	75	2

Notes: * References to the Polonnaruwa, Batticaloa and Amparai districts mean those parts within System B.

** Excludes Tract 9, which is not irrigated at present.

Source: Department of Census and Statistics

Present land use in the project area is similar to that in the rest of the Dry Zone. Paddy, to the near exclusion of all other crops, completely dominates the irrigated area.

Area and Cropping Intensity

Official statistics on the asweddumized land area and cropping intensities recorded for irrigated areas in the project area during 1973 - 1979 are indicated in Table 6.2.

Under all schemes, cropping intensities are higher in the Maha season than in Yala and distinctly higher in the Polonnaruwa District than in Batticaloa. However, even in the Polonnaruwa District in Maha, the mean cropping intensity does not exceed 94 percent and in no instance is the cropping intensity in Yala even half that in Maha. The overall cropping intensities in Yala under the major and minor irrigation schemes are 32 percent and 24 percent respectively. Present differences in cropping intensity between Maha and Yala largely reflect the inadequacy of the present water supply.

Yields

There have been no previous attempts to collect statistically valid rice yield estimates specific to the project area. The present study included

- reprocessing of the Department of Census and Statistics 1973 - 1978 crop-cutting survey data for all parts of the project

- monitoring by the Agronomist and his counterpart of a DCS crop-cutting survey in Yala 1979.

- execution of a separate crop-cutting survey in the Pimburettewa Scheme in Yala 1979 by the Agronomist and his counterpart.

- execution of a separate crop-cutting survey in both Pimburettewa and Vakaneri schemes in Maha 1979/1980 by the Agronomist and his counterpart.

The surveys took the form of stratified random sampling of villages and fields (Kumburas) within each village, weighted for extent. Results are summarized in Table 6.3.

The principal observations and conclusions of the various surveys are as follows.

- In the Polonnaruwa District, yields are higher for the major schemes than for the minor schemes or for rainfed areas. Maha yields are considerably higher than Yala yields.

- Yields in the Batticaloa District average about one-half those observed in the Polonnaruwa District and the differences between major irrigation schemes and the others are less marked.

- The above differences reflect the importance of a reliable water supply on which the effectiveness of the other components of a total input package so largely depend.

- Acres' surveys (Sources 3, 4 and 5 in Table 6.3) suggest that yields are only marginally lower than those indicated by the DCS surveys.

TABLE 6.3

ESTIMATED IRRIGATED AND RAINFED PADDY YIELDS IN SYSTEM B (t/ha)*

Source	Year/Season	Polonnaruwa District**			Batticaloa District**		
		Major Schemes	Minor Schemes	Rainfed	Major Schemes	Minor Schemes	Rainfed
1	1973-78 Maha	6.6	4.0	4.0	2.8	2.4	2.4
	1973-78 Yala	4.0	2.3	na	2.7	2.6	2.0
2	1979 Yala	4.9	2.7	-	-	-	-
3	1979 Yala	4.1	-	-	-	-	-
4	1979-80 Maha 1R	5.4	-	-	-	-	-
	2R	5.0	-	-	-	-	-
5	1979-80 Maha						
	1958 Batalagoda Release (H4)	-	-	-	2.7	-	-
	1971-1975 Batalagoda Releases (BG34-8, BG94-1, BG94-2)	-	-	-	3.4	-	-

Notes: * Reference to the Polonnaruwa and Batticaloa Districts means those parts within System B.
** Yields for sources 3, 4 and 5 are corrected for moisture content. Yields for sources 1 and 2 were processed originally in terms of volume (bu/acre) and do not, therefore, require a correction factor.

Sources: 1 - Reprocessed data/simple 5-year average for 1973/74 - 1977/78 inclusive. Data incomplete. Dept. of Census and Statistics.
2 - 20 random fields under major schemes; 28 random fields under minor schemes, mean. Dept. of Census and Statistics.
3 - Acres International Ltd., Pimburettewa Scheme, 19 randomly selected fields, mean.
4 - Acres International Ltd., 45 fields in the Pimburettewa Scheme for Land Classes 1R and 2R.
5 - Acres International Ltd., 24 fields in the Vakaneri Scheme, means for various cultivars.

- Yield differences between the 1R and 2R Land Classes tend to narrow when adequate water is available.

- The recent (1971 onward) Batalagoda releases (the "BG" series) are higher yielders than the older Batalagoda releases (the "H" series). Use of the newer cultivars is already extensive in the project area.

Further details of the crop-cutting survey results are presented in Annex E.

Existing Technology

Statistical data gathered by DCS show a progressive spread of recently bred rice varieties and an accompanying obsolescence of traditional and other varieties in the Polonnaruwa District. Transplanting has also become more popular. In the Batticaloa District, on the other hand, all of the paddy crop is broadcast, and the traditional and older improved varieties still predominate. Both preferences are attributable to the uncertainty of the water supply. The recently bred cultivars are dwarfs or semidwarfs which are unable to resist the weed competition that water stress aggravates.

Fertilizer use indicates no perceptible trend in either district. On the other hand, the use of insecticides has shown a marked increase in both districts, whereas the use of weedicide is generally limited to the Batticaloa District. Other survey data indicate that transplanting, fertilization, and insecticide application are more pronounced in major schemes than in minor schemes.

A summary of prevailing practices is provided in Table 6.4.

TABLE 6.4

CULTURAL PRACTICES IN THE PROJECT AREA 1977 - 1978
(percent of fields)

Practice	Polonnaruwa District		Batticaloa District	
	Yala 1977	Maha 1977-78	Yala 1977	Maha 1978
Transplanting	100	84	0	0
Fertilizer	33	78	100	99
Weedicides	0	16	21	75
Insecticides	17	81	54	84
New Varieties				
older releases	0	0	38	71
recent releases	100	80	33	10

Source: Department of Census and Statistics

6.2 - Potential Development

6.2.1 - The Land Resource

Soil and topographical surveys executed during the present feasibility study* indicate the availability of a net (outside major tank schemes) irrigable area of 34 330 ha which is suitable for the double cropping of paddy. By contrast, the net area of irrigable uplands available for irrigated cropping is only some 1,500 ha. Clearly, the Maduru Oya project should be considered to be a predominantly paddy project. The subdivision of the 34 300 ha of paddy soils into land classes and soil categories is as follows.

Land Class	Great Soil Group and Dominant Soil Series	Extent (ha)
1R	Old Alluvials - Moogamana Ela Alluvials - Timbiri Aru, Odigar Villu Low Humic Gleys - Kuda Oya Reddish Brown Earths - Alawakumbura, Padamunda Kulam and Horaborawewa	14 960
2R	Old Alluvials - Ulpothawewa Noncalcic Brown Soils - Boattewewa Solodized Solonetz - Vakaneri	19 370
Total		34 330

There is a possibility of substituting upland crops for paddy in the Yala season on the imperfectly drained Reddish Brown

*Followed by the assessment of the area reduction required to achieve a water balance, as described in Section 4.3.3.

Earths midway down the catena, i.e. on the Alawakumbura, Padamunda Kulam and Horaborawewa series. However, this rotation is unlikely to be accepted by farmers on a large scale, due to their greater familiarity with paddy cultivation.

6.2.2 - Lowland Paddy Production

6.2.2.1 - Technology

A package of improved practices applicable to System B is indicated below and in Table 6.5.

Rice Varieties

The universal use of improved varieties along with the appropriate package of inputs is a prime objective. The yield potential under best farm management conditions of the various cultivars is as follows.

Cultivar	Year of Release	Growth Duration (months)	Yield Potential (t/ha)
BG 34-8	1971	3.0	7.2
BG 34-6	1971	3.5	7.2
BG 94-1	1975	3.5	7.1
BG 11-11	1970	4.5	7.2
BG 90-2	1975	4.0	8.9
H - 4	1958	4.5	5.7

The cultivars specifically recommended for System B are BG 11-11 (4 to 4.5 months) in Maha and BG 34-8 (3 to 3.5 months) in Yala. In the floodplains, BG 34-8 should be sown in both the Maha and Yala seasons due to the need to shorten the growing season.

TABLE 6.5

PHYSICAL CROP INPUTS

(per ha)

	Paddy	Groundnuts (Maha)	Soybeans (Yala)	Tobacco (Yala)	Cotton (Yala)	Sugarcane (Plant cane)
Seed	52 kg	96 kg	68 kg	15 000 seedlings	34 kg	6 t
Seed Treatment	-	-	0.35 kg[5]	-	-	-
Fertilizer						
Urea	215 kg	90 kg	62 kg	112 kg	125 kg	185 kg
Triple Super Phosphate	75 kg	125 kg	125 kg	225 kg	125 kg	94 kg
Muriate of Potash	50 kg	60 kg	46 kg	-	125 kg	100 kg
Sulphate of Potash	-	-	-	140 kg	-	-
Crop Protection Chemicals	11 kg[1]	-	-	-	-	-
	8 kg[11]	1 kg[3]	0.7 L[6]	1.1 L[7]	10 kg[9]	-
	226 ml[12]	-	-	-	5.6 L[6]	-
	23 kg[2]	2.25 kg[4]	1.5 kg[4]	-	-	0.6 kg[10]
	-	-	-	2.0 kg[8]	-	-
Labor (man-days)						
Land preparation/planting	65	20	20	122	30	55
Maintenance	37	29	41	57	77	56
Harvesting, transport, etc.	73	64	68	123	90	75
Farm Power						
Buffalo (pair-days)	36	-	-	-	-	-
2-wheel tractor (hours)	-	30	30	-	30	-
4-wheel tractor (hours)	-	-	-	-	-	20

Notes:
1 - BHC 10% Dust
2 - Saturn 6% Granules
3 - Tamaron
4 - Linuron
5 - Rhizobium inoculum
6 - Monocrotophos 60% EC
7 - Thiodan
8 - Perenox
9 - Carbaryl
10 - Paraquat
11 - Furadan
12 - Diomethoate 40% EC

Field Water Management

Uninterrupted water flow over the cropped area, whatever the peripheral benefits from temperature control, is wasteful of irrigation water and should not be encouraged. Moreover, fertility losses may result from the leaching of fertilizers and the removal of the finer soil particles.

There is broadly a choice between two systems of field water management

- Continuous submergence - involving the maintenance of a 50- to 100-mm depth of water on the field from the initiation of flower primordia (24 days before heading) until the completion of grain filling (15 days after heading). The water level is lowered for fertilizer topdressings.

- Intermittent irrigation - a system under which the inflow of water is cut off once the field is flooded, and is not resumed until the water has been completely consumed by evapotranspiration, percolation and seepage.

Research results elsewhere in the Dry Zone (Maha Illuppallama) indicate that intermittent irrigation gives lower yields and is not, therefore, recommended. The continuous submergence method can, however, be modified to allow rotational water deliveries, as long as prolonged drying of fields is not permitted.

Field water management should aim at maintaining a minimum water level of 30 mm after transplanting, to ensure adequate weed control and nutrient availability. While short-term drying of fields at certain stages of growth (from 14 days

after transplanting to 54 days before harvest) may not be harmful to the crop, staggering of transplanting dates will make it difficult to plan for variations in water deliveries to suit the growth stage. Irrigation deliveries, which will be made on a "roster" or "rotational" basis, should aim at keeping the field water levels between a minimum of 30 and a maximum of 100 mm. Careful attention by farmers to bund maintenance and reduction of irrigation deliveries after heavy rains will allow maximum possible use of rainfall during the Maha season.

Transplanting

The weed control and yield benefits from transplanting are well known (possibly 1 t/ha). With the adequate water supply that the proposed project ensures, transplanting should completely replace broadcasting in System B. Judicious nursery fertilization will ensure that seedlings are neither chlorotic nor stunted at transplanting time, about 3 weeks after sowing.

Fertilizer and Chemicals

The recommended fertilizer and chemical application rates for selected crops are summarized in Table 6.5.

With respect to paddy the following should be noted

- Nitrogen should be applied as a topdressing at the initiation of flower primordia, with a smaller topdressing just before heading.

- Furadan is used to control brown plant hopper, gall midge and yellow stem borers. The new cultivars BG 400-1 and BG 276-5 are resistant to gall midge.

- Unless weed control is effective, the use of dwarf and semidwarf cultivars is not practicable.

The only troublesome disease likely to occur in System B is blast. The recommended cultivars, BG 11-11 and BG 34-8, are considered to be adequately resistant to this disease.

6.2.2.2 - Expected Yields

The recorded yields of various rice varieties under best farm management conditions have been indicated in Section 6.2.2.1. The recommended varieties for System B, BG 11-11 and BG 34-8, both have potential yields of 7.2 t/ha.

Yields under existing field conditions have also been discussed in considerable detail in Section 6.1.2. Using the cultivars BG 11-11 and BG 34-8 in major irrigation schemes in the Polonnaruwa District, Maha yields ranging from 5.8 t/ha to 7.1 t/ha have already been observed (DCS Survey). Acres' survey results indicate mean yields of 5.4 t/ha and 5.0 t/ha on the 1R and 2R Land Classes respectively in Maha 1979/80.

Conditions in the Pimburettewa Scheme approximate what is envisaged "with the project" in System B and accordingly present Pimburettewa yields may be used to indicate "with the project" yields. For purposes of economic analysis, the following yields were employed for both Maha and Yala seasons

Land Class 1R 4.6 t/ha
Land Class 2R 4.1 t/ha.

The above levels are about 80 to 85 percent of those indicated by the Maha 1979/80 crop-cutting survey (Source 4) on the Pimburettewa Scheme and have been used as conservative indicators of "with the project" yields once adequate irrigation water is available in both seasons. They reflect the input package recommended above and the magnitude of the proposed development in System B.

6.2.2.3 - Cropping Patterns

If the above recommendations are followed for the lowlands, double cropping with paddy will include a 135-day variety, BG 11-11, in Maha and a 105-day variety, BG 34-8, in Yala. To permit transplanting in early October, nurseries must be sown 3 weeks earlier. The sequence illustrated in the cropping calendar in Figure 17 is identical with that now practised in most System B lowlands.

Transplanting in the floodplains should be deferred until after January 15, when the risk of damaging floods has declined. This pattern differs from the lowlands only in that a 105-day cultivar, preferably BG 34-8, is recommended for both seasons.

6.2.2.4 - Water Requirements

Water requirements for lowlands and floodplains are given in Table 6.6. Water for land preparation during a 15-day period has been estimated by Joshua[13] at approximately 180 mm and this estimate has been employed in the present calculations.

TABLE 6.6

CROP WATER REQUIREMENTS FOR THE LOWLANDS AND FLOODPLAINS

(mm)

		J	F	M	A	M	J	J	A	S	O	N	D
		Lowlands Paddy (135 d)/Paddy (105 d)											
ET paddy - Maha		149	109	23							81	135	127
ET paddy - Yala					84	211	228	165	31				
Land preparation				60	120					60	120		
Percolation losses	1R	90	75	30	75	90	90	75	15	15	75	90	90
	2R	180	150	60	150	180	180	150	30	30	150	180	180
Field water requirements	1R	239	184	113	279	301	318	240	46	75	276	225	217
	2R	329	259	143	354	391	408	315	61	90	351	315	307
		Floodplains Paddy (105 d)/Paddy (105 d)											
ET paddy - Maha			72	182	162	66							
ET paddy - Yala							89	217	222	94			
Land preparation		60	120			40	120	20					
Percolation losses	1R	15	75	90	85	25	65	90	90	45			
	2R	30	150	180	170	50	130	180	180	90			
Field water requirements	1R	75	267	272	247	131	274	327	312	139			
	2R	90	342	362	332	156	339	417	402	184			

In the case of lowland rice, deep percolation rates for paddy fields were derived by referring to experimental work done in Sri Lanka on the paddy field water balance. The greater porosity of the sandier soils which occur in System B, (most of which are assigned to a separate land class), was recognized by adopting a higher deep percolation rate for the Class 2 paddy soils. The rates adopted for this study were 3 mm/day for Land Class 1R and 6 mm/day for Land Class 2R.

6.2.3 - Upland Crops

The net area available for irrigated upland cropping is about 1,500 ha, which is less than 5 percent of the net irrigable area in System B. The choice of potential crops is, however, wide. The agronomic characteristics of some upland crops which have potential for widespread cropping in System B are considered below.

6.2.3.1 - Alternative Crops

Sugarcane

The upland Reddish Brown Earth soils found in System B are suitable for the cultivation of irrigated sugarcane. A plant crop plus three ratoons should be possible and, with good management, an average yield of 67 tonnes of cane per hectare should be possible. Although sugar production can be shown to be economically attractive when grown on a large scale in Sri Lanka, the extreme fragmentation of the Reddish Brown Earth soil group in the project area renders this crop unattractive. Even a 400-TCD "mini factory" would need a sugarcane area of at least 800 ha. Large blocks of this size are not to be found in the project area.

Cotton

The potential for successful cotton growing in System B exists. The crop demands that rains be minimal at the time of both flowering and boll formation, and that control of the formidable range of pests be effective. It can be regarded as a soil depleting crop, and should be grown in rotation with soil building crops such as soybeans or groundnuts. Cotton can only be grown in the Yala season under irrigation. The heavy Maha rains rule out cotton in that season.

The successful cultivation of cotton in System B and elsewhere in the Dry Zone will largely depend on the establishment of an effective support structure to assist farmers with the specialized agronomic, entomological and credit requirements of intensive cotton cultivation. With good management, a yield of 1.7 t/ha should be possible, with accompanying attractive financial and economic returns. Because of this potential, it is recommended that further consideration be given to the cultivation of this crop on the upland soils. Early work should be carried out on the Experimental Demonstration Farm.

In view of the uncertainty surrounding the true potential of cotton cultivation in System B, however, it is not recommended for inclusion in the cropping pattern for purposes of economic benefit calculations.

Tobacco

Tobacco, which is currently grown in System B, could be considered as an attractive upland Yala crop. It is a soil-depleting crop, however, and should be grown one Yala season

in two or three, in rotation with a soil-building crop. It requires substantial fertilizer inputs and specialized farm management techniques. An initial yield of 800 kg/ha can be anticipated and a yield of 1.2 tonnes of cured leaf per hectare is possible under good management conditions.

Groundnuts, Soybeans and Pulses

These crops can be grown either under irrigation or under rainfed conditions. Their contribution to soil fertility maintenance warrants their inclusion in various crop rotations. Moreover, they are very suitable as intercrops, particularly with maize and sugarcane.

The light-textured upland soils in System B are ideal for groundnuts. With soybeans, the seed or the soil should be inoculated with an effective strain of the nodule bacterium (*Rhizobium japonicim*). Yields of 1.5 to 2.0 t/ha can be expected for groundnuts and pulses and 1.3 to 2.0 t/ha for soybeans.

Kenaf and Sunnhemp

Much research has been concentrated on the agronomy of these two fiber crops at Maha Illuppallama and experience of their cultivation under rainfed conditions is available within System B. Diseases are not serious problems with kenaf, but sunnhemp is susceptible to wilt and rust. Sunnhemp is a good green manure crop, particularly when grown in rotation with tobacco. Potential yields in terms of fiber are 2.5 to 4.5 t/ha for kenaf and 1.25 to 2.5 t/ha for sunnhemp.

6.2.3.2 - Cropping Patterns

Some of the cropping patterns which are possible on well-drained Reddish Brown Earths are tabulated below.

Maha	Yala
Kenaf (140 d)	Tobacco (140 d)
Soybeans (105 d)	Chillies (160 d) Onions (90 d)
Vegetables (90 to 120 d)	Cowpea (75 d)
Maize (120 d)	Pulses (60 to 75 d)
Groundnuts (110 d)	Cotton (150 d)
Groundnuts (110 d)	Soybeans (105 d)

From a purely agronomic point of view, the potential cropping patterns are almost endless. Although agronomic considerations will be one of the factors by which the eventual choice of an upland cropping pattern will be made, it is likely that other factors (such as potential markets, infrastructure support, and farm financial returns) will be more important in the decision.

For purposes of the present study an "indicative" cropping pattern - groundnuts in Maha and soybeans in Yala - has been selected as a conservative indicator of the economic benefits obtainable from the uplands. The input package for these crops is shown in Table 6.5 and the crop calendar is shown on Figure 17.

6.2.3.3 - Water Requirements

Water requirements for an upland crop rotation are shown in Table 6.7. A groundnuts/cotton* rotation has been assumed as an index rotation for this calculation. Water for land preparation during a 15-day period has been estimated at 40 mm.(13) Percolation and other losses on upland soils have been incorporated into the farm and distribution efficiency factors.

6.2.4 - Experimental Demonstration Farm

An Experimental Demonstration Farm is to be established under FAO sponsorship in System B near the Pimburettewa Tank Scheme (see Figure 6). The farm will occupy an area of some 40 ha and will include all four series of the Noncalcic Brown soil group.

The farm will provide an opportunity for experimentation on this soil group, which covers 35 percent of the overall project area. Research on other soil series can be carried out, where needed, on outlying farms.

Work at the Maha Illuppallama research station has contributed significantly to the solution of agricultural problems on the Reddish Brown Earth soils in Agroecological Zone DL 1. The System B farm will provide supplementary information for Agroecological Zone DL 2, which has a different precipitation pattern.

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*Cotton was used as an index Yala crop since its longer duration (150 days vs 105 days) will result in conservatively high project water requirements.

TABLE 6.7

CROP WATER REQUIREMENTS FOR THE UPLANDS

(mm)

	Cropping Pattern for Uplands - Groundnuts (110 d)/Cotton (150 d)											
	J	F	M	A	M	J	J	A	S	O	N	D
ET Groundnuts	107	34								35	61	102
ET Cotton			34	116	110	207	182	75				
Land preparation			75							75		
Gross field water requirements	107	34	109	116	110	207	182	75	-	110	61	102

Note: Cotton was used as an index Yala crop to arrive at conservatively high crop water requirements. The index Yala crop used in the economic analysis is Soybeans.

The activities of this farm are expected to include a research program which covers

- soil - plant - water relationships

- the effects of water management practices on crop growth and development, weed control, fertilizer response, nutrient availability, and soil toxicities

- the formulation of cropping patterns appropriate to the soil categories in System B

- adaptive research which will help to bridge the gap between experimental station results and "on-farm" achievements.

As its name implies, the farm will also be active in the demonstration of agricultural practices. This will be most useful during the early years of farm settlement.

6.2.5 - Homesteads

Recent experience with homesteads in irrigation schemes in Sri Lanka (e.g. System H) has centered around parcels of 0.2 ha. However, the initial evidence suggests that this plot size is not sufficient to permit the diverse range of activities necessary to allow the settler to adequately supplement paddy production and total family income. In particular, potential livestock production is severely limited with 0.2-ha plots. The potential for sharing the homestead with a second generation family (in a separately constructed dwelling) is also limited.

Considering the availability of sufficient quantities of nonirrigable uplands in System B, and further considering the overall land-use balance for the area, 0.4-ha homesteads are proposed for all paddy farmer settlers in System B. For irrigated upland farmers, it is proposed to locate a homestead plot of 0.3 ha adjacent to each 1.5-ha plot of commercial crop land. For the settlers producing irrigated rice on the lowlands, the homestead would be located on nearby uplands, separate from the 1.0 ha of paddy land.

The relatively large 0.4-ha homestead plot is required to support three basic activities of the paddy farmers: residence, food crop production; and livestock production.*

The "living space" and the land required for multipurpose cattle will require about half the total homestead area. The area allocated to cattle will not support draft animals, which are assumed to graze paddy stubble and public grazing lands. The remaining land is available for food crop production, only a small part of which would enter the local market, the balance being consumed at home. The homestead area can also support some scavenger livestock, such as poultry, swine, goats, or sheep.

The concept of a 0.4-ha homestead will result in less compact communities, inhabited by settlers who will have a greater opportunity of attaining a high degree of food and income self-sufficiency than would be possible with smaller plots. It is recommended as an important basic requirement for the project's success.

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*Livestock area would not be required by the upland farmers.

6.2.6 - Livestock

On the basis of planned settlement proposals and existing livestock production and resources, three possible systems to increase livestock production have been identified

- integration of draft buffalo into irrigated agriculture
- supplementary livestock production on arable nonirrigated uplands
- development of private herds on public grazing lands.

These alternatives could, in practice, all be developed simultaneously.

Murrah Buffalo, for Draft Animals Milk and Surplus Stock

Crossbred (Murrah) buffalo cows would be bred to supply draft bulls. These cows would be zero-grazed (cut-and-carry) on a rainfed pasture mixture. About 0.33 ha of improved pasture would be necessary for one cow plus an average of 1.185 followers. This land would be an integral part of the homestead plot. They could also utilize crop stubble not consumed by draft animals. In total, about 8,600 buffalo cows would be required to generate eventually 29 000 more draft animals for anticipated irrigated farm power requirements in the region. This means that approximately one out of every four settlers would be assigned a buffalo cow at the time of their arrival in the project area.

To obtain the basic breeding stock, it would be necessary for the National Livestock Development Board (NLDB) to import Murrah or Surti from India and breed and multiply these on government farms. These could then be crossed with indigenous buffalo purchased from local herds. The heifers should be 2-1/2 yr of age, and in calf, before distribution to settlers.

Zebu/Temperate Cattle,
for Supplementary Meat and Milk

Crossbred Zebu/Temperate cows and followers could also be zero-grazed on a similar improved pasture to that described for the Murrah buffalo. They would also have access to stubble and, in fact, could be rotated with dry land crops. A similar carrying capacity of one cow and followers on 0.33 ha is required.

In this case, cattle could first be accumulated and bred on government farms using imported Sahiwal, AMZ and Jersey semen. Alternatively, they could be purchased from improved private herds already in existence. These heifers should be in calf and about 2 yr of age before distribution to settlers.

Development of Private Herds
on Public Grazing Land

Alternatively, the development of indigenous cattle for dairy and beef production on the villu/damana lands might be encouraged by providing milk collection points. In this case, the herd size sould be sufficient to provide an adequate standard of living to a family without any other source of income.

Grazing reserves should be set aside to protect this form of production from encroachers. Grazing licences might also be required. The grazing capacity of public lands is expected to be about one cow equivalent for every 2 ha of pasture. Cooperation with NLDB would initially be necessary to increase the supply of breeding stock in the project area.

All proposed livestock programs in the region will require the simultaneous development of effective producer organizations and adequate government support services. Implementation of any livestock schemes for System B should be the responsibility of a Regional Dairy Development Bureau which would provide extension services to local farm cooperatives.

