PD-ABA-546

Best available copy -- annexes missing

~~D. Hartgmark~~
PD-ABA-546
65038

Democratic Socialist Republic of Sri Lanka

Ministry of Mahaweli Development

Maduru Oya Project

Feasibility Report

Main Report

Acres International Limited, Niagara Falls, Canada

Initial Issue
November 1979

ACRES

154, Deans Road,
Colombo 10.

File : P5152.900

December 4, 1979

Mr.N.G.P. Panditharatne,
Director-General,
Mahaweli Authority,
500, T.B. Jayah Mawatha,
Colombo 10.

MADURU OYA PROJECT

Dear Sir :

We have pleasure in submitting herewith our Feasibility Report on the Maduru Oya Project. This is the initial issue of the report, the final issue awaiting completion of the mapping still required for some 33 per cent of the project area.

We are reasonably confident that the concluding studies to be performed next year should not materially affect the present results.

Much of our study work has been dependent on the topographic and soils mapping which was carried out by the Survey Department and Land Use Division, who accelerated their programmes in order to deliver the maps to us by early September, 1979. We also acknowledge with thanks the help and co-operation we have received from your own

ACRES INTERNATIONAL LIMITED
5259 Dorchester Road, P.O. Box 1001, Niagara Falls, Canada L2E 6W1
Telephone 416-354-3831 Cables ACRESCAN Niagara Falls
Telex 061-5107 ACRES NFS

contd..... 2./

office, the Ministries of Mahaweli Development and Agriculture, the Mahaweli Development Board, the Departments of Irrigation and Census and Statistics and numerous other organizations.

We look forward to resuming our studies when the remaining data are available, which, we now understand, may not be until April or May, 1980. We are, however, making contingency plans for key staff to be available on a visiting basis from the end of January, 1980.

In the meantime we will be completing in our Home Office the various annexes supporting the present issue. Most of these annexes will be presented as early as possible in the new year.

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

Yours very truly,

W.G. Lockett
Study Director

WGL:gsdes

ACRES INTERNATIONAL LIMITED

F O R E W O R D

The Feasibility Report on the Maduru Oya Project, of which this Volume forms a part, is made up as follows :

Main Report

Annex A - The Project Area — detailed of Chp 3 of main report (mainly basic data)

Annex B - Soils and Land Classification — published & rec'd already

Annex C - Hydrology and Water Balance — Ritchie

Annex D - Engineering Works — is primarily ~~the~~ detailed build up of the cost estimates

Annex E - Agronomic Studies - editorial completion proceeding in Lanka

Annex F - Livestock — should be avail by end Jan

Annex G - Agro-Economic Studies — Chisholm can handle questions

Annex H - Forestry — by end Jan

Annex I - Settlement Planning — requires several months + more work in field

✓ Annex J - Environmental Aspects - PJD has copy now

Annex K - Implementation, Organisation and Management — several more months

Annex L - Economic and Financial Analysis — Chisholm has full detail

TABLE OF CONTENTS

LIST OF TABLES
LIST OF FIGURES

SUMMARY AND CONCLUSIONS

		Page
1.	INTRODUCTION	1
1.1	The Context of the Maduru Oya Project	1
1.2	Objective of the Project	2
1.3	Logic and Format of the Report	3
1.4	Limitation of Initial Issue of the Report	4
2.	BACKGROUND	6
2.1	Sri Lanka - Physical Geography	6
2.2	Sri Lanka - General Economic Geography	7
2.3	Other Studies of Maduru Oya Project	9
3.	PROJECT AREA	11
3.1	Physical Features	11
3.2	Climate and Hydrology	13
	3.2.1 Rainfall Data	14
	3.2.2 Streamflow Data	14
3.3	Present Land Use	15
3.4	Communications and Access	16
3.5	Existing Development	17
4.	THE PROJECT	18
4.1	General Description	18
4.2	Land Classification	19

		Page
	4.2.1 Mapping	19
	4.2.2 Soils	20
	4.2.3 Land Classification	23
4.3	Water	26
	4.3.1 Irrigation Water Requirements	27
	4.3.2 The Water Supply	27
	4.3.3 Water Balance	29
	4.3.4 Flood Hydrology	31
4.4	Irrigation Works	34
	4.4.1 Headworks	34
	4.4.2 Main and Branch Canals	39
	4.4.3 Tertiary Irrigation and Drainage Systems	40
4.5	Schedule and Cost Estimates	45
	4.5.1 Schedule	46
	4.5.2 Cost Estimates	47
5.	SETTLEMENT PLANNING	51
5.1	Settlement Planning	51
	5.1.1 Number of Settlers	51
	5.1.2 Selection of Settlers	55
	5.1.3 Rate of Settlement	59
	5.1.4 Assistance to Settlers	62
5.2	Planning of Settlements	65
	5.2.1 Regional Context	65
	5.2.2 Planning for the System B Project Area	68
	5.2.3 Settlements in System B	71
	5.2.4 Road	74b
	5.2.5 Social Infrastructure	74f

Table of Contents - 3

		Page
6.	AGRICULTURAL DEVELOPMENT AND PRODUCTION	75
6.1	Present Situation	75
	6.1.1 Rainfed Cropping	75
	6.1.2 Irrigated Cropping	75
6.2	Potential Development	79
	6.2.1 The Land Resource	79
	6.2.2 Lowland Rice Production	80
	6.2.2.1 Technology	80
	6.2.2.2 Expected Yields	84
	6.2.2.3 Cropping Patterns	85
	6.2.2.4 Water Requirements	85
	6.2.3 Upland Crops	86
	6.2.3.1 Alternative Crops	86
	6.2.3.2 Cropping Patterns	88
	6.2.3.3 Water Requirements	89
	6.2.4 Experimental-Demonstration Farm	90
	6.2.5 Homesteads	91
	6.2.6 Livestock	92
	6.2.7 Fisheries	95
	6.2.8 Forestry	95
7.	AGRICULTURAL PROJECT BENEFITS	98
7.1	Introduction	98
7.2	Product Potential and Prices	99
	7.2.1 Product Potential	99
	7.2.2 Financial and Economic Costs and Prices	101
7.3	Net Economic Benefits of Project	102
	7.3.1 Irrigated Crop Production	102
	7.3.2 Homestead Food Crop Benefits	105
	7.3.3 Livestock Production	106
	7.3.4 Fisheries	107
	7.3.5 Forestry	109

		Page
7.4	Financial Farm Income	111
	7.4.1 Farm Budgets	111
	7.4.2 Implications for Farmers	112
7.5	Implications for Project	115
8.	ORGANISATION AND MANAGEMENT	120
8.1	Construction Phase	120
	8.1.1 Irrigation Works - Expatriate Contractors	120
	8.1.2 Irrigation Works - Local Forces	123
	8.1.3 Non-Irrigation Infrastructure	124
	8.1.4 Construction Labour Force	127
8.2	Operational Phase	127
	8.2.1 Water Management	128
	8.2.2 Extension Services	131
	8.2.3 Settlement - Related Services	132
8.3	Project Management Infrastructure	135
9.	ENVIRONMENTAL ASPECTS	137
9.1	Existing Conditions	137
9.2	Impact of the Project	139
10.	PROJECT APPRAISAL	144
10.1	Introduction	144
10.2	Scenario A	145
	10.2.1 Direct Project Costs	145
	10.2.2 Allocation of Upstream Costs	146
	10.2.3 Project Benefits	147
	10.2.4 Net Cash Flow	149

	Page
10.3 Scenario B	149
10.3.1 Project Costs	149
10.3.2 Project Benefits	149
10.4 Benefit- Cost Assessment	150
10.4.1 Base Case Results	150
10.4.2 Sensitivity Analysis	150
10.4.3 Other Evaluation Criteria	152
10.5 Summary	153

LIST OF TABLES

Number	Title
2 - 1	Sri Lanka Population by District - 1978.
3 - 1	Summary of Climatic Means and Extremes.
3 - 2	Rainfall Stations Located Near System B.
3 - 3	Summary of Characteristics of Maduru Oya Streamflow Gauging Stations.
3 - 4	Summary of Present Land Use in System B.
4 - 1	Summary of Land Classes Within Gravity Command
4 - 2	Summary of Key Assumptions Used in Computing Water Requirements.
4 - 3	Monthly Water Requirements for System B.
4 - 4	Summary of Simulation Results.
4 - 5	Design Features of Main and Branch Canals.
4 - 6	Estimation of Net Irrigable Area - Paddy Land.
4 - 7	Estimation of Net Irrigable Area - Uplands.
4 - 8	Headworks - Summary of Capital Costs.
4 - 9	Main and Branch Canals - Scenario A - Summary of Capital Cost.

List of Tables - 2

4 - 10 Main and Branch Canals - Scenario B - Summary of Capital Cost.

4 - 11 Tertiary Systems, Drainage and Land Development Summary of Capital Cost.

4 - 12 Scenario A - Irrigation Works - Schedule of Capital Costs.

4 - 13 Scenario B - Irrigation Works - Schedule of Capital Costs.

4 - 14 Irrigation Works - Annual Operation and Maintenance Costs.

5 - 1 Summary of Settler Families and Population in System B.

5 - 2 Arrival of Farmer Settlers One Crop before first crop Harvested.

5 - 3 Arrival of Farmer Settlers Two Crops before first crop Harvested.

5 - 4 Non-Irrigation Works - Summary of Capital Costs.

5 - 5 Population of Maduru Oya Region.

5 - 6 Present (1979) and Future (2,000) Land Use in System B.

5 - 7 Land Use for Homesteads and Settlements.

List of Tables - 3

5 - 8 Illustration of Possible Range of Settlements.

5 - 9 Summary of Road Costs.

6 - 1 Rainfed Upland Cropping Area in System B Maha 1977/1978 (HA).

6 - 2 Area and Cropping Intensity of Rice Production in System B, 1973 - 1979.

6 - 3 Estimated Irrigated and Rainfed Rice Yields in System B.

6 - 4 Cultural Practices in the Project Area 1977/78.

6 - 5 Physical Crop Inputs (Per Hectare).

6 - 6 Crop Water Requirements for the Lowlands and Flood Plains.

6 - 7 Crop Water Requirements for the Uplands (mm).

7 - 1 Ranking of Product Potential.

7 - 2 Summary of Financial (Economic) Prices.

7 - 3 Estimated Area, Yield and Net Return of Existing Rice Production in System B.

7 - 4 Projected Economic Crop Budget Summary.

7 - 5 Initial Agricultural Production.

List of Tables - 4

7 - 6 Net Economic Returns from Irrigated Crop Production.

7 - 7 Projected Homestead Benefits from Food crops.

7 - 8 Annual Budget for 1,000 Murrah Buffalo Cows.

7 - 9 Annual Buffalo Cow Purchases During Project Implementation.

7 - 10 Potential Livestock Benefits With Project.

7 - 11 Fisheries Economic Benefits.

7 - 12 Net Cash Flow - Forestry.

7 - 13 Financial Farm Cash Flow Projections At Project Maturity.

8 - 1 Labour Requirements for Development Scenario A.

8 - 2 Labour Requirements for Development Scenario B.

9 - 1 Summary of Major Environmental Impacts in System B.

10 - 1 Project Costs for Economic Analysis.

10 - 2 Scenario A Capital and Operating Costs for Economic Analysis.

10 - 3 Scenario A - Summary of Net Project Benefits.

List of Tables - 5

10 - 4 Scenario A - Net Cash Flow Summary.

10 - 5 Capital and Operating Costs for Economic Analysis.

10 - 6 Scenario B - Summary of Net Project Benefits.

10 - 7 Scenario B - Net Cash Flow.

10 - 8 Summary of IRR Estimates.

LIST OF FIGURES

Number	Title
1	Project Location
2	Accelerated Mahaweli Programme
3	System B - Regional Context
4	Present Land Use
5	Availability of Mapping to September 20,1979
6	Overall Land Classification Map
7	Pattern of Rainfall and Runoff
8	Location Map - Headworks
9	Link Tunnel - Plan and Section
10	Rockfill Dam - Plan and Section
11	Layout of Main Canals
12	Alternative Implementation Schedules
13	Proposed Major Roads and Communities
14	Crop Calendar
15	Wildlife Areas
16	Construction Phase - General Organisation Chart

GLOSSARY OF TERMS AND ABBREVIATIONS

Acres	Acres International Limited
Asswedumized	prepared by surrounding with bunds
Ganga	A river with significant flows throughout the year
Maha	the season of the northeast monsoon (approximately December to February)
Oya	A river with little or no flow during the dry season
Yala	the season of the southwest monsoon (approximately May to September)
FAO	Food and Agriculture Organisation of the United Nations
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
MA	Mahaweli Authority
MDB	Mahaweli Development Board

O & M	Operation and Maintenance
PMB	Paddy Marketing Board
Rs	Sri Lanka Rupees (Rs.16.00 = US $ 1.00 approximately)
UNDP	United Nations Development Programme

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 130,000 hectares.

The climate is typical of the "Dry Zone" of Sri Lanka with 75 per cent of the average annual rainfall occuring in the Maha season.

About 54 per cent of the total area is forest covered, 26 per cent is under slash-and-burn "Chena" cultivation and 11 per cent 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 Right Bank Trans-basin Canal in Mahaweli Valley.

- Main Canal Systems

  Left Bank Canal - capacity - 48 m^3/s

  Right Bank Canal - capacity - 35 m^3/s

- Tertiary Systems, drainage, land levelling, etc.

- Non-irrigation infrastructure

4. Proposed Land Use

Land classification based on soils and topographic mapping covering about two-thirds of the area indicates that irrigable soils under command of the proposed canal system amount to some 52,300 hectares. Of these about 75 per cent have been found suitable for paddy cultivation. The remaining 25 per cent are considerably dispersed and include certain soil types (non-calcic browns) the performance of which will require to be examined in a programme 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 is as follows :

(a) Lowlands

Irrigable soils within command	..	39,500	ha
Net area allotted to farms	..	31,900	ha
Farm size	..	1.0	ha
Cropping pattern (Maha/Yala)	..	paddy/paddy	
Number of paddy farmers	..	31,900	

(b) Uplands

Irrigable soils within command	..	12,800	ha
Net area allotted to farms	..	5,500	ha
Farm size (including homestead)	..	2.0	ha
Representative cropping pattern	..	groundnuts/soybeans	
Number of upland farmers	..	2,750	

Homesteads for the paddy farmers (0.5 ha each) will be located on the uplands, generally on non-irrigable land. In addition, a holding of 0.2 ha per family has been proposed for an estimated 8,650 non-farm settlers.

The approximate gross land use is estimated to be :

Agriculture	..	52,000 ha
Settlement	..	22,000 ha
		74,000 ha

The total number of settler families (farm and non-farm) is estimated to be 43,300.

After development, the population of the area will be about 225,000.

5. Anticipated Yields

Government crop cutting surveys carried out from 1973-1978, and more detailed surveys carried out in September 1979 in the project area, indicate paddy yields, under favourable conditions, in the range 5.8 to 7.1 tonne/ha.

The following yields have been adopted in the present studies :

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

basic economic analysis was done on this basis

	Maha	(t/ha)	Yala	(t/ha)
Land Class	1R	2R	1R	2R
Base Case	4.4	3.6	4.6	3.8
Higher	4.9	4.0	5.1	4.2
Lower	4.0	3.2	4.2	3.4

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 a contract is placed by February 1, 1980 for the construction of the headworks, and provided water is available for diversion from the Mahaweli by February 1983, it should be possible to harvest the newly-developed hectarage in the 1983 Yala season. Thereafter two scenarios for the completion of this project have been studied :

Area of new land harvested (total of 37,400 ha)

	Scenario A	Scenario B
1983	4,700	2,300
1984	10,700	4,600
1985	12,600	6,200
1986	9,400	6,700
1987		6,700
1988		6,400
1989		4,500

7. Project Costs

The estimated cost (mid-1979 economic prices) of the Project is summarised below :

	Million Rupees		
	Sri Lankan	Foreign	Total
Headworks	429.7	936.6	1366.3
Main and Branch Canals*	464.3	872.4	1336.7
Tertiary System etc.	630.4	70.0	700.4
Sub-total, Irrigation Works	1524.4	1879.0	3403.4
Non-irrigation infrastructure	530.0	50.0	580.0
Total	2054.4	1929.0	3983.4
	(51.6%)	(48.4%)	(100.0%)

---

* Estimate for Scenario A.
Add total Rs.30 million for Scenario B.