6.2.7 - Fisheries

The potential for fish production in the Maduru Oya scheme is good. The most appropriate method to develop this resource is through the stocking of the larger reservoirs: the Maduru Oya Reservoir and the Pimburettewa and Vakaneri tanks. This approach appears most suitable because management of fisheries in large reservoirs requires a minimum of technical and labor input and the investments required are comparatively small.

It is anticipated that the water bodies can be stocked with *Tilapia*, a species which is currently produced by the Polonnaruwa fish station. In total, approximately 5,000 ha of reservoir area (area at median reservoir level) is available for fish production, with an expected yield of 150 kg/ha/yr.

Fish is an excellent source of protein and would be a welcome addition to the diet of the settlers. Some 200 fisherman families could be expected to make a living from fishing in the Maduru Oya Reservoir and major tanks. Additional subsistence fishing could be carried out on the smaller tanks and rivers.

6.2.8 - Forestry

At present, 66 700 ha or 54 percent of the project area is covered by some type of forest. The distribution of forest by class is as follows

Dense forest	1 300 ha
Medium forest	49 800 ha
Light forest (parkland)	11 200 ha
Plantation	4 400 ha
Total	66 700 ha

Although the exact areas to be cleared will not be known until detailed planning and design of farms and settlements is undertaken, it is estimated that some 34 000 ha or 50 percent of the present forest cover will be cleared for development. In settlement areas more selective clearing practices can be applied.

The project will bring about the systematic harvesting of the forest resource. If left under present conditions, it is likely that much of the remaining forest would be degraded by chena cultivators who are already active on over 25 percent of the System B area. It is therefore appropriate to claim economic benefits for the project from the forest areas that are to be cleared. These areas will yield a modest quantity

of commercial timber and considerable quantities of fuel wood and building materials. Yields and total quantities are summarized as follows

Commercial timber (172 ft^3/ha)*	4.8 million ft^3
Poles and posts (200/ha, each 8 ft)	5.6 million items
Firewood (500 ft^3/ha)	14.1 million ft^3

To ensure future availability of forest products, particularly fuel wood, reforestation is proposed. Such reforestation will be of the plantation type, supplemented by introduction of better utilization methods for parkland areas, and selected plantings on canal banks and in settlement areas. The active participation of the farmer/settler in the forestation programs will be essential.

To meet the needs of the farm families, 1,560 ha of plantation must be harvested annually. Based on a 7-yr rotation, a total plantation area of 11 000 ha will be required.

*Weighted average yield from dense and medium forest and plantation areas.

7 - AGRICULTURAL PROJECT BENEFITS

7.1 - Introduction

Calculation of the economic benefits of the project is undertaken with economic prices, which represent real costs to the national economy. The market or financial prices which exist today often do not reflect actual costs. Examples of this include fertilizers, which are heavily subsidized, and paddy, the price of which is well below current international levels. Prices are expressed at levels which are expected to prevail during the life of the project. For commodities traded internationally, prices of both inputs and agriculture products are based on IBRD forecasts for 1990[14] which are expressed in 1979 constant currency. Prices are calculated on the basis of import substitution or export. For prices of commodities not traded internationally, current local prices are used as representing future price levels expressed in 1979 constant currency. Markets and prices are briefly examined in Section 7.2.

Agricultural project benefits accrue to the project from several areas. These include new areas under irrigation, augmentation of the area cropped under existing tank schemes, agricultural production on homestead plots, and benefits from fisheries, forestry, and livestock. Benefits from irrigated crop production are considered in Section 7.3 on a "without the project" basis and a "with the project" basis so that net benefits can be obtained. All other benefits from agriculture are computed as incremental benefits directly attributable to the project.

Two final sections (Sections 7.4 and 7.5) examine financial farm income and identify some of the more important micro-economic implications of the project.

Further details on the calculation of economic and financial prices can be found in Annex L (Economic and Financial Analysis) while details in other areas can be found in Annex G (Agroeonomic Studies).

7.2 - Product Potential and Prices

7.2.1 - Product Potential

The list of potential crops which can be grown under irrigated conditions in System B, and the Accelerated Mahaweli Scheme in general, is long. Numerous criteria can be used to determine the suitability of a specific crop for production under irrigation.

The suitability of crops for System B has been examined with reference to the following criteria

- national market prospects
- international market prospects
- agronomic considerations
- environmental considerations
- farm management
- infrastructure support
- relative financial profitability
- relative economic profitability.

The first two factors relate to marketing of the crop in either the international or domestic markets. Thus, import substitution crops such as sugar, rice and cotton, and good

export crops such as tobacco and rice, would rank high using the national and international market criteria respectively. Alternatively, crops for which the country is self-sufficient or those for which international market prospects are poor would rank low.

Agronomic factors relate to soil characteristics, irrigation technique constraints, and the susceptibility of the crop to insects, diseases, etc.

Environmental constraints include climatic factors such as the amount of rainfall and other ecological factors.

Farm management criteria include technological issues - start-up costs, local experience with the crop, and certain social-cultural constraints - all of which impinge on farmer adoption rates. Also included are the credit requirements which relate to the farmers' aversion to risk and his desire for self-reliance.

The public support criterion includes all forms of support necessary to make the product a success, including marketing and production facilities, input supply, and extension services. These factors need not be in place for a crop to rank highly but at the very least they should be well developed somewhere within the country.

The profit criterion incorporates both financial and economic profitability. Financial profitability refers to the return the farmer actually receives after deducting his production costs, including that of credit. Economic profitability, on the other hand, refers to the return to the country after adjustments are made for subsidies, real labor costs, and world market prices.

Table 7.1 illustrates an ordinal ranking of the eight criteria (10 being excellent and 1 being poor) for crops which have been considered for production in System B. The "Aggregate Assessment" column is a simple average of the ordinal rankings of all eight factors and, as such, can be termed a relative indicator for crop selection.

Not unexpectedly, the results indicate that paddy ranks highest and should therefore be grown to the maximum extent possible. On the uplands, promising crops include soybeans, groundnuts, tobacco, and possibly cotton. Pulses, vegetables and fruits also appear attractive but output is limited to regional/local markets. Thus, extensive cultivation of these crops should not be considered at this time, as more attractive alternatives exist. The potential for dairy/beef products and other livestock products also appears attractive.

Table 7.1 also indicates the key factors in the analysis which, if a rigorous weighting procedure were employed, might override the aggregate assessment. The reader is cautioned that the indicator is relative only and is based on an assessment of eight factors, which are extremely difficult to reduce to an aggregate ranking.

7.2.2 - Financial and Economic Costs and Prices

A summary of the prices of the major inputs and various agricultural produce which were used to calculate project benefits is shown in Table 7.2. Where economic prices differ from financial prices, the economic prices are shown in brackets and are used to calculate the agricultural benefits. Further details can be found in Annex G (market assessments) and Annex L (price calculations).

TABLE 7.1

RANKING OF PRODUCT POTENTIAL

Product	Market Potential Nat (1)	Market Potential Int (2)	Agronomic Considerations (3)	Environ. Considerations (4)	Farm Management (5)	Public Support (6)	Financial Profit (7)	Econ. Profit (8)	Aggregate Assessment (9)	Current Recommendations
Paddy	$\boxed{10}$	8	8	9	$\boxed{10}$	8	4	8	8	Maximum extent possible
Groundnuts	5	7	9	8	7	7	$\boxed{6}$	6	7	Serious consideration on Uplands
Soybeans	4	7	9	8	7	7	$\boxed{6}$	6	7	
Tobacco	4	8	4	8	6	$\boxed{9}$	7	9	7	
Cotton	10	2	$\boxed{3}$	8	$\boxed{5}$	6	6	7	6	Possibility on Uplands
Sugarcane	10	1	7	4	$\boxed{5}$	$\boxed{4}$	5	$\boxed{5}$	5	Not recommended
Fibers	6	3	7	6	4	6	$\boxed{3}$	3	5	
Pulses	$\boxed{8}$	1	9	8	8	9	3	4	6	Supply regional/local mkt + self-sufficiency
Vegetables	$\boxed{9}$	1	8	8	9	9	10	9	8	
Cassava	7	3	6	5	6	7	$\boxed{3}$	4	5	Not recommended
Maize	6	1	6	7	7	7	$\boxed{3}$	3	5	
Sorghum	6	1	6	7	7	7	$\boxed{3}$	3	5	
Fruits	$\boxed{8}$	4	5	5	7	7	7	8	6	Supply regional/local mkt + self-sufficiency
Dairy/Beef	$\boxed{6}$	1	6	5	6	6	7	5	6	Potential with livestock-crop integration
Other Livestock	$\boxed{7}$	2	6	5	7	6	7	5	6	

Notes: $\boxed{}$ - Key Factor in Assessment.

1 ⟶ 10
poor ⟶ good

1 - Domestic market outlook
2 - International market outlook
3 - Soils, irrigation constraints, insects, diseases
4 - Climatic conditions
5 - Technology, local experience, social-cultural constraints, and risk
6 - Infrastructure and extension support
7 - Farmer profitability
8 - Returns to national economy
9 - Simple average of ordinal rankings

TABLE 7.2

SUMMARY OF FINANCIAL (ECONOMIC) PRICES

Item	Financial (Economic) Price*
Fertilizer	
- Urea	Rs 980/t (Rs 3,899/t)
- TSP	Rs 1,335/t (Rs 4,145/t)
- Muriate of Potash	Rs 1,065/t (Rs 2,649/t)
- Sulphate of Potash	Rs 1,420/t (Rs 3,532/t)
Crop Protection Chemicals	
- Monocrotophos	Rs 189/L
- Diomethoate	Rs 11/113 ml
- Thiodan	Rs 87/L
- BHC 10 percent Dust	Rs 4.40/kg
- Saturn 6 percent Granules	Rs 8/kg
- Linuron	Rs 40/kg
- Furodan	Rs 12/kg
- Perenox	Rs 23/kg
Farm Power	
- 2-wheel tractor	Rs 20/hr (Rs 24.70/hr)
- Pair of buffalo	Rs 50/d
Farm Labor	
- Hired	Rs 16/d (Rs 6/d)
- On-farm	Nil (Rs 6/d)
Agricultural Produce	
- Paddy	Rs 1 900/t (Rs 3 500/t)
- Soybeans	Rs 5 100/t
- Groundnuts	Rs 5 600/t
- Pulses	Rs 5 300/t
- Maize	Rs 2 000/t
- Chillies	Rs 19 000/t
- Cassava (fresh)	Rs 500/t
- Vegetables	Rs 1 000/t
- Bananas	Rs 11/bunch
Livestock Products	
- Milk	Rs 1.31/L (Rs 2.21/L)
- Beef culls	Rs 3.30/kg live weight (LW)
- Beef Heifers	Rs 6.60/kg LW
Forest Products	
- Commercial Timber	Rs 4/ft^3
- Firewood	Rs 0.30/ft^3
- Poles and Posts	Rs 3.00/ea
Fish	
- Tilapia	Rs 4/kg

*Unless indicated in brackets, the economic price is taken as equivalent to financial price.

The major areas where economic and financial prices differ are for fertilizer and paddy. At present, the cost of fertilizer to the farmer is heavily subsidized by the government, which provides fertilizer at about one-third its actual cost. At the same time, the price for paddy under the Guaranteed Price Scheme is about two-thirds of the present world market price. One result of these differences is an economic return from paddy production which varies considerably from its financial return.

7.3 - Net Economic Benefits of Project

7.3.1 - Irrigated Crop Production

Irrigated crop production must be examined on the basis of the "without the project" situation as well as the "with the project" situation so that net benefits for the project can be determined.

Without the Project

The present situation with respect to agricultural activity in System B has been described in detail in Section 6. The intent of this section is to quantify the current level of existing benefits from crop production for purposes of economic analysis.

The economic return from paddy production is assumed to be similar to the return for the "with the project" situation with comparable yields. Table 7.3 summarizes the area cropped, the yields achieved in each season and estimated current economic returns per year. The areas are taken from present land-use estimates, as documented in Annexes A and E.

TABLE 7.3

ESTIMATED AREA, YIELD AND NET RETURN
OF EXISTING RICE PRODUCTION IN SYSTEM B

Area	Net Irrigable Area[1] Maha (ha)	Net Irrigable Area[1] Yala (ha)	Yields Maha/Yala (t/ha)	Net Return/Yr (Rs Millions)
Pimburettewa	1 260	1 160	4.4/4.4[2]	23
Vakaneri/Punanai	3 530	880	2.8/2.8[3]	18
Small Tanks	2 700	540	3.2/2.4[4]	16
Rainfed	4 000	-	3.2/0[5]	22
Total	11 490	2 580		79

Notes:

1 - Areas estimated by referring to the map of present land use (Fig 5) and official statistics. See Annex A for comparison with DCS figures.
2 - Estimated. Crop cutting experiments by the consultants (see Chapter 6) indicated yields of over 4.4 t/ha, but this figure was adopted to be consistent with "With Project" assumptions.
3 - Latest 5 yr "mean" - DCS Batticaloa District - Major Tanks. Confirmed by Maha 1979/80 crop cutting experiments on the Vakaneri Scheme.
4 - Latest 5 yr "mean" - DCS Polonnaruwa & Batticaloa Districts - Minor Tanks
5 - Latest 5 yr "mean" - DCS Polonnaruwa & Batticaloa Districts - Rainfed.

Although some minor improvements in yields may be expected in the situation where the project does not exist, it is assumed that the net economic return remains unchanged. In effect, this means that additional returns from yield improvements are offset by lower product prices or higher production costs. This is in line with the "with the project" methodology, where net returns are assumed to remain unchanged once the target yields have been achieved.

In addition, about 33 000 ha or 25 percent of the gross project area is under chena cultivation, with approximately 4,000 families engaged in this activity. Because of the long-term detrimental effects of chena cultivation, the net economic return is considered to be zero in both the "without the project" and "with the project" situations. Much of the present chena cultivation takes place in areas which are not to be developed in any case.

With the Project

Under project conditions, the benefits from irrigated agriculture will accrue primarily from the production of paddy in newly irrigated areas, but also from an increase in the production from existing tank schemes and from the production of upland crops. The upland crops account for only about 4 percent of the total projected area under irrigated agriculture in System B. Section 6 has detailed those crops which can be grown successfully from an agronomic point of view on the upland soils. However, the upland areas represent a small proportion of the total irrigated area and agricultural returns from upland crops are more uncertain than the returns from rice production, due to marketing factors, infrastructure requirements, etc.

A representative return for the upland crops is, therefore, calculated on the basis of a groundnuts/soybean rotation in Maha/Yala on Class 2U upland soil, but applied to the total area allocated to upland crops (i.e. both 1U and 2U Land Classes).

Agricultural benefits from paddy production in new areas have been calculated on the basis of paddy yields of 4.6 and 4.1 t/ha on Land Classes 1R and 2R respectively. This applies to both Maha and Yala crops.

Maximum economic returns are not achieved in the first year of agricultural production. For paddy, a 5-yr development period is assumed, while for upland crops, an 8-yr development period is anticipated. Each begins with 60 percent of the net benefit achieved in the first year of production. These build-up factors reflect not only lower yields but also situations which may impact the economic return, such as poor initial leveling of the land, water stress due to start-up problems with the delivery system, shortage of inputs, etc. The economic return for 1 ha of paddy and the representative upland crop rotation is shown in Table 7.4. This table also illustrates the return during the build-up period. After the target economic return is reached, no further increases are assumed. Economic benefits of improved yields are assumed to be offset by lower crop prices or higher production costs. To calculate the annual economic return from each 1-ha farm, a cropping intensity of 98 percent in Maha and 90 percent in Yala is used. This return is further reduced by 5 percent to account for bunds and other minor land losses on each farm.

TABLE 7.4

PROJECTED ECONOMIC
CROP BUDGET SUMMARY
(Rs/ha)

	Paddy (Maha/Yala) 1R	Paddy (Maha/Yala) 2R	Groundnuts (Maha) 2U	Soybeans (Yala) 2U
Target Yield (t/ha)	4.6	4.1	1.5	1.6
Economic price (Rs/t)	3,467	3,467	5,572	5,143
A - Gross Value of Production (Rs)	15,948	12,481	8,358	8,229
Cost of Production (Rs)				
Fertilizer	1,281	1,281	1,028	882
Crop Protection	399	399	156	192
Farm Power	1,800	1,800	741	741
Labor	1,050	1,050	678	774
Miscellaneous (seeds, bags, etc.)	863	863	1,045	836
B - Total Cost of Production	5,393	5,393	3,648	3,425
C - Net Value of Production/Crop (A-B)	10,555	8,822	4,710	4,804
Net Value Year 1	6,333	5,293	2,826	2,882
Year 2	7,389	6,175	3,062	3,123
Year 3	8,444	7,058	3,297	3,363
Year 4	9,500	7,940	3,533	3,603
Year 5	10,555	8,822	4,004	4,083
Year 6	10,555	8,822	4,239	4,324
Year 7	10,555	8,822	4,475	4,564
Year 8	10,555	8,822	4,710	4,804

Section 4 details the net irrigable areas which can be allocated to farms. Two development scenarios are considered; Table 7.5 indicates the rates at which different sectors and land classes in each sector come into production. These areas include small tanks and rainfed areas which presently exist but exclude the Pimburettewa, Vakaneri and Punanai schemes, which are treated separately. Upland areas do not include homestead allocations.

Agricultural benefits also result from increased areas which can be cultivated in the Pimburettewa, Vakaneri and Punanai schemes. This increase occurs primarily in the Yala season, with Maha 1983/84 being the first season for which these additional benefits are calculated. The net irrigable areas (and projected yields) for these schemes which can be cropped in Maha and Yala when additional irrigation water is available are shown below.

Area	Net Irrigable Area (ha)	Projected Yields Maha/Yala (t/ha)
Pimburettewa	1 660	4.4*
Vakaneri/Punanai	3 530	4.2**

For Pimburettewa, Vakaneri and Punanai schemes, a similar 5-yr buildup from present yield levels to the above levels is assumed.

* Weighted average of 65 percent Land Class 1R and 35 percent Land Class 2R.

**Weighted average of 25 percent Land Class 1R and 75 percent Land Class 2R.

TABLE 7.5

INITIAL AGRICULTURAL PRODUCTION

Year		Area in hectares IR		2R		Uplands (1U + 2U)		Total
Scenario A								
1984	Maha	3 220	(1)	1 680	(1)			4 900
	Yala	1 730	(1)	2 390	(1)			4 120
1985	Maha	1 902	(2)	2 995	(2)			4 897
	Yala	2 389	(2)	4 007	(2)			6 396
1986	Maha	782	(3)	2 577	(3)	625	(1)	3 984
	Yala	1 923	(3)	2 672	(3)	630	(2)	5 225
1987	Maha	2 035	(3)	2 313	(3)			4 348
	Yala	974	(3)	741	(3)	245	(3)	1 960
Total		14 955		19 375		1 500		35 830
Scenario B								
1984	Maha	1 680	(1)	640	(1)			2 320
	Yala	1 770	(1)	1 450	(1)			3 220
1985	Maha	1 210	(1)	1 370	(1)			2 580
	Yala	1 267	(1,2)	1 468	(1,2)			2 735
1986	Maha	929	(2)	2 260	(2)			3 189
	Yala	779	(2)	1 701	(2)			2 480
1987	Maha	1 604	(2)	2 183	(2)			3 787
	Yala	431	(3)	1 546	(3)			1 977
1988	Maha	589	(3)	2 489	(3)	625	(1)	3 703
	Yala	1 300	(3)	816	(3)			2 116
1989	Maha	824	(3)	1 682	(3)	630	(2)	3 136
	Yala	1 598	(3)	1 029	(3)			2 627
1990	Maha	974	(3)	741	(3)	245	(3)	1 960
		14 955		19 375		1 500		35 830

Notes: 1 - 1984 Maha = Maha 83/84

2 - Bracketed numbers indicate sector number.

Using the areas in Table 7.5 and returns shown in Table 7.4, net economic returns from irrigated crop production in the "with the project" situation are calculated and summarized in Table 7.6. Returns from small tank areas and rainfed paddy are included until these areas are developed under the project. In the case of the small tanks, some rehabilitation will be necessary; costs for this have been included in the capital cost estimates.

7.3.2 - Homestead Food Crop Benefits

Using the available data on existing production and consumption patterns, the net revenue from a homestead plot has been estimated at Rs 1,800 per homestead per year (see Annex G). This is an implicit economic value for homestead production, irrespective of its final destination. This estimate is based on the productivity potential of a 0.4-ha homestead, after allocations have been made for livestock, buildings and "living space".

Total benefits would be realized in either 4 or 7 years, depending on the project development rate. Two alternative schedules are provided in Table 7.7.

7.3.3 - Livestock Production

Only the Murrah buffalo development plan has been evaluated to determine the economic contribution of such a program to total project benefits from agriculture. These buffalo would supply draft power and supplement farm incomes with milk and surplus stock disposal.

IRRIGATED CROP PRODUCTION
NET ECONOMIC RETURNS UNDER THE PROJECT

(million Rs)

	Scenario A					Scenario B				
Year	A	B	C	D	E	A	B	C	D	E
1 (1980)	38	41	-	-	79	38	41	-	-	79
2	38	41	-	-	79	38	41	-	-	79
3	38	41	-	-	79	38	41	-	-	79
4	34	41	-	-	75	34	41	-	-	75
5	26	67	-	72	165	30	67	-	41	138
6	6	74	-	191	271	26	74	-	109	209
7	-	81	5	315	401	20	81	-	186	287
8	-	90	8	441	539	6	90	-	275	371
9	-	92	9	510	611	-	92	3	365	460
10	-	92	10	552	654	-	92	7	452	551
11	-	92	11	576	679	-	92	8	521	621
12	-	92	11	587	690	-	92	9	551	652
13	-	92	12	587	691	-	92	10	572	674
14	-	92	13	587	692	-	92	11	584	687
15	-	92	13	587	692	-	92	12	587	691
16	-	92	13	587	692	-	92	12	587	691
17	-	92	13	587	692	-	92	13	587	692
18 and over	-	92	13	587	692	-	92	13	587	692

A - Small tanks, rainfed areas

B - Pimburettewa, Vakaneri, Punanai schemes

C - Upland crops

D - New paddy areas (includes areas previously included under Category 'A' after additional irrigation water is available)

E - Total

TABLE 7.7

PROJECTED HOMESTEAD BENEFITS FROM FOOD CROPS

Year	Scenario A		Scenario B	
	Number of Settlers (Cumulative)	Net Benefits (Million Rs)	Number of Settlers (Cumulative)	Net Benefits (Million Rs)
1	9 020	16.2	5 540	10.0
2	20 313	36.6	10 855	19.5
3	29 104	52.4	16 524	29.7
4	35 330	63.6	22 288	40.1
5			27 899	50.2
6			33 452	60.2
7			35 330	63.6

Notes:

1. Year 1 corresponds to 1984 for both Scenarios A and B.
2. Total number of settlers is based on 34 330 paddy farmers and 1 000 upland farmers.

The principal objective of the livestock program is eventually to generate all the draft power required by paddy farmers in System B. The projected deficiency is 29 000 head. In total, about 8,600 buffalo cows would be assigned to approximately 1 out of every 4 settlers at the time of their arrival in the project area.

To estimate the net economic benefits of such a program, two initial calculations are required

- a budget which forecasts annual net revenue on a per-unit basis

- a schedule indicating the number of buffalo cows which must be introduced into the project area annually during the implementation period so that a herd of 29 000 draft animals can eventually be generated.

The budget is summarized in Table 7.8 and the schedule is shown in Table 7.9. Further details are provided in Annex F.

With these data, budgets for each annual subprogram were compiled and then aggregated to obtain a net revenue estimate for each year during the economic life of the project. To this total, some Rs 2.25 million/yr was added as an additional net benefit resulting from existing draft animals which will subsequently be used for 2 crops/yr instead of 1. The resulting estimates are provided in Table 7.10.

7.3.4 - Fisheries

Fish production is to be developed in System B for approximately 5,000 ha of reservoir area as follows.

TABLE 7.8

ANNUAL BUDGET FOR 1,000 MURRAH BUFFALO COWS

('000 Rs)

Year	Gross Revenue (1)	Total Costs (2)	Net Revenue (3)
1 (1984)	1,124	6,511	(5,387)
2	1,124	603	521
3	1,349	603	746
4	1,679	603	1,076
5	2,003	603	1,400
6	2,321	603	1,718
7	2,632	603	2,029
8	2,938	603	2,335
9	3,240	603	2,637
10	3,533	603	2,930
11	3,929	603	3,326
12	4,211	603	3,608
13	4,486	603	3,883
14	4,846	603	4,243

TABLE 7.9

ANNUAL BUFFALO COW PURCHASES
DURING PROJECT IMPLEMENTATION*

Year	Scenario A	Scenario B
1 (1984)	2 270	1 390
2	2 840	1 338
3	1 994	1 424
4	1 527	1 450
5	-	1 303
6	-	1 295
7	-	431
	8 631	8 631

* Total allocated according to irrigation settlement rates.

TABLE 7.10

POTENTIAL LIVESTOCK BENEFITS WITH PROJECT
(million Rs)

Year	Scenario A	Scenario B
1 (1984)	(9.9)	(5.2)
2	(11.8)	(4.2)
3	(5.2)	(3.7)
4	(0.4)	(2.3)
5	10.9	0.5
6	13.4	2.9
7	16.2	10.4
8	18.9	15.2
9	21.5	18.0
10	24.3	20.6
11	27.1	23.4
12	30.6	26.1
13	32.2	28.6
14	35.0	31.4
15	37.1	33.7
16	38.3	35.7
17	39.0	37.2
18	39.0	38.1
19	39.0	38.7
20-over	39.0	39.0

Note: Livestock benefits include an amount which represents the improved utilization (from 2 crops per year) of 5,000 existing draft animals in the project area.

Maduru Oya Reservoir	3 900 ha
Pimburettewa Tank	580 ha
Vakaneri Tank	240 ha
Various small tanks	280 ha
Total	5 000 ha

With a yield of 150 kg/ha/yr and a price of Rs 4/kg, the net economic return to the project is Rs 2 million/yr. Table 7.11 illustrates the economic budget.

The recurring costs include the operating costs of a fish station, which will be shared by Systems B and C. System B's share of the capital cost of this station is approximately Rs 1 million. Other major capital cost items include the removal of trees from Pimburettewa Tank and the cost of boats, nets, tools, etc. Total capital costs are estimated to be Rs 3 million.