Allocated Cost (in economic analysis)

	Million Rupees
	Total
Right Bank Transbasin Canal*	214
Annual operation and maintenance	56

8. Project Benefits

Based on economic prices the following tabulation shows the benefits estimated for the Base Case (see paragraph 9 below) after full development has been achieved.

	Million Rupees			
	Without Project	With Project	Net	% of Total
Paddy	79	577	498	75.3
Upland	-	35	35	5.3
Homesteads	-	60	60	9.1
Livestock	-	36	36	5.4
Fisheries	-	2	2	0.3
Forestry (average annual)	-	11	11	1.7
Power	-	19	19	2.9
Total	79	740	661	100.0

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

---

* Based on 25 per cent of cost of canal works. 50 per cent of all Minipe-Ratkinda diversion works (i.e.50% of Rs.1,267) used in sensitivity analysis.

9. 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, Scenario A, is :

- Base Case paddy yields (see para 5 above)
- Build-up of net benefits from paddy - 60% to 100 % in 5 years.
- Allocation of Right Bank Transbasin Canal Costs - 25% of canal costs (see paragraph 7 above).

The above case has also been applied to Scenario 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.

The results of these analyses are as follows :

Case	Internal Rate of Return	
	Scenario A	Scenario B
Base Case	10.7 %	10.2 %
Sensitivity Tests :		
- Higher Paddy Yields	12.3	11.6
- Lower Paddy Yields	9.2	8.8
- Paddy net benefit build-up - 8 years	10.4	9.8
- Right Bank Transbasin Canal Cost Allocation-50% of total cost	9.6	-
- Capital Costs up 10 per cent	9.9	-
- Net benefits down 10 per cent	9.4	-
- Scenario A planned and built, Scenario B benefits realised	9.5	-

10. 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.

11. Farm Income

Financial farm incomes (based on present price levels) are estimated to be about Rs.6,000 per year for both paddy and upland farmers, after allowing for basic food requirements.

12. Conclusions

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

(b) Based on direct economic costs and benefits the indicated internal rate of return is 10.7 per cent. A range of 8.8 per cent to 12.3 per cent is indicated by the sensitivity tests carried out.

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

(d) Two rates of development have been considered. Simultaneous activities on other major projects

(not only those within the Mahaweli complex) could impose constraints on the availability of specialised manpower and should be taken into consideration in the detailed planning of the development of the downstream area.

13. Outstanding Issues

(a) Completion of the topographic and soils mapping for the remaining 33 per cent of the project area is a matter of urgency.

(b) Exploration by test-pitting of the Maduru Oya Right Bank Canal alignment should also be urgently pursued.

(c) Policies should be finalised as soon as possible regarding the organisation to be adopted for the implementation and settlement planning aspects of the project.

(d) The results of this feasibility study and those of current studies on other Mahaweli projects should be examined together in the context of the Mahaweli Development as a whole. This comprehensive examination could take the form of an updating of the NEDECO studies, which were based on preliminary assumptions regarding this and certain other component projects.

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 hydro-electric 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 on 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 hectares.

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

- The Ministry of Mahaweli Development,
- The Mahaweli Authority (having overall co-ordinating responsibility),
- The Mahaweli Development Board, referred to as "MDB",
- The Irrigation Department,
- The Central Engineering Consultancy Bureau, referred to as "CECB".

System B, covering an area of some 130,000 hectares, will be served by the Maduru Oya Project, comprising a 550 million cubic meter 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.

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 maximising 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 of prime importance by the Government. The productive settlement of 40,000 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 equalising 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 favoured 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. Appraisal of the projects feasibility is followed by a concluding chapter on outstanding issues.

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

1.4 Limitations of Initial Issue of the Report

As will be described in the course of this report, the gross project area considered in System B is estimated to to be 130,000 hectares. Soils and topographic mapping of an adequate standard will not be completed for the whole area before mid 1980. However, it was decided that a report based on mapping covering about 60 per cent of the area should be submitted in the first instance, and on the premise that such mapping would be made available through July and August 1979, completion of the initial issue of the report was planned

for November 30, 1979. In the event the mapping received by mid September, 1979, covered some 89,000 hectares or about 67 per cent of the gross area.

It is considered that assessment of the agricultural potential of these 89,000 hectares has been achieved to an acceptable standard for feasibility analysis. The remaining 41,000 hectares have been treated at the reconnaissance level and will be re-examined when the complete mapping is made available. Final issue of the Feasibility Report may be expected about three months thereafter.

Other aspects for which full consideration will have to be deferred, for various reasons, until the final issue include :

- the design to "feasibility level" of the Right Bank Main Canal and branch canals;
- the elaboration of irrigation system layouts on "sample areas" which are, at present, unmapped ;
- cost estimates to the "feasibility level" associated with the above ;
- town and country planning aspects ; and
- organisation and management aspects. The status of a number of current proposals and issues should be clarified by the government before this work can be completed.

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 sq.km. A general map is presented on Figure 1.

The central and southern part of the island is quite mountainous, with peaks rising to 2500 metres 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 locations in these climatic zones are shown in the following tabulation :

Zone	Location	Average Rainfall (mm)		
		Oct-Mar (Maha)	Apr-Sep (Yala)	Total
Wet	Ratnapura	1641	2247	3888
Dry	Anuradhapura	999	448	1447
Intermediate	Kurunegala	1116	959	2075

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 in the dry zone tend virtually to dry up in the Yala 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 north-eastern part of the dry zone, discharges into the Bay of Bengal near Trincomalee.

In its natural state Sri Lanka must have been substantially covered by forest. However, while in the Wet Zone this would have included extensive areas of equatorial rain forest (of which the Sinharajaha Forest is but a remnant), the vegetation in the Dry Zone would be better described as "scrub jungle". Much of the forest cover in the mountanous 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 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 recognised 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 AD.

Since the 16th century AD trading and commercial ventures by Portugues, 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 per cent of Sri Lanka's export trade while additional exports result from minor export crops such as cocoa and various spices.

Rice is the major non-plantation crop although a large variety of minor food crops is also grown for domestic consumption. In total, agricultural activities account for 30% of national income. In terms of employment, over 50% of the work force is engaged in agriculture. The country's total labour force is estimated at 7 million; of this labour 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 location of the Districts of Polonnaruwa, Batticaloa, and Amparai is shown on Figure 3, which also indicates the principal towns, roads and railways in the Maduru Oya Project area.

2.3 Other Studies of Maduru Oya Project

While the Maduru Oya Project and the development of System B was envisaged in the FAO Master Plan of 1968[1], definitive study of the project may be said to date from the inception of the Accelerated Mahaweli Programme in 1978. Preliminary layouts of the headworks, comprising the Maduru Oya dam and the link tunnel from the Minipe Right Bank Canal, were prepared by CECB[2] in association with SOGREAH of France. At the same time study of the main canal systems was carried out by MDB.

The overall studies of the Mahaweli development, undertaken by NEDECO[3] included the hydrological input necessary to determine a preliminary water balance and thus confirm the approximate magnitude of the engineering works, in terms of :

- Anticipated irrigation water demand.
- Capacity of diversion works in the Mahaweli basin.
- Required storage capacity and elevation of Maduru Oya Reservoir.
- Capacity of link tunnel.

TABLE 2-1

SRI LANKA POPULATION BY DISTRICT - 1978

DISTRICT	POPULATION (000's)	PER CENT
1. Colombo	2,972	20.95
2. Kalutara	808	5.69
3. Kandy	1,285	9.06
4. Matale	354	2.50
5. Nuwara Eliya	468	3.30
6. Galle	814	5.74
7. Matara	660	4.65
8. Hambantota	388	2.74
9. Jaffna	801	5.65
10. Mannar	90	0.63
11. Vavuniya	111	0.78
12. Batticaloa	300	2.12
13. Amparai	316	2.23
14. Trincomalee	223	1.57
15. Kurunegala	1,159	1.87
16. Puttalam	437	3.08
17. Anuradhapura	458	3.23
18. Polonnaruwa	190	1.34
19. Badulla	665	4.69
20. Monaragala	228	1.61
21. Ratnapura	739	5.21
22. Kegalle	718	1.06
TOTAL	14,184	100.00

Source : Registrar General's Dept.

These studies continued till about mid-1979, and thus overlapped the feasibility studies which are the subject of the present report. In particular the NEDECO and CECB studies were considered sufficiently refined by October 1978, for the capacities of the reservoir and link tunnel to be regarded as essentially fixed. However, subsequent review and the updating of reservoir topography led respectively to an increase in the design capacity of the tunnel and a lowering (for the same reservoir volume) of the Maduru Oya dam.

Simulation studies by NEDECO of the operation of the Mahaweli project as a whole provided estimates of water availability for the present feasibility studies.

In November 1978 it was decided that the design of the headworks should be advanced to the tender stage, including specifications and the preparation of tender documents. This work was assigned to CECB/SOGREAH for the dam, and to Acres for the link tunnel.

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 on 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 centres of Trincomalee, Polonnaruwa and Batticaloa. It will be seen that the area is bounded in the north and west by Systems A and C.

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 metres above sea level. These hills are pre-cambrian 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 south-easterly 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 meters above sea level.

The irrigation area lies along either side of the Maduru Oya downstream from the Maduru Oya dam site, which is

located approximately 32 km south of Welikanda. It is bounded on the southwest by the Hungamala Ella and System C, on the northwest by the flood plain 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 Miyangolla Ella. Physiographically the area is a peneplain, an old erosion surface with generally subdued topography broken by outcrops of rock ridges or isolated knobs. These outcrops become less frequent in the northern part of the project area.

The geology of the area is characterised by Pre-Cambrian 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 500 metres (Gunner's Quoin) above the general level of the surrounding plain. The elevation of the latter varies from about 80 metres above sea level in the south to under 30 metres in the extreme north. The mantle covering the peneplain rock is generally thin and sometimes non-existent, as in areas of rock knob plain and outcropping flat rock.

Two very different soils have developed on the Pre-Cambrian 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 two per cent and some times four. 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

greater than four per cent. 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 now 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-February) and Southwest (May-September) monsoons. The Northeast monsoon (Maha) brings most of the annual rainfall, and therefore runoff, in the catchment area (see Figure 7). The Southwest monsoon (Yala) is typically dry due to the orographic effect of the Central Highlands of Sri Lanka. Rainfall in the inter-monsoon periods can be caused by either convective or cyclonic storms. Table 3-1 summarizes mean and extreme values of three key hydrometeorological indicators - temperature, precipitation and streamflow. These figures illustrate the relatively minor temperature fluctuations which 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.

TABLE 3-1

SUMMARY OF CLIMATIC MEANS AND EXTREMES

	MAXIMUM, MINIMUM OR AVERAGE	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
		MONTH												
Temperature (°C)[1]	Maximum	31.4	33.6	35.4	36.6	37.4	38.2	37.4	37.8	37.6	36.2	33.3	32.1	38.2
	Average	25.4	25.7	26.8	28.0	29.0	29.5	29.1	28.6	28.4	27.3	26.3	25.5	27.5
	Minimum	17.1	17.4	19.1	21.7	20.9	21.2	21.1	20.6	20.4	20.4	18.0	19.0	17.1
Rainfall (mm)[2]	Maximum Year	152	402	0	0	102	0	28	7	38	173	579	1465	2946
	Average	236	147	65	87	62	22	65	64	75	192	319	432	1765
	Minimum	128	0	116	0	0	0	0	0	18	26	269	315	871
Streamflow ($10^6 m^3$)[3]	Maximum Year	59	107	14	2	4	0	0	0	0	0	81	630	897
	Average	95	48	20	14	13	4	3	4	4	15	50	112	331
	Minimum	36	9	6	14	0	1	0	1	0	9	25	53	154

Notes : (1) Data for Batticaloa. Maxima and minima are extremes recorded over the period of record.

(2) Data for Welikanda. Maximum year - 1957, minimum year - 1968

(3) Data for Maduru Oya at Damsite. Maximum year - 1957, Minimum year - 1956

3.2.1 Rainfall data

Daily rainfall data for long periods (over 100 years 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*. The periods of record of these stations are summarized in Table 3-2. Observations at two of the most useful stations from an agricultural point of view (Welikanda and Vakaneri) were unfortunately discontinued in recent years.

The Meteorological Department has indicated that these two stations can 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 3-3). The long period over which no flow measurements were made (1960-1978) was a source of concern at the time of writing of the Interim Report. Results from the 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

---

* 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.

TABLE 3-2

RAINFALL STATIONS LOCATED NEAR SYSTEM B

STATION NAME	PERIOD OF RECORD BEGIN	PERIOD OF RECORD END	MISSING DATA TOTAL MONTHS	MISSING DATA MAJOR PERIODS MISSING
Batticaloa	Jan. 1869	-	0	
Ekiriyankumbura	Jan. 1943	July 1977	14	Aug. 1959 - Dec. 1959
Horaborawewa	Nov. 1909	-	18	Feb. 1971 - Feb. 1972
Polonnaruwa	Jan. 1940	-	5	-
Trincomalee	June 1869	-	0	-
Vakaneri	Oct. 1900	Nov. 1972	18	Jan. 1968 - Dec. 1968
Welikanda	Jan. 1942	June 1973	21	Feb. 1967 - Jan. 1968

TABLE 3-5

SUMMARY OF CHARACTERISTICS OF MADURU OYA
STREAMFLOW GAUGING STATIONS

LOCATION	DRAINAGE AREA (Km^2) 1	STAGE OBSERVATIONS			MAXIMUM EST'D FLOW (m^3/Sec) 2	FLOW MEASUREMENTS			
		BEGIN	END	MISSING		BEGIN	END	MAX.STAGE (ft.)	MAX.FLOW (m^3/ Sec.)
Maduru Oya at Dunsite	452	Feb. 1951	Sept. 1957	2 months	415	Nov. 1951	Mar. 1957	9.50	156
Maduru Oya below Dunsite	459	Jan. 1978	present		27	Oct. 1978	present	N.A. 3	N.A. 3
Maduru Oya at Welikanda	956	Feb. 1946	present	15 months	1800	Nov. 1953 Dec. 1978	June 1950 present	11.0 8.30	202 77

1. Measured from 1 inch = 1 mile maps

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

3. N.A. - Not Available

the establishment of supplementary staff gauges to allow water surface profile calculations to be performed.

Flows at the Maduru Oya dam site have been estimated for the ungauged period using a regression equation development 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 dam site should be adequate for use in reservoir operation studies.

3.3 Present Land Use

The availability of high quality up-to-date (March 1979) aerial photographs, coupled with field investigations, has facilitated the preparation of a map of existing land use to a scale of 1 : 50,000. This map is presented in Figure 4. Table 3-4 summarizes the areal distribution of seven main categories. It is interesting to note from this table that of the 123,800 hectares total area thus mapped in System B, some 66,700 hectares are still forest-covered. This forest cover is in the process of active encroachment, as evidenced by the considerable area - 32,800 hectares - affected by chena or slash and burn activity. Not including the 3,900 hectares of rock outcrop, the remaining 20,400 hectares are variously committed to permanent settlement : small paddy farming, homesteads, large farms and reservoirs.

TABLE 3-4

SUMMARY OF PRESENT LAND USE IN SYSTEM B[1]

Land Use Category	Areas (ha) Left Bank	Right Bank	Total	Percent of Total
Paddy - Major Schemes[2]	4,900	-	4,900	4.0
- Minor Schemes + Rainfed	4,300	4,500	8,800	7.1
- Sub total	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
- Sub total	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

Notes :

1. The project area excludes the Mahaweli flood plain, but includes Pimburettewa, Vakaneri and Punanai Schemes.
2. Pimburettewa, Vakaneri and Punanai Schemes. Note that Figure 4 does not include all of the Vakaneri Scheme. The tabulated figures have been adjusted to include the 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 air photo coverage being limited to about 94 percent of the project area.

It may be concluded from this survey of present land use that existing human commitments in the area should not constitute more than modest constraints to development. On the other hand a major impact on the natural environment is already making itself felt through uncontrolled chena activity.

3.4 Communications and Access

The project area is traversed by the main road and rail connections between Habarana (on the main route from Colombo to Trincomalee) and Batticaloa on the east coast. Thus 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 development, to the Maduru Oya dam site. Another road leads north from Welikanda to Kandakaddu. On the right bank, 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 Valachchenai.

With a view to construction activity in System B the general condition of these lines of communication must be regarded as poor. Upgrading of the Habarana - Polonnaruwa - Batticaloa road will be required and duplication of the bridge across the Mahaweli at Manampitiya is very desirable. The railway itself is, basically, well suited to serve the project area,

provided that sidings and terminal facilities at Manampitiya and Welikanda are established. Apart from this, investment in railway improvements should be concentrated on upgrading of the signalling system, rolling stock and traffic management.

Within the project area, of course, a considerable network of secondary roads will be required to serve the ultimate development. This is considered in Chapter 5 and Annex I.

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 dam site falls within the district of Amparai. The boundaries between these districts are shown on Figure 3.

The population of the area is approximately 25,000, which indicates an average intensity of about 20 persons per square kilometer. As may be inferred from Section 3.3 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 towards the southwest part of the area, 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.

Further discussion of the existing situation may be found in succeeding chapters.

4. THE PROJECT

4.1 General Description

The layout of the physical features of the Maduru Oya Project is shown on Figure 11. 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 Right Bank transbasin 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 Chapter 5. The following paragraphs provide a concise description of the irrigation works and studies related thereto. Further details may be found in Annexes C (Hydrology and Water Balance), D (Engineering Works) and I (Settlement Planning).

As already discussed in Section 2.3 the magnitude of the irrigation works has been the subject of a series of inter-related 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
Right Bank canal design capacity	..	35 m^3/s

The present feasibility studies, based on up-dated water requirements, serve to demonstrate the adequacy of a project having the above dimensions to meet these demands.

4.2 Land Classification

Reliable land classification is a prerequisite for all other studies related to the planning of an irrigation project. The characterisation and delineation of lands to be developed allows the agricultural, engineering and socio-economic 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

Medium intensity soils mapping, with overlapping topographic mapping at scales of 1 : 5000 or 1 : 3168*,

* 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.

is available from the Land Use Division (LUD) of the Irrigation Department for about 67 per cent of the project area. The available coverage is shown in Figure 5. The balance of the project area is covered by 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. The limitations imposed by this coverage are reflected in the land classification work reported herein. On completion of semidetailed soils and 1 : 5000 topographic mapping in early 1980, it is proposed that feasibility-level land classification be carried out for the remaining 33 per cent of the project area.

4.2.2 Soils

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

1. The Reddish Brown Earths (RBE)
2. The Non Calcic Brown Soils (NCB)
3. The Low Humic Gley Soils (LHG)
4. The Recent Alluvial Soils (RAL) of the Maduru Oya and Mahaweli Ganga
5. The Old Alluvial Soils (OAL)
6. 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.

Upland Soils

The upland category consists of well to moderately well drained RBE, NCB and upper levee bank soils. This group is never water-logged for any appreciable time during the year. Large areas of shallow, steeply sloping (slopes exceeding four per cent), 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.

The well to moderately well drained Non Calcic Brown Soils identified by LUD are the Maduru and Welikanda Series. The Maduru Series consists of moderately deep, dark greyish 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 fifteen per cent. This soil is darker in colour and may represent a transition zone to the brown phase of the Reddish Brown Earths.

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.

Lowland Soils

The imperfectly drained soils are naturally water-logged 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, Muthugalla, Manampitiya and Ulhitiya Series form the upper members. Four series - the Alawakumbura, Mawa Kulam, Horaborawewa and Padumunda Kulam - have been identified.

The imperfectly drained Non Calcic 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.

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.

The Old Alluvial soils in old tributary valleys vary in texture and drainage. Whereas the Ulpothawewa Series is an imperfectly drained, pale brown to greyish brown, sandy loam underlain at about 60 cm by gleyed sandy clay loam ; the Moogamana Ela Series is a poorly drained, gleyed grey to dark grey sandy clay loam with a thin sandy loam layer on the surface. The Kumarapuragama and Arasanagar Series are deep, medium to coarse sands with the first being well drained and the second imperfectly drained.

The Solodized Solenetz Soils, which occur on nearly level land, consist of light brownish to white sand, overlying grey to olive grey, 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 one per cent of the area mapped to date.

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 Damanawila Series - both sandy clay loam over sandy clay in texture.

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 :

(a) Most of the area and irrigation water would be given to annual crops.

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

(c) 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).

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

(e) 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 :

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

(2) Lowland (designated "R") for the imperfectly, poorly and very poorly drained soils of the lower slopes and bottomlands.

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 require higher land development costs and/or inputs of fertiliser 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 Class 1 and 2. This includes both arable and non-arable land. Non-arable land is designated "6N" and includes rock, roads, tank bunds, tanks and watercourses. 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 Non Calcic 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 $2R_s$". 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 summarises the distribution of the upland and lowland land classes, according to the Map Areas shown in Figure 5. The limits of gravity command by the irrigation system are accounted for in this table, so that the areas in the Upland ("1U" and "2U") and Lowland ("1R" and "2R")land classes represent the gross areas available for irrigation by gravity. It should be noted

TABLE L-1

SUMMARY OF LAND CLASSES WITHIN GRAVITY COMMAND IN 1000 HECTARES

MAP AREA	DEVELOPMENT AREA: WITHIN GRAVITY COMMAND: UPLANDS 1U	UPLANDS 2U	UPLANDS 1U+2U	LOWLANDS 1R	LOWLANDS 2R	LOWLANDS 1R+2R	NON IRRIGABLE	TOTAL	ABOVE GRAVITY COMMAND: IRRIGABLE 1U+2U	IRRIGABLE 1R+2R	NON IRRIGABLE	TOTAL	FINGERSTONA SCHEME: UPLANDS 1U	UPLANDS 2U	LOWLANDS 1R	LOWLANDS 2R	NON IRRIGABLE	TOTAL	TOTAL AREA: UPLANDS 1U	UPLANDS 2U	LOWLANDS 1R	LOWLANDS 2R	NON IRRIGABLE	GRAND TOTAL
1	1.61	2.09	3.70	6.26	5.10	11.36	10.67	26.23	0.83	0.15	5.94	6.92	0.19	0.19	1.23	0.55	1.90	4.11	2.35	2.53	8.04	1.[illegible]	19.51	37.[illegible]
2	1.62	0.22	1.85	2.92	2.53	4.55	3.55	9.[illegible]	0.75	0.23	1.33	2.31							2.16	0.44	2.11	2.67	4.88	12.7
3A	0.20	0.27	0.47	1.15	1.34	2.49	6.63	9.59				0.68												10.7
3B	0.58	1.34	1.92	2.32	3.03	5.35	8.24	15.51	0.63	0.49	3.08	4.20							0.71	1.85	2.47	3.37	11.31	19.7
3C	0.20	0.27	0.47	0.60	1.33	1.93	1.01	3.38				0.73												3.[illegible]
Sub Total	2.61	2.10	4.71	6.29	8.20	14.29	19.43	38.43				7.42												45.[illegible]
4	0.37	1.36	1.73	1.57	4.68	6.50	5.69	13.92	0.54	0.55	3.22	4.69							0.11	2.46	1.82	5.33	8.92	19.[illegible]
5A	0.07	0.83	1.03	2.45	2.92	5.40	5.32	12.02				2.28												14.3
5B	0.44	0.60	1.04	0.66	0.73	1.44	9.60	12.28				3.00												15.[illegible]
Sub Total	1.18	3.19	4.37	4.96	8.38	13.34	20.51	38.22				9.90												48.[illegible]
Grand Total	5.40	7.38	12.78	17.81	21.68	39.49	50.61	102.[illegible]				24.24	0.19	0.19	1.23	0.55	1.90	4.11						1[illegible].[illegible]

Notes : 1. Areas for Map Areas 1,2,3B and 4 are based on detailed land classification

Areas for Map Areas 3A,3C,5A and 5B are based on interpretation of FAO Reconnaissance Soils Map (see annex B)

2. See Figure 5 for delineation of Map Areas.

that the information presented in this table is based on feasibility-level land classification over 67 per cent of the project area (Map Areas 1, 2, 3B and 4), and reconnaissance-level land classification over the balance (Map Areas 3A, 3C, 5A and 5B). The estimate of irrigable land under gravity command for the latter area will be revised in early 1980, as a prerequisite for the issue of the Final Report.

The areas of irrigable land shown in Figure 6 and summarised 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 per cent 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 under 400 ha in extent, and only 6,670 ha of the 12,780 ha area classed as "1U" or "2U" occurs in blocks of over 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, while the second relates to the evaluation and accomodation 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 - 1977 simulation period adopted by NEDECO[3] was based on the following generalised equation :

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

Where : ET_c^* = Crop evapotranspiration (mm)

LP^* = Land preparation requirement (mm)

P^* = Deep percolation losses (mm)

e = Overall efficiency factor

This equation was solved for five different land class types - one upland, two lowland (Classes "1R" and "2R") and two flood plain (Classes "1R" and "2R"). Effective rainfall for the 28 year 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.[5] The key assumptions underlying the calculation of the project water requirements are summarised in Table 4-2, while the total monthly water requirements for System B are shown in Table 4-3.

4.3.2 The Water Supply

Quantity

The irrigation water demands presented in Section 4.3.1 are much larger than the available water supply in the

---

* The derivation of these parameters is explained in Section 6.2.4

A 4-2

UMMARY OF KEY ASSUMPTIONS USED IN COMPUTING WATER REQUIREMENTS

	LAND CLASS GROUPING				
	LOWLANDS		FLOOD PLAIN		UPLANDS
	1R	2R	1R	2R	1U + 2U
..rt..s (ha)	11,480	15,850	2,240	2,320	5,460
..ar Preparation (mm)	180	180	180	180	75
..er-olation Rate (mm/day)	3	6	3	6	-
..alculation of Effective ..ainfall	LUD Formula[1]	LUD Formula[1]	LUD Formula[1]	LUD Formula[1]	FAO Paper 24
..arm/distribution ..fficiency	.70	.70	.70	.70	.50
..a ..anal Efficiency	.90	.90	.90	.90	.90
..verall Efficiency	.63	.63	.63	.63	.45

..otes: 1. LUD Formula : ER (mm) = .67 (MR-25) Max. ER = 225 mm

TABLE 4-3

MONTHLY WATER REQUIREMENTS FOR SYSTEM B

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR TOTAL
1950	75	102	19	152	158	203	172	22	8	105	79	62	1162
1	29	90	75	100	149	208	171	51	33	117	23	50	1099
2	29	104	82	121	159	203	154	53	48	116	50	52	1176
3	53	118	88	126	177	193	102	21	17	70	35	21	1021
4	29	90	57	118	166	208	167	46	48	86	81	21	1119
5	39	68	89	91	173	208	172	34	4	114	99	53	1144
6	67	105	89	151	177	169	155	30	42	74	23	31	1112
7	90	14	90	152	139	208	162	58	46	95	23	21	1098
8	84	101	57	105	115	203	139	21	44	111	92	21	1101
9	39	125	90	142	167	206	172	40	34	74	39	37	1165
1960	29	14	83	104	150	208	107	59	41	125	23	76	1019
1	29	23	49	151	147	203	141	59	24	107	23	21	982
2	94	124	75	147	154	205	135	58	26	54	48	25	1148
3	29	14	52	112	176	208	171	56	9	74	23	21	948
4	73	56	40	152	137	208	110	23	48	93	111	88	1139
5	113	14	89	116	171	208	172	21	48	117	23	21	1115
6	63	124	40	137	170	204	168	14	21	41	23	52	1057
7	116	66	74	128	171	205	170	55	44	74	23	21	1147
8	99	125	49	150	177	203	172	58	48	132	46	40	1304
9	117	97	90	54	173	208	168	21	35	57	91	21	1132
1970	87	43	79	123	137	197	172	45	29	122	38	47	1119
1	53	118	78	111	169	208	146	35	42	106	85	21	1172
2	140	124	87	147	138	188	170	57	6	41	58	30	1186
3	145	105	57	121	138	168	92	46	2	94	69	21	1058
4	146	111	85	102	160	204	168	55	21	149	73	57	1331
5	94	72	19	85	149	204	61	35	47	87	48	21	922
6	69	124	90	137	174	193	164	39	29	113	23	21	1176
7	91	113	40	85	147	202	131	37	20	72	23	21	982
Average	76	85	68	123	158	202	149	41	31	94	50	35	1112

Maduru Oya basin. The approach taken for this study is to allow for the diversion of sufficient water into the Maduru Oya reservoir to supplement the natural flows. The combined inflows will be re-regulated, using the storage provided by the Maduru Oya reservoir, to supply the irrigation water requirements computed for the full development area. 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 300 µmhos/cm in the Maduru Oya. The maximum computed Sodium Adsorption Ratio (SAR) is 2.25. According to the standards published by the US Department of Agriculture[6] (USDA) and the Food and Agriculture Organisation of the United Nations (FAO)[7], 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 prime objective of the water balance analysis conducted for this study has, therefore, been to verify that the headworks are capable of delivering a reliable water supply to satisfy the newly calculated water requirements.

Table 4-4 summarizes the results of simulation runs which were executed by MDB staff, using the NEDECO computer program. The program considers the interaction of Systems B and C, given a set of upstream regulation conditions. These runs allow the following conclusions to be drawn :

(1) At full development, with the Victoria and Kotmale Dams providing upstream regulation, the full demands of Systems B and C can be met, with minor shortages. The shortages which were computed for System B during the hydrological sequence used in the simulation program would have resulted in a 15 per cent Yala crop loss in one year, and 2 - 8 per cent Yala crop losses

TABLE 4-4

SUMMARY OF SIMULATION RESULTS

IRRIGATION DEMAND LEVEL		MINIPE R.B. CANAL CAPACITY	LINK TUNNEL CAPACITY	UPSTREAM REGULA-TION	AVERAGE ANNUAL SPILL AT MADURU OYA	SHORTAGES IN SYSTEM B	
System B	System C	(m^3/sec)	(m^3/sec)		(10^6 m^3)	Years[2]	Volume[3] (10^6 m^3)
Full Demands	Full Demands	62.0	34	Victoria, Kotmale	232	4	161
Full Demands	Full Demands	55.8	34	Victoria, Kotmale	192	11	695
Full Demands	Full Demands	68.2	34	Victoria, Kotmale	N.A.[4]	0	0
50% Demands	50% Demands	62.0	34	Kotmale only	N.A.[4]	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.

(4) Not available. Run executed with incorrect rule curve. Annual spill figures not correct.

in 3 other years. Thus average Yala crop production would be 99 per cent of potential production over the simulation period.

(2) Reduction of the capacity of Minipe Right Bank Canal by 10 per cent causes larger shortages to be simulated in System B, but none in System C.

(3) Before the Victoria Dam is completed, 50 per cent of the ultimate demands of both Systems B and C can be met with acceptable shortage frequencies. The implementation schedules of both projects can be drawn up to reflect this condition, which will occur for the last time in Yala 1984.

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 behaviour 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 per cent increase in May-July water demand in System C would, therefore, deprive System B of the same amount of water - an average of 62 million cubic metres per year. The frequency and magnitude of shortages in System B would increase as a result.

4.3.4 Flood Hydrology

The Maduru Oya

The Maduru Oya dam will control the runoff from some 47 per cent of the drainage area at Welikanda. It can be expected to provide substantial flood control benefits in the flood plain 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 any 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 ten year average recurrence interval) floods. The unit hydrograph analyses indicated the following effects on flood peaks at Welikanda :

Average Recurrence Interval	Before Dam	After Dam
5 years	907 m^3/sec	677 m^3/sec
10 years	1190 m^3/sec	875 m^3/sec
25 years	1590 m^3/sec	1130 m^3/sec

Topographic and rating curve information (available only for the area upstream from Welikanda at the time of report preparation) indicates that the reduced 5 and 10 year peaks would still cause significant damage to crops, particularly in the area close to Welikanda, where the narrow flood plain 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 flood plain 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/sec, versus the "pre-dam, whole season" 5 year peak of 967 m^3/sec. The former flow would probably* result in very minor flooding in the lower flood plain.

The Mahaweli Ganga

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

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

(1) The location of the System A weir. If the originally envisaged site near Kandakaddu is chosen, backwater effects from the weir will

---

* This is to be confirmed by hydraulic analyses which can only be performed when complete topographic mapping for the flood plain is available.

modify the flood regime. The extent of this modification will be intimately related to the configuration of headpond dykes. If the site at Kalinga Nuwara is chosen, the System A Main Canal will run along the edge of the flood plain, isolating it completely from System B.

(2) 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 finalised for most of the reservoirs.

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

The Mahaweli flood plain 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[8]. 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 Canal and Link Tunnel (Figures 8 and 9)

In the Mahaweli Ganga valley the existing anicut at Minipe serves a centuries-old irrigation system 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 Development. The 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 metres 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 trash racks 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 Wellikanda. This creates a narrow gap which, superficially, forms an attractive dam site.