The resulting cash flow for the fisheries activities in System B is shown below.

Year	Net Benefits (Rs million)
1 (1984)	(1)
2	(1)
3	(1)
4	1
5	1
6 - over	2

The above cash flow schedule is applicable to both development scenarios.

TABLE 7.11

FISHERIES ECONOMIC BENEFITS

Yield	150 kg/ha
Price	Rs. 4/kg
Gross Return	Rs. 600/ha
Recurring Costs	Rs. 75/ha
Labor Costs	Rs. 96/ha
Net Economic Return	Rs. 429/ha
Annual Economic Return for project at full development	Rs. 2 million

At full development, the fisheries activity will yield 750 000 kg/yr, which amounts to about 3 kg/capita, a small portion of the anticipated annual per capita fish consumption. All output should therefore be marketable within the project area without difficulty.

7.3.5 - Forestry

Two types of forestry benefits have been identified

- benefits from clearing forest
- benefits from reforestation.

Benefits from Clearing Forest

Four classes of clearing benefits have been included in the assessment of project benefits.

Commercial Timber

Commercial timber yields vary from 90 ft^3/ha in "plantation" areas to 215 ft^3 in the "Type I" forest areas. The value of this wood resource is taken at Rs 4/ft^3. The area to be cleared* would yield 4.84 million ft^3 with a resultant value of Rs 19.4 million.

Poles and Posts

The yield per hectare is expected to be some 200 poles and posts of average length of 2.4 m and average diameter of 5 cm. Total yield is about 5.65 million items. The value has been set at Rs 3 per post or pole, for a total benefit of Rs 16.9 million.

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*Includes the following approximate areas
Type I - 700 ha
Type II - 24 600 ha
Plantation - 2 930 ha.

Firewood

Some 500 ft^3 of firewood can be extracted per hectare. The economic value of firewood has been set at Rs 0.30/ft^3 and total benefits are estimated to be Rs 4.2 million.

Cost of Clearing

In the construction estimates, allowance is made for the full cost of forest clearing. However, once the merchantable timber, etc has been harvested, it is considered that the actual cost of clearing will be lower than that which was allowed as a cost in the development of the irrigation system. A reduction of Rs 500/ha in clearing cost has therefore been taken as a forestry benefit, although it could also have been taken as a reduction in the system development cost. This has been applied to the areas of Type I and Type II forest and plantation areas which will be cleared in the cropped areas. Total benefits are therefore Rs 8.2 million.

The total clearing benefits are as follows.

	Rs Million
Commercial timber	19.4
Poles and posts	16.9
Firewood	4.2
Reduction in clearing cost	8.2
Total	48.7

Benefits of Rs 48.7 million have been applied over the period 1981 to 1985 for Scenario A, and over the period 1981 to 1988 for Scenario B.

Benefits from Reforestation

About 1,570 ha must be harvested annually to satisfy the fuel wood needs of 36 000 farm families. With a rotation of 7 yr about 11 000 ha are required. The species proposed is Ipil-Ipil (*Leucaena leucocephala*). Planting would be spread over a 7-yr period and harvesting would begin in the eighth year. The cost of reforestation is estimated at Rs 1,375/ha, or Rs 2.2 million in each of the first 7 yrs.

After 7 yrs, the yield is estimated at 2,000 ft^3/ha, valued at Rs 3/ft^3. This results in a benefit of Rs 9.4 million for the 1,570 ha harvested annually.

Table 7.12 illustrates the net cash flow for forestry benefits resulting from clearing and reforestation.

7.4 - Financial Farm Income

7.4.1 - Farm Budgets

Large economic benefits to agriculture do not necessarily imply that farming will actually be a viable proposition for the individual producer. This peculiarity can arise for three reasons:

- The economic analysis is conducted using "shadow" prices and costs which may bear very little resemblance to existing financial prices in the country. The latter reflect taxes, subsidies, export and import controls, and other prevailing institutional constraints.

- The economic analysis is conducted on an annual basis. Within a year cash flow considerations are usually ignored.

TABLE 7.12

FORESTRY BENEFITS
CASH FLOW SUMMARY

(million Rs)

Year	Reforestation Cash Flow (both Scenarios)	Clearing Cash Flow		Total Cash Flow	
		Scenario A	Scenario B	Scenario A	Scenario B
1 (1980)	-	-	-	-	-
2	(2.2)	9.7	6.1	7.5	3.9
3	(2.2)	9.7	6.1	7.5	3.9
4	(2.2)	9.7	6.1	7.5	3.9
5	(2.2)	9.7	6.1	7.5	3.9
6	(2.2)	9.7	6.1	7.5	3.9
7	(2.2)	-	6.1	(2.2)	3.9
8	(2.2)	-	6.1	(2.2)	3.9
9	9.4	-	6.1	9.4	15.5
10	9.4	-	-	9.4	9.4
11	9.4	-	-	9.4	9.4
12	9.4	-	-	9.4	9.4
13	9.4	-	-	9.4	9.4
14	9.4	-	-	9.4	9.4
15	9.4	-	-	9.4	9.4
16-22	7.2	-	-	7.2	7.2
23-29	9.4	-	-	9.4	9.4
30-36	7.2	-	-	7.2	7.2
37-40	9.4	-	-	9.4	9.4

- The economic analysis is a "long-run" analysis, covering a period of 40 or 50 yrs. A farmer who plants a crop which does not "bear fruit" almost immediately may well go bankrupt before the benefits accrue.

Financial budgets* for the paddy and upland farms indicate the following annual income (including income-in-kind) estimates.

Paddy farmer** (with buffalo) on 1 ha	Rs 11,128
Upland farmer on 1.5 ha	Rs 12,313

About one-third of the paddy farmer's income is income-in-kind, a desirable aspect of small-farm agriculture. About 15 percent of the upland farmer's income is income-in-kind; he must purchase many essential food items (including rice). Once an adjustment is made for the value of home production (rice, homestead food plot production and livestock products), the remaining disposable incomes for both farm types are similar (some Rs 4 to 5,000/yr).

7.4.2 - Implications for Farmers

A number of points pertinent to successful farm development should be stressed.

(a) It is highly desirable that the paddy farmer have his own draft buffalo. Buffalo ownership reduces his farm costs by 25 to 30 percent and reduces his cash food outlay considerably. The saving is about Rs 2,000/yr, which is particularly beneficial just prior to harvest

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* Based on existing (1979) prices for inputs and paddy. See Annex G for details.

**Based on Land Class 2R.

when a cash squeeze is inevitable. With his own buffalo, less short-term production credit would be required and more income security would be the result. The financial benefit from livestock production far exceeds the economic importance of livestock to the project as a whole.

(b) It is equally desirable that all farm families quickly establish a highly productive homestead. A good homestead will improve the farm cash flow by about Rs 1,800/yr, the ramifications of which are similar to those of buffalo ownership. This financial benefit also far exceeds the economic importance of homesteads to the project as a whole.

(c) Even with (a) and (b) above, the first few years may be difficult. For example if a farmer only obtains a yield of 60 percent of that expected, the family disposable income level after basic necessities are secured would just cover his costs. This reemphasizes the need for good support services, particularly in the early years of project development, as discussed in Section 7.5 and in Section 8 following.

(d) The commercial character of the entire farm operation must be appreciated. Economic interdependence with the nonfarm sectors will be established, thereby exposing the farmer to risks from factors beyond his control. Short-term production credit and other public infrastructure must be available, as must farm supplies and product markets.

(e) Once basic cost of living expenses are paid, both paddy farmers and upland crop farmers will have approximately equivalent disposable incomes in the order of Rs 4 to 5,000/yr.

Once an allowance is made for consumption and investment over-and-above the farmer's basic cost of living, very little in the way of farm liquidity remains. About Rs 1,000/farm could be considered to be the farmer's repayment capacity.

Annual operating and maintenance costs for the Maduru Oya project are estimated at Rs 61 million at full development. If allocated on a per-farm basis, this would result in a farm charge of Rs 1,700/farm/yr. It is probable that the annual operating and maintenance costs could only be partially recovered through a water tax, land charge or similar feature.

The emphasis placed on cost recovery will depend on what farm standard-of-living is acceptable to policymakers. It is important to consider that earnings must be sufficiently large to provide adequate incentives to the farmer so that he will participate in the project. In this context, the choosing of an income level which provides an allowance for consumption and investment over-and-above the basic cost of living is a matter of informed subjective judgment and is best made by the policymaker.

(f) The present price structure for paddy and inputs results in financial returns to paddy cultivation which are substantially less than economic returns. Revision of farm-gate prices to economic levels would provide farmers with substantially higher incomes and would give further encouragement to farmers to adopt improved cultural practices.

7.5 - Implications for Project

Sections 6.2 and 7.3 have both emphasized that the agricultural production technology proposed dictates the use of farm inputs in the correct amounts and in relatively fixed proportions. This is especially true of the new high yielding rice varieties. Supply constraints with respect to any one of the farm inputs required will have serious consequences, particularly during the early years of the proposed project. The purpose of this section is therefore to indicate the general magnitude of total project requirements in terms of (a) farm labor, (b) farm power, (c) other farm inputs and services, and (d) farm credit. For illustrative purposes, only Scenario A is considered in the calculations which follow. Cost estimates are expressed in terms of mid-1979 Rupees and must be taken as being order of magnitude only. They are generally indicative of levels in input but cannot be used for purposes of detailed planning.

(a) Farm Labor

All farm labor requirement calculations have assumed that the farmer and his family contribute about 2.8 man-years equivalents to agricultural production. Still, there are peak periods when on-farm labor is inadequate and hired labor is required. This occurs during planting and, to a lesser extent, during harvest. Labor requirements are particularly acute during the transplanting of rice, a highly desirable agronomic practice. If off-farm labor is not available, the farmer will broadcast his seed and yields will be reduced accordingly.

A newly settled area may be subject to off-farm labor shortages, particularly during the initial years of project development. The peak number of off-farm laborers will be as high as one laborer/farm during the transplanting and harvesting periods (relatively short duration periods). Staggering of transplanting dates throughout the project will reduce the project-wide peak requirement somewhat, although it will remain large. In the early years, special incentives for part-time workers may be required.

(b) Farm Power

Inadequate planning could result in an acute shortage of farm power in the region. A program to obtain buffalo for lowland paddy farmers has already been outlined (see Sections 6.2.6 and 7.3.3). However, even with full implementation of this livestock program, a farm power shortage will occur for at least three reasons

- a delay because of the buffalo buildup period

- upland tractor requirements

- supplementary farm power requirements on paddy farms.

A large number of tractors will be needed in the short run, and some will always be needed. A tractor hire service will be required in the initial years of project development. Approximately 750 four-wheel tractors will be required in the first 4 yrs (Scenario A) of development.

(c) Other Farm Inputs and Services

The timely provision of adequate farm supplies (especially fertilizer and chemicals) is mandatory. At full development, the seasonal fertilizer requirements are about 11 to 12 000 tonnes. Rice production at full development is about 260 000 tonnes and will require the following infrastructure

Village hullers	51
Collection centres	49
Milling, drying, storage complexes	25

(d) Farm Credit

Commercial farming is not possible without adequate credit facilities. Credit requirements, particularly during the start-up period, are substantial. Intermediate-term (5-yr) credit must be available for capital purchases, and short-term (6 months) production credit will be required twice yearly.

Total farm credit requirements for Scenario A are expected to be approximately as follows.

Year	Intermediate Term (million Rs)	Short Term (million Rs)
1 (1984)	4.8	9.0
2	6.0	20.3
3	4.2	29.3
4	3.2	35.3
5 - over	-	35.3

8 - ORGANIZATION AND MANAGEMENT

However well conceived an irrigation project may be, its success or failure will be greatly influenced by the effectiveness of the administrative structure responsible for its execution. Many types of activity, both technical and nontechnical, will be involved.

It is convenient to consider these activities and the manner of organizing them under two broad headings: Construction Phase and Operation Phase. It will be evident from the schedules presented in Section 4 that these phases will overlap to a considerable degree in the course of developing the farming area of the project.

8.1 - Government Agencies

The Mahaweli Authority of Sri Lanka (MASL) was formed in 1979 with the objective of implementing the complete development and operation of the Mahaweli Scheme. The Authority was invested with wide powers to facilitate the coordination of the many government agencies and departments which would be involved.

It was decided that the Mahaweli Development Board (MDB) and the Central Engineering Consultancy Bureau (CECB) would be the principal agencies responsible to MASL for the construction aspects of the Maduru Oya project.

A corporation is in the process of being formed to which MASL will delegate its functions and responsibilities during the

operation phase. While not yet* formally constituted, this organization, which is to be known as the Mahaweli Economic Agency (MEA) has already appointed senior staff and outlined its proposed management structure for System C.

The above agencies, together with other organizations which will be involved in the implementation of the Maduru Oya project, are indicated on the General Organization Chart, Figure 15.

Annex K is devoted largely to a description of the organization of these government agencies involved in the construction and operation phases of the project.

8.2 - Construction Phase

It has already been mentioned in Section 4 that the construction of the project works will be undertaken partly by expatriate forces and partly by Sri Lankan forces. The relationship between these forces and the government agencies involved is illustrated in Figure 15.

8.2.1 - Work Undertaken by Expatriate Forces

As noted in Section 4.5, both the headworks and the main and branch canals are expected to fall in this category. Engineering and construction supervision services are similarly expected to be furnished by expatriate consulting firms. However, due to the anticipated mode of financing, these two project areas will be undertaken independently.

*July, 1980

This means that two foreign contractors and two foreign consultants will be operating at the same time in the project area.

The consultants and contractors for the headworks, as well as the consultants for the main and branch canals, have already been selected.

Role of Contractor

While not contemplating all-embracing contracts of the "turnkey" variety it is intended that the expatriate contractor will have full responsibility for day-to-day construction management subect to supervision by the consultant.

Thus the contractor will undertake (inter alia)

- provision and importation of construction equipment

- supply and (where necessary) importation of construction materials

- engaging of labor

- in the case of the headworks contractor, services to the equipment manufacturer during the erection of the mechanical and electric plant.

Role of Consultant

The expatriate consultant will be responsible for the final design of the works. In the case of the headworks, as already noted, the definitive design has already been accomplished with the completion of the tender drawings.

Further work will be required on the preparation of detailed construction drawings.

The expatriate consultants may elect to assign some of this work to their home office which, in principle, should lead to savings in cost.

During the construction phase the expatriate consultant will supervise the operations of the contractor to ensure that specification requirements are met. He will also monitor the schedule, agree with the contractor the measurements required for progress payments, and certify the contractor's invoices for payment by the Government. The consultant will also be the first arbiter in cases of contractor's claims.

In the case of the main and branch canals, where current designs are to "feasibility level", the expatriate consultant will first be engaged on the final design of the works and the preparation of tender documents. To expedite the start of construction it is possible that tenders will be called in the first instance for the canal works in Sector 1. Provision would be made in such a contract for the scope to be expanded to include Sectors 2 and 3 at a later date.

During the construction phase of the main and branch canals, the expatriate consultant's functions will be similar to those described above in the case of the headworks.

While the main and branch canals are the prime responsibility of the expatriate consultant, the design of representative sample areas in the tertiary systems is also included.

Provision is also being made for the furnishing of a team of technical advisors to MDB, in connection with the latter's responsibility for the tertiary system. Advisors

on nonirrigation aspects -- environment, settlement planning, operations and maintenance, etc, may also be required.

Role of Government Agency

The government agency involved - CECB in the case of the headworks and MDB in the case of the main and branch canals - is seen as having important but not exhaustive responsibilities. Its main functions will be to satisfy the Mahaweli Authority as to the performance of the expatriate organizations (consultants and contractors), to process payments to the contractors for work carried out and duly certified by the consultants, to participate in claims negotiations (being advised by the consultants) and generally to act as liaison, when required, with other Government Departments in matters such as customs, licensing etc.

8.2.2 - Works Undertaken by Local Forces

Irrigation Works

These comprise the tertiary systems including land leveling, secondary and tertiary drainage, and the improvement of main drainage channels. As mentioned in Section 4.5 it is envisaged that, in general, labor-intensive methods would be used.

It is planned that MDB will have responsibility for the execution of this work. Detailed layout and design will be the first task. Four approaches may be considered for construction

- direct labor, engaged by MDB
- "settler/workers", organized in small groups; their activities would normally be confined to on-farm works

- small local contractors
- medium to large local contractors.

Nonirrigation Infrastructure

MDB will also have responsibility for coordinating the work on nonirrigation infrastructure to be carried out simultaneously with the construction of the canal systems. It is anticipated that access roads, irrigation system roads, and link and settlement roads will be constructed by local contractors under the direct supervision of MDB.

Primary roads and bridges planned for the area may be financed by the Asian Development Bank and engineered by expatriate consultants. It is anticipated in this case that MDB would play a coordinating role.

Other construction works to be organized by MDB would be the villages and hamlets required for the 35 000 farming families who will settle in the area during the initial years of the development.

The physical aspects of the Experimental Demonstration Farm would also be undertaken by MDB, in close cooperation with the MEA field organization.

8.2.3 - Organization of MDB

In view of its comprehensive role in the construction of the project, the organization of MDB's field activities deserves special attention. The proposed organization, based mainly on MDB's own concept, is described in some detail in Annex K. The most important features are summarized on the following page.

- A Project Manager, supported by his own technical and administrative staff, would be responsible for the whole of System B.

- Four "Divisions", each under the direction of Divisional Resident Engineer, would be established, corresponding to Sector 1, Sector 2, and two divisions in Sector 3.

- Each Division would be subdivided into "Zones" of about 3,000 ha.* Twelve Zones are envisaged, each directed by a Resident Engineer.

- Further subdivision would result in some 70 "Sections" each covering about 500 ha and each in the charge of a Project Engineer.

- Four additional Resident Engineers would be required, one assigned to each of the Divisions, to take responsibility for all the on-farm works within his Division.

Staff requirements for the MDB field organization are summarized as follows.

Level	Technical	Clerical	Support	Total
System	3	9	5	17
Division (each)	10	17	9	36
Zone (each)	7	6	7	20
Section (each)	7		1	8

*Areas refer to net hectarage allocated to farms.

TABLE 8.1

LABOR REQUIREMENTS FOR DEVELOPMENT SCENARIO A

Construction Activities	Period of Construction	Peak Year	Number of Skilled and Unskilled Workers: Peak Year Level	Number of Skilled and Unskilled Workers: Average Year Level	Total Man Years
Dam and tunnel[1]	1980 to 1983	1982	1 600	1 000	3 000
Main and Branch Canals[1]	1981 to 1986	1983	1 500	1 000	5 000
Tertiary irrigation system[2]	1981 to 1987	1983	36 000	24 000	120 000
Nonirrigation infrastructure	1981 to 1987	1983	2 500	1 700	12 000
Overall project	1980 to 1987	1983	40 000	20 000[3]	140,000

Notes:

[1]Assuming machine-intensive construction by international contractors.

[2]Assuming labor-intensive construction methods.

[3]Average over 8 yr.

TABLE 8.2

LABOR REQUIREMENTS FOR DEVELOPMENT SCENARIO B

Construction Activities	Period of Construction	Peak Year	Number of Skilled and Unskilled Workers: Peak Year Level	Number of Skilled and Unskilled Workers: Average Year Level	Total Man Years
Dam and tunnel[1]	1980 to 1983	1982	1 600	1 000	3 000
Main and Branch Canals[1]	1981 to 1988	1985	1 000	625	5 000
Tertiary irrigation system[2]	1981 to 1989	1985	20 000	13 333	120 000
Nonirrigation infrastructure	1981 to 1989	1985	1 800	1 200	12 000
Overall project	1980 to 1989	1985	22 800	14 000[3]	140,000

Notes:

[1]Assuming machine-intensive construction by international contractors.

[2]Assuming labor-intensive construction methods.

[3]Average over 10 yr.

The nominal total requirements based on the above establishment would be 961. In practice, due to phasing of the development of the sectors, it is envisaged that staff would be transferred as areas were completed. Peak staff requirements have been estimated to be 840 in Scenario A and 575 in Scenario B.

8.2.4 - Construction Labor

Approximate estimates have been made of the labor requirements during the construction phase. Evidently these estimates depend greatly on the degree of mechanization, particularly in those areas referred to in Section 8.2.2 above, where labor-intensive methods are aimed at with a view to easing the unemployment situation.

Estimates have been prepared on the assumption that this objective is met, and are summarized in Tables 8.1 and 8.2, respectively for Scenarios A and B.

8.3 - Operation Phase

As already mentioned, the Mahaweli Economic Agency (MEA) is being formed to undertake the comprehensive management of the project, apart from the physical construction discussed above.

The headquarters of MEA, assumed to be located in Colombo, will provide broad policy direction and support to the various projects, and will also have the vital responsibility of overall water management at the Mahaweli system level. It is intended, however, that the normal direction of activities within each project area will be decentralized. This section will therefore concentrate on the MEA organization

proposed for System B, which is discussed in further detail in Annex K.

8.3.1 - MEA Field Organization

The organization proposed has been adapted from that envisaged by MEA for System C. Its general structure is illustrated in Figure 16.

The basic principle is that there should be close cooperation with the farmers at the grass-roots level. Small "Units", comprising a Unit Manager and two Field Officers, would live in the villages and have responsibility for about 250 ha. This corresponds to 250 paddy farms, or about 12 - 20 turnout groups depending on the physical layout of the tertiary system. Thus each Field Officer will deal with some 6 to 10 turnout groups.

These Unit Managers and Field Officers are envisaged as "generalists" who would be the principal contact with the farmers. They would be supported at the Block level by an Agrarian Service Team which would comprise personnel similar to the Field Officers, but who have undergone further training in such areas as

- water management
- agronomy
- livestock
- cultivation practices and mechanization
- rural credit and bookkeeping
- supply of inputs and marketing of outputs
- community development.

This functional organization, operating within the MEA structure, is referred to as the Agrarian Development Service

and is described in further detail in Annex K. The arrangement is considered to have the advantage of a single contact (the Field Officer) who can (a) become familiar with the farmers in the turnout groups under his surveillance and (b) call upon readily available specialist advice when questions arise which he is unable to deal with directly.

The Block Managers and their Agrarian Service teams would receive technical direction and support from the professional staff in the local Sector offices.

An important function of the staff at the system level will be to interpret and reformulate for System B the policy guidelines and general directives issued from the MEA headquarters. While the ultimate line of authority from top to bottom of the MEA organization will be as shown in Figure 16, it is intended that matters of technical interest should be communicated (in both directions) between the junior and senior specialists involved, without going through formal channels.

The estimated staff requirements for the MEA field organization discussed above are summarized in Table 8.3.

Settlement service teams are envisaged for the settlement period and the initial years of operation. They would be phased out as the ultimate development of the area is achieved. See also Section 5 and Annex I.

8.3.2 - Water Management

Since the Maduru Oya project will be a major component of a complex water resource system, water management will play an important part in the realization of benefits both inside and

TABLE 8.3

MAHAWELI ECONOMIC AGENCY
FIELD ORGANIZATION
SUMMARY OF STAFF REQUIREMENTS

System Level -	Managers	8
	Agrarian Development Center	20
	Experimental Demonstration Farm	
	Clerical and Support Personnel	84
	Subtotal	112
Sector Level -	Manager	21
	Clerical and Support Personnel	63
	Subtotal	84
Block Level -	Managers	14
	Agrarian Service Teas	100
	Settlement Service Teams*	42
	Support Personnel	78
	Subtotal	234
Unit Level -	Managers	140
	Field Officers	280
	Subtotal	420
Total Field Organization (including 540 personnel whose activities would be primarily devoted to the MEA Agrarian Development Service proposed for System B)		850

outside* the project boundaries. Water management organization and procedures should, therefore, be considered on two levels - the project level and the Mahaweli system level.

Project Water Management

Project-level water management will call for project monitoring and operational decisions on a daily and weekly basis. It must be based on two strong types of organization--the project water management organization and farmer or water user association.

The project water management organization will have as its prime responsibility the coordination of water deliveries to the distributary and subdistributary channels. These deliveries should be based on reliable knowledge of the following factors:

- daily flows at all key control points - head and tail regulators from the main canals down to the subdistributaries

- crop status, based on monitoring of planting dates

- recent rainfall, based on a network of rain gauges

- field water conditions, based on farmer and staff reports and possibly a network of representative field plots

*The interaction of water demands in System B and C, discussed in Section 4.3.3, is one example of the effect that water management in one component project can have on the performance of another.

- theoretical water requirements, based on regularly updated calculations

- performance capability, based on routine monitoring of actual water use in each zone, supplemented by more detailed monitoring in smaller sample areas.

The data gathering system required to supply this information will be the focus of routine project operations. With this information at hand, the project water management team can build a sense of trust among the farmers that their reasonable water requirements can be met.

Equally important will be the establishment of effective water user organizations to coordinate the allocation of water among the farmers at the turnout level. It is recognized that rotational irrigation at the farm level has the greatest chance of ensuring fair allocation of water among farmers. If rotation at a higher level (distributary or subdistributary) is used, the likelihood of inequitable water distribution will significantly increase. If effective water user organizations are not formed, however, it may be necessary to adopt such higher-level rotation (which can be administered by project staff) as the only means of economizing on water use.

Water management is based on surveillance by one Field Officer per 125 farmers*. A priority task of the Field Officers will be to encourage and actively assist the farmers in organizing themselves in water user associations at the turnout level. The officers would be responsible for liaison with the water user assocations, implementing operational policies, organizing cultivation meetings, etc.

*About 6 to 10 turnout areas per officer.

System Water Management

System-level water management will call for water use monitoring and operational decisions at short-term and seasonal intervals. A central organization for coordinating water management in the Mahaweli System as a whole will be required. This organization will require a system-wide computer simulation program which has been carefully calibrated to represent actual system performance. Potential conflicts between irrigation, flood control and hydroelectric power generation will need to be addressed and resolved with the aid of the program. Once reservoir operating policies are fixed, a modified program can be used as an operational tool to forecast shortages, and to fix diversion schedules at key control points. Short-term alterations of policy necessitated by unforeseen factors reported by individual projects can then be evaluated and decisions made with maximum comprehension of the potential consequences.