The main rock types observed at the dam site are quartzofelspathic 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 metres, below which the bedrock may be affected by weathering to depths generally in the range 2 to 8 metres. Weathering occurs to a depth of over 20 metres on the left flank where the bed rock consists of calc-gneiss.

Three types of dams have been considered during the course of the studies : earthfill, rockfill and concrete gravity. It was concluded that the earthfill option was less favourable than the other two, but comparative cost studies failed to show a clear advantage between the rockfill 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. More recent studies, taking into account the rapidly increasing price of cement in Sri Lanka, have indicated a widening margin in favour of the rockfill alternative. For the purpose of this report, therefore, the folowing description and engineer's cost estimate are based on the rockfill dam.

The proposed rockfill dam incorporates a central impervious core protected on each side by filter zones of appropriately graded material. The main shell of the dam comprises rockfill obtained from an adjacent quarry and compacted in layers. The maximum height of the dam is 40 m and the crest length 1008 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 meter margin for wind set-up and wave action.

On the downstream face, a 10 metre 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.

Two saddle dams are required to ensure closure of the reservoir rim at Elevation 101.0 m. These embankments are formed of compacted homogenous fill protected on the upstream face by rip rap.

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 trash racks 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 power house 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 x 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 the generating unit 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.

On the left bank, a natural depression is deepened to form a channel capable of passing the maximum left bank irrigation

72

demand ($48^{*}m^3/s$), 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 meter 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. At the time of writing, tenders are in the course of preparation by three groups of Canadian contractors.

---

* This figure has been revised to 54 m^3/s, based on updated calculations of water requirements.

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

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 11. 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	:	54 m^3/s
Right Bank system	:	26 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.

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 virtually impracticable and certainly undesirable to design an unlined system with a view to lining it in the future if leakage proves excessive. All the data available when the canal designs were being prepared indicated that the materials in which the canals would be located were quite pervious 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.

---

* These delivery rates are based on the crop water requirements presented in Section 4.2, and differ somewhat from the flows used to design the main canals (see Table 4-5). The difference for the Left Bank Main Canal is not significant. The re-design of the Right Bank Main Canal, to be undertaken in early 1980, will be based on the updated design flow.

A program of field investigations, involving the digging of test pits and the performance of infiltration tests, was initiated during the preliminary design phase. Results from these investigations have been meagre up to the time of writing. There are some indications, however, that the permeability of the soils may not be as high as originally supposed. It is therefore recommended that the tests should be pursued and the question of lined versus unlined canals reviewed during the definitive design stage, as discussed in further detail in Annex D.

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 canal is left unlined and 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 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.

TABLE 4-5

DESIGN FEATURES OF MAIN AND BRANCH CANALS

	LENGTH	UPSTREAM DESIGN FLOW[1]	HYDRAULIC STRUCTURES		
			CROSS REGULATORS	MAJOR OFFTAKES	OTHERS[2]
	(km)	(m^3/sec)	(Nos.)	(Nos.)	(Nos.)
Left Bank Sector 1					
Tailrace Canal	2.1	48	0	0	1
Main Canal	31.7	48	6	4	5
Branch Canal No.1	13.4	4.4	1	-	-
Branch Canal No.7	17.9	4.5	1	-	-
Branch Canal "D"	6.7	4.0	1	-	-
Branch Canal "E"	3.9	2.0	1	-	-
Sub-total Sector 1	75.7	-	10	4	6
Left Bank Sector 2					
Main Canal	23.6	33	7	8	7
Branch Canal No.2	2.4	2.3	1	-	-
Branch Canal No.3	7.2	2.5	1	-	-
Branch Canal No.4	2.2	2.5	1	-	-
Branch Canal No.5	2.8	2.2	1	-	-
Branch Canal No.6	22.1	7.0	1	-	-
Branch Canal "A"	2.0	1.5	1	-	-
Branch Canal "B"	4.9	1.5	1	-	-
Branch Canal "C"	3.2	1.5	1	-	-
Sub-total Sector 2	70.4	-	15	8	7
Right Bank Sector 3					
Main Canal	51.7	35	13	2	7
Branch Canal No.1	21.2	5.0	1	2	-
Branch Canal No.1A	4.2	2.0	1	-	-
Branch Canal No.1B	2.7	1.0	1	-	-
Branch Canal No.2	6.0	2.0	1	-	-
Sub Total Sector 3	85.8	-	17	4	7
Grand Total	231.9	-	42	16	20

1. Design flows were based on preliminary estimates of water requirements.

2. Kuda Oya level crossing, siphon at railway, bridges across main canals.

For this issue of the Feasibility Report, the number of possible sample areas was restricted by availability of land classification and topographic mapping. Two sample areas, the location of which are shown on Figure 11, have been examined in detail to date. The final issue of the Feasibility Report will incorporate a minimum of three additional sample areas.

Sample Area 1, located in Sector 1 to the north of the Pimburettewa Scheme, is representative of the paddy-dominated parts of the project. It is served by Branch Canal "F", which takes off from Km 22.5 of the Left Bank Main Canal. It has an overall area of 820 ha, all of which is within gravity command. Some 460 ha are allocated to paddy farmers in 1 ha plots, while the remainder is either occupied by irrigation canals, roads, etc. or is classified as non-irrigable.

Sample Area 2, which is located in Sector 2, is representive of those parts of the project having substantial irrigable upland areas. It is served by Branch Canal No.4, which takes off from the Left Bank Main Canal at Km 45.5. It has an overall area of 2260 ha, 2000 ha of which is within gravity command. Irrigable land in the area can be allocated to farmers as follows :

- paddy farms : 730 ha
- upland farms : 290 ha
- Total area allocated :1020 ha

Design Features

Separate delivery systems are recommended for upland and lowland areas, along the lines suggested by Hunting

Technical Services Limited for System C_9. 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 - 1.0m^3/sec)

- The channels are 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 off-take at the farthest turnout when the Distributary Channel is operating at 2/3 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.

(b) Sub-distributary Channels (Capacity up to 0.28 m^3/sec)

- The channels are unlined.

- The 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 - 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.

(d) Drains - Lowlands

- The objective of drain design in paddy areas is to prevent flood 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 8 litres/sec/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. They discharge into a 1.2 m deep contour drain which runs along the bottom of the upland area. This drain discharges into the delivery system for the lower paddy areas.

- The discharge capacity of the drains should be computed using recognised soil drainage formulae, and checked against a storm drainage flow of 10 litres/sec/ha.

(f) Secondary and Major Drains

- These drains will be formed out of existing watercourses.

- 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.

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 :

- areas prone to serious flooding (paddy areas only) ;
- small isolated areas which will not be served with water ;
- irrigation and other infrastructure ; and
- areas occupied by existing communities (upland areas only).

Tables 4-6 and 4-7 summarise 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 discussions with MDB regarding probable pasture reserves in the flood plain near Welikanda. For the areas further downstream, approximate allowances were made pending receipt of topographic maps and the completion of hydraulic analyses. Isolated area losses were taken as 2 per cent, while irrigation and other infrastructure losses were taken as 14 per cent.*

For the upland areas, only those blocks having areas exceeding about 40 ha were considered to be manageable as independent irrigation units. Losses for irrigation infrastructure were taken as 18 per cent, to reflect the greater land losses in the uplands to social infrastructure (major roads, etc.).

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 :

---

* This figure is based on analysis of the sample areas, assuming MDB's land reservation allowances. A reduction to eleven per cent is theoretically possible, if smaller reservations are adopted.

TABLE 4-[illegible]

ESTIMATION OF NET IRRIGABLE AREA - PADDY LAND

AREAS IN 1000 HA

SECTOR	MAP AREA	GROSS IRRIGABLE AREA IN COMMAND 1R	GROSS IRRIGABLE AREA IN COMMAND 2R	LOSSES - FLOODED 1R	LOSSES - FLOODED 2R	LOSSES - ISOLATED AREAS 1R	LOSSES - ISOLATED AREAS 2R	LOSSES - IRRIG. INFRASTRUCTURE 1R	LOSSES - IRRIG. INFRASTRUCTURE 2R	NET IRRIGABLE AREA 1R	NET IRRIGABLE AREA 2R	NET IRRIGABLE AREA TOTAL 1R + 2R
	1	6.76	5.10	0.68		0.12	0.10	0.85	0.71	5.11	4.29	9.40
1		6.76	5.10	0.68		0.12	0.10	0.85	0.71	5.11	4.29	9.40
	2	2.02	2.53			0.04	0.05	0.28	0.35	1.70	2.13	3.83
	3A	1.15	1.34			0.02	0.03	0.16	0.18	0.97	1.13	2.10
	3B	2.32	3.03			0.05	0.06	0.32	0.42	1.95	2.55	4.50
	3C	0.60	1.30	0.20		0.01	0.02	0.06	0.18	0.33	1.10	1.43
2		6.09	8.20	0.20		0.12	0.16	0.82	1.13	4.95	6.91	11.86
	4	1.32	4.68	0.40	0.10	0.03	0.09	0.20	0.64	1.19	3.85	5.04
	5A	2.48	2.92	0.20		0.05	0.06	0.32	0.40	1.91	2.46	4.37
	5B	0.66	0.78			0.01	0.02	0.09	0.10	0.56	0.66	1.22
3		4.46	8.38	0.60	0.10	0.09	0.17	0.61	1.14	3.66	6.97	10.63
Total		17.81	21.69	1.48	0.10	0.33	0.43	2.28	2.98	13.72	18.17	31.89

Note: Excludes Pinturetown, Vakneri and Punanai Schemes

TABLE 4-7

ESTIMATION OF NET IRRIGABLE AREA - UPLANDS

SECTOR	MAP AREA	GROSS IRRIGABLE AREA IN COMMAND			LARGE UPLAND BLOCKS			SMALL UPLAND BLOCKS					NET IRRIGABLE AREA[3]		
					GROSS AREA IN COMMAND	IRR. INFR. LOSSES[2]	NET IRRI. AREA	GROSS AREA IN COMMAND	LOSSES-EXISTING COMMUNITIES	LOSSES-FLOOD PRONE AREAS	LOSSES-NEW SETTLEMENTS & ISOLATED AREAS	NET IRRIGABLE AREA			
		1U	$2U_a$	$2U_t$	1U + 2U		TOTAL	TOTAL	TOTAL	TOTAL			1U	2U	TOTAL 1U + 2U
	1	1.61	1.68	0.41	1.74	0.31	1.43	1.96	0.34	0.27	1.35	Nil	0.62	0.81	1.43
1	3.70	1.61	1.68	0.41	1.74	0.31	1.43	1.96	0.34	0.27	1.35	Nil	0.62	0.81	1.43
	2	1.63	0.22	-	1.02	0.18	0.84	0.83	-	-	0.83	-	0.77	0.07	0.84
	3A	0.20	0.18	0.09	0.25	0.05	0.20	0.22	0.20	-	0.02	-	0.09	0.11	0.20
	3B	0.58	0.34	1.00	1.37	0.25	1.12	0.55	-	-	0.55	-	0.36	0.76	1.12
	3C	0.20	0.18	0.09	0.25	0.05	0.20	0.22	-	-	0.22	-	0.09	0.11	0.20
2	4.71	2.61	0.92	1.18	2.39	0.53	2.36	1.82	0.20	Nil	1.62	Nil	1.31	1.05	2.36
	4	0.97	1.11	0.55	0.61	0.11	0.50	1.12	-	0.09	1.03	-	0.02	0.48	0.50
	5A	0.57	0.53	0.30	0.37	0.16	0.71	0.73	-	-	0.73	-	0.26	0.45	0.71
	5B	0.44	0.40	0.20	0.55	0.10	0.46	0.48	-	-	0.43	-	0.17	0.29	0.46
3	4.37	1.13	2.14	1.05	2.04	0.37	1.67	2.33	0.00	0.09	2.24	Nil	0.35	1.22	1.67
TOTAL	12.78	5.40	4.74	2.64	6.57	1.21	5.46	6.11	0.54	0.36	4.21	Nil	2.33	3.08	5.46

1. Contiguous blocks having areas >40 ha, not coinciding with existing settlements. 2. Taken as 18 percent of the gross area.

3. Proportions of 1U and 2U estimated from proportions in gross irrigable area

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 MDB, which envisages the initial delivery of water in time to irrigate the Yala crop of 1983. Assuming a 3 - year development period for downstream works this schedule would indicate completion of the irrigation system in 1986.

Commencement of irrigation deliveries in March 1983 calls for the completion of the Maduru Oya Dam in time to impound the 1982-83 Maha run-off -- that is, not later than November 1982. At the same time, to avoid the risk of this Maha run-off being too low to store enough water in the reservoir, it is essential that the link tunnel be completed not later than the end of January 1983.

It is due to this urgency that tenders have been called from prospective contractors so that an award can be made in time to permit substantial construction progress on the headworks in 1980. If this is achieved and maintained through the succeeding two years, the meeting of the above deadlines is considered to be practicable. Of course, it is implicit that the Minipe diversion and Right Bank Transbasin Canal must also be completed in time to deliver water to the link tunnel.

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 Yala 1983 is a prime objective. The first, referred to as "Scenario A", approximates the MDB schedule referred to above, the basic difference being that a smoother rate of land development (maximum 12,600 ha as opposed to 24,000 ha per annum) is envisaged. In this scenario land is brought under irrigation in the course of 7 growing seasons - Yala 1983 to Yala 1986.

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 buildup of land brought under irrigation is spread over 13 growing seasons - Yala 1983 to Yala 1989.

A consolidated bar chart showing the schedules discussed above is presented in Figure 12.

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. Thus it has been possible to prepare engineer's estimates for these works at a greater level of detail than is normal for feasibility studies.

The layouts of the main and branch canals have been based on mapping to scales appropriate for feasibility studies, except for the right bank system where lack of the 1 : 5000 scale topographic maps necessitated the use of the earlier and less reliable 1 : 31,680 scale mapping. Test pits (on the left bank only) at 1 - 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 two sample areas referred to in Section 4.4.3. Construction by local forces using labour-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 price of cement appears to be fluctuating considerably. For example, the following prices of the domestic product have been quoted by the Ceylon Cement Corporation:

January 1979	: Rs.18.50 per 42 kg bag
October 1979	: Rs.28.75 per 50 kg bag
Early November 1979	: Rs.53.00 per 50 kg bag
Mid November 1979	: Rs.45.00 per 50 kg bag
Late November 1979	: Rs.43.00 per 50 kg bag

In response to interim variations in the price of cement the capital cost estimates for the different elements of the project have been up-dated from time to time during the course of the study.

At mid November 1979, a final review of cement prices was made. For purposes of this study it is assumed that half of the project requirement will have to be imported. A weighted average price of Rs.50 per 50 kg bag has been adopted as effective "mid 1979". Transportation to the project area has been allowed for separately.

The previously-prepared cost estimates have been adjusted by applying the necessary corrections to the estimated cement requirements. These adjustments have been exposed in the capital cost estimates to facilitate future up-dating, if required.

It should be noted that if significantly larger quantities of cement were required (e.g. for a concrete dam), it is probable that a greater proportion would have to be imported and the weighted average price would increase.

The following tables summarise the cost estimates of the irrigation works, as discussed above :

Number	Title
4 - 8	Headworks - Summary of Capital Costs.
4 - 9	Main and Branch Canals - Scenario A - Summary of Capital Costs.
4 - 10	Main and Branch Canals - Scenario B - Summary of Capital Costs.
4 - 11	Tertiary Systems, Drainage and Land Development - Summary of Capital Costs.
4 - 12	Irrigation Works - Scenario A - Schedule of Capital Costs.
4 - 13	Irrigation Works - Scenario B - Schedule of Capital Costs.
4 - 14	Irrigation Works - Annual Operation and Maintenance Costs.

Full details of the build-up of the cost estimates are contained in Annex D.