The establishment of the system-wide operational organization, backed up by suitable computational tools, should be considered as a matter of high priority. Investment decisions for further use of Mahaweli water should only be made when it is known that water can be made available. This can best be decided when realistically achievable water usage rates in the committed areas are known.

Cost of Project Management and Operation

The cost of the management functions described in this section has been estimated under a number of different headings.

The unit rates for the tertiary system include a burden for government services which is considered adequate to cover the

cost of MDB's organization, but does not include the infrastructure (accommodation, offices, transportation) required in the field. This has therefore been estimated separately.

Similarly estimates have been made for the infrastructure required for the MEA management during the operation phase. Allowance has been made for some re-use of construction-phase accommodation.

Annual operation and maintenance costs of the engineering works have been allowed for on the basis of commonly used percentages of the capital cost. The estimated cost of the MEA field organization has been added. This combination of approaches to the operation and maintenance cost is considered conservative but prudent.

The estimated costs referred to above are summarized in Tables 8.4 and 8.5.

TABLE 8.4

COST ESTIMATE - PROJECT MANAGEMENT INFRASTRUCTURE

	Million Rs
Accomodation (housing and offices)	130
Transportation	15
Total Project Management Infrastructure	145

Schedule of Costs - Million Rs

Year	Scenario A	Scenario B
1980	20	14
1981	20	14
1982	20	14
1983	20	14
1984	20	14
1985	20	14
1986	20	14
1987	5	14
1988		14
1989		14
1990		5

TABLE 8.5

COST ESTIMATE - ANNUAL COST OF OPERATION MANAGEMENT

	Million Rs
Operation and Maintenance, engineering works	44.0
Cost of MEA Organization	14.2
Subtotal	58.2
General Overhead - allow approximately 5 percent	2.8
Total Annual Cost of Operation Management	61.0

Schedule of Annual Cost - Million Rs

Year	Scenario A	Scenario B
1981	1	1
1982	4	3
1983	5	4
1984	25	20
1985	36	28
1986	49	35
1987	61	44
1988	61	53
1989 and on	61	61

9 - ENVIRONMENTAL ASPECTS

Annex J presents details on the existing environment in the project area and an overall evaluation of the potential environmental impacts arising from the proposed project. The following paragraphs emphasize the more important features, beginning with a description of the existing environment, followed by a summary of the principal environmental impacts to be expected.

9.1 - Existing Conditions

A description of the physical and climatic features of the project area can be found in Sections 2 and 3. The following paragraphs relate to the living communities which have developed as a result of these features and of the influence of man over the centuries.

9.1.1 - Terrestrial

Forest cover in Sri Lanka has declined drastically in recent years. According to the forest inventory of 1960, based on aerial photography taken in 1956, the area under forest vegetation was 44 percent of the total land area of Sri Lanka. Since then, heavy inroads into forested land have been made either for development projects or shifting cultivation. At the present time, forest cover of Sri Lanka amounts to 20 to 22 percent of the total land area, well below a generally accepted minimum desirable level of 25 percent. Even more serious, forest cover in the Wet Zone has decreased to 8 percent. The Wet Zone mountainous region is where the catchments of the country's major rivers, including the Mahaweli, are located. Deforestation in these upland

areas can cause serious erosion and surface runoff problems. Due to this overexploitation of the forest to meet the demands for timber, the country's natural forests have been rendered unproductive and degraded.

Extensive damage to the forests of the project area has been caused by chena farming, and is still continuing. Analysis of 1979 aerial photographs indicates that the forest cover of the project area is slightly over 50 percent, excluding forest plantations. Most of this forest is of poor quality - extensive areas have been "high graded" or else affected by recent chena farming.

Of a total of 115 mammalian species and subspecies found in Sri Lanka, 58 are likely to be found in the project area. Species observed during field trips included elephant, leopard, monkey (Gray Langur, Toque Macaque), old-world porcupine, black-naped hare, jackal, mongoose and sambhur.

Elephant signs (footprints and droppings) can be found in most parts of the project area. Two large herds of elephants were observed from a helicopter on September 25, 1979. The first group of 50 to 60 elephants was found between Pimburettewa Tank and the Maduru Oya. The second group of 35 or more was spotted in the forest north of the highway near Welikanda (near the Nelugala Jungle Corridor).

Of the 427 species listed in Phillip's "Checklist of the Birds of Ceylon"(15), 92 species can be found as breeding residents specific to the low-country Dry Zone. Breeding residents are found in their largest concentrations in the Dry Zone during the breeding season, which extends roughly from December to May (the northeast monsoon and subsequent wet conditions). Many other species that are breeding residents in all zones or are winter visitors will be found in the Dry Zone as well.

The most recent list (U.S. Federal Register, Vol 44, No. 12, 1979) of endangered and threatened species shows that there are 6 endangered species and 2 threatened species within the Accelerated Mahaweli project area. Of these, the elephant and leopard will be the most affected by the proposed development in System B.

9.1.2 - Aquatic

Because of their seasonal nature, the Maduru Oya and smaller streams show little evidence of phytoplankton, zooplankton, benthic invertebrates or aquatic vegetation. By contrast, the "villu" or swamp areas along the Mahaweli Ganga are maintained in wet condition throughout most dry seasons. These areas, as well as the numerous small tanks scattered throughout the project area, are important centers of aquatic and terrestrial life, particularly in the dry season.

The estuarine areas of the Maduru Oya and Mahaweli Ganga have well developed commercial and subsistence fisheries. They provide nursery grounds for shrimp and breeding and nursery areas for a number of important finfish.

9.2 - Impact of the Project

Five major environmental issues have been identified for analysis. These issues are

- public health
- forest conservation
- wildlife protection
- aquatic environment
- energy supplies.

TABLE 9.1

SUMMARY OF MAJOR ENVIRONMENTAL IMPACTS IN SYSTEM B

Environmental Component	Causes	Effects-Direct and Indirect	Mitigating Measures
Public Health			
Vector-borne diseases, especially malaria	Construction effort of 150 000 man-years. Permanent settlement of over 200 000 people	Dramatic increase in disease incidence will take place due to creation of habitats conducive to vector-borne disease Possibility of malaria incidence of epidemic proportion Construction and farm labor productivity will suffer from exposure to malaria	Vector control programs Issue of malaria pills Prepare malaria epidemic emergency contingency plan
Snake bites	Habitat disturbance		Make sufficient quantity of antivenin available at appropriate locations
Waterborne diseases, especially gastro-intestinal disorders	Population density drastically increased	Incidence of intestinal diseases will be, for some years, higher than the (already high) national average due to instability in quality of surface water sources Sanitation will become a problem in some areas	Design irrigation system according to WHO specifications to ensure proper sanitation and safe water supplies Presettlement checkups Preliving checkups Step up education campaign to boil domestic water Public health orientation course for new settlers
Forest Conservation	Deforestation of over 25 000 ha for agricultural development and settlement (change in land use)	Moisture regimes (discharge/recharge rates, groundwater table) Microclimate alteration (wind, humidity, temperature, etc)	Use selective logging and clearing techniques so that some trees are left along edges of paddy fields

Table 9.1
Summary of Major Environmental Impacts in System B - 2

Environmental Component	Causes	Effects-Direct and Indirect	Mitigating Measures
Forest Conservation (contd)		Catchment areas are deforested leading to reservoir siltation, loss of valuable soil, reduction of moisture storage capacity etc	Restrict width of forest clearing beyond canals and roads to 5 m
			Reforestation programs including canal banks, riverbanks, plantations, archaeological reserves
		Diversity of plant and animal life declines	Use of indigenous trees in Maduru Oya National Park and catchment areas for habitat enrichment, slope stabilization, etc
			Practice selective clearing and leave stands of trees in settlement areas
Wildlife Protection			
Mammals, especially the elephant	Loss of habitat, especially for the larger forest-dwelling mammals	Seasonal migratory routes are disrupted	Plan wildlife/forested areas along rivers and streams and upland areas (in addition to Maduru Oya National Park)
		Wildlife leaves the area (to where?)	
		Wildlife conflicts with man, cause damage to property, crops, etc	Plan corridor relocation routes
		Wildlife is shot by man for food and other reasons	Capture and sell or transport to suitable areas
Birds	Loss of habitat for forest-dependent birds	Decline in numbers and species diversity	Retain or substitute forest habitat wherever possible
Pest Control	Adoption of intensive agriculture methods	Water quality changes, change in predator-prey-parasite balance, pest proliferation	Restrict usage of chemicals, adopt integrated pest control program
Aquatic Environment	Reservoir and irrigation system is constructed. Area is settled with complete infrastructure	Terrestrial, aquatic and estuarine ecosystems drastically modified	Leave adequate forest cover in the project area and especially in the catchment areas (25 percent minimum)
		Flora and fauna species composition and numbers will be altered	Fisheries development in reservoir and canals

Table 9.1
Summary of Major Environmental Impacts in System B - 3

Environmental Component	Causes	Effects-Direct and Indirect	Mitigating Measures
Aquatic Environment (contd)		Erosion risk increased (loss of soil fertility, siltation of reservoirs)	Practice recommended water management and farm management techniques
		Water quality problems (pesticides, agricultural runoff, eutrophication, leaching etc)	Use biodegradable pesticides and integrated pest control techniques
		Aquatic weed infestation	Deal with water quality problems and aquatic weed infestations before the problem becomes too widespread
		Change of wet-dry cycle encourages proliferation of water-dependent insect pests and diseases	
Long-Term Energy Supplies	Ongoing requirement of over 100 ft^3 of firewood per family per year	Cost and transportation difficulties will escalate	Plan for firewood yielding forests within walking distance
		Shortages of firewood may develop	Plant fast-growing tree species
		Cost of family firewood will increase with collection distance	Charcoal excess wood from clearing program
		Removal of natural forest for firewood, resulting in a long-term decline in forest cover	Promote manufacture of inexpensive domestic charcoal burners
			Promote manufacture of inexpensive but efficient firewood burners
			Investigate the use of biogas

A summary of these major environmental issues, and the associated causes, effects and mitigating measures, is presented in Table 9.1.

9.2.1 - Public Health

Malaria is expected to be the most significant health problem, but construction and management measures should, if implemented, keep this disease under control. A complete list of malaria prevention and control measures can be found in Annex J.

Other vector-borne diseases such as filariasis, dengue fever and even schistosomiasis could possibly arise, and here the emphasis should be placed on prevention. Provided that efficient and appropriate sanitation techniques are used and stress is placed on community hygiene and health education, waterborne diseases such as gasto-enteritis, cholera, enteric fever, hepatitis, amoebic dysentery and polio should be prevented from becoming major problems.

9.2.2 - Forest Conservation

Although clearing of over 25 000 ha of forest will take place, preservation of adequate natural forested areas as well as reforestation programs for fuel wood supplies, watershed protection, wildlife habitat protection and erosion control should reduce the magnitude of this impact. Forest clearing programs must be carefully controlled and monitored to minimize the potentially negative effects on the hydrology and microclimate of the area. It should be noted that extensive areas of forest (over 30 000 ha) of System B are being used for slash-and-burn agriculture (chena farming). Every effort should be made to stop this practice, to sustain the remaining forest, and to activate a reforestation program.

9.2.3 - Wildlife Protection

Wildlife species composition and numbers will be greatly affected by the development. Deforestation of large tracts of forest will result in the elimination of significant areas of wildlife habitat. Particularly affected will be those species that depend on the forest, and are unable to leave the area or adapt to a new environment. Sensitive species, therefore, will include large mammals (particularly elephants) and other forest-dependent species such as birds, reptiles and insects. Predator-prey-parasite relationships may also be upset. Birds and mammals that live in or near water (ducks, waders, etc) should benefit, however, from the increased year-round supply of water in the paddy fields, canals, tanks and reservoirs.

Since intensive irrigated agriculture and large mammals (particularly elephants) are potentially incompatible, planning must allow for either accommodation of the animals' needs or removal of the animals to more suitable habitat. The emphasis should be on the provision and monitoring of escape routes for the sensitive wildlife species to move to parks, reserves, etc. The proposed Maduru Oya National Park is intended to augment the system of parks and reserves in and around the Mahaweli Scheme development area. A system of wildlife corridors has been proposed by the Department of Wildlife Conservation to interconnect these reserves. One of the longest and most exposed to future agricultural development will be the Nelugala Jungle Corridor (Figure 6), which bisects the project area in a north-south direction. Before this corridor is committed for perpetual use, the consequences of conflicts between elephants and farmers along the corridor should be carefully assessed. Because of the

seriousness of this proposal and the land-use changes* implemented by it, Section 10 contains an economic assessment of the effects of allocating the corridor area to natural habitat, rather than to irrigated agriculture.

9.2.4 - Aquatic Environment

The major effect of the project will be to provide a regular supply of water for irrigation. The main consequence of this change will be positive, since one of the limiting factors for both flora and fauna is water. However, some negative impacts expected include agricultural runoff causing soil erosion and deterioration of water quality from the use of pesticides, herbicides and fertilizers, as well as aquatic weed infestations. Proper management and monitoring programs can keep these negative aspects under control.

The impacts from reduced flood discharges into the Maduru Oya estuary could be significant. Coastal fisheries which depend on the estuarine areas for breeding and/or nursery areas may be adversely affected.

9.2.5 - Energy Supplies

Long-term energy supplies can be met with fuel wood, but this aspect must be carefully planned. Reforestation (using fast-growing tree species in strategic locations) is essential. Conservation methods (the use of efficient wood-burning stoves and the the use charcoal) will help to preserve fuel-wood supplies and diversify the energy base.

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*Changes to the development plan and changes to existing settlements. The village of Uthuchenai (see Annex A) is located in the middle of the 3-km wide corridor.

It is technically feasible to solve many of the potential environmental problems expected to arise from this development provided adequate staff, budgets and time are made available. Provision of an environmental coordinator to work with the design and implementation teams would be worthwhile. This monitoring and liaison work could be combined with a fisheries development program.

10 - PROJECT APPRAISAL

10.1 - Introduction

To assess project viability, the economic costs and benefits of the Maduru Oya project over its life are calculated and the economic internal rate of return is determined. Benefits include not only direct benefits from irrigated crop production but also incremental benefits from homesteads, livestock, fisheries, forestry, and power production. Costs include all direct costs necessary to achieve the benefits as well as basic settlement and infrastructure costs.

The project benefits are based on prices which are expected to prevail during the life of the project. For those commodities which are traded internationally, IBRD commodity price forecasts for 1990(14) are employed to determine economic farmgate prices on the basis of import substitution or export. For those products which are not internationally traded, current local prices are used on the assumption that they reflect real levels during the life of the project. The IBRD commodity forecasts are also used to calculate the economic prices for a number of farm inputs. All economic costs and benefits are expressed in constant mid-1979 prices, a procedure which assumes that all relative prices and costs will remain the same during the inflationary years ahead.

The economic analysis is undertaken in Sri Lankan currency and foreigh exchange costs are converted to local currency using the following exchange rates:

$1 U.S. = Rs 16
$1 Can = Rs 13.

The decision to use rates which approximate existing official exchange rates implies no overvaluation of the Sri Lanka Rupee and negates the necessity to shadow price foreign cost components.

Shadow pricing has been employed, however, in the calculation of three economic costs: those of cement, diesel fuel, and farm labor.

Cement (delivered)	- Rs	1,200/tonne
Diesel fuel	- Rs	21.50/gal
Farm labor (incl. hired)	- Rs	6/d

For the economic analysis, all construction and operational labor is valued at its actual cost.

Two scenarios are evaluated. The first, Scenario A, involves the last group of settlers harvesting their first crop in Yala 1987. For the second, Scenario B, this occurs in Maha 1989/90. The schedules are detailed in Section 4.5.1, and the land areas developed under each schedule are summarized in Table 7.5.

10.2 - Scenario A

10.2.1 - Direct Economic Project Costs

Direct project costs include the cost of the irrigation works consisting of the dam, link tunnel, main and branch canals and the tertiary irrigation system. Adjustments to the financial costs have been made for the economic prices of cement and diesel fuel. Both economic and financial costs are detailed in Section 4.

Other costs which are chargeable to the project include those associated with the Experimental Demonstration Farm, primary and access roads, settlement assistance and project management. Costs of marketing and processing facilities and certain inputs such as tractors and threshing machines are accounted for in the crop budgets. Social infrastructure costs such as health and education are not considered as direct project costs.

All capital costs, including operation and maintenance costs after project implementation, are summarized in Table 10.1. The annual phasing of the capital costs, which was used in the economic analysis, is shown in Table 10.2.

10.2.2 - Allocation of Upstream Costs

The total cost of the Right Bank Transbasin Canal, including the Minipe diversion works and the Ulhitiya and Ratkinda reservoirs, was originally estimated by the System C team to be Rs 1,267 million. Recently tenders have been received for the Right Bank Canal.* Using the average of the six lowest bids, the revised estimate of the total cost is about Rs 1,000 million. Of this total an amount of Rs 600 million represents the estimated cost of those parts of the works, (the canal itself plus the level crossings) the size and cost of which vary directly with the flow conveyed.

Since the Transbasin Canal serves both Systems B and C, a cost allocation must be made. Two methods can be considered. First, the incremental cost of sizing the canal for both systems as compared with the cost of sizing it only for

*Excluding Ulhitiya and Ratkinda reservoirs but including the tunnel and part of the section from Minipe.

TABLE 10.1

ECONOMIC PROJECT COSTS
(MID-1979 PRICES)

	Rs Million
Capital Costs	
Irrigation Works	
Headworks (dam and tunnel)*	1,703
Main and branch canals	1,712
Tertiary System, drainage, land development	740
Subtotal Irrigation Works	4,155
Other Costs	
Experimental-Demonstration farm	13
Roads (including access roads)	311
Settlement	165
Project management infrastructure	145
Upstream costs	150
Subtotal Other Costs	784
TOTAL CAPITAL COSTS	4,939
Annual Operating Expenses	
Dam and tunnel	8
Irrigation System	36
Mahaweli Economic Agency**	14
Overheads	3
TOTAL ANNUAL OPERATING EXPENSES	61

Note: Costs for irrigation works include contingencies and engineering and construction supervision.

* Based on the tendered bid, November 1979.
**Includes project management, extension, settler assistance, community development, etc.

TABLE 10.2

SCENARIO A - ECONOMIC COSTS
CAPITAL AND OPERATING COSTS
(million Rs)

Year	Headworks	Main and Branch Canals	Tertiary Irrigation System	Upstream Costs	Experimental Demonstration Farm	Roads	Settlement	Project Management Infrastructure	O+M	Total
1(1980)	204	-	-	18	-	-	-	20	-	242
2	562	123	49	49	6	51	-	20	1	861
3	596	292	125	53	7	52	24	20	4	1,173
4	341	457	206	30	-	52	44	20	5	1,155
5	-	411	172	-	-	52	46	20	25	726
6	-	252	96	-	-	52	42	20	36	498
7	-	177	76	-	-	52	9	20	49	383
8	-	-	16	-	-	-	-	5	61	82
9-over	-	-	-	-	-	-	-	-	61	61

System C is considered.* It is estimated that 75 percent of the cost of the flow-related works (Rs 600 million) would be incurred if the canal were sized only for System C. Thus, 25 percent or Rs 150 million of this cost is allocated to System B. All other components of this conveyance system are necessary to supply System C demands and thus are not allocated to System B. This cost allocation procedure is used for the Base Case.

A second procedure allocates costs of the entire conveyance system, including dams, according to the projected water demands of Systems B and C. This results in an approximate equal sharing of conveyance system costs, where Rs 504 million would be charged to System B. This allocation is used in a sensitivity test.

Other upstream costs have not been charged to the Maduru Oya project. In their 1978 analysis of cost allocation, NEDECO(3) estimated that power benefits would pay for only a portion of the cost of the Victoria and Kotmale dams, and that the remainder of their costs should be allocated to the irrigation systems benefiting from the storage. Recent dramatic increases in fuel costs, however, would change the results of the analysis.** In fact, it is anticipated that economic power benefits alone would more than cover the cost of these dams, leaving no further costs to be allocated to irrigation systems. Consequently, the cost of upstream storage has been considered as a "sunk cost", and no cost allocation has been made to the Maduru Oya project.

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* This can be justified if System C is regarded as the "first" project due to its physical location upstream from System B, and due to its higher IRR.

**Hunting Technical Services(9) concluded that power benefits alone would justify Victoria and thus no upstream storage costs were included in the economic analysis of System C.

10.2.3 - Project Benefits

Project benefits include returns from irrigated crops, homestead plots, livestock, fisheries, forestry and power production. The benefit from irrigated crops is developed in Section 7.3.1 on the basis of "without the project" and "with the project" conditions. In the latter, the benefits begin in Project Year 5 and reach a maximum in Project Year 14. All other project benefits are tabulated as incremental benefits directly attributable to the project.

The benefits from homestead plots are assumed to begin in Project Year 5, when the first farmers are settled, and reach their maximum level in Project Year 8, when the last group is settled. These benefits have been developed in Section 7.3.2.

Livestock benefits are developed in Section 7.3.3 and do not begin until Project Year 9. They reach their maximum level in Project Year 21.

Benefits from fisheries and forestry have been developed in Sections 7.3.4 and 7.3.5 respectively.

Power benefits are also included in the project analysis. The estimated annual output from the Maduru Oya powerhouses is 31 GW·h and is classed as secondary energy. NEDECO[3] has indicated the necessity for thermal capacity in the system by 1983 and thus this secondary energy has been assumed to be 100 percent usable throughout the life of the project. This power is valued at the cost savings resulting in its use (i.e. the variable costs of thermal generation, which are primarily fuel). Updating NEDECO's estimate to mid-1979 levels results in a valuation of Rs 0.61/kW·h, or an annual benefit of Rs 19 million over the life of the project, beginning in Project Year 5 (1984).

A summary of anticipated project benefits is provided in Table 10.3.

10.2.4 - Net Cash Flow

The net cash flow for determining the basic economic internal rate of return for the project for Scenario A is provided in Table 10.4

10.3 - Scenario B

10.3.1 - Project Costs

In this scenario, direct project costs are comparable to those in Scenario A. Construction of the irrigation system (main and brnach canals and tertiaries) is spread over 9 years as compared to 6 to 7 years in Scenario A. The headworks construction schedule is similar to Scenario A as is the schedule for the Right Bank Transbasin Canal. A summary of the annual phasing of the capital costs used in the economic analysis of Scenario B is shown in Table 10.5.

10.3.2 - Project Benefits

The delayed benefits from the project for Scenario B have been developed in Section 7. As in Scenario A, power benefits are included in the total project benefits Rs 19 million beginning in Project Year 5. A summary of the project benefits for Scenario B is provided in Table 10.6.

The net cash flow for determining the economic internal rate of return for the project for Scenario B is provided in Table 10.7.

TABLE 10.3

SCENARIO A

SUMMARY OF PROJECT ECONOMIC BENEFITS
(million Rupees)

Year	Irrigated Crops			Homestead	Livestock	Fisheries	Forestry	Power	Total
	Without*	With	Net						
1	79	79	-	-	-	-	-	-	-
2	79	79	-	-	-	-	8	-	8
3	79	79	-	-	-	-	8	-	8
4	79	75	(4)	-	-	-	8	-	4
5	79	165	86	16	(10)	(1)	8	19	118
6	79	271	192	37	(12)	(1)	8	19	243
7	79	401	322	52	(5)	(1)	(2)	19	385
8	79	539	460	64	-	1	(2)	19	542
9	79	611	537	64	11	1	9	19	635
10	79	654	575	64	13	2	9	19	682
11	79	679	600	64	16	2	9	19	710
12	79	690	611	64	19	2	9	19	724
13	79	691	612	64	22	2	9	19	728
14	79	692	613	64	24	2	9	19	730
15	79	692	613	64	27	2	9	19	734
16	79	692	613	64	31	2	7	19	736
17	79	692	613	64	32	2	7	19	737
18	79	692	613	64	35	2	7	19	740
19	79	692	613	64	37	2	7	19	742
20	79	692	613	64	38	2	7	19	743
21	79	692	613	64	39	2	7	19	744
22	79	692	613	64	39	2	7	19	744
23-29	79	692	613	64	39	2	9	19	746
30-36	79	692	613	64	39	2	7	19	744
37-40	79	692	613	64	39	2	9	19	746

*Includes rainfed paddy.

TABLE 10.4

SCENARIO A

NET CASH FLOW SUMMARY
(million Rupees)

Year	Economic Capital and Operating Costs	Total Project Economic Benefits	Net Cash Flow
1	242	-	(242)
2	861	8	(853)
3	1,173	8	(1,165)
4	1,155	4	(1,151)
5	726	118	(607)
6	498	243	(255)
7	383	385	2
8	82	542	461
9	61	635	574
10	61	682	621
11	61	710	649
12	61	724	663
13	61	728	667
14	61	730	669
15	61	734	673
16	61	736	675
17	61	737	676
18	61	740	679
19	61	742	681
20	61	743	682
21	61	744	683
22	61	744	683
23-29	61	746	685
30-36	61	744	683
37-40	61	746	685

Sources: Tables 10.2 and 10.3

TABLE 10.5

SCENARIO B - ECONOMIC COSTS
CAPITAL AND OPERATING COSTS
(million Rs)

Year	Headworks	Main and Branch Canals	Tertiary Irrigation System	Upstream Costs	Experimental Farm	Roads	Settlement	Project Management Infrastructure	O&M	Total
1(1980)	204	-	-	18	-	-	-	14	-	236
2	562	92	39	49	6	31	-	14	1	794
3	596	153	61	53	7	35	11	14	3	933
4	341	251	105	30	-	35	27	14	4	807
5	-	251	119	-	-	35	28	14	20	467
6	-	301	124	-	-	35	30	14	28	532
7	-	239	113	-	-	35	24	14	35	460
8	-	142	70	-	-	35	24	14	44	329
9	-	142	65	-	-	35	21	14	53	330
10	-	142	44	-	-	35	-	14	61	296
11	-	-	-	-	-	-	-	5	61	66
12-over	-	-	-	-	-	-	-	-	61	61

TABLE 10.6

SCENARIO B

SUMMARY OF PROJECT ECONOMIC BENEFITS

(million Rupees)

Year	Irrigated Crops			Homestead	Livestock	Fisheries	Forestry	Power	Total
	Without*	With	Net						
1	79	79	-	-	-	-	-	-	-
2	79	79	-	-	-	-	4	-	4
3	79	79	-	-	-	-	4	-	4
4	79	75	(4)	-	-	-	4	-	-
5	79	138	59	10	(5)	(1)	4	19	86
6	79	209	130	20	(4)	(1)	4	19	167
7	79	287	208	30	(4)	(1)	4	19	256
8	79	371	292	40	(2)	1	4	19	354
9	79	460	381	50	1	1	16	19	468
10	79	551	472	60	3	2	9	19	565
11	79	621	542	64	10	2	9	19	647
12	79	652	573	64	15	2	9	19	682
13	79	674	595	64	18	2	9	19	707
14	79	687	608	64	21	2	9	19	723
15	79	691	612	64	23	2	9	19	728
16	79	691	612	64	26	2	7	19	730
17	79	692	613	64	29	2	7	19	733
18	79	692	613	64	31	2	7	19	736
19	79	692	613	64	34	2	7	19	739
20	79	692	613	64	36	2	7	19	741
21	79	692	613	64	37	2	7	19	742
22	79	692	613	64	38	2	7	19	743
23-29	79	692	613	64	39	2	9	19	746
30-36	79	692	613	64	39	2	7	19	744
37-40	79	692	613	64	39	2	9	19	746

*Includes rainfed paddy.