TABLE 4-8

HEADWORKS

SUMMARY OF CAPITAL COSTS

	ALL COSTS IN MILLION RUPEES		
	SRI LANKA	FOREIGN	TOTAL
Link Tunnel	67.5	201.6	269.1
Dam (Rock fill)	240.2	516.1	756.3
Misc. Works (Access, Power, clearing, saddle dams)	46.6	79.2	125.8
Sub Total	354.3	796.9	1151.2
Contingency on headworks	35.4	79.7	115.1
Engineering	40.0	60.0	100.0
Total Headworks at Mid 1979 Cost Level	429.7	936.6	1366.3
CASH FLOW SUMMARY (Scenario A&B)			
1980	102.6	233.6	336.2
1981	165.4	387.2	552.6
1982	137.4	265.5	402.9
1983	24.3	50.3	74.6
	429.7	936.6	1366.3

TABLE 4-9

MAIN AND BRANCH CANALS - SCENARIO A
SUMMARY OF CAPITAL COST

		ALL COSTS IN MILLION RUPEES		
		SRI LANKA	FOREIGN	TOTAL
SECTOR 1				
Canals		143.9	244.7	388.6
Contingencies		21.6	36.7	58.3
Sub Total		165.5	281.4	446.9
Engineering and construction supervision		15.0	42.0	57.0
Total		180.5	323.4	503.9
Schedule of cost	1980	3.8	10.5	14.3
	1981	63.4	111.8	175.2
	1982	63.4	111.8	175.2
	1983	49.9	89.3	139.2
SECTOR 2				
Canals		73.8	138.8	212.6
Contingencies		11.1	20.8	31.9
Sub Total		84.9	159.6	244.5
Engineering and construction supervision		8.0	23.0	31.0
Total		92.9	182.6	275.5
Schedule of cost	1980	2.0	5.8	7.8
	1981	32.6	63.2	95.8
	1982	32.6	63.2	95.8
	1983	25.7	50.4	76.1
SECTOR 3				
Canals		151.2	279.5	430.7
Contingencies		22.7	41.9	64.6
Sub Total		173.9	321.4	495.3
Engineering and construction supervision		17.0	45.0	62.0
Total		190.9	366.4	557.3
Schedule of cost	1980	4.3	11.2	15.5
	1981	66.9	126.9	193.8
	1982	66.9	126.9	193.8
	1983	52.8	101.4	154.2
Totals- Sectors 1, 2 and 3		464.3	872.4	1336.7

TABLE 4-10

MAIN AND BRANCH CANALS - SCENARIO B
SUMMARY OF CAPITAL COST

		ALL COSTS IN MILLION RUPEES		
		SRI LANKA	FOREIGN	TOTAL
SECTOR 1				
Canals incl. contingencies		165.5	281.4	446.9
Engineering and construction supervision		22.0	46.0	68.0
Total		187.5	327.4	514.9
Schedule of costs	1980	3.8	9.8	13.6
	1981	49.1	85.2	134.3
	1982	49.3	85.0	134.3
	1983	49.3	85.0	134.3
	1984	36.0	62.4	98.4
SECTOR 2				
Canals incl. contingencies		84.9	159.6	244.5
Engineering and construction supervision		12.0	26.0	38.0
Total		96.9	185.6	282.5
Schedule of costs	1982	2.4	5.2	7.6
	1983	25.4	48.2	73.6
	1984	25.4	48.2	73.6
	1985	25.4	48.2	73.6
	1986	18.3	35.8	54.1
SECTOR 3				
Canals incl. contingencies		173.9	321.4	495.3
Engineering and construction supervision		26.0	48.0	74.0
Total		199.9	369.4	569.3
Schedule of costs	1984	5.2	9.6	14.8
	1985	52.2	96.4	148.6
	1986	52.2	96.4	148.6
	1987	52.2	96.4	148.6
	1988	38.1	70.6	108.7

TABLE 4-11

TERTIARY SYSTEMS, DRAINAGE AND LAND DEVELOPMENT
SUMMARY OF CAPITAL COST

SECTOR AND LAND CLASS	ALL COSTS IN MILLION RUPEES		
	SRI LANKA	FOREIGN	TOTAL
SECTOR 1			
Pimburettewa, Vakaneri,+ Punanai + Small tanks, Rainfed	26.2	2.9	29.1
New Lands - (Lowlands 1R, 2R) incl. main drains	113.5	12.6	126.1
Sub Total	139.7	15.5	155.2
Contingencies	21.0	2.3	23.3
Total for Sector 1 (Lowlands etc.)	160.7	17.8	178.5
New Lands - Uplands (1U, 2U)	27.5	3.0	30.5
Contingencies	4.1	0.5	4.6
Total for Sector 1 (Uplands)	31.6	3.5	35.1
Total for Sector 1	192.3	21.3	213.6
SECTOR 2			
Small tanks, Rainfed	10.4	1.2	11.6
New Lands - (Lowlands 1R, 2R) incl. main drains	159.9	17.8	177.7
Sub Total	170.3	19.0	189.3
Contingencies	25.6	2.8	28.4
Total for Sector 2 (Lowlands etc.)	196.0	21.8	217.8
New Lands - Uplands (1U, 2U)	46.4	5.2	51.6
Contingencies	6.9	0.8	7.7
Total for Sector 2 (Uplands)	53.3	6.0	59.3
Total for Sector 2	249.3	27.8	277.1

TABLE 4-11 (Page 2)

	ALL COSTS IN MILLION RUPEES		
	SRI LANKA	FOREIGN	TOTAL
SECTOR 3			
Small Tanks, Rainfed	29.0	3.2	32.2
New Lands - (Lowlands 1R, 2R) incl. main drains	104.3	11.6	115.9
Sub total	133.3	14.8	148.1
Contingencies	20.0	2.2	22.2
Total for Sector 3 (Lowlands etc.)	153.3	17.0	170.3
New Lands - Uplands (1U, 2U)	30.9	3.4	34.3
Contingencies	4.6	0.5	5.1
Total for Sector 3 (Uplands)	35.5	3.9	39.4
Total for Sector 3	188.8	20.9	209.7
Grand Total - Sectors 1, 2 and 3	630.4	70.0	700.4

Notes : + 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 4-12

SCENARIO A

IRRIGATION WORKS
SCHEDULE OF CAPITAL COSTS

ALL COSTS IN MILLION RUPEES

WORK	SECTOR		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Headworks		SL	102.6	165.4	137.4	24.2	-	-	-	-	-	-
		F	233.6	387.2	265.5	50.3	-	-	-	-	-	-
Main and Branch Canals	1	SL	3.8	63.3	63.3	50.1	-	-	-	-	-	-
		F	10.5	111.8	111.8	89.3	-	-	-	-	-	-
	2	SL	-	2.0	32.6	32.6	25.7	-	-	-	-	-
		F	-	5.8	63.2	63.2	50.4	-	-	-	-	-
	3	SL	-	-	4.3	66.9	66.9	52.8	-	-	-	-
		F	-	-	11.2	126.9	126.9	101.4	-	-	-	-
Tertiary Systems	1-Lowlands	SL	-	58.4	58.4	43.9	-	-	-	-	-	-
		F	-	6.4	6.4	5.0	-	-	-	-	-	-
	1-Uplands	SL	-	-	3.3	15.8	12.5	-	-	-	-	-
		F	-	-	0.4	1.7	1.4	-	-	-	-	-
	2-Lowlands	SL	-	-	71.3	71.3	53.4	-	-	-	-	-
		F	-	-	7.9	7.9	6.0	-	-	-	-	-
	2-Uplands	SL	-	-	-	4.1	26.7	22.5	-	-	-	-
		F	-	-	-	0.5	3.0	2.5	-	-	-	-
	3-Lowlands	SL	-	-	-	55.8	55.8	41.7	-	-	-	-
		F	-	-	-	6.2	6.2	4.6	-	-	-	-
	3-Uplands	SL	-	-	-	-	15.7	15.7	4.1	-	-	-
		F	-	-	-	-	1.7	1.7	0.5	-	-	-
	Totals	SL	106.4	289.1	370.6	364.7	256.7	132.7	4.1	-	-	-
		F	244.1	511.2	466.4	351.0	195.6	110.2	0.5	-	-	-
Grand Total			350.5	800.3	837.0	715.7	452.3	242.9	4.6	-	-	-

Notes : SL - Sri Lanka Component
F - Foreign Component

TABLE 4-13

SCENARIO B

IRRIGATION WORKS
SCHEDULE OF CAPITAL COSTS

ALL COSTS IN MILLION RUPEES

WORK	SECTOR		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Headworks		SL	102.6	165.4	137.4	24.2	-	-	-	-	-	-
		F	233.6	387.2	265.5	50.3	-	-	-	-	-	-
Main and Branch Canals	1	SL	3.8	49.1	49.3	49.3	36.0	-	-	-	-	-
		F	9.8	85.2	85.0	85.0	62.4	-	-	-	-	-
	2	SL	-	-	2.4	25.4	25.4	25.4	18.3	-	-	-
		F	-	-	5.2	48.2	48.2	48.2	35.8	-	-	-
	3	SL	-	-	-	-	5.2	52.2	52.2	52.2	38.1	-
		F	-	-	-	-	9.6	96.4	96.4	96.4	70.6	-
Tertiary Systems	1-Lowlands	SL	-	42.9	42.9	42.9	32.0	-	-	-	-	-
		F	-	4.7	4.7	4.7	3.7	-	-	-	-	-
	1-Uplands	SL	-	-	-	11.5	11.5	8.6	-	-	-	-
		F	-	-	-	1.3	1.3	0.9	-	-	-	-
	2-Lowlands	SL	-	-	-	52.3	52.3	52.3	39.1	-	-	-
		F	-	-	-	5.7	5.7	5.7	4.7	-	-	-
	2-Uplands	SL	-	-	-	-	-	19.4	19.4	14.5	-	-
		F	-	-	-	-	-	2.2	2.2	1.6	-	-
	3-Lowlands	SL	-	-	-	-	-	40.8	40.8	40.8	30.9	-
		F	-	-	-	-	-	4.5	4.5	4.5	3.5	-
	3-Uplands	SL	-	-	-	-	-	-	-	15.7	15.7	4.1
		F	-	-	-	-	-	-	-	1.7	1.7	0.5
	Totals	SL	106.4	257.4	232.0	205.6	162.4	198.7	169.9	123.2	84.7	4.1
		F	243.4	477.1	360.4	195.2	130.9	157.9	143.5	104.2	75.8	0.5
Grand Total			349.8	734.5	592.4	400.8	293.3	356.6	313.4	227.4	160.5	4.6

TABLE 4-14

IRRIGATION WORKS - ANNUAL OPERATION AND MAINTENANCE COSTS

	PERCENT OF CAPITAL COST[1]	MILLION RUPEES PER YEAR
Headworks	0.5	6.3
Irrigation System	1.5	28.3
Sub Total		34.6
Right Bank Transbasin Canal[2]	1.0	6.0
Total		40.6

1. Excluding Engineering
2. Applicable only in case where 50 per cent of R.B. Transbasin canal capital costs changed to Maduru Oya Project (see Section 10.2.2.) Used in sensitivity analysis only.

5. SETTLEMENT PLANNING

The settlement of close to a quarter million persons is discussed in this chapter.

Settlement planning, as discussed under 5.1, refers to the process of settling families - what is required to bring about relocation and migration and what should be considered in a government sponsored migration programme.

Settlements planning, as discussed under 5.2, refers to the planning of settlements, i.e. the land use, regional and town planning aspects that require consideration if the project area is successfully to accommodate the settlers. The settlement planning studies have been materially aided by the Regional and Physical Planning Division and the Settlement Planning and Redevelopment Division, MDB, which conducted a socio-economic survey of System B_{10}. Analyses of settlement experience in the H area (in terms of both the settlement process and the planning of settlements) also provided important contributions.

5.1 Settlement Planning

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 Program in general, is that it is

the intention of the Government of Sri Lanka to allocate one hectare of paddy land to Mahaweli settlers. Agro-economic studies have indicated that one hectare of paddy land provides sufficient income for, and can properly be worked by, one family.

The estimated net irrigable area suitable for paddy cultivation is 31,900 ha. This is the amount of land that can be allocated in one hectare parcels to settlers.

The estimate excludes paddy land in the major tank schemes in and adjacent to System B - Pimburettewa, Vakaneri and Punanai. However, it does include areas currently under small tanks within the System and rainfed paddy lands, totalling 6,700 net irrigable hectares. The claims to these lands by present cultivators will have to be satisfied before the areas can be considered for Mahaweli settler allocation. Undoubtedly, some of the rainfed areas are being worked without claim or permit.

The promise of one hectare of irrigated Mahaweli land will in most cases be adequate compensation for giving up a larger area currently worked as rainfed land or under a small tank, considering that currently Yala production is negligible.

Hence the assumption is made that ultimately all 31,900 ha of net irrigable paddy land identified by the study can be allocated in one hectare parcels. Proper integration of all small tanks within the overall irrigation system is planned for. Re-levelling and re-bunding of areas under small tanks would be called for in a number of instances, thus facilitating the process of re-allocation. The estimate of the number of one hectare

parcels may however somewhat overstate what can actually be achieved with existing small tanks, in terms of re-allocation although not in terms of production.

On 31,900 ha net irrigable paddy land, 31,900 paddy farmers can be settled.

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 net irrigable area of 5,500 ha in blocks of 40 or more ha. Smaller blocks are not deemed suitable for separate irrigation systems.

For purposes of this study, it has been assumed that 'pure' upland farmers can be induced to settle, when allocated two ha, which would include 0.5 ha of homestead. This would allow 2,750 farmers to be settled.

However, experimentation with upland soils at the proposed System B demonstration farm could indicate that larger upland farm units might be more appropriate. This could then reduce the number of farmer settlers but it would at the same time create a need for hired farm labour. A minimum viable upland bolding of two hectares has been adopted to achieve maximum settlement.

Total upland and lowland settlers would be 34,650.

The existing number of families in System B is about 4,000,not including resident Pimburettewa, Vakaneri and Punanai settlers. A large proportion of the 4,000 families would likely qualify for settlement under the Mahaweli Programme, being near-landless and earning below-average incomes. Most are presently engaged in farming.

Considering that at least 3,000 present System B families can qualify for Mahaweli Land, an additional 31,660 settler families would be selected from outside System B.

For the development of a balanced rural society, it is important that, in the planning stages, attention is paid to the non-farm population. Already, among the existing, sparsely distributed population there is an element of non-farm employment, on the order of 15 to 18 per cent. A minimum of 20 per cent non-farm employment and population is deemed necessary for the basic functioning of a rural society. This non-farm component would include services to farmers, general commercial and farm industry activities, social and personal services and government. It does not include hired farm labour for seasonal peaks, which will be satisfied through migrant labour movement. It also does not include the construction and supervision work force present during the implementation period for System B.

The non-farm settlers who will make a permanent home in the area would total 8,650 families, assuming the 20 per cent guideline. It is recognised that certain non-farm functions will be performed, from time to time, by unmarried individuals (e.g. teaching). To the extent this is so, the non-farm family and population estimates will be overstated. The farmer settlers are all considered to be families.

The total number of settler families, including those now in the area, should number 43,300 towards the end of the 1980's, considering that certain categories of non-farm settlers might not settle in the early years.

Towards the end of the century the area families should number some 55,000 once the non-farm population increases from 20 per cent of the total, to one-third of the total, as it will do, if the development is successful (i.e. generates acceptable standards of living). Creation of one non-farm job for every two farm jobs is well within the reach of the resources of the area. As a result of the development of System B, the population of the area will increase from about 25,000 to over 225,000 in the next ten years. The influx of such a large number of people into relatively virgin territory over a brief period of time will require a planning effort commensurate with the size of this migration.

The movement of people into System B will be in sharp contrast to the experience in System H, where only one-third of the farm settlers are from 'outside', as shown below :

	System H	System B
Farm Families from area	17,000	3,000
Farm Families from 'outside'	9,000*	31,650
Total	26,000	34,650

Table 5-1 shows a summary of the settler population estimates. While by no means precise, the figures serve to indicate the general 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. Hence there is experience with settler selection.

---

* As of November 1979, about half these families had been settled.

TABLE 5-1

SUMMARY OF SETTLER FAMILIES AND POPULATION IN SYSTEM B

	FAMILIES	POPULATION AT 5 PERS/FAM.
A. Paddy Settlers	31900	159500
Upland Settlers	2750	13750
Farmer Settlers	34650	173250
Non-Farm Settlers	8650	43250
Total Settlers	43300	216500
B. Farmer Settlers Required	34650	173250
Present in Area	3000	15000
Settlers from 'Outside'	31650	158250
C. Non-Farm Settlers Reqd.	8650	43250
Present in Area	1000	5000
Settlers from 'Outside'	7650	38250
D. By late eighties :		
Farm Population	34650	173250
Non-Farm Population	8650	43250
Existing Schemes Population	1800	9000
Total	45100	225500
E. By year 2000 :		
Farm Population	36450	182250
Non-Farm Population	18200	91000
Total	54650	273250

Notes: Pimburettewa, Vakaneri 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.