TABLE 10.7

SCENARIO B

NET CASH FLOW SUMMARY

(million Rs)

Year	Economic Capital and Operating Costs	Total Project Economic Benefits	Net Cash Flow
1	236	-	(236)
2	794	4	(790)
3	933	4	(929)
4	807	-	(807)
5	467	86	(379)
6	532	167	(365)
7	460	256	(204)
8	329	354	25
9	330	468	138
10	296	565	269
11	66	647	581
12	61	682	621
13	61	707	646
14	61	723	662
15	61	728	667
16	61	730	669
17	61	733	672
18	61	736	675
19	61	739	678
20	61	741	680
21	61	742	681
22	61	743	682
23-29	61	746	685
30-36	61	744	683
37-40	61	746	685

Source: Tables 10.5 and 10.6

10.4 - Benefit-Cost Assessment

10.4.1 - Base Case Results

For the Base Case analysis of Scenarios A and B, the benefits have been calculated on the basis of paddy yields of 4.6 and 4.1 t/ha on Land Classes 1R and 2R respectively. These yields apply to both Maha and Yala crops. The resulting economic IRR is 10.1 percent for Scenario A and 9.8 percent for Scenario B. Thus the slower development schedule in Scenario B results in about a 0.3 percent decline in the project economic IRR.

10.4.2 - Sensitivity Analyses

A number of sensitivity tests have been undertaken for Scenarios A and B. In addition, the sensitivity of the economic IRR with respect to a number of different areas under irrigated agriculture has been conducted for Scenario A. With reference to the Base Case paddy yields discussed above, project benefits were recalculated on the basis of higher and lower paddy yields (±10 percent) as follows.

	Yields (t/ha)			
	Lower		Higher	
	Maha	Yala	Maha	Yala
Land Class 1R	4.1		5.1	
Land Class 2R	3.7		4.5	

An 8-yr period to realize the maximum economic benefits from paddy production (compared to 5 yr) was also tested for both

development scenarios. The results of the yield sensitivity calculations are shown below.

	Scenario A (percent)	Scenario B (percent)
Base Case	10.1	9.8
Higher yields	11.6	11.2
Lower yields	8.6	8.4
8 yr to maximum paddy benefit (with Base Case yields)	9.8	9.4

The IRR estimate is sensitive to yield levels. A 10 percent change in yields would change the IRR by about 1.5 percent. Changes in paddy prices and cropping intensities would have similar effects on the resulting IRR estimate. On the other hand, increasing the length of time required to obtain maximum paddy benefits from 5 to 8 yr has a relatively minor impact on the project IRR.

A number of sensitivity tests were also undertaken to determine the impact of increases in capital costs for the main irrigation system (headworks, main and branch canals, and tertiary system, which together represent 84 percent of the total costs used in the economic analysis) on the project IRR. The results indicated an approximately linear relationship in which the project IRR falls about 0.7 percent for every 10 percent increase in capital costs. Thus a 10 percent increase in capital costs for the Base Case would result in a project IRR of 9.4 and 9.1 percent for Scenarios A and B respectively.

In addition, the impact of a decline in overall project benefits was examined. Again, an approximately linear relationship was established wherein the project IRR would fall by 1.0 percent for every 10 percent decline in project benefits. Thus, if total project benefits are actually overestimated by 10 percent in the Base Case, the IRR would drop to 9.1 and 8.8 percent for Scenarios A and B respectively. It is noted that the approximately linear relationships established in the sensitivity tests for capital cost increases and reductions in project benefits are indicative and either a decrease in capital costs or an increase in project benefits would have equal and opposite impact on the economic IRR of the project.

In Section 10.2.2 two cost allocation methods for the Right Bank Canal from Minipe to Ratkinda were discussed. The incremental cost approach is used in the Base Case. If, however, costs were allocated on an equal basis between Systems B and C, the project IRR would fall by about 0.7 percent.

Two sensitivity tests were undertaken on Scenario A for the inclusion of alternate irrigated areas in the analysis. The first relates to the full development of System B where all areas identified as irrigable in land classification studies would be developed. This could be achieved if water usage rates are lower than estimated in Annex C. In this case the project IRR would increase to 10.6 percent.

The second sensitivity test is based on the inclusion of the Nelugala Jungle Corridor (see Section 9) as a wildlife protection measure in the land-use planning for System B. In this case the areas commanded by Branch Canals LB-L10 and LB-R8 would be developed, as a water balance could be achieved by not developing land within the Nelugala Corridor.

For this option, the project IRR would be 10.3 percent--not a significant change from the Base Case IRR.

Finally, the impact of an unplanned delay in project implementation was examined. The unplanned delay scenario was simulated by combining the capital and operating cost streams from Scenario A with the project benefit stream from Scenario B. This resulted in a project IRR of 9.1 percent. Clearly, a planned rescheduling of project implementation yields more attractive economic results than does an unplanned delay.

The results of the Base Case analysis and the sensitivity tests described above are summarized in Table 10.8. The economic IRR is estimated to be about 10 percent. Allowing for risk and uncertainty the IRR actually achieved could range from a low of 8 percent to well over 11 percent.

10.4.3 - Other Evaluation Criteria

Decision-makers may actually want to analyze the socio-economic viability of the proposed project from a slightly different perspective. Questions arise regarding

- the socially desirable impact of selecting relatively poor families for settlement in the region

- the regional impact during the construction period which would be generated by worker expenditures in the area

- long-term regional growth of the secondary and tertiary sectors which is directly dependent on the agricultural population in the project area.

TABLE 10.8

SUMMARY OF PROJECT IRR ESTIMATES
(percent)

	Scenario A	Scenario B
Base Case	10.1	9.8
Higher yields	11.6	11.2
Lower yields	8.6	8.4
Eight years to maximum paddy benefits (with Base Case yield)	9.8	9.4
Capital costs up 5 percent	9.7	9.4
10 percent	9.4	9.1
15 percent	9.1	8.8
20 percent	8.8	8.5
Project benefits down 5 percent	9.6	9.3
10 percent	9.1	8.8
15 percent	8.6	8.3
20 percent	8.0	7.7
50 percent share of Right Bank Transbasin Canal	9.4	9.0
Full development	10.6	-
Nelugala Corridor	10.3	-
Unplanned delay in Implementation Schedule	9.1	

The implications of these investigations with respect to the basic economic analysis conducted are summarized below.

Consideration	Impact on Basic IRR
The net social benefit of assistance to relatively low income families	Add from 1.1 percent to 2.4 percent to basic IRR
The regional impact of construction worker expenditure in the area	Add 1.5 percent to basic IRR
The net socioeconomic benefits of long-term regional spin-offs	Add 2.0 percent to basic IRR

10.5 - Financial Aspects

10.5.1 - Farm Financial Returns

Financial farm incomes are discussed in Section 7. Both paddy farmers and upland farmers would have disposable incomes of about Rs 4,000 to 5,000/yr once basic cost-of-living expenses have been deducted from the farm cash flow. However, once an allowance has been made for consumption and investment over and above the farmer's basic cost-of-living, farm liquidity in the amount of about Rs 1,000 would remain.

If annual operating and maintenance costs of the project (Rs 61 million at full development) are allocated on a perfarm basis, the annual farm charge would be about Rs 1,700/farm/yr. Thus, the annual operation and maintenance

costs could only be partially recovered through a water tax, land charge or other similar instrument.

The emphasis placed on cost recovery will depend on what farm standard of living is acceptable to policymakers. It is important to consider that earnings must be sufficiently large to provide adequate incentives to the farmer so that he will participate in the project. In this context, the choosing of an income level which provides an allowance for consumption and investment over and above the basic cost of living is a matter of informed, subjective judgment and is best made by the policymaker.

10.5.2 - Total Financial Project Costs

Project economic capital costs for purposes of economic analysis are Rs 4,939 million (see Table 10.1). For the irrigation works, both financial and economic costs have been developed in Section 4. For the other costs detailed in Table 10.1, the financial costs have been calculated and used in the economic analysis.

The above costs are not the total financial project capital costs. The costs of social infrastructure and the agriculture processing and services infrastructure have not been included directly in the economic analysis. The former are not considered as project charges and the latter are accounted for in the crop budgets and the pricing of various agriculture commodities. This section provides a 10-yr summary of the financial costs for the Maduru Oya project, broken down into both local and foreign currency components. This is provided for both Scenarios A and B.

As indicated previously, the financial costs of the head-works, main and branch canals, and tertiary irrigation system are presented in Section 4 and Annex D. The total financial cost expressed in 1979 prices is Rs 3,997.5 million, of which the foreign exchange component is about 60 percent. Tables 10.9 and 10.10 illustrate the phasing of these costs over the construction period for Scenarios A and B respectively.

The costs of roads, settlement, and social infrastructure are detailed in Section 5 and Annex I. These costs total Rs 835 million and their phasing is shown in Tables 10.9 and 10.10.

The capital costs of the project management infrastructure total Rs 145 million and are presented in Section 8 and Annex K.

The agricultural processing and services category includes tractor and thresher hire services, village hullers, collection centers, and paddy milling complexes. Requirements for these facilities and services have been discussed in Annex G (Agroeconomic Studies) and their costs over the 10-yr period are shown below for Scenarios A and B.

	Scenario A	Scenario B
	(million Rs)	
Tractor services	268.7	231.2
Thresher services	12.2	11.4
Village hullers	5.6	5.6
Collection centers	22.8	22.8
Milling, drying, storage complexes	375.0	375.0
TOTALS	684.3	646.0

Tables 10.9 and 10.10 show the phasing of these costs over the 10-yr period for Scenarios A and B.

Also included in the financial capital costs of the project is the Experimental Demonstration Farm at a cost of Rs 13 million.

Table 10.11 illustrates a 10-yr summary of annual financial capital costs for Scenarios A and B with local and foreign cost components shown separately. The financial costs shown in Table 10.11 are in 1979 prices. It is instructive to examine these costs in the light of expected future inflation in both Sri Lanka and the rest of the world. Table 10.12 shows the local and foreign component expenditure over the next 5 yr, assuming an annual rate of domestic inflation of 15 percent* and an annual rate of international inflation of 10 percent.

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*A recent IBRD report indicates that inflation accelerated to an annual rate of 32 percent in 1979.

TABLE 10.9

MAGHUGOYA PROJECT
CAPITAL ITEMS - FINANCIAL CASH FLOW (1979 PRICES)
SCENARIO A

Category	1980			1981			1982			1983			1984			1985			1986			1987			1988			1989			TOTAL		
	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T	L	F	T
Headworks	92.0	149.3	201.3	142.[illegible]	410.[illegible]	553.6	151.6	435.6	587.2	86.[illegible]	248.9	335.5																					
Main & Branch Canals				42.6	74.8	117.4	100.1	179.8	279.9	155.0	282.1	437.1	137.6	254.4	392.0	84.4	155.9	240.3	59.6	109.6	169.4										433.[illegible]	1244.5	1677.6
Tertiary Irrigation System				41.4	4.6	46.0	104.1	11.6	115.7	171.9	19.1	191.0	142.6	15.9	158.5	79.6	8.8	88.4	62.7	7.0	69.7	12.8	1.4	14.2							579.5	1056.5	1636.0
Experimental Farm				5.4	0.6	6.0	6.3	0.7	7.0																						615.1	68.4	683.5
Roads				60.3	10.7	71.0	60.3	10.7	71.0	60.3	10.7	71.0	60.3	10.7	71.0	60.3	10.7	71.0	61.2	10.8	72.0										11.7	1.3	13.0
Settlement							16.8	7.2	24.0	30.8	13.2	44.0	32.2	13.8	46.0	29.4	12.6	42.0	6.3	2.7	9.0										362.7	64.3	427.0
Project Management Infra.	13.0	6.0	20.0	14.0	6.0	20.0	14.0	6.0	20.0	14.0	6.0	20.0	14.0	6.0	20.0	14.0	6.0	20.0	14.0	6.0	20.0	3.5	1.5	5.0							115.5	49.5	165.0
Agricultural Processing & Services										82.4	91.1	173.5	105.5	115.1	220.6	75.8	90.1	165.9	56.5	59.5	116.0	0.8	2.5	3.3	0.6	2.1	2.7	0.5	1.8	2.3	101.5	43.5	145.0
Social Infrastructure				12.6	5.4	18.0	22.4	9.6	32.0	40.6	17.4	58.0	41.3	17.7	59.0	37.1	15.9	53.0	16.1	6.9	23.0										322.1	362.2	684.3
TOTAL L	66.0			319.2			475.6			641.6			533.5			380.6			276.6			17.1			0.6			0.5			170.1	72.9	243.0
F		155.3			512.8			661.2			688.5			433.6			300.0			202.5			5.4			2.1			1.8		2711.3		
T			221.3			832.0			1136.8			1330.1			967.1			680.6			479.1			22.5			2.7			[illegible]		2963.1	
																																	5674.4

TABLE 10.10

MADURU OYA PROJECT
CAPITAL ITEMS - FINANCIAL CASH FLOW (1979 PRICES)
SCENARIO B

Category		1980 L	1980 F	1980 T	1981 L	1981 F	1981 T	1982 L	1982 F	1982 T	1983 L	1983 F	1983 T	1984 L	1984 F	1984 T	1985 L	1985 F	1985 T	1986 L	1986 F	1986 T	1987 L	1987 F	1987 T	1988 L	1988 F	1988 T	1989 L	1989 F	1989 T	TOTAL L	TOTAL F	TOTAL T
Headworks		52.0	149.3	201.3	142.9	410.7	553.6	151.6	435.6	587.2	86.6	248.9	335.5																			433.1	1244.5	1677.6
Main and Branch Canals					32.0	56.1	88.1	53.3	93.5	146.8	85.2	154.6	239.8	85.1	154.6	239.7	101.0	186.0	287.0	79.8	148.6	228.4	47.7	87.7	135.4	47.7	87.7	135.4	47.7	87.7	135.4	579.5	1056.5	1636.0
Tertiary Irrigation System					33.1	3.7	36.8	50.6	5.6	56.2	87.6	9.7	97.3	98.9	11.0	109.9	103.0	11.4	114.4	93.6	10.4	104.0	58.2	6.5	64.7	53.7	6.0	59.7	36.4	4.1	40.5	615.1	68.4	683.5
Experimental Farm					5.4	0.6	6.0	6.3	0.7	7.0																						11.7	1.3	13.0
Roads					36.5	6.5	43.0	40.8	7.2	48.0	40.8	7.2	48.0	40.8	7.2	48.0	40.8	7.2	48.0	40.8	7.2	48.0	40.8	7.2	48.0	40.8	7.2	48.0	40.8	7.2	48.0	362.9	64.1	427.0
Settlement								7.7	3.3	11.0	18.9	8.1	27.0	19.6	8.4	28.0	21.0	9.0	30.0	16.8	7.2	24.0	16.8	7.2	24.0	14.7	6.3	21.0				115.5	49.5	165.0
Project Management Infra.		9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	9.8	4.2	14.0	98.0	42.0	140.0 *
Agricultural Processing and Services											51.9	55.2	107.1	47.4	54.2	101.6	54.5	58.6	113.1	53.9	55.8	109.7	46.6	51.2	97.8	45.6	47.3	92.9	14.7	9.1	23.8	314.6	331.4	646.0
Social Infrastructure					7.0	3.0	10.0	15.4	6.6	22.0	28.7	12.3	41.0	30.1	12.9	43.0	28.7	12.3	41.0	24.5	10.5	35.0	21.7	9.3	31.0	14.0	6.0	20.0				170.1	72.9	243.0
TOTAL	L	61.8			266.7			339.5			409.5			331.7			358.8			319.2			241.6			226.3			149.4			2700.5		
	F		153.5			484.8			556.7			500.2			252.5			288.7			243.9			173.3			164.7			112.3			2930.6	
	T			215.3			751.5			892.2			909.7			584.2			647.5			563.1			414.9			391.0			261.7			5631.1

* Further expenditures in 1990 would bring the total cost of this item to Rs145 million, as for Scenario A.

TABLE 10.11

SUMMARY OF ANNUAL
CAPITAL COSTS
1979 FINANCIAL PRICES

(million Rupees)

		Scenario A	Scenario B
1980 -	Local	66.0	61.8
	Foreign	155.3	153.5
	TOTAL	221.3	215.3
1981 -	Local	319.2	266.7
	Foreign	512.8	484.8
	TOTAL	832.0	751.5
1982 -	Local	475.6	335.5
	Foreign	661.2	556.7
	TOTAL	1,136.8	892.2
1983 -	Local	641.6	409.5
	Foreign	688.5	500.2
	TOTAL	1,330.1	909.7
1984 -	Local	533.5	331.7
	Foreign	433.6	252.5
	TOTAL	967.1	584.2
1985 -	Local	380.6	358.8
	Foreign	300.0	288.7
	TOTAL	680.6	647.5
1986 -	Local	276.6	319.2
	Foreign	202.5	243.9
	TOTAL	479.1	563.1
1987 -	Local	17.1	241.6
	Foreign	5.4	173.3
	TOTAL	22.5	414.9
1988 -	Local	0.6	226.3
	Foreign	2.1	164.7
	TOTAL	2.7	391.0
1989 -	Local	0.5	149.4
	Foreign	1.8	112.3
	TOTAL	2.3	261.7

Source: Tables 10.9 and 10.10

TABLE 10.12

FINANCIAL COSTS, 1980 to 1984
(Current* prices, Rs millions)

	Scenario A			Scenario B		
	Local	Foreign	Total	Local	Foreign	Total
1980	75.9	170.8	246.7	71.1	168.9	240.0
1981	422.1	620.5	1,042.6	352.7	586.6	939.3
1982	723.3	880.1	1,603.4	510.3	741.0	1,251.3
1983	1,122.2	1,008.0	2,130.2	716.2	732.3	1,448.5
1984	1,073.1	698.3	1,771.4	667.2	406.7	1,073.9
Totals	3,416.6	3,377.7	6,794.3	2,317.5	2,635.5	4,953.0

Notes: Assumes a domestic inflation rate of 15 percent and an international inflation rate of 10 percent.

Refer to Tables L-6.1 and L-6.2 for (1979 currency) costs from 1985 onward.

*Year of expenditure.