However, the size of the anticipated programme is such that extraordinary measures will be required.

System C, which is to be implemented during the same period as System B, calls for the settlement of some 17,000 farm families. Adding these families to the System B requirements, some 52,000 farm families are to be settled in about half a dozen years.

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

Selection criteria have been the subject of study and administrative innovation for many years. However, the manner in which the criteria are applied can at times carry more weight than the formal selection guidelines. In the early years of System H a point score system was used for selection. This method was subsequently abandoned.

It would be appropriate that the selection criteria for System B settlers, and those for System C, be carefully reviewed once again, in the light of (a) experience gained in H, and (b) the characteristics of development proposed for the two systems, as detailed in this

report and the report prepared by Hunting Technical Services Limited. There should be a common approach to settlement issues for both Systems B and C.

Typical characteristics of the System B development plan are :

- most settlers will be exclusive paddy farmers ;
- all paddy farmers will have a large, separately located, homestead plot for which homestead crops are planned, as well as livestock ;
- the use of buffaloes is encouraged, and planned for ;
- there will be a small number of exclusive upland farmers, whose homestead will be on the farm area ;
- communities will be low-density, reflecting the large homestead plots ;
- most settlers will come from outside the area ; and
- non-farm settlement is proposed as an integral component of the development of the area.

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

- Those now living in the area should have a high priority for settlement. In the near future it should be made known to area residents what length of residency the government intends to employ, if indeed it intends to employ this concept. A positive view of encroachers should

be taken ; their suitability as settlers rather than their status as encroachers should be considered. Those living in the area not selected for farming should be given non-farm plots.

- The areas near System B should be considered as preferred areas for settler selection. The coastal area between Trincomalee and Batticaloa, the area south of System B and the area north of Polonnaruwa should all be able to supply settlers who are familiar with living conditions in the Dry Zone. In general, the districts of Trincomalee, Polonnaruwa, Batticaloa and Amparai would cover the near areas.

- The settlers to be attracted from areas further away should also preferably have Dry Zone experience.

- The ultimate ethnic composition of the System should be viewed in the context of the overall Accelerated Mahaweli Programme. It will have to be determined whether the settlement plan is to be based on concepts of integration or segregation of the various cultural groups.

- The settlers should have farming experience, preferably paddy farming. Since over 50 per cent of the labour force of Sri Lanka is currently engaged in agricultural activity, it should not be difficult to satisfy this criterion. At a minimum, the farmer settlers should originate from rural areas.

- The settlers should not have any significant assets, nor should they now have incomes that approach the projected family income for the System.

- The settlers should be young, in their twenties or early thirties, and energetic. While most farmer settlers will be married, the possibility of selecting related but unmarried settlers (brothers, sisters, cousins) should not be ruled out.

- A specific programme should be developed for non-farm settlers. To qualify for a non-farm plot of 0.2 ha, the settler should be willing to live and work in the area, with the skill or trade he brings to the area to be a key determinant. Individuals should also be considered for non-farm plots.

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. Especially in the case where the settler is expected to provide labour for a period of time, the physical and contractual working conditions under which this labour is to be provided should be communicated clearly.

5.1.3 Rate of Settlement

The rates of settlement follow the development Scenarios A and B, discussed in Chapter 4. Scenario A shows the

phasing of construction to allow for the bringing into production (first crop) on 4,700 ha in the Yala of 1983. To obtain a Yala 83 crop, settlers have to be established, at the latest, in the previous season, namely the Maha 1982/83. This would leave the minimum possible time for the preparation of fields. Settlers would be brought into the area late 1982 and early 1983 and work on their fields, in preparation for the planting of the 1983 Yala crop. This would be the first crop they would harvest.

On the basis of this scenario settlement would take place from the Maha 1982/83 to the Maha 1985/86, under Scenario A, and from the Maha 1982/83 to the Maha 1988/89, under Scenario B (see Table 5-2).

Similarly, a rate of settlement has been detailed which assumes that the settlers arrive two seasons (1 year) before they harvest their first crop. The first settlers would come in the Yala of 1982, work on their fields and homestead throughout the Maha 1983 then plant and harvest the Yala 1983 crop. This approach is illustrated in Table 5-3.

Under either approach the settlement for Scenario A is achieved in four years, and the settlement for Scenario B in seven years.

It is conceivable that settlers could be brought in earlier than two crops before the first harvest. In such a situation they would likely be engaged on construction aspects of the tertiary system. Ideally they would be allocated their homestead while employed as construction labour, so that progress can be made on the homesteading part of settling (constructing shelter, clearing the plot, planting fruit trees, etc.).

TABLE 5-2

ARRIVAL OF FARMER SETTLERS
ONE CROP BEFORE FIRST CROP HARVESTED

		SCENARIO A	SCENARIO B
1983	M	4700	2300
	Y	4700	2300
1984	M	6000	2300
	Y	6600	2500
1985	M	5300	3350
	Y	6500	3350
1986	M	850	3000
	Y	-	2900
1987	M	-	3200
	Y	-	3200
1988	M	-	2600
	Y	-	3225
1989	M	-	425
Total		34650	34650

Note : 1983 M = Maha. 1982 - 1983, etc.
Y = Yala.

TABLE 5-3

ARRIVAL OF FARMER SETTLERS
TWO CROPS BEFORE FIRST CROP HARVESTED

		SCENARIO A	SCENARIO B
1982	M	-	-
	Y	4700	2300
1983	M	4700	2300
	Y	6000	2300
1984	M	6600	2500
	Y	5300	3350
1985	M	6500	3350
	Y	850	3000
1986	M	-	2900
	Y	-	3200
1987	M	-	3200
	Y	-	2600
1988	M	-	3225
	Y	-	425
Total		34650	34650

Note : 1982 M = Maha 1981 - 1982, etc.
Y = Yala

The advantages and disadvantages of bringing in settlers much before they can be productively employed on their allocated paddy lands should be weighed carefully.

Based on two crops before first harvest, the first settlers would arrive in 1982, 4,700 in the case of Scenario A and 2,300 in the case of Scenario B. To settle 4,700 families over a six month period implies a rate of 800 per month. With 24 working days per month this would be 33 settlers per day, or 165 persons. Settler families and their belongings are transported by MDB lorries, allowing two families and effects per lorry. To bring 33 settler families per day requires 17 lorry trips. This rate will increase to 23 lorries arriving per day by the Maha of 1983/84, when 6,600 families are being settled. In general Scenario A calls for the uninterrupted daily arrival of some 20 lorries, each carrying two families, from mid-1982 to mid-1985.

For Scenario B, the daily quota of lorry-loads of families would be 10, for the period mid-1982 to mid-1990, six days per week.

The above has assumed that the influx of settlers is spread evenly throughout each season which may not be practicable or equitable in all cases.

The rate of settlement illustrated under Scenario A has as its basis the earliest dates the immigration system and lands can be physically developed. To sustain the rate of settlement called for under Scenario A will require a supreme logistic, organisational and administrative effort in line with the overall thrust of the Accelerated Mahaweli Programme. Under Scenario B such effort would be less intense.

110

5.1.4 Assistance to Settlers

Assistance to settlers will have to be provided, if only to ensure that the investment of over Rs.100,000 in each ha of irrigated land is being utilised with economic efficiency.

Considering the size of the investment in the irrigation system, the investment in settler assistance is comparatively minor. It could be changed without significantly affecting the economic return of the project.

For the estimates of economic settlement cost, a base of 35,000 families has been used. It is understood that the residing families to be resettled will also receive assistance.

- Selection, orientation and training.
  The cost of these activities is estimated at Rs.200 per family. Total cost is Rs.7 million.

- Transportation of settlers
  Transportation of settlers from place of origin to new homestead. At Rs.200 per family, the total cost is also Rs.7 million.

- Temporary shelter
  These would be the camps where settlers stay for a short while, allowing them an opportunity to construct a hut on their homestead. Some 70 camps may be required, for a total cost of Rs. 1½ million.

- Tools
  Each settler would receive some basic tools. At Rs.200 per settler, this totals Rs.7 million.

- Housing Allowance

  This would be to construct a core shelter. While it should not be the object of the assistance to promote private capital formation, shelter to some basic standard is necessary. Rs.1,000 per family, while more than is presently given to H area settlers, is necessary to provide for the building materials (mostly posts, poles and cadjan) out of which a modest shelter can be fashioned. Although not allowed for here, latrine plates and mosquito nets could also be considered basic necessities. Total cost for housing allowance is Rs.35 million.

- Wells

  It has been estimated that a well, to serve 20 families, can be constructed for Rs.12,000 or Rs.600 per family. Wells are extremely important from the public health point of view and should be constructed at the time of settlement. Total cost is Rs.21 million.

  In areas with particularly poor groundwater conditions, wells may have to be located sufficiently close to the tertiary irrigation system for conveyance leakage to provide the necessary recharge. Wells could also be located adjacent to lined canals, with a filtration gallery to provide water.

- World Food Aid

  Settlers in System H receive food aid for 15 months to allow them to sustain themselves while prepared farm and homestead, and anticipating the preparing

first crop. The aid usually consists of wheat flour, cereal, sugar and dry fish. The value to a family is about Rs.220 per month. Eight months of aid has been taken as the cost to the project, while the remaining months would be a form of income supplement like the foodstamps to which settlers would also be entitled. Total cost (at Rs.1,760 per family) would be Rs.62 million.

- Hamlet, Village and Town Planning ; Surveying of Homesteads
  While the cost of designing the lands under development has specifically been taken into account in the irrigation system cost, no similar allowance has been included for the design, planning and surveying of settlements. This matter requires a considerable amount of attention. Rs.500 per plot has been allocated, for a total cost of Rs.17 million.

- Overhead
  On the above items ten per cent has been added to allow for management and administration. Total overhead is Rs.17 million.

- Total settlement costs amount to Rs.187 million or Rs.5,343 per family.

Currently settlers in System H also receive Rs.200 in seed materials. This cost is considered an agricultural input rather than a settlement cost. Similarly, settlers can be paid for work they perform on jungle clearing and levelling and bunding of their farm area. While income to the settlers, the cost is included under the tertiary system.

The settlement costs have been allocated under the scenarios as follows, based on their arrival one crop before harvest :

	Scenario A	Scenario B
1983	Rs. 41 m	Rs. 15 m
1984	Rs. 68 m	Rs. 26 m
1985	Rs. 64 m	Rs. 34 m
1986	Rs. 14 m	Rs. 32 m
1987		Rs. 35 m
1988		Rs. 29 m
1989		Rs. 14 m

It should be noted that social infrastructure is not included in settlement costs. This matter is discussed further on this chapter.

Table 5-4 shows a summary of the capital cost of non-irrigation works. Roads and project management infrastructure costs are discussed in subsequent sections. These costs, in common with other capital cost estimates presented in this report, reflect economic prices and are used in the analysis described in Chapter 10.

5.2 Planning of Settlements

5.2.1 Regional Context

The regional context of System B is illustrated on Figure 3.

There are various ways in which the region can be defined. In one sense, it could be referred to as the area to

TABLE 5-4

NON-IRRIGATION WORKS
SUMMARY OF CAPITAL COSTS
(RS. MILLIONS, MID-1979 PRICES)

	MILLION RUPEES	
ROADS		
Access Roads	45	
Primary Roads	90	
Irrigation System Roads	15	
Link Roads	60	
Roads within Settlements	60	270
SETTLEMENT		
Selection, Orientation, Training	7	
Transportation	7	
Temporary Camps	14	
Tools	7	
Housing Allowance	35	
Wells	21	
Food Aid	62	
Physical Planning and Surveying	17	
Overhead	17	187
PROJECT MANAGEMENT INFRASTRUCTURE		
Irrigation System	35	
Agricultural Extension	35	
Settlers Assistance, Com. Dev. etc.	30	
General Project Management	10	110
Total		567

Note : The above estimates include the following approximate Foreign Exchange components.

Roads - Rs. 30 million

Project Management Infrastructure - Rs. 20 million

the east of the Mahaweli Ganga. In another sense, the region should be considered as that area containing at least one major centre. In yet another sense, it could be considered to be the area encompassed by the Accelerated Mahaweli Development Programme - Systems A, B, C and D.

The context in which System B is portrayed in this report takes the broad regional view : the area bounded by the towns of Trincomalee, Dambulla, Matale, Kandy, Mahiyangana, Batticaloa and Valachchenai forms the region in Figure 3. In terms of the highway network, it is the area bounded by highway A6 and A9 on the north and west, B38 and A5 on the south and A15 on the east, while being bisected by A11 and the railroad.

The highway and railroad running through System B are the main infrastructure assets of the area. Administratively, the region falls within a number of districts. The population of the four Dry Zone districts is shown in Table 5-3. Currently these districts have a population in excess of one million. The rate of growth in the Dry Zone districts over the last few years has been considerably higher than the national rate. This is thought to reflect in part the introduction of some colonisation schemes and the influx of chena cultivations. With the Mahaweli Project, the population of the region could double over the next twenty years. The development 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 Scheme will generate road improvements. One such improvement will be a primary road from Manampitiya to the south, across the Madura Oya

TABLE 5-5

POPULATION OF MADURU OYA REGION[1]
(1000)

DISTRICT	1968	1978	NOVEMBER 68-78 NUMBER	%
Trincomalee	165	223	58	35
Polonnaruwa	134	190	56	42
Batticaloa	233	300	67	29
Amparai	251	316	65	26
Total	783	1029	246	31
Sri Lanka	11992	14190	2198	18

1. Matale and Badulla districts not included due to predominantly intermediate zone oriented.

Dam, then linking with A5, thus serving the Gal Oya population (see Figure 12). Another important road will be from Mahiyangana to Mananpitiya, through System C and Sector 1 of System B. Eventually this road could continue north, direct or by way of Welikanda, to connect with A15, thus facilitating north-south traffic through Systems A, B and C.

One of the key elements in the transportation network of the Madura Oya region is the road/railway bridge across the Mahaweli Ganga, at the westerly entrance to System B. While adequate at present, a new bridge will be required once the population east of the river increases significantly. According to the Department of Highways, the World Bank is considering the financing of such a bridge.

The proposals for an extension to the existing railroad, to serve Systems B and C, should be examined with reference to the feasibility reports for these Systems. Particular attention should be paid to freight projections, and to the comparative cost of commercial transportation by the improved future road system referred to above.

Within the region, four component systems of the Accelerated Mahaweli Programme are being studied, designed and implemented. Systems B and C, studied by separate teams of consultants, will be under the implementation supervision of the MDB. Systems A and D, also studied by separate teams of consultants, will be implemented by the Irrigation Department. System E, on the bank of the Mahaweli, opposite System C, also forms part of the region (see Figure 2). All activity is co-ordinated by the Mahaweli Authority.

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

- principal transportation facilities (road, rail, air, water) ;
- relationships between the Mahaweli systems :
- functions of major centres :
- hierachy of subordinate centres :
- demographic and cultural aspects :
- potential of farm and non-farm sectors ;
- incentives required to meet development objectives ; and
- adminstrative boundary matters.

A regional plan would produce a blueprint of how a region should develop and how it can be made to develop along the lines indicated.

5.2.2 Planning for the System B Project Area

Central to the physical planning for System B is the change in land use that will result from the introduction of irrigated agriculture.

Table 5-6 shows the elements of major change. Agricultural lands will increase from 14,000 ha to 52,000 ha ; land for homesteads and settlements will increase from 3,000 to 25,000 ha ; and chena and forest land will decrease from 100,000 ha to 40,000 ha. About 60,000 ha, or half of the overall area, will undergo drastic a change in land use, while indirect effects will be felt on the remaining 50 per cent.

Distribution of future land use between chena and forest requires further study. Chena and forest presently account for 100,000 ha., of which 60,000 ha will be required for cropland, homesteads and settlements. If all of the chena land were used, some 27,000 ha of forest would still be required. However, since chena land is scattered, not all of it would be used. Hence the requirement for forested areas could exceed 27,000 ha.

The physical impact on the existing project area population is thought to be modest : the existing population of 25,000 will for the most part be able to continue to live in or near their present locations. No homes will be inundated. Like in the H area the dwellings now situated on what will become paddy land will require relocation to nearby upland (not suitable for irrigation). However, the present settlement pattern already favours the uplands. Any settlement should not entail great expense to families since most existing homes are not of a permanent nature.