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FIGURES

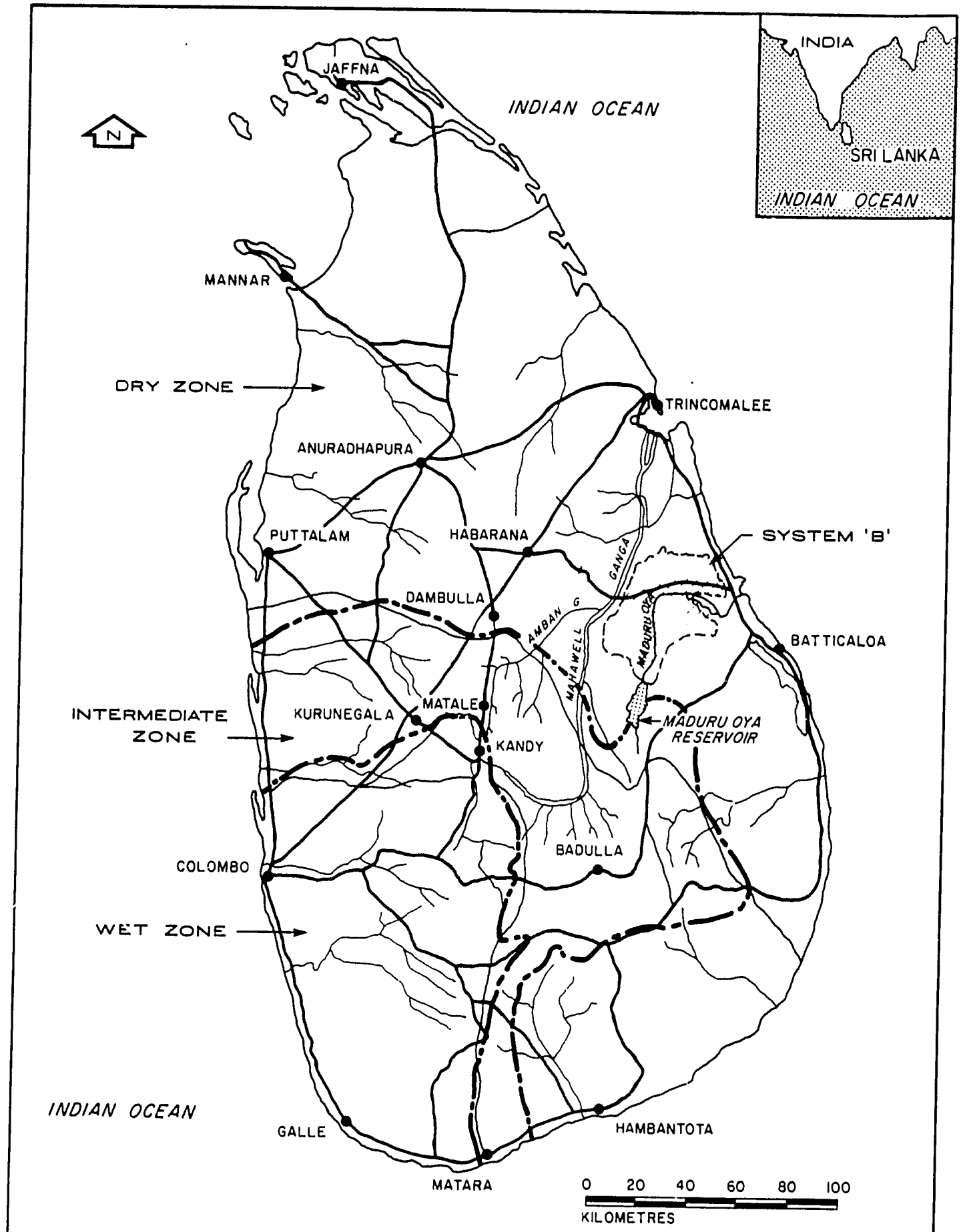


FIG. 1

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

PROJECT LOCATION

ACRES

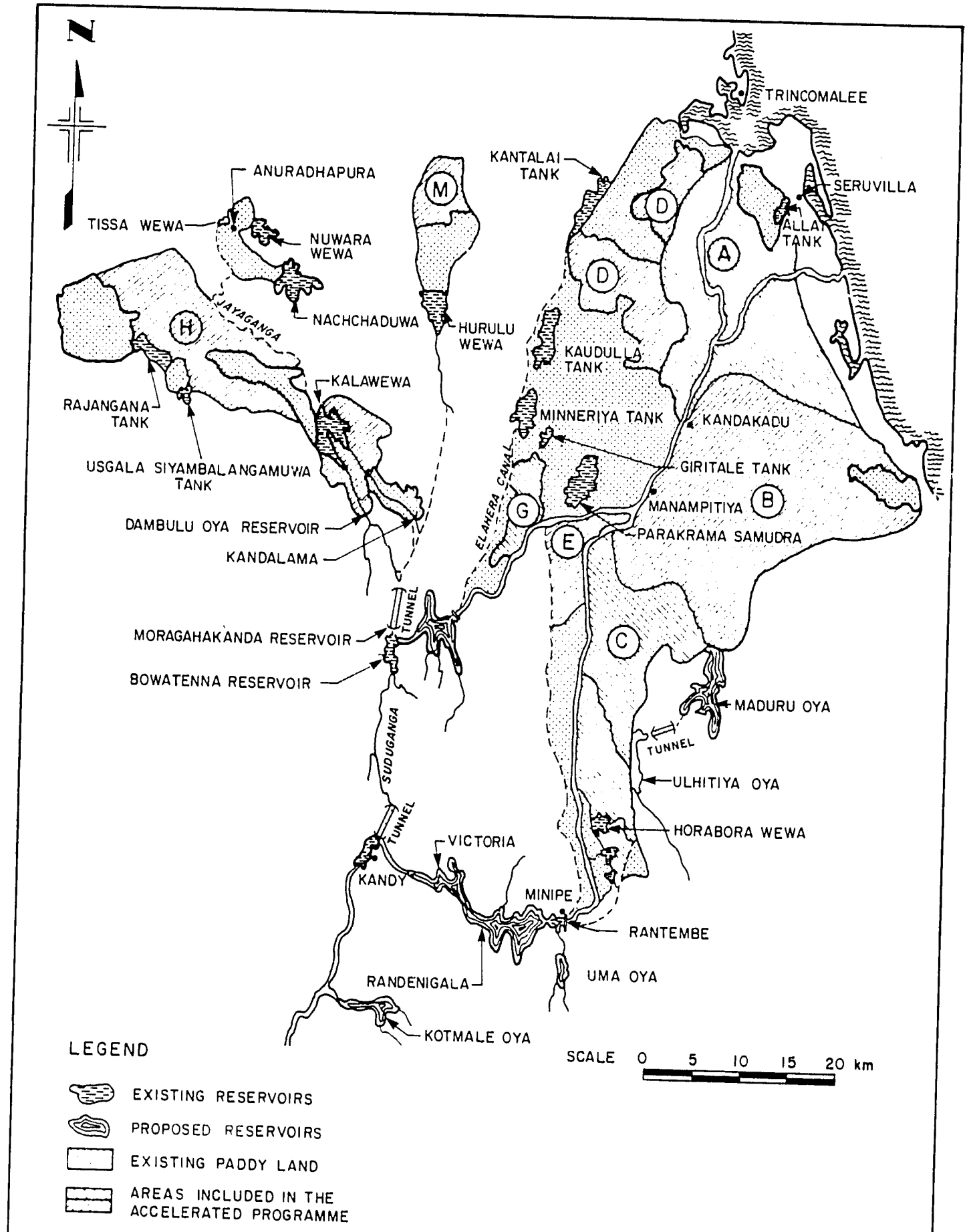
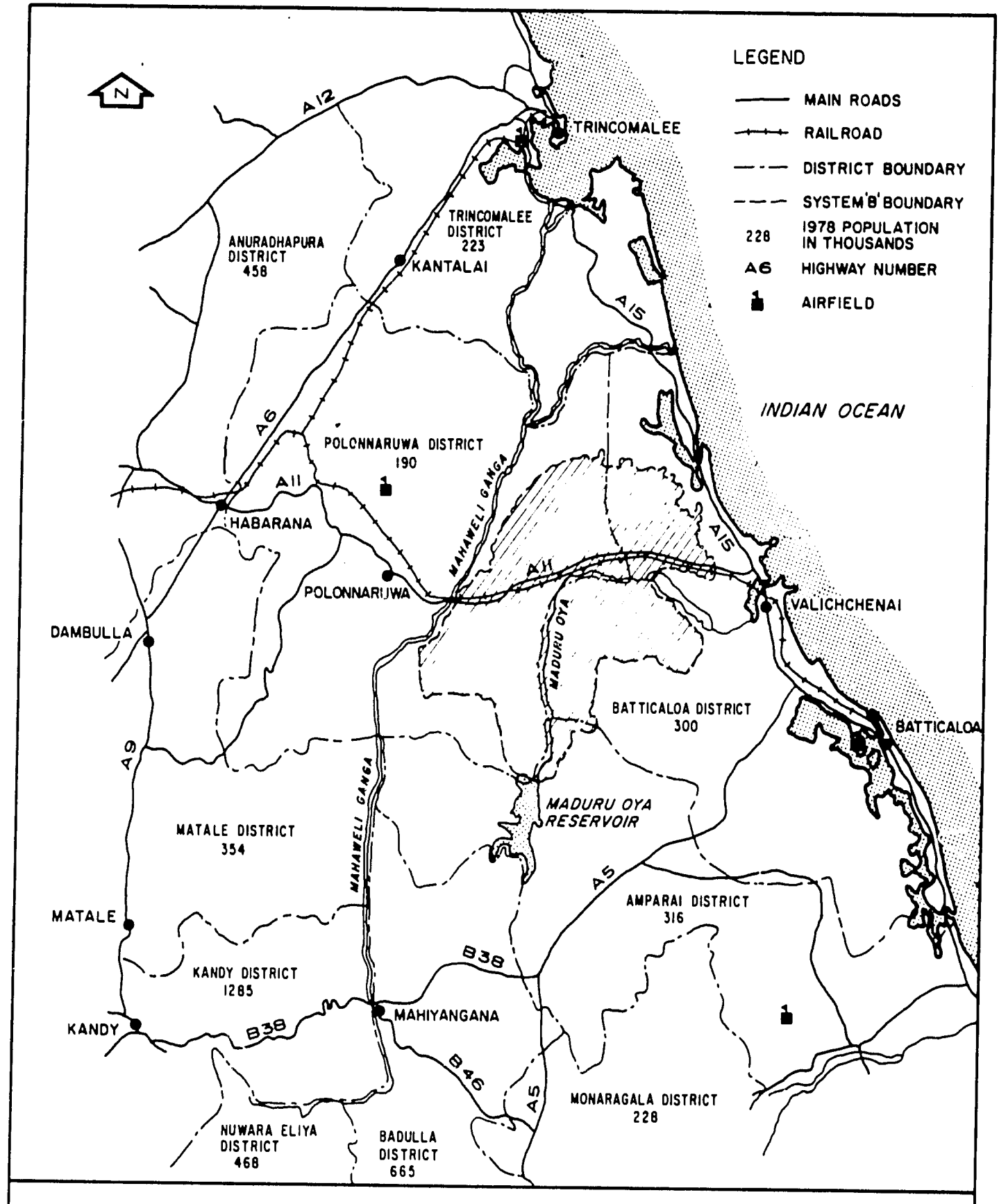


FIG. 2

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

ACCELERATED MAHAWELI PROGRAMME

ACRES

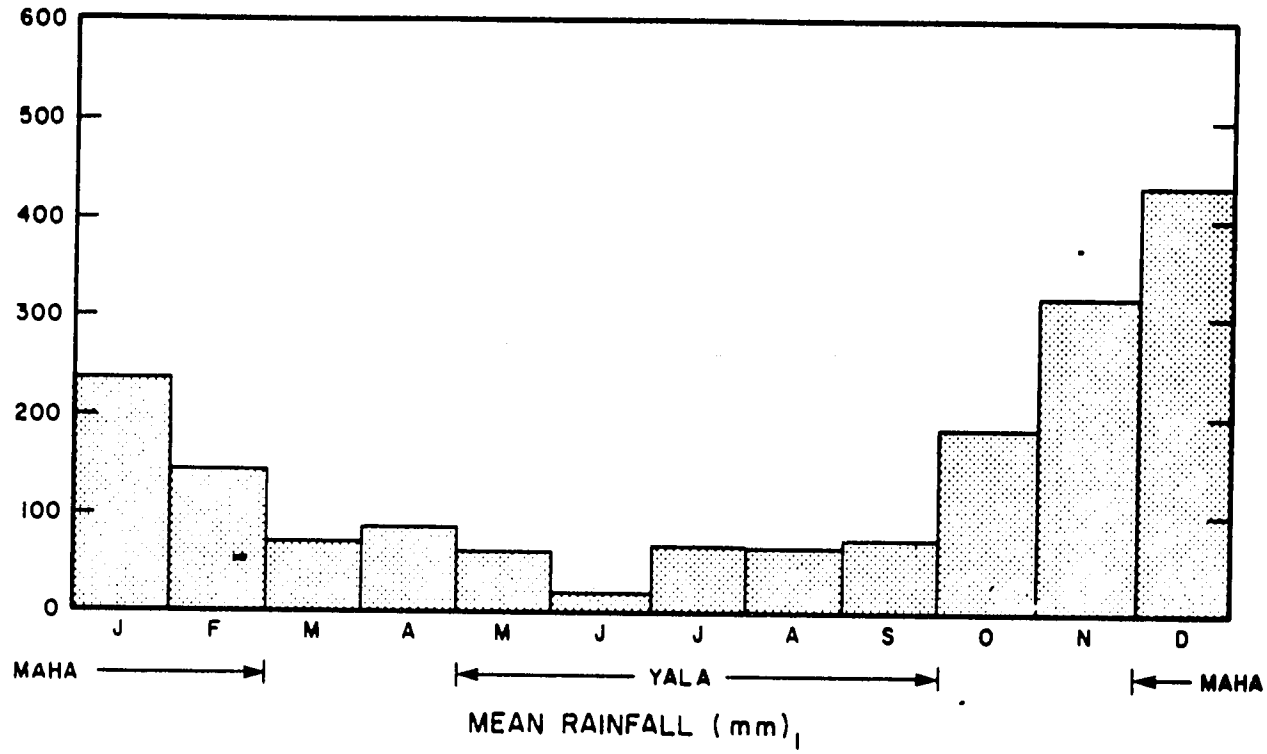


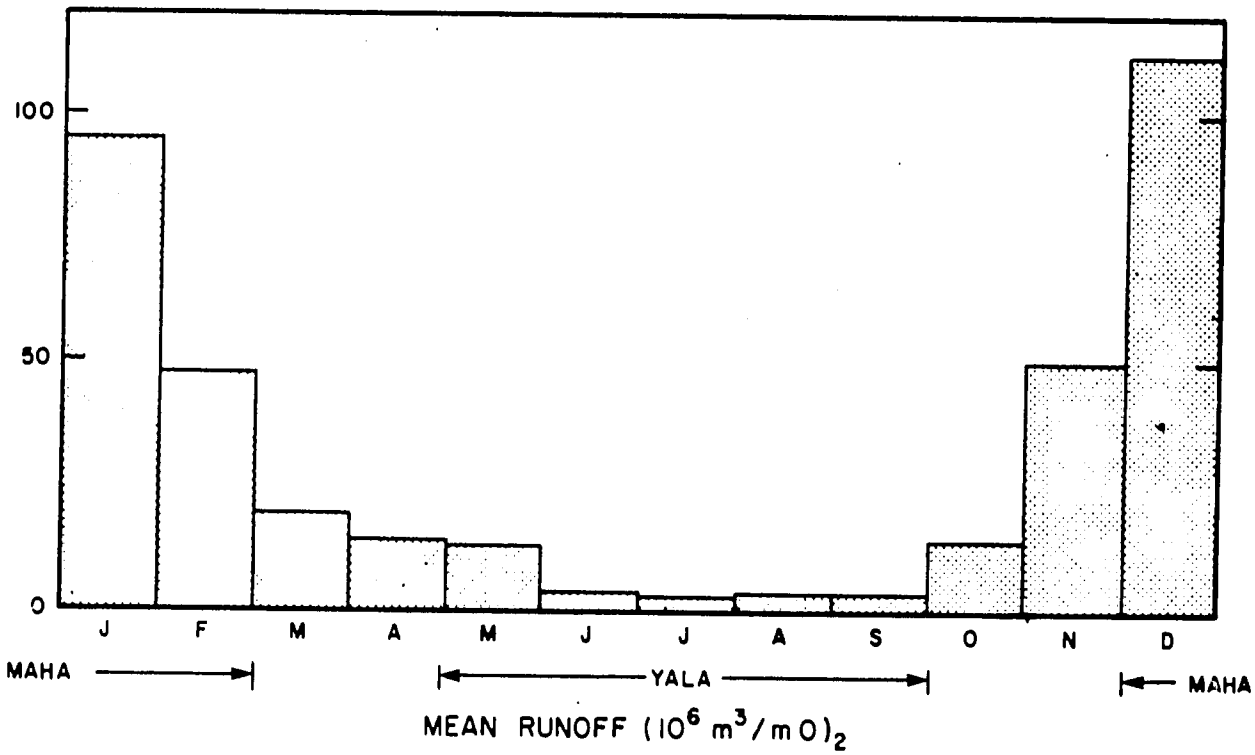
0 25
KILOMETRES

FIG. 3

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
REGIONAL CONTEXT

ACRES





NOTES

1 MEAN RAINFALL AT WELIKANDA

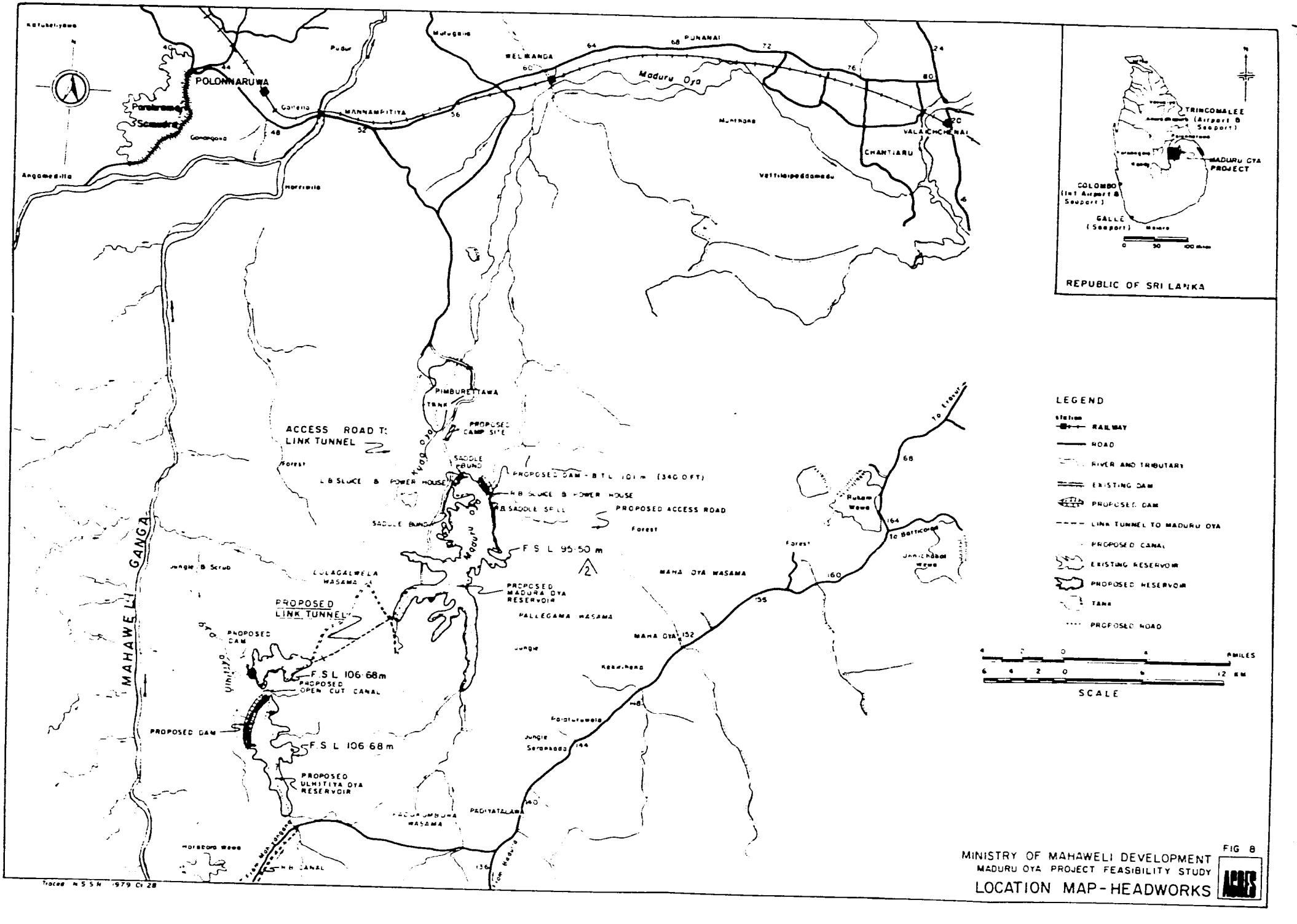
2 MEAN RUNOFF AT MADURU OYA DAM SITE

FIG. 4

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

PATTERN OF RAINFALL AND RUNOFF

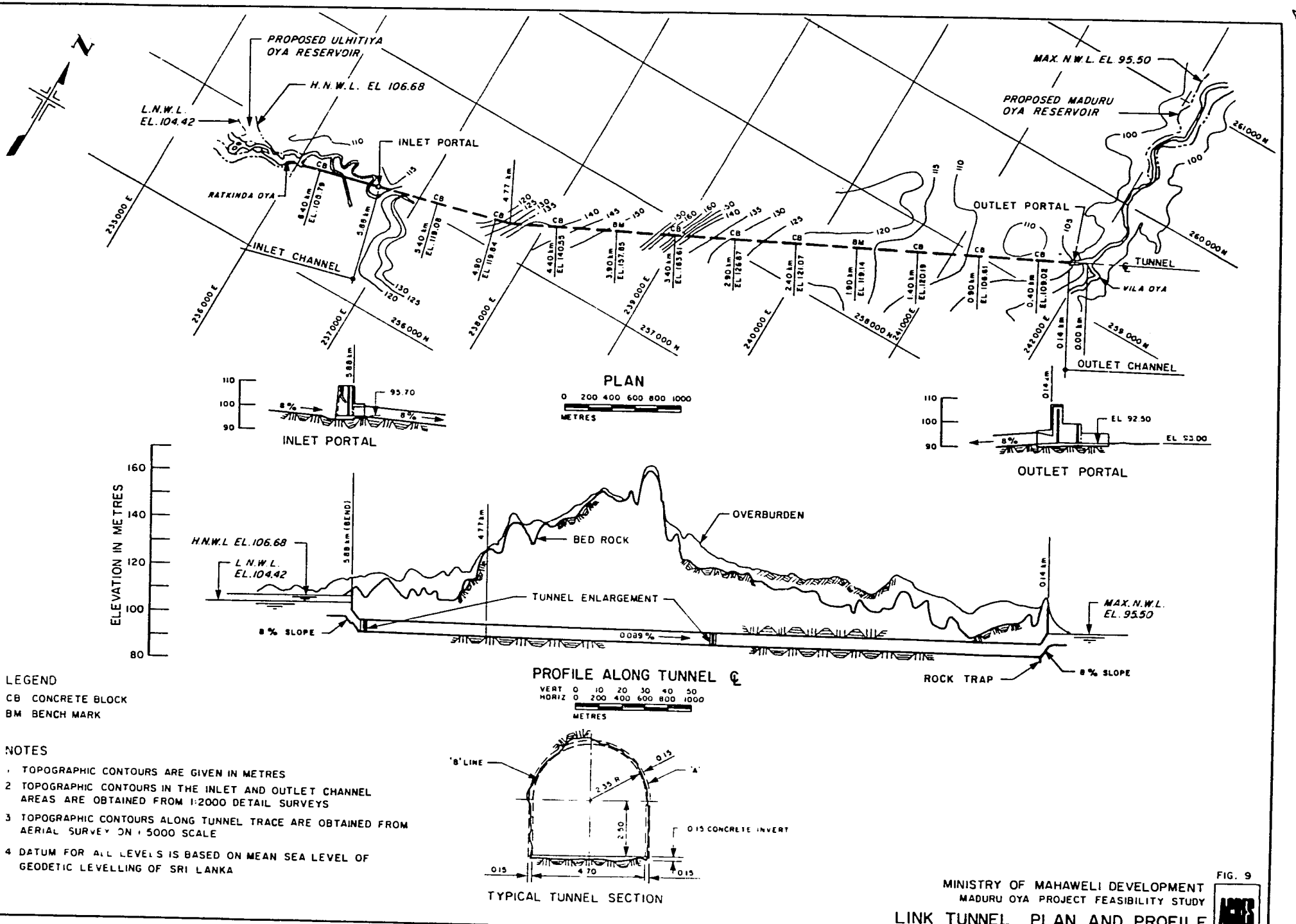
AGRES



MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
LOCATION MAP - HEADWORKS

FIG 8

ACRES



LEGEND

CB CONCRETE BLOCK

BM BENCH MARK

NOTES

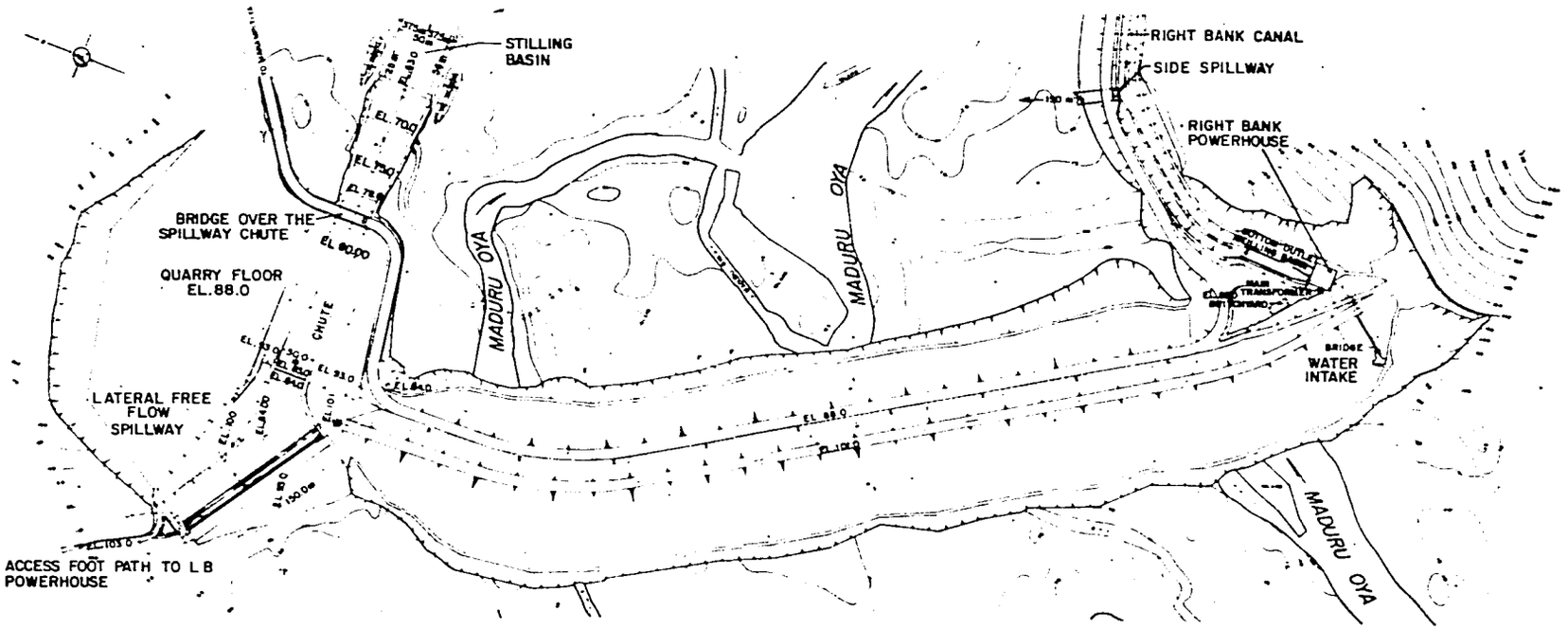
1. TOPOGRAPHIC CONTOURS ARE GIVEN IN METRES
2. TOPOGRAPHIC CONTOURS IN THE INLET AND OUTLET CHANNEL AREAS ARE OBTAINED FROM 1:2000 DETAIL SURVEYS
3. TOPOGRAPHIC CONTOURS ALONG TUNNEL TRACE ARE OBTAINED FROM AERIAL SURVEY ON 1:5000 SCALE
4. DATUM FOR ALL LEVELS IS BASED ON MEAN SEA LEVEL OF GEODETIC LEVELLING OF SRI LANKA