Figure 4, the map of present land use, shows existing settlement areas. Some 25 communities (one or more clusters of dwellings) can be identified. Few villages have more than 100 dwellings. Few clusters have to be moved to make way for new paddy lands. This becomes clear when the present settlements and the areas to be irrigated are examined (see Figure 6).

Detailed planning of settlements still has to be undertaken. From the information available to date, it is apparent, however, that the future settlement pattern would tend to be diffused rather than concentrated due to the widespread nature of the lands that will be irrigated. Proposed agricultural land which comprises 42 per cent of the project area, is located in such a pattern that it will be difficult to plan settlements with only a small range of settlement sizes in mind.

The main criterion for the location of settlements is the the distance between the paddy field and the homestead. A second factor, perhaps of similar importance, is the distance between the homestead and the nearest elementary school.

System B is about 45 km by 50 km in extent and covers an area of some 1,300 km^2. From a present population density of about 20 per km^2, the area will reach a density of about 175 per km^2. This compares with a national density of about 225 persons per km^2.

System B is divided into three planning sectors as shown on Figure 13. Sectors 1 and 2 comprise the left bank area of the Maduru Oya ; Sector 1 is the area south of the railway and Sector 2 is the remaining area of the the left bank. Sector 3 is the right bank area.

In terms of expected farmer settlement the sectors are more or less equal : Sector 1 will accommodate about 10,000 settler families, Sector 2 about 13,000 and Sector 3 about 11,500.

Sector 1, which also includes the Pimburettewa Tank Scheme, presently contains the largest share of the

System B population. In future it will have the highest population density, while Sector 2 will have the lowest.

The estimated present population is :

Sector 1	..	15,000
Sector 2	..	7,000
Sector 3	..	3,000
	Total	25,000

A detailed land use, settlements and infrastructure should be prepared for Sector 1 of System B, the area proposed for initial development. The intergration of the Pimburettewa Scheme into Sector 1 and the future role of the township of Aralaganwila should be addressed. This plan should be prepared in 1980, concurrent and in close co-operation with the engineering design of the irrigation systems for Sector 1.

5.2.3 Settlements in System B

The land currently in use for homestead and settlement is about 3,000 ha. If the proposed 0.5 ha homestead concept is accepted, the land requirement for farmers' homesteads would total some 20,000 ha. Non-farm settlers on 0.2 ha plots would increase the requirement to 22,000 ha. To accommodate future increases in the non-farm population and to provide a reserve of settlement land a further 3,000 ha should be identified. For homesteads and settlements some 25,000 ha is to be planned for (see Table 5-7).

TABLE 5-7

LAND USE FOR HOMESTEAD AND SETTLEMENTS

	(ha)
31900 Paddy farmers 0.5 ha homesteads	15,950
allow 20% total for community infrastructure	4,000
Total land requirement	19,950
6850 non-farm settlers 0.2 ha plots	1,730
allow 20% of total for community infrastructure	420
Total land requirement	2,150
Total homesteads settlement land requirement to year 1990	22,100
Total requirement to year 2000 (allowing for more non-farm settlers and small reserve)	25,000

Notes :

1. Homesteads for upland farmers not included, as these are situated on-farm.

2. Allowance of 20% for infrastructure (roads, public uses etc.) considered sufficient in view of large plots; with smaller homesteads, infrastructure requirement would proportionately be higher.

Much of this area will be part of the economic base of the area, providing homestead crops and accommodating livestock. While the proposals call for the allotment of plots to non-farm settlers, land use provisions should also be made to allow for a measure of spontaneous non-farm immigration and settlement. Such immigration, if it were to occur, would be an indication of the attraction of the area ; it should therefore not be hampered for lack of land for legitimate settlement.

For the N area, and to date in the planning of System B and C, the basic settlement units considered by MDB are :

- the hamlet, with 100 to 125 households and a population of 500 - 600 ;
- the village, with 400 to 500 households and a a population of 2,000 - 2,500 (or combination of 4 to 5 hamlets) ; and
- the township, with 2,500 to 4,000 households an and a population of 12,500 to 20,000 (or combination of 5 to 8 villages).

For each settlement type certain facilities are planned. The hamlet would have a primary school, a co-operative store and post box, while the village and township would have higher levels of services.

It is not certain at this time whether the settlements for System B would closely correspond to this arrangement. The detailed settlements planning for the area is still at an early stage at MDB, as it must build on the land classification information only recently compiled.

As a basis for discussion, the following organisation of settlements for System B is suggested:

Regional Centre

Whether the area should have its own regional centre or whether it should rely on Polonnaruwa to serve this function is still a matter to be determined. The town of Polonnaruwa presently has a population of less than 20,000. With a projected population for System B of over 200,000, a district regional centre could well develop, probably at a location like Welikanda, especially if district administrative functions would be located there. However, if the project area remains divided between Districts of Polonnaruwa and Batticaloa it is less likely that a regional centre would develop.

Towns

Settlements of significance in the area include Aralaganwila (a new village resulting from the Pimburettewa development), Manampitiya and Welikanda. The latter two are situated along the main east-west road and railroad. 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 be appropriate to concentrate development at Manampitiya in the early years of implementation, to assist this community in reaching a size sufficient for attracting commerce and services. With the development of Sectors 2 and 3, the emphasis would shift eastwards to Welikanda, but by that time Manampitiya as a functional centre would be established. For Sector 2, north of the railroad, Trikonamadu could well develop as a township, serving population from System A as well.

For the right bank area, a new community, Meyankolla, could develop to serve the needs of the population.

To provide full access to Sector 3, two bridges across the Maduru Oya will probably be required ; east of Aralaganwila and south of Welikanda. The upgrading of the existing causeway at Miran will also again be required. It would be possible to develop the area adequately without a crossing near Aralaganwila ; all of Sector 3 could be oriented north and northwest. (see Figure 13). Planning proposals for this area cannot be formulated until land classification is completed and the extent of land to be irrigated firmly established.

Table 5-8 shows the indicated towns and the population sizes they might attain. On a combined basis, the towns would account for some 25 per cent of the area population.

For each town, an official land use and development plan is requried. For Welikanda, MDB is in the process of preparing such a plan. For Aralaganwila, an Irrigation Department plan exists which requires attention. For towns and villages it will be important to determine optimum dimensions for homestead and non-farm plots to achieve best utilisation of the plots consistent with minimum land requirements.

Villages

In the illustration of settlement sizes that may be considered for System B, the village would be 600 families or 3,000 persons. This is slightly larger than the village size of 2,000 to 2,500 persons currently used for planning purposes. The difference is not considered significant ; perhaps the larger village would be sufficiently large to allow a few more items of social service.

126

TABLE 5-8

ILLUSTRATION OF POSSIBLE RANGE OF SETTLEMENTS
BASED ON AREA POPULATION OF 200,000

Regional Centre* - Future establishment in System B uncertain		
Towns (or Townships)		
e.g. Welikanda	17,000 (3400 fam.)	
Manampitiya	10,000 (2000 fam.)	
Aralaganwila	9,000 (1800 fam.)	
Meyankolla	7,000 (1400 fam.)	
Trikonamadu	7,000 (1400 fam.)	50,000
Villages 10 of 600 fam or 3000 pop		30,000
Small Villages 20 of 300 fam or 1500 pop		30,000
Hamlets 50 of 150 fam or 750 pop		37,500
Subhamlets 100 of 50 fam or 250 pop		25,000
Scattered Groupings of less than 50 fam		27,500
Total		200,000

* if established, the number of towns and town population would be less.

Small Villages

With 300 families or 1,500 population, such communities would still be able to offer a basic range of services, including health services. Thirty villages and small villages would, with a total population of 60,000 (or 2,000 per community on average) account for thirty per cent of the total population.

Hamlets

Similar to the MDB hamlet, but slightly larger, a community of 150 families can provide a number of commercial and co-operative services.

Sub-hamlets

These communities, with a size of 50 families or 250 persons would be the smallest grouping of dwellings to which a social service can be allocated. It is considered that a sub-hamlet could support an elementary school with one or even two teachers. The 50 families would contain a schoolage population of about 800 persons. To bring education facilities to settlements of this size might well increase the enrolment ratio. A typical sub-hamlet could have 60 elementary students.

Scattered Settlement

The sub-hamlet with 50 homesteads of 0.5 ha would require a gross area of 30 ha, equal to an area of 500 m by 600 m. Below the sub-hamlet level there will still be a requirement

to settle families in smaller clusters on strips, depending on geographical conditiosn, present settlement patterns, access conditions, location of paddy paddy fields, etc. Such small clusters should in all cases be within easy walking distance from a higher order settlement, so that access to schools is ensured. 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 0.5 ha homestead plot proposal, and with the spatial distribution of paddy lands within the project area indicated by Figure 6.

5.2.4 Roads

Five categories of roads are identified : access roads, the primary road network, irrigation system road link roads and roads within settlements. Their costs are summarised in Table 5-9.

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 225 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.45 million. This cost is included in the roads budget.

TABLE 5-9

SUMMARY OF ROAD COSTS

(MILLION RUPEES)

TYPE	LENGTH	RS/KM	TOTAL	INCLUDED IN ECON. COST OF PROJECT
1. Access Roads	225	200,000	45	45
2. Primary Roads	135	1,320,000	178	90 (50% of ADB estimate)
3. Irrigation System Roads	225	200,000	45	15
		(Incremental)		(1/3 total length)
4. Link Roads	300	200,000	60	60
5. Roads within settlements	600	100,000	60	60
Total				Rs. 270 m.

Allocation of costs by Scenario is as follows :

	Scenario A	Scenario B
1981	Rs 45 m	Rs 30 m
1982	45	30
1983	45	30
1984	45	30
1985	45	30
1986	45	30
1987		30
1988		30
1989		30

Primary Road Network

Highway A11 through System B is a "national" road ; the bridge across the Mahaweli is a "natinnal" 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 the following economic costs (about 1 million Rupees per kil metre) for left bank primary roads in System B* :

	Length	Cost Rs.million
- Manampitiya - Aralaganwila	20 km	21.6 Rs.million
- Aralaganwila - Maduru Oya Dam Site	18 km	19.1 Rs.million
- Welikanda - Trikonamadu	22 km	22.6 Rs.million
	60 km	63.3 Rs.million

The above three left bank roads now exist ; the estimated cost is to bring them to primary road condition, as justified by their importance in the system. (However, the Aralaganwila - Maduru Oya road is not "prime" for operation of System B ; its present condition is satisfactory for construction use).

Other primary roads studied by the ADB team include :

- System C spine road, connecting at Manampitiya. This road will serve Sector 1 of System B to some degree, but should primarily be viewed as a System C road.

---

* Full formation, 24 ft pavement, including structures, gravel surface (metal surface is estimated to cost 20% more).

- Right Bank roads :

	Length	Cost
Welikanda - Meyankolla	17 km } 38km	Rs. 57 million
Meyankolla - Kiran	21 km }	
Meyankolla - Punanai	14 km	Rs. 21 million
Aralaganwila - Meyankolla	23 km	Rs. 37 million
Total length on right bank	75 km	Rs.115 million

The cost per km is about Rs.1.5 m, and includes two bridges across the Maduru Oya. Although some "cart tracks" now exist, the right bank roads should be considered to be new.

It is not clear at this time whether the above right bank roads will all be required, and if so, to which standard and width they should be constructed. A less expensive main road system may well be adequate. For this reason, the roads and bridges studied by the ADB team are included in the economic analysis at half their estimated cost per km, reflecting the probability that a lower standard of road and/or shorter overall primary network will be suitable.

Right Bank	75 km	Rs. 115	50 %	=	Rs. 58
Left Bank	60 km	Rs. 63	50 %	=	Rs. 32
Total	135 km	Rs. 178			Rs. 90

The primary roads considered are presented in Figure 13.

Irrigation System Roads

These roads will be on the banks of the canals and branches. As such they make a major contribution to

the internal road network of System B ; some 225 km of such road will be constructed. While a large proportion will be suitable for moderate traffic volumes, some canal roads will require extra width and/or gravelling and metalling. This basic road network is constructed as part of the irrigation system, and the costs are included under system construction. For surfacing and widening a cost Rs.200,000 has been allocated to one-third of the network. The total cost is Rs.15 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. Many link roads already exist but many would still be required. Much will depend on the pattern of settlement ; many settlements will be near the basic irrigation road system. It has been estimated that 300 km of link road would be required, at a total cost of Rs.60 million.

Roads within settlements

These are the internal roads that serve homesteads. They are not required to take any volume of motorized traffic ; most need not be more than 12 feet in width. Allowing for the incorporation of existing homesteads into the System, some 30,000 new homesteads will be added to the area. Each would have some 20 metres of road, for a total length of 600 km. At a cost of Rs.100,000/km, this totals Rs.60 million.

5.2.5 Social Infrastructure

A significant amount of social infrastructure is required for the project area. The cost of providing schools, hospitals, post offices, police stations etc is not considered an economic project cost as these services should be available at no cost to Sri Lankans, wherever they choose to live on the island. The financial cost of constructing social infrastructure facilities might exceed Rs.5,000 per family. This, and the operating costs, would normally be borne by the various responsible Departments and Ministries, although MDB in most cases would organise construction. Staffing and staff housing requirements will be considerable, as can be deduced from the following illustration :

Illustration of typical social infrastructure required to support population of 200,000 :

- 130,000 m^2 educational facilities (or 300 to 400 schools) ;
- 1,600 teachers ;
- 400 hospital beds ;
- 30 doctors ;
- 80 nurses ;
- 300 policemen ;
- 200 religious leaders ;
- 35 sub post offices ; and
- 35 dispensaries.

Detailed social infrastructure and operations planning has already been commenced by MDB but more work on standards and benchmarks is required.

6. AGRICULTURAL DEVELOPMENT AND PRODUCTION

6.1 Present Situation

Traditionally the 1900 mm (75 inch) isohyet separates Sri Lanka's Wet and Dry Zones. Rainfall at Welikanda has a mean annual value of 1765 mm, and places the centre of System B within the Dry Zone. The amount of rainfall increases towards the east - Vakaneri, with an annual rainfall of 1926 mm, lies on the fringe of the Dry Zone.

Agriculture in System B follows the centuries-old Dry Zone pattern. Rice is grown on all 8,000 hectares 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 agro-ecological Zone DL 2, which is characterised 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 1977/78 is indicated in Table 6-1. Figures for the considerable areas under tobacco and coconut, and for the two

Kenaf/sunhemp farms established at Welikana and Punanai by the Cashew Corporation and the Paper-Mill Corporation respectively are not included.

The slightly higher Maha rainfall in the eastern part of the project area represented by Batticaloa District contributes to the larger unirrigated area documented for that district. In both districts, the dominant crops are maize and cassava.

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. With somewhat higher rainfall and fewer irrigation facilities, the Batticaloa District has more rainfed rice. The growing of rainfed rice 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 approximately 7,321 hectares. Two of the major schemes, Pimburettewa and Vakaneri, cover 1,770 ha and 3,275 ha respectively. Pimburettewa is a colonization scheme, as is Wadumunai (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.

---

* traditional

TABLE 6-1

RAINFED UPLAND CROPPING AREA IN SYSTEM B
MAHA 1977/1978
(HA.)

CROP	POLONNARUWA[1] DISTRICT	BATTICALOA[1] DISTRICT	TOTAL
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 & Onions	67	61	137
Perennials	80	520	600
Total	597	1306	1903

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

Source : Department of Census and Statistics.

ABLE 6-2

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

DISTRICT	MAJOR IRRIGATION SCHEMES			MINOR IRRIGATION SCHEMES			RAINFED		
	ASWEDDUMIZED AREA (HA.)	CROPPING INTENSITY (%)		ASWEDDUMIZED AREA (HA.)	CROPPING INTENSITY (%)		ASWEDDUMIZED AREA (HA.)	CROPPING INTENSITY (%)	
		MAHA	YALA		MAHA	YALA		MAHA	YALA
Polonnaruwa[1]	1232	94	41	1895	86	26	764	92	2
Batticaloa[1]	3789	76	30	399	72	13	5615	73	2
Amparai	-	-	-	6	67	50	66	39	0
Total	5021	81	32	2300	83	24	6445	75	2

Note : Reference to the Polonnaruwa, Batticaloa and Amparai Districts mean those parts within System B.