FIG. 9

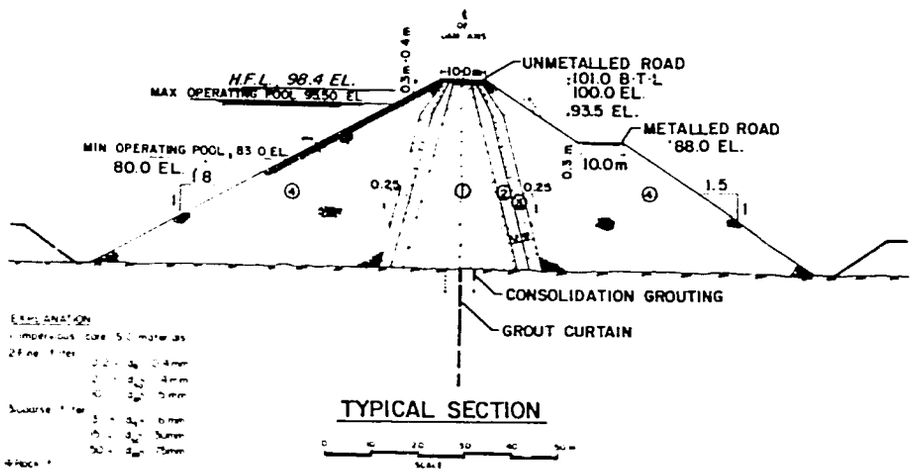
MINISTRY OF MAHAWELI DEVELOPMENT

MADURU OYA PROJECT FEASIBILITY STUDY

LINK TUNNEL PLAN AND PROFILE



PLAN



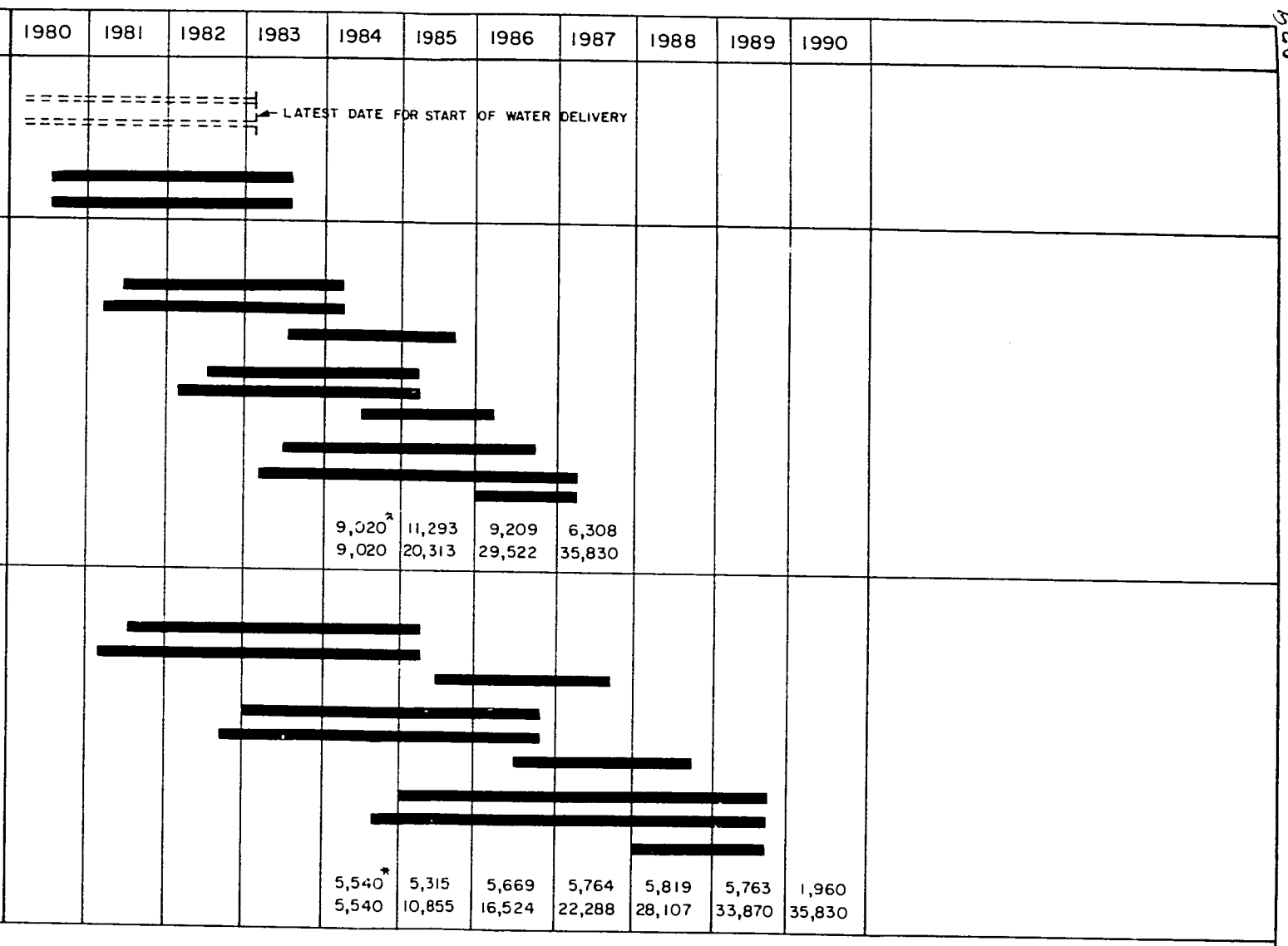
TYPICAL SECTION

SOURCE:
BASED ON DESIGN BY CENTRAL ENGINEERING CONSULTANCY BUREAU DRG. NOS. 112-T3R-03; 04

FIG. 10

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

ROCKFILL DAM- PLAN AND SECTION



NOTE *

+3150 YALA CROP HECTARES IN PIMBURETTEWA VAKANERI AND PUNANAI SCHEMES

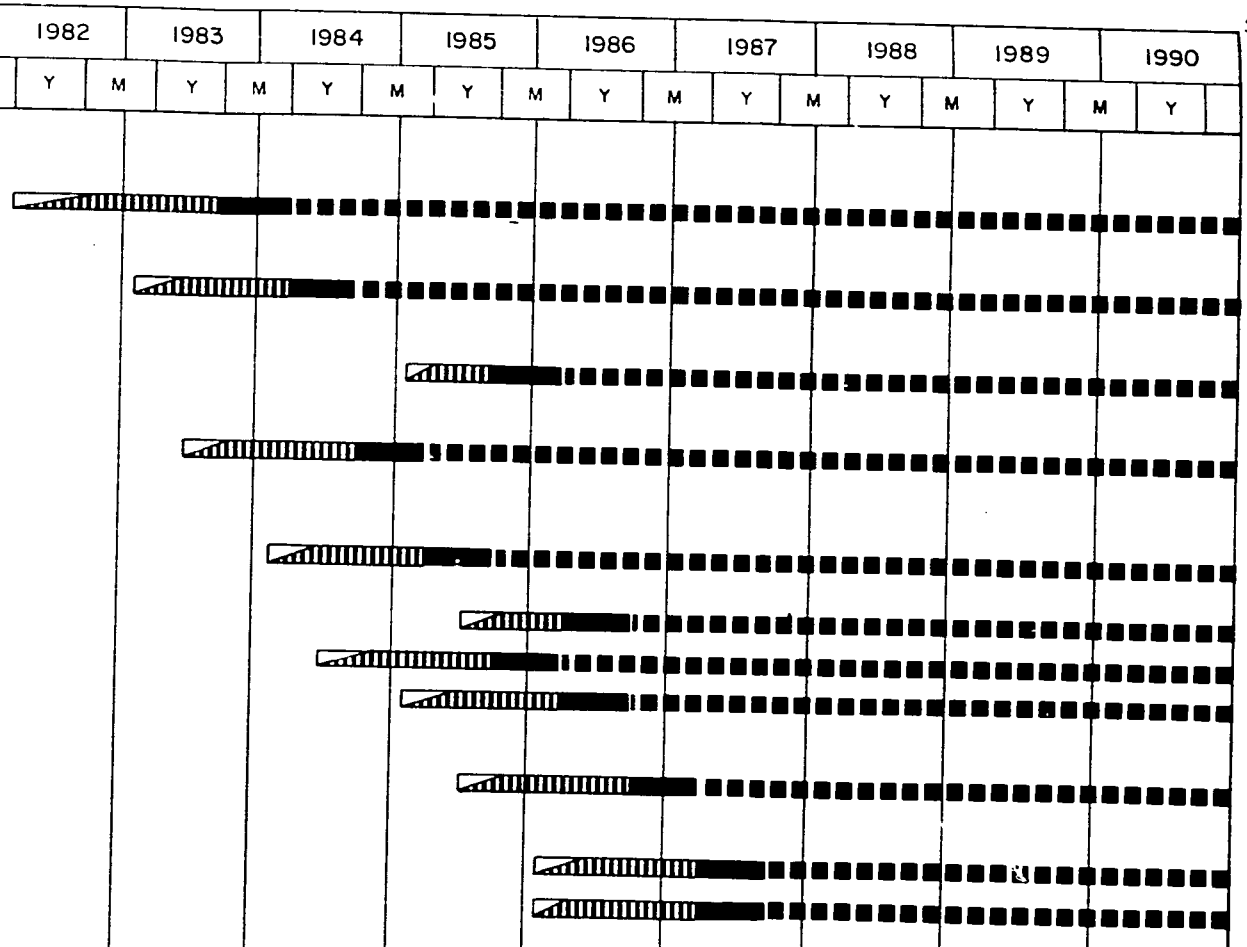
FIG. 11

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

ALTERNATIVE IMPLEMENTATION SCHEDULES

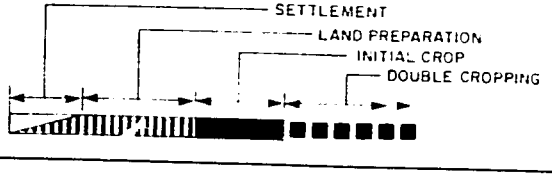
DEVELOPMENT PROGRESS

SECTOR	CANAL COMPLETED AS FAR AS: BRANCH/AREA	km	LAND TYPE	ha
1	LB-R1, LBDA-1, LB-L1	14.0	PADDY	4900
	DA-2, LB-L2, DA-3, DA-4, DA-5, DA-6, LB-R2, LB-L4 DA-7, DA-8, DA-9	31.7	PADDY	4120
			UPLANDS	625
2	LB-L5, LBDA-10, LB-R3, LB-R4, LB-L6, LB-L7 (A,B,C), DA-16 DA-17	41.5	PADDY	4897
	DA-12, LB-L8, LB-R5, LB-R6, DA-13, LB-R7, LB-L9, DA-14	58.5	PADDY	6396
			UPLANDS	630
3	DA-1, RB-L1, RBDA-1a, RB-L2	22.5	PADDY	3359
	RB-R1 (COMPLETE)	23.5	PADDY	4595
	DA-2, RB-L3, DA-4, DA-5, DA-6, RB-L4, DA-7, DA-8 DA-9, DA-10	40.7	PADDY	4348
	RB-L5	47.3	PADDY	1715
			UPLANDS	245



	1982	1983	1984	1985	1986	1987	1988	1989	1990
SETTLERS PER YEAR	4,900	9,000	9,800	9,700	1,900				
SETTLERS CUMULATIVE	4,900	13,900	23,700	33,400	35,300	35,300	35,300	35,300	35,300
TOTAL PRODUCTION ha PER YEAR			9,020	11,293	9,209	6,308			
TOTAL PRODUCTION CUMULATIVE			9,020	20,313	29,522	35,830	35,830	35,830	35,830

LEGEND



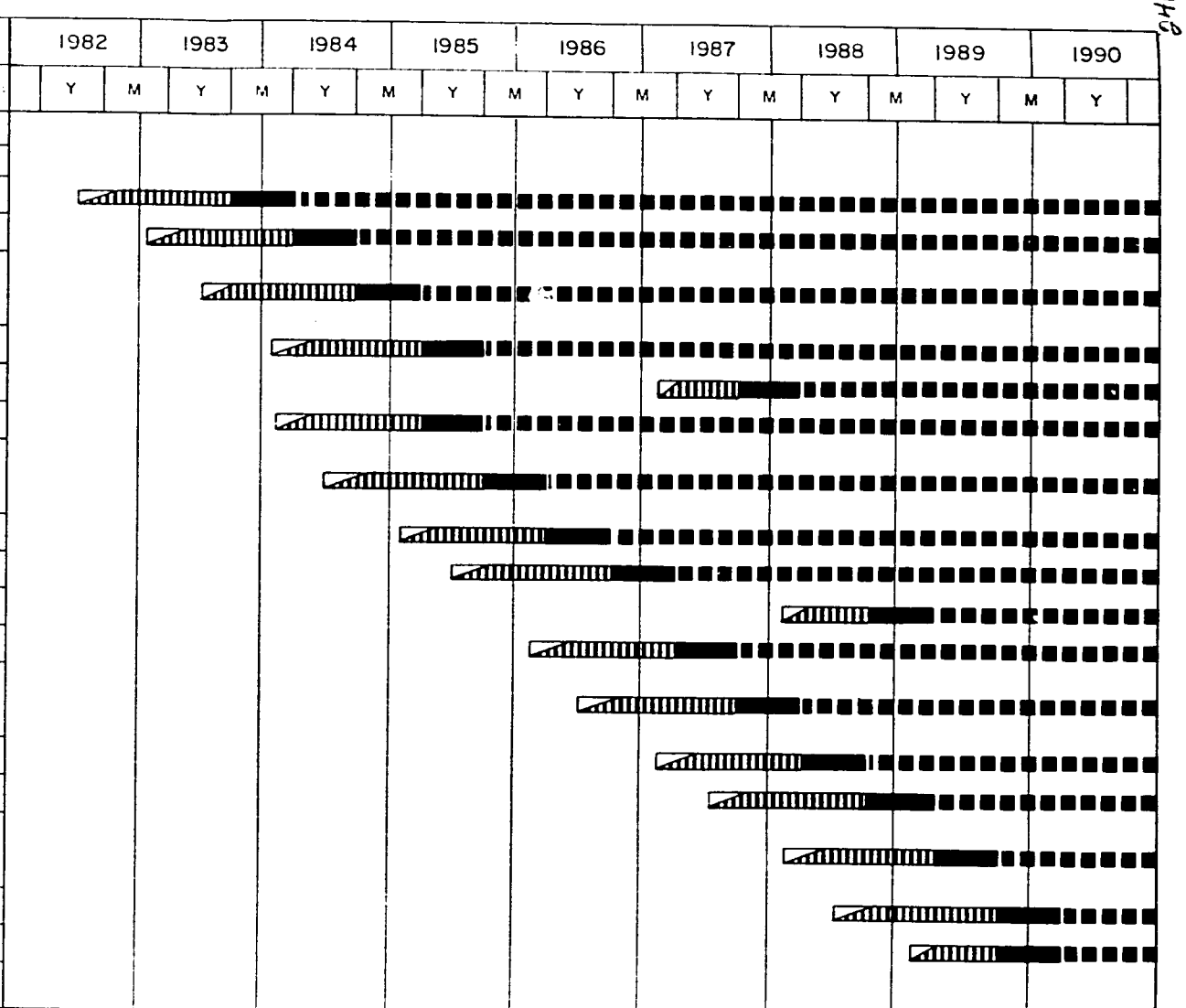
MINISTRY OF MAHAWLI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

DEVELOPMENT PHASING SCENARIO 'A'

FIG. 12

DEVELOPMENT PROGRESS

SECTOR	CANAL COMPLETED AS FAR AS: BRANCH/AREA	km	LAND TYPE	ha
1	LB-R1, LBDA-1	14.0	PADDY	2320
	LB-L1, DA-2, LB-L2, DA-3	17.0	PADDY	3220
	DA-4, DA-5, DA-6, LB-R2 LB-L3, LB-L4	25.0	PADDY	2580
	DA-7, DA-8, DA-9	31.7	PADDY	900
			UPLANDS	625
2	LB-L5, LBDA-10, LB-R3, LB-R4	38.1	PADDY	1835
	LB-L6, DA-11, LB-L7(A,B,C) DA-16, DA-17, DA-12	47.0	PADDY	3189
	LB-L8, LB-R5, LB-R6, DA-13	53.6	PADDY	2480
	LB-R7, LB-L9, DA-14	58.5	PADDY	3787
			UPLANDS	630
3	DA-1, RB-R1, RBDA-1a	21.0	PADDY	1977
	RB-L2, RB-R1, DA-3, DA-11 DA-12, RB-R1A, DA-13	23.5	PADDY	3078
	DA-14, DA-15, RB-R1B	23.5	PADDY	2116
	DA-16, DA-2, RB-L3	26.9	PADDY	2500
	DA-4, DA-5, DA-6, RB-L4 DA-7, DA-8, DA-9, DA-10	40.7	PADDY	2627
	RB-L5	47.3	PADDY	1715
			UPLANDS	245



	1982	1983	1984	1985	1986	1987	1988	1989	1990
SETTLERS PER YEAR	2,300	5,800	5,900	6,300	5,100	5,000	4,700	200	
SETTLERS CUMULATIVE	2,300	8,100	14,000	20,300	25,400	30,400	35,100	35,300	35,300
TOTAL PRODUCTION ha PER YEAR			5,540	5,315	5,669	5,764	5,819	5,763	1,960
TOTAL PRODUCTION CUMULATIVE			5,540	10,855	16,524	22,288	28,107	33,870	35,830

LEGEND

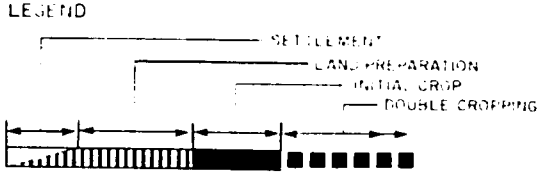
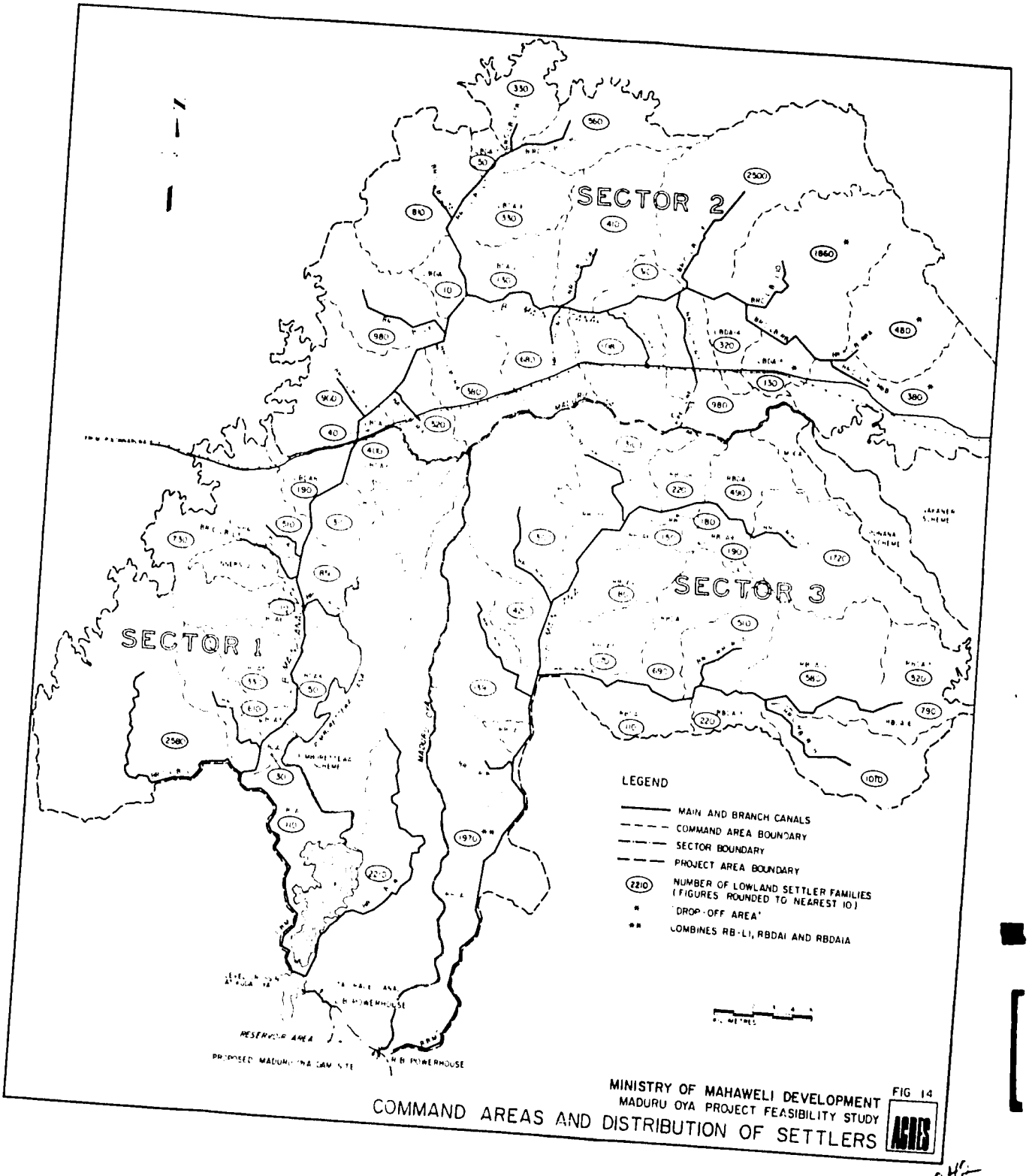


FIG 13

MINISTRY OF MAHAWLI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

DEVELOPMENT PHASING SCENARIO 'B'

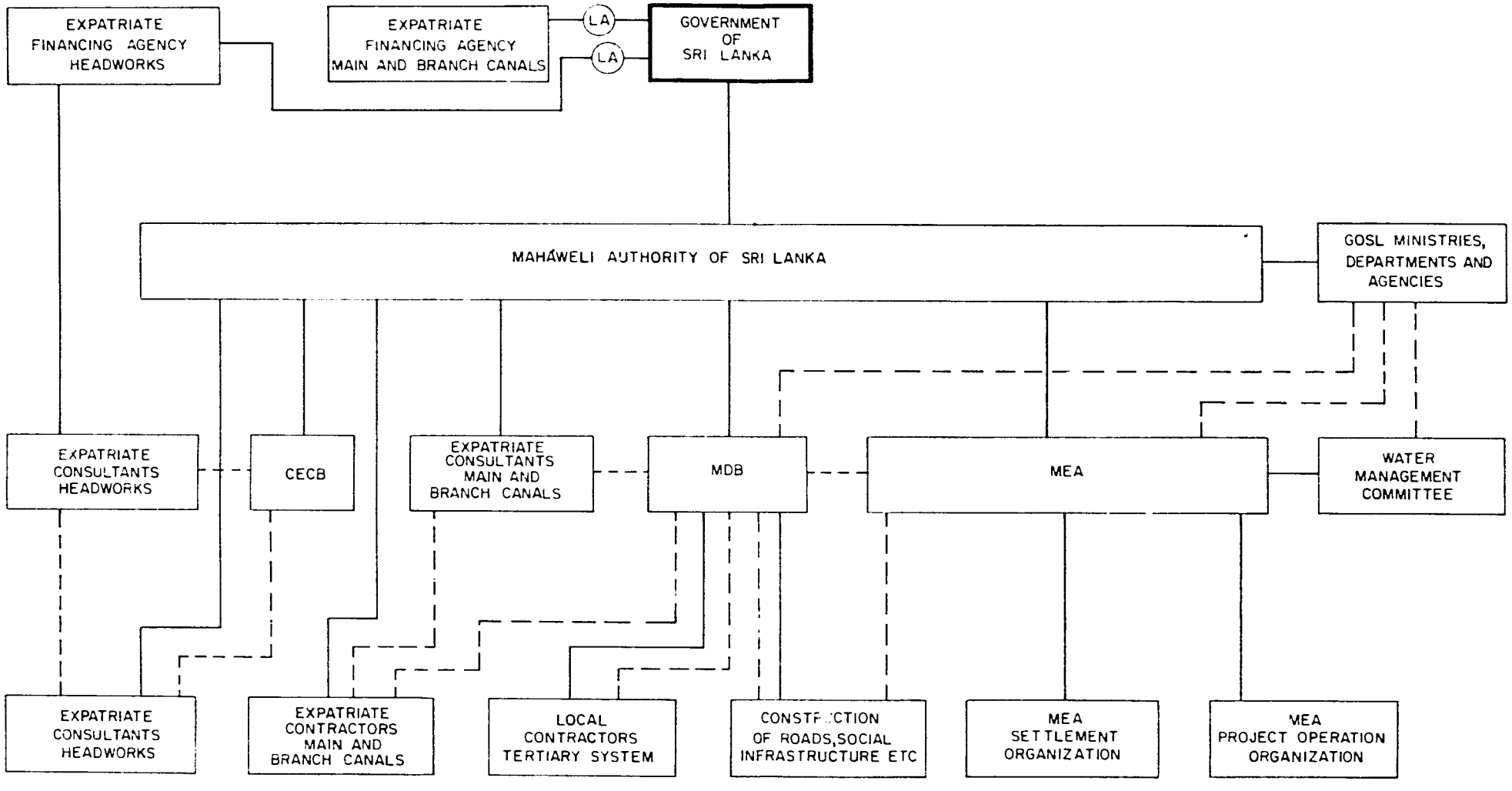


MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

FIG 14

COMMAND AREAS AND DISTRIBUTION OF SETTLERS

ACRES



LEGEND

CECB - CENTRAL ENGINEERING CONSULTANCY BUREAU

MDB - MAHAWELI DEVELOPMENT BOARD

MEA - MAHAWELI ECONOMIC AGENCY

(LA) - LOAN AGREEMENT

——— LINE OF AUTHORITY AND CONTRACTUAL LINKS

- - - - - WORKING COMMUNICATION

FIG 15

MINISTRY OF MAHAWELI DEVELOPMENT

MADURU OYA PROJECT FEASIBILITY STUDY

GENERAL ORGANIZATION CHART

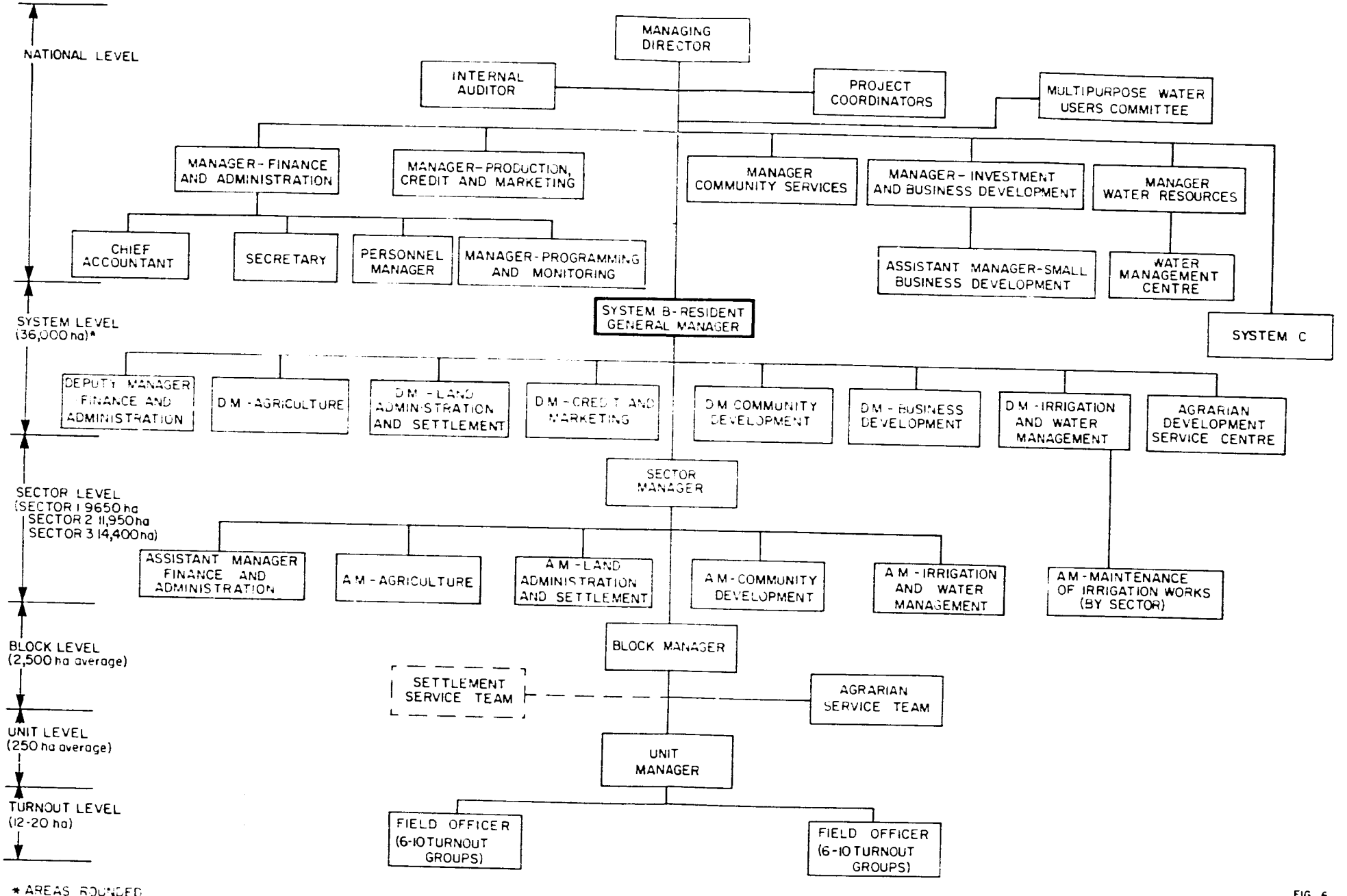


FIG 6

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
MAHAWELI ECONOMIC AGENCY

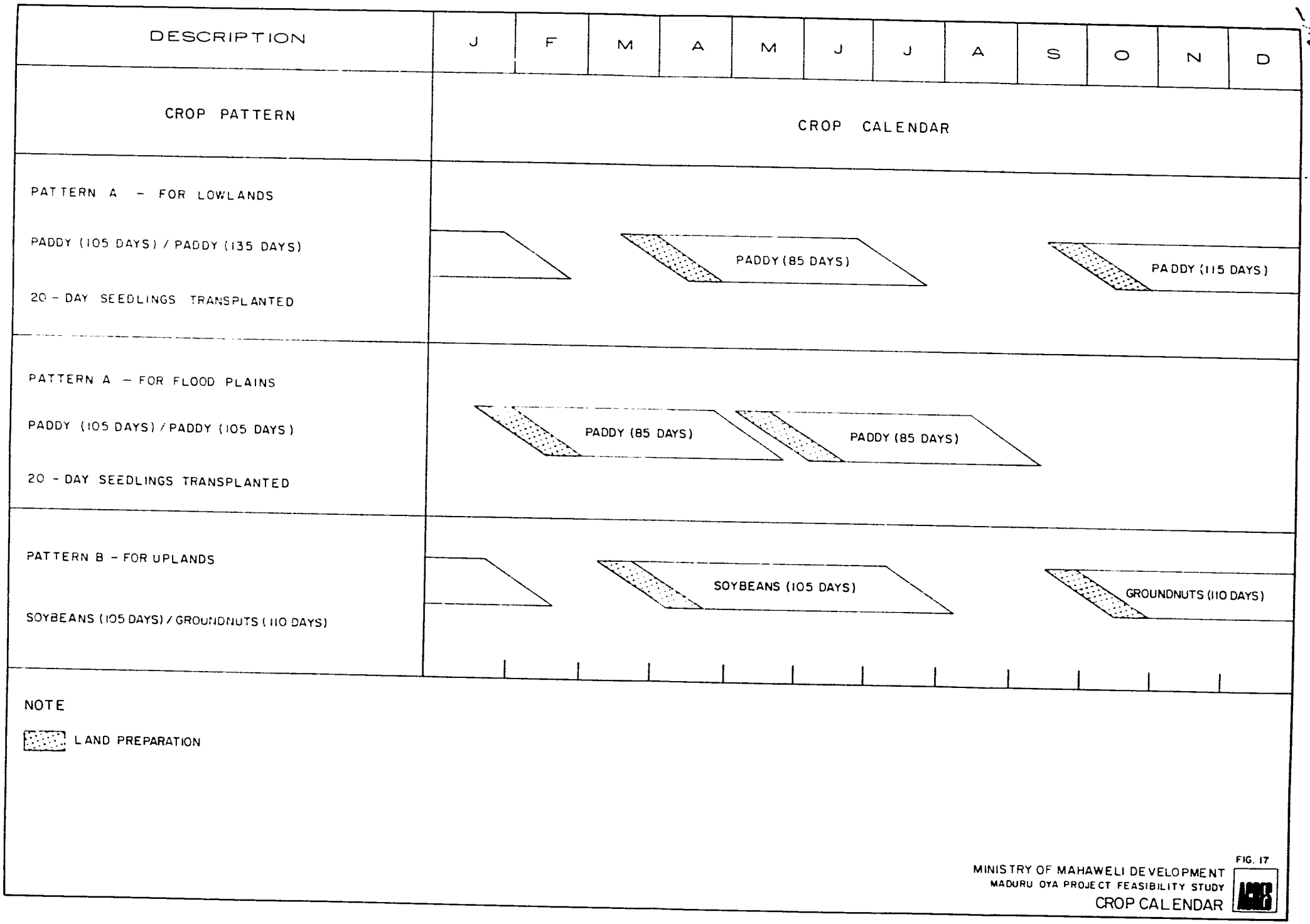


FIG. 17

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
CROP CALENDAR

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON D.C. 20523

September 10, 1980

MEMORANDUM

TO: ASIA/PD, Michael C. Demetre

FROM: ASIA/TR/STEP, Jane E. Stanley J.E. Stanley

SUBJECT: Comments on the Environmental Annex of Acres Feasibility Report of the Maduru Oya Project.

I have reviewed the subject report and find that is much less detailed and comprehensive than TAMS' Environmental Assessment of the Accelerated Mahaweli Program(AMP). This is understandable since the Acres report states that it has limited its analysis to three major environmental and health issues; public health aspects, forest conservation and wildlife protection, and it acknowledges several times that TAMS is undertaking a more detailed analysis of environmental issues related to the project. Nevertheless I do have the following comments to make on inconsistencies between Acres and TAMS data and the contents of the Acres report:

Section 2 Existing Conditions

1. This section contains baseline data that differs from data provided by TAMS. These discrepancies in baseline data are listed below:

   (a) Acres states there are 39 endemic species of animals in System B, and TAMS states there are 42 endemics in the entire AMP area. While Acres lists 3 less fish species than TAMS, (probably because there are fewer species of endemic fish in System B), it lists more amphibians and reptiles than TAMS. If Acres figures are correct, TAMS information on endemics must be low. It is impossible to identify the exact differences between the two reports as the listings of endemics in both reports are incomplete (the endemic species listed in both reports do not add up to numbers listed in the texts);

   (b) Acres lists one less endangered species than TAMS. This may be because TAMS identified one more endangered crocodile quite recently or because this crocodile does not exist in System B;

   (c) Acres states that there are 18,000 fishing units currently operating out of Trincomalee, while TAMS notes 13,000 units. This difference may be due to a typographical error in either one of the reports;

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(d) Acres' listing of present land use in System B differs somewhat from TAMS information on present land use. Although part of the difference may be due to different methods of land classification, there are major differences between the two reports in their estimation of amount of land in paddy and forests.

I recommend that we should try to resolve differences noted above.

2. This section of the report does not mention the project area's flora, except for tree species. More information on important plant species should be provided.

3. Section 2.81 (Public Health) focuses solely on disease incidence. In order to give an entire picture of the public health situation, the report should discuss health facilities and programs.

4. I am glad that Acres has addressed Archaeology (Section 2.82). Unfortunately we did not require TAMS to address archaeological sites in their terms of reference.

Section 4 Expected Impacts

1. Acres (p.37) states that no migratory fish have been identified which would normally pass a damsite, yet TAMS notes that dams will adversely affect the migration routes of some fish.

2. Acres (p. 43) lists more hectares of forest in the AMP (160,000 ha) than TAMS (114,700 ha). I believe Acres data is a little out-dated.

3. Acres (p. 44) suggests that animals affected by habitat destruction can escape to protected or undeveloped areas, such as the proposed Maduru Oya National Park. This is not true. Many wild animals, such as elephants, will not leave their habitat unless killed or translocated.

4. The section on Conservation Measures (p. 48) does not list all of TAMS wildlife protection recommendations.

5. Acres (p. 58) states that: "Although the pesticides BHC and Thiodan are known to be toxic and quite persistant, if properly applied and used only as indicated by crop need, the residual impacts can be minimized." BHC and Thiodan are very dangerous chemicals and are not registered for use in the United States. We should not condone their use in other countries.

6. The discussion of other pest species (p. 54) should include elephants, wild boar and rats. It should also note that the clearing of jungle for agricultural use could lead to the development of new pests.

Section 5 Recommendations

1. This section is quite weak. It does not recommend mitigation measures for many significant impact areas (such as villu destruction and disruption of estuarine ecosystems) that are discussed in the report. Also, it does not make any recommendations on institution-building or institutional changes needed to implement its wildlife and forestry recommendations.

3. This section recommends that the Nelugala Corridor, the Maduru Oya - Wasgomuwa Corridor and the Wasgomuwa - Somawathiya Corridor be implemented, at least on a temporary basis, until wildlife can leave or be translocated. The recommendation that these corridors be maintained on a temporary basis is not sound as many species of wildlife will not leave their habitat permantly unless killed or translocated, and Sri Lanka does not have the institutional capability to translocate wildlife.

4. The recommendation for habitat enrichment of Maduru Oya National Park will only result in the crowding of animals in a small area. When crowded in small areas, elephants do extensive damage to habitat, thereby reducing its carrying capacity.

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CNB0129 TCAC126 137 FR

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J. PINNEY ASIA/PD/ENGR

UNITED STATES AGENCY FOR INTERNATIONAL

DEVELOPMENT (USAID) ROSSLYN PLAZA CENTER

1601 NORTH KENT ST ROOM 613 ROSSLYN, VIRGINIA

PS152.11 SEPTEMBER 8, 1980 PLS REFER MAIN REPORT AND ANNEX C OF MADURU OYA PROJECT FEASIBILITY REPORT SENT WITH OUR LETTER PS152.900 OF AUGUST 28, 1980. AN - FOLLOWING TYPO CORRECTIONS ARE NEEDED. 1. TABLE C4.2 OF ANNEX C (P. 45) - RUN 4 CAPACITY OF LINK TUNNEL WAS 39 CMS NOT 100 CMS. PLS REPLACE 100 BY 39 IN COL. 3. 2. TABLE 4.4 OF MAIN REPORT (P. 40) IS AN OLD VERSION AND HAS TO BE REPLACED BY TABLE C4.2 DULY CORRECTED AS ABOVE. BB - CORRECTED REPLACEMENT SHEET (P.39 AND 40 MAIN REPORT) BEING SENT BY MAIL. INCONVENIENCE IS REGRETTED. REGARDS

B.M. SEONI ACRES CONSULTING SERVICES NIAGARA FALLS CANADA

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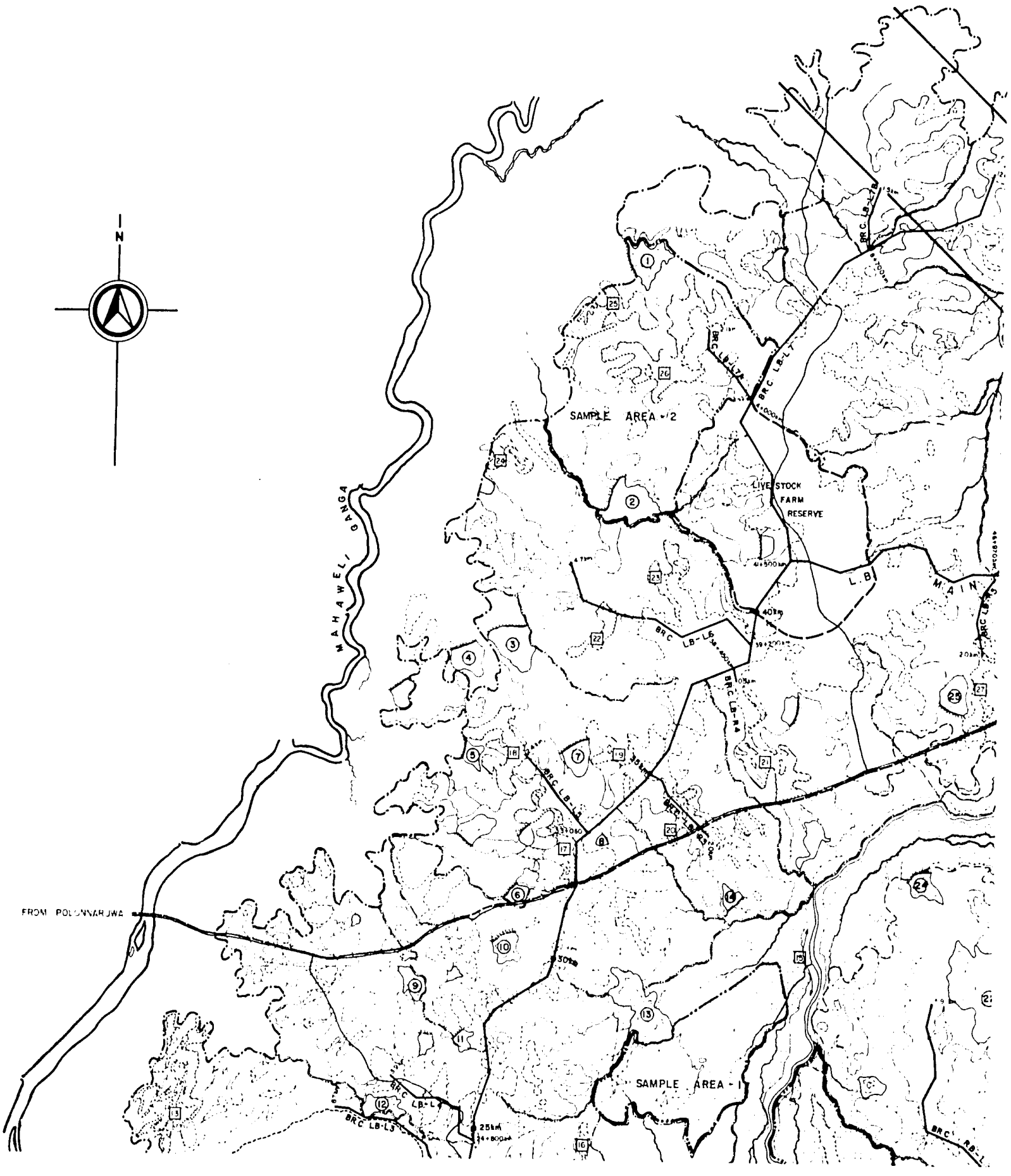
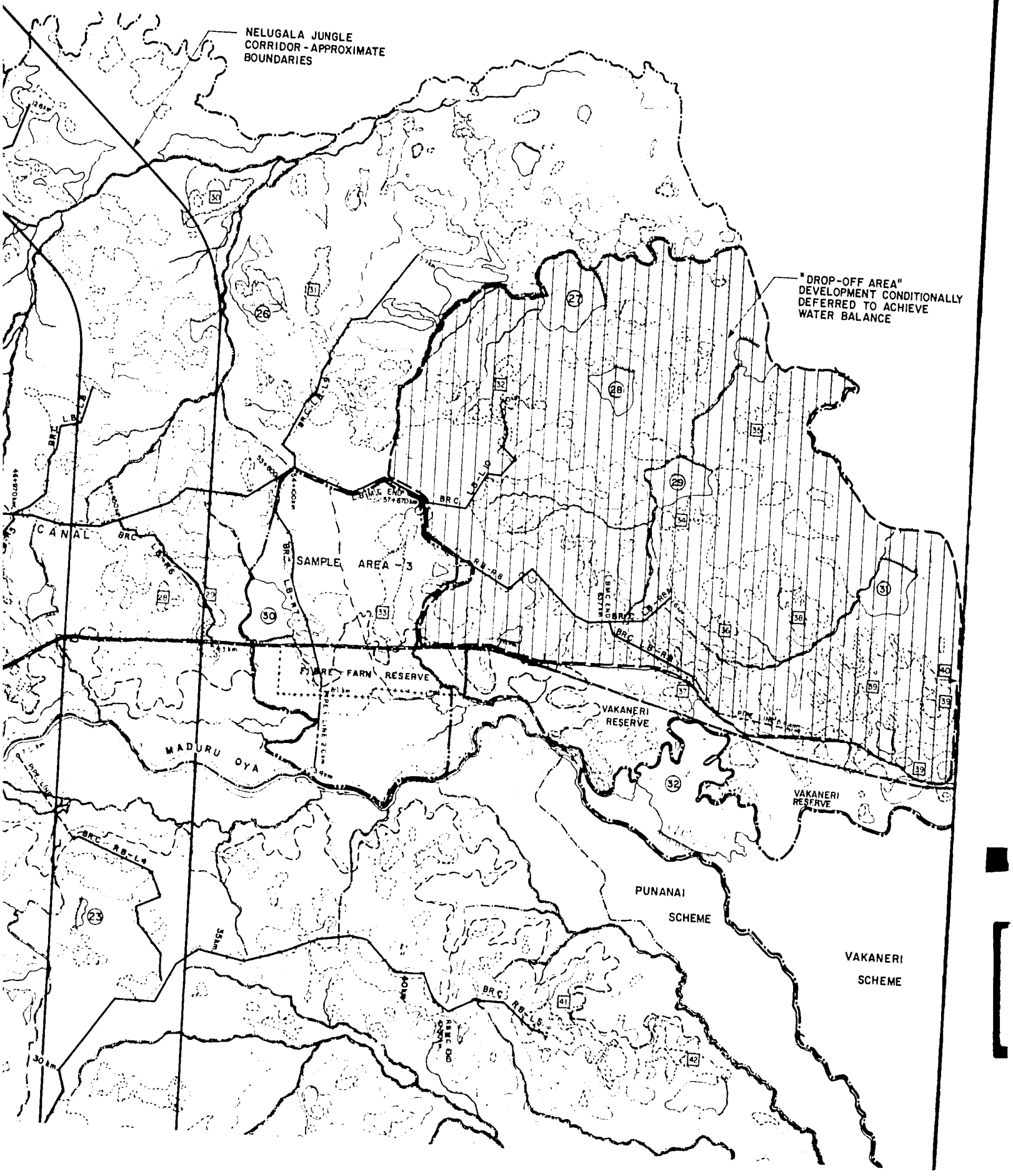
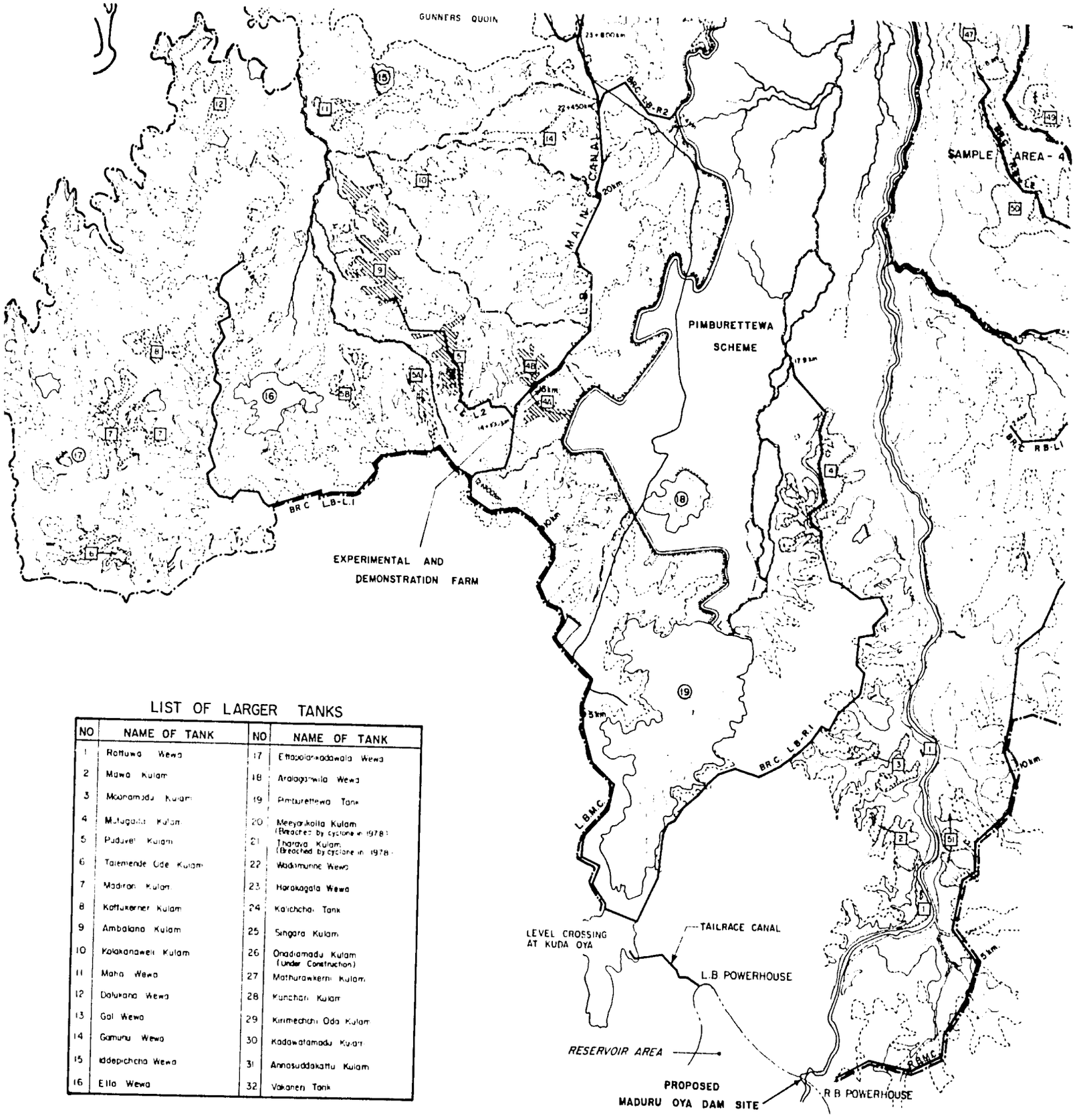
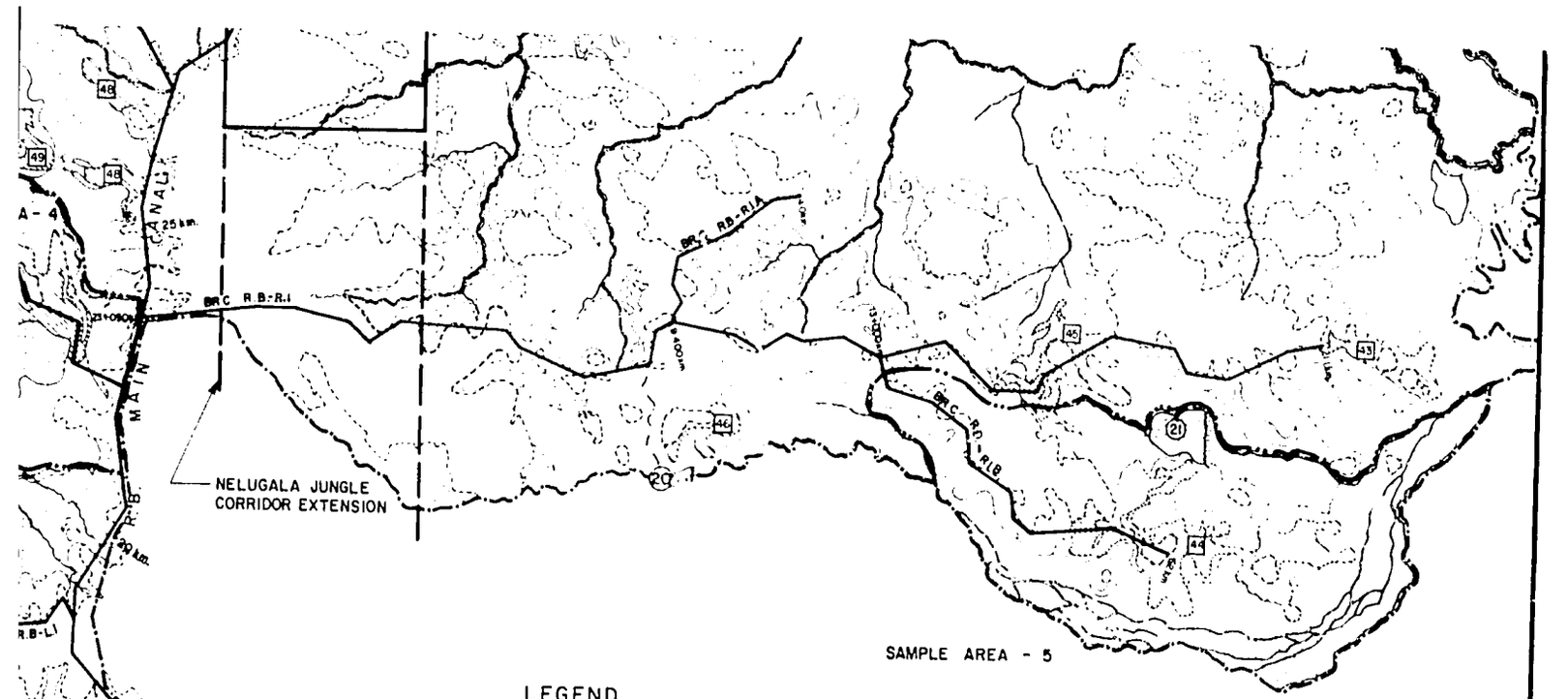

N
MAHAWELI GANGA
FROM POLONNARUWA
SAMPLE AREA - 2
SAMPLE AREA - 1
LIVE STOCK FARM RESERVE
L.B MAIN
BRC LB-L6
BRC LB-L4
BRC LB-L3
BRC LB-L7
BRC LB-L7A
BRC LB-L5
BRC LB-R4
BRC LB-L1
25km
30km
35km
40km


NELUGALA JUNGLE CORRIDOR - APPROXIMATE BOUNDARIES
"DROP-OFF AREA" DEVELOPMENT CONDITIONALLY DEFERRED TO ACHIEVE WATER BALANCE
SAMPLE AREA - 3
CANAL
MADURU OYA
VAKANERI RESERVE
VAKANERI RESERVE
PUNANAI SCHEME
VAKANERI SCHEME



LIST OF LARGER TANKS

NO	NAME OF TANK	NO	NAME OF TANK
1	Rottuwa Wewa	17	Ettapolamaddawala Wewa
2	Mawa Kulam	18	Aralagamwila Wewa
3	Moonamadu Kulam	19	Pimburettewa Tank
4	Mutugalla Kulam	20	Meeyankolla Kulam (Breached by cyclone in 1978)
5	Puduvel Kulam	21	Tharava Kulam (Breached by cyclone in 1978)
6	Talemende Ode Kulam	22	Wadimunne Wewa
7	Madiran Kulam	23	Harakagala Wewa
8	Kottukerner Kulam	24	Kalichchai Tank
9	Ambalana Kulam	25	Singara Kulam
10	Kolakandawela Kulam	26	Onadamadu Kulam (Under Construction)
11	Maha Wewa	27	Mathurawkerni Kulam
12	Dalukana Wewa	28	Kunchari Kulam
13	Gal Wewa	29	Kirimechchi Oda Kulam
14	Gamunu Wewa	30	Kadawatamadu Kulam
15	Iddepichcha Wewa	31	Annasuddakattu Kulam
16	Ella Wewa	32	Vakaneri Tank



LEGEND

- Paddy Areas (Classes IR and 2R)
- Upland Areas (Classes IU and 2U), blocks exceeding 40 ha.
- Area above Gravity Command
- Tanks with reference numbers
- Roads
- Railroads
- Existing tank scheme boundary
- Project boundary
- Existing canal
- Proposed canal
- Command area boundary
- Reserve boundary
- Approximate limit of flooded area Nov. 24, 1978 cyclone
- Sample Area boundary
- Upland blocks exceeding approx 40 ha in area

NOTE : Reduced from land classification maps made from semi-detailed soil maps provided by the Land Use Division of the Irrigation Department, and 1 : 3168 and 1 : 5000 topographic maps provided by the Survey Department.

0 1 2 3 4 5
KILOMETRES

FIG. 6

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

SYSTEM B - GENERAL MAP

ACRES