Source : Department of Census and Statistics

Present land use in the project area is similar to that in the rest of the Dry Zone. Rice, 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 1973-79 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 per cent and in no instance is the cropping intensity in Yala even half that in Maha. The over-all cropping intensities in Yala under the major and minor irrigation schemes are 32% and 24% 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 the following :

(1) Reprocessing of the 1973-79 crop-cutting survey data for all parts of the project. These data were made available through the Department of Census and Statistics (DCS) ;

(2) Monitoring by team members of a special crop-cutting survey in the Polonnaruwa District in Yala 1979, also conducted by the DCS ;

(3) Execution of a special crop-cutting survey in the Pimburettewa Scheme, conducted by team members.

Survey methods consisted of stratified random sampling of villages and fields (Kumburas) within each village, weighted for extent.

Table 6-3 summarises the average yields obtained from these experiments. The data indicate that, in the Polonnaruwa District, yields are higher for the major irrigation schemes than for the minor schemes or for rice grown under rainfed conditions. Yields in Batticaloa District average about one-half those observed in Polonnaruwa District and the differences between major irrigation schemes and the others are less marked. In Batticaloa District, even the major schemes appear to manifest water stress. In general, the yield data demonstrate the importance of a reliable water supply upon which the effectiveness of the other components of a total input package so largely depend. Maha yields observed from 1973-78 for major schemes in Polonnaruwa District ranged from 5.8 t/ha to 7.1 t/ha and are indicative of the potential yield from improved rice varieties under field conditions with an adequate water supply. Conversely, yields drop to very low values (less than 2 t/ha) under extreme water stress.

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

TABLE 6-3

ESTIMATED IRRIGATED AND RAINFED RICE YIELDS IN SYSTEM B
(TONNES/HA - DRYSTALK PADDY)

SOURCE	YEAR/SEASON		POLONNARUWA DISTRICT[1]			BATTICALOA DISTRICT[1]		
			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
		Yala	4.0	2.3	n.a	2.7	2.6	2.0
2)	1979	Yala	4.9 ± 0.23	2.7 ± 0.15	-	-	-	-
3)	1979	Yala	4.5 ± 0.31	-	-	-	-	-

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

Sources :

(A) Reprocessed data/Simple five-year average for 1973/74 - 1977/78 inclusive. Data imcomplete. Department of Census and Statistics.

(B) 20 random fields under major schemes; 28 random fields under minor schemes, mean ± standard error. Department of Census and Statistics.

(C) Acres International Ltd., Pimburettewa Scheme, 19 randomly selected fields, mean ± standard error.

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 rice 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 semi-dwarfs 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, while the use of weedicide is generally limited to 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.

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 31,900 ha

TABLE 6-4

CULTURAL PRACTICES IN THE PROJECT AREA 1977/78
(PERCENT OF FIELDS)

PRACTICE	POLONNARUWA DISTRICT		BATTICALOA DISTRICT	
	YALA 77	MAHA 77/78	YALA 77	MAHA 78
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.

which is suitable for the double-cropping of rice. By contrast, the net area of irrigable uplands available for arable cropping is only some 5,500 ha. Clearly, the Maduru Oya Project should be considered to be a predominantly rice project. The subdivision of the 31,900 ha of rice soils into land classes and soil categories is as follows :

Land Class	Great Soil Group and Dominant (Soil Series)	Extent (ha)
1 R	Old Alluvials - Moogammana Ela Alluvials - Timbiri Aru, Odigar Villu Low Humic Gleys - Kuda Oya, Damminewela Reddish Brown Earths - Alawakumbura, Padimunda Kulam and Horaborawewa	13,720
2 R	Old Alluvials - Ulpothawewa Non Calcic Brown Soils - Boattewewa Low Humic Gleys - Mailadeniya	18,170
TOTAL	.. .. ..	31,890

There is a possibility of substituting upland crops for paddy in the Yala season on the imperfectly drained Reddish Brown Earths midway down the catena, i.e. on the Alawakumbura, Padimunda 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 and the more attractive financial return under anticipated price levels.

6.2.2 Lowland Rice 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 - 4.5 months) in Maha and BG 34-8 (3 - 3.5 months) in Yala. In the flood plains, BG 34-8 should be sown in both the Maha and Yala seasons due to the need to shorten the growing season.

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 :

145

(1) Continuous submergence - involving the maintenance of a 50 - 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.

(2) 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 Illupalama) 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 ton/ha). With the adequate water supply that the proposed project ensures, transplanting should completely replace broadcasting in System B. Judicious nursery fertilisation will ensure that seedlings are neither chlorotic nor stunted at transplanting time, about three weeks after sowing.

Fertilizer and Chemicals

The recommended fertilizer and chemical application rates for selected crops are summarised in Table 6-5.

With respect to rice, 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 semi-dwarf 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.

TABLE 6-3

PHYSICAL CROP INPUTS (PER HECTARE)

	RICE	GROUNDNUTS(MATA)	SOYBEANS(TALA)	TOBACCO(TALA)	COTTON(TALA)	SUGARCANE(PLANT CANE)
Seed	52 kg	96 kg	68 kg	15,000 seedlings	34 kg	6 tonnes
Seed Treatment	-	-	0.35 kg[5]	-	-	-
Fertilizer						
- Urea	215 kg	90 kg	62 kg	112 kg	125 kg	135 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] 226 ml[12]	1 kg[3]	0.7 litre[6]	1.1 litre[7]	10 kg[9] 5.6 litres[6]	
	23 kg[2]	2.25 kg[4]	1.5 kg[4]	-	-	0.6 kg[10]
	-	-	-	2 kg[8]	-	-
Labour						
- Land preparation + planting	65 m/d	20 m/d	30 m/d	122 m/d	30 m/d	50 m/d
- Maintenance	37 m/d	29 m/d	41 m/d	57 m/d	77 m/d	35 m/d
- Harvesting, transport etc.	73 m/d	64 m/d	63 m/d	123 m/d	30 m/d	75 m/d
Farm Power						
- Buffalo Pair-Days	36 pair days	-	-	-	-	-
- 2 wheel tractor hours	-	30 hours	30 hours	-	30 hours	-
- 4 wheel tractor	-	-	-	-	-	70 hours

Notes :

1 - BHC 10% Dust
2 - Saturn 56
3 - Tamaron
4 - Linuron
5 - Rhizobium inoculum
6 - Monocrotophos 60% SC
7 - Thiodan
8 - Ferenox
9 - Carbaryl
10 - Paraquat
11 - Furadan
12 - Dimethoate 40% SC

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 a potential yield of 7.2 tonnes per hectare.

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.

Given the input package recommended above, and recognising the magnitude of the proposed project, it is estimated that the following average rice yields can be obtained on a project-wide basis.

	Maha	Yala
Land Class 1R	4.4 t/ha	4.6 t/ha
Land Class 2R	3.6 t/ha	3.8 t/ha

The following higher yields are presented as also being practically attainable, given better farm management conditions. They are suggested for use in sensitivity tests in the economic analyses.

	Maha	Yala
Land Class 1R	4.9 t/ha	5.1 t/ha
Land Class 2R	4.0 t/ha	4.2 t/ha

6.2.2.3 Cropping Patterns

If the above recommendations are followed for the lowlands, double cropping with rice 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 three weeks earlier. The sequence illustrated in the cropping calendar in Figure 14 is identical with that now practised in most System B lowlands.

Transplanting in the flood plains 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 flood plains are given in Table 6-6. Water for land preparation during a 15 day period has been estimated by Joshua[11] at approximately 180 mm and this estimate has been employed in the present calculations.

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 recognised by adopting a higher deep percolation rate for the Class 2 paddy soils.

TABLE 6-6

CROP WATER REQUIREMENTS FOR THE LOWLANDS AND FLOOD PLAINS (mm)

		J	F	M	A	M	J	J	A	S	O	N	I
					Lowlands: Paddy (135 d)/ Paddy(105 d)								
ET paddy-Maha		149	109	23							81	135	12
ET paddy-Yala					84	211	228	165	31				
Land preparation				60	120					60	120		
Percolation Loss	1R	150	125	50	125	150	150	125	25	25	125	150	15
	2R	300	250	100	250	300	300	250	50	50	250	300	30
Field Water Requirements	1R	299	234	133	329	361	378	290	56	85	326	285	27
	2R	449	359	183	454	511	528	415	81	110	451	435	42
					Flood Plains; Paddy (105 d)/ Paddy(105 d)								
ET paddy-Meda			72	182	162	66							
ET paddy-Yala							89	217	222	94			
Land preparation		60	120			40	120	20					
Percolation	1R	25	125	150	142	42	108	150	150	75			
	2R	50	250	300	284	84	217	300	300	150			
Field Water Requirements	1R	85	317	332	304	148	317	387	372	169			
	2R	110	442	482	446	190	425	537	522	244			

6.2.3 Upland Crops

The net area available for irrigated upland cropping is about 5,500 hectares, less than 15 % 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

Sugar Cane

The upland Reddish Brown Earth soils found in System B are suitable for the cultivation of irrigated sugar cane. A plant crop plus three ratoons should be possible and, with good management, an average yield of 67 tonnes of cane/ha 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 sugar cane area of at least 800 hectares. 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 soy beans or groundnuts. Cotton can only be grown in the Yala season under irrigation. The heavy Maha rains rule cotton out 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 specialised agronomic, entomological and credit requirements of intensive cotton cultivation. With good management, a yield of 1.7 tons/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, it is not recommended for inclusion in the cropping pattern for purposes of economic benefit calculations, however.

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 specialised farm management techniques. A yield of 1.2 tons of cured leaf/ha 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 inter-crops, particularly with maize and sugar cane.

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 1.7 tonnes/ha can be expected for groundnuts and pulses and 1.6 tonnes/ha for soybeans.

Kenaf and Sunhemp

Much research has been concentrated on the agronomy of these two fibre crops at Maha Illuppalama and experience of their cultivation under rainfed conditions is available within System B. Diseases are not serious problems with kenaf, but sunhemp is susceptible to wilt and rust. Sunhemp is a good green manure crop, particularly when grown in rotation with tobacco. Potential yields in terms of fibre are 1.9 tonnes/ha for kenaf and 0.5 tonnes/ha for sunhemp.

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 days)	Tobacco (140 days)
Soybeans (105 days)	Chillies(160 days)Onions(90 days)
Vegetables (90 to 120 days)	Cowpea (75 days)
Maize (120 days)	Pulses (60 - 75 days)
Groundnuts (110 days)	Cotton (150 days)
Groundnuts (110 days)	Soybeans (105 days)

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 "index" 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 14.

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 (Joshua[11]). Percolation and other losses on upland soils have been incorporated into the farm and distribution efficiency factors.

---

* 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 (110d)/COTTON (150d)											
	J	F	M	A	M	J	J	A	S	O	N	D
ET Groundnuts	107	34								35	61	102
ET Cotton			34	116	110	261	182	75				
Land preparation			75							75		
Gross Field Water Requirements	107	34	109	116	110	261	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.

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 hectares and will include all four series of the Non Calcic Brown Soil Group.

The farm will provide an opportunity for experimentation on this soil group, which covers over 30 per cent of the overall project area. Research on other soil series can be carried out, where needed, on outlying farms.

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

The activities of this farm are expected to include a research programme 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 ; and
- 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 practises. 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 non-irrigable uplands in System B, and further considering the overall land use balance for the area, 0.5 hectare homesteads are proposed for all farmer settlers in System B. For irrigated upland farmers, it is proposed to locate the homestead adjacent to each 1.5 hectare 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 hectare of paddy land.

The relatively large 0.5 hectare homestead plot is required to support three basic activities :

- residence ;
- food crop production ; and
- livestock production.

The "living space" and the land required for multi-purpose cattle will require slightly over one-third of 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 20 per cent of which would enter the local market, the balance being consumed at home. Most of this area would be allocated to maize, cassava, fruit trees, and pulses. The homestead area can also support some scavenger livestock, such as poultry, swine, goats, or sheep.

The concept of a 0.5 hectare 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.

6.2.6 Livestock

Based on 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 non-irrigated uplands.
- Development of private herds on public grazing land.

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

Murrah Buffalo, for Draft Animals,
Milk and Surplus Stock

Cross bred (Murrah) buffalo cows could be bred to supply draft bulls. These cows would be zero grazed (cut and carry) on a rain-fed 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 8,000 buffalo cows would be required to generate eventually 27,000 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 2½ years of age, and in calf, before distribution to settlers.

Zebu/Temporate Cattle,
for Supplementary Meat and Milk

Cross bred Zebu/Temporate 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 dryland 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, A.M.Z., and Jersey semen. Alternatively, they could be purchased from improved private herds already in existence . These heifers should be in calf and about two years 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 should 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 licenses might also be required.

The grazing capacity of public lands is expected to be about one cow equivalent for every two hectares of pasture.

Co-operation with the NLDB would initially be necessary to increase the supply of breeding stock in the project area.

All proposed livestock programmes 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 co-operatives.

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 labour 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/ annum.

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% 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 25,000 ha will be cleared for development. In settlement areas more selective clearing practises 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 already are active on over 25 % 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 fuelwood and building materials. Yields and total quantities are summarised as follows :

- Commercial timber (5 m^3/ha) 125,000 m^3
- Poles and posts (200/ ha, each 2.4m) 12 x 10^6 linear m
- Firewood (14 m^3/ha) 350,000 m^3

To ensure future availability of forest products, particularly fuelwood, 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 reforestation programs will be essential.

Reforestation of 7,500 ha is proposed as an initial program. One hectare of reforestation with eucalyptus can be expected to yield 85 m^3 by year 15 and a further 64 m^3 by year 30. A plantation of 7,500 ha will yield about one million m^3 of forest products.

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 subsidised, 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 which are expressed in 1979 constant currency[12]. 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 below.

Agricultural project benefits accrue to the project from several areas. These include new areas under irrigation, augmentation of the area cropped in 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 project" basis and a "with 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 and macro-economic implications of the project.

TABLE 7-1

RANKING OF PROFIT POTENTIAL

PRODUCT	MARKET POTENTIAL DOM. (1)	MARKET POTENTIAL INT. (2)	AGRONOMIC CONSIDERATIONS (3)	ENVIRON. CONSIDERATIONS (4)	FIRM MANAGEMENT (5)	PUBLIC SUPPORT (6)	FINANCIAL PROFIT (7)	ECON. PROFIT (8)	AGGREGATE RANKING (9)	CURRENT RECOMMENDATION
Rice	[10]	8	9	9	[10]	8	4	8	8	Maximum Extent Possible
Groundnuts	5	7	9	8	7	7	[6]	6	7	Serious consideration on Uplands
Soybeans	4	7	9	9	7	7	[6]	6	7	
Tobacco	4	9	4	8	6	[9]	7	9	7	
Cotton	10	2	[5]	9	[5]	6	6	7	6	Possibility on Uplands
Sugarcane	10	1	7	4	[6]	[4]	5	[8]	5	Not recommended
Fibres	5	3	7	6	4	4	[3]	3	5	
Dale	[3]	1	9	9	9	9	3	4	6	Supply regional/local mkt + self-sufficiency
Vegetables	[3]	1	8	8	9	9	10	9	7	
Cassava	7	3	5	5	6	7	[3]	4	5	Not recommended
Maize	5	1	5	7	7	7	[3]	3	5	
Sorghum	5	1	5	7	7	7	[3]	3	5	
Fruits	[5]	4	5	5	7	7	7	5	6	Supply regional/local mkt + self-sufficiency
Dairy/Beef	[4]	1	6	5	5	6	7	5	6	Potential with livestock-crop integration
Other Livestock	[5]	2	6	5	7	6	7	5	6	

[ ] - 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 + extension support
7) Farmer profitability
8) Returns to national economy
9) Simple average of ordinal rankings

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 Programme 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 the crop to insects, diseases, etc.

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

TABLE 7-2

SUMMARY OF FINANCIAL (ECONOMIC) PRICES

	ITEM	FINANCIAL (ECONOMIC) PRICE[1]
Fertilizer	- Urea	Rs. 980/ tonne (Rs. 3899/tonne)
	- TSP	Rs. 1335/ tonne (Rs. 4145/tonne)
	- Muriate of Potash	Rs. 1065/ tonne (Rs. 2649/tonne)
	- Sulphate of Potash	Rs. 1420/ tonne (Rs. 3532/tonne)
Crop Protection Chemicals	- Monocrotophos	Rs. 189/ litre
	- Diomethoate	Rs. 11/113 ml.
	- Thiodan	Rs. 87/ litre
	- BHC 10% Dust	Rs. 4.40/kg
	- Saturn 6% G	Rs. 8/kg
	- Linuron	Rs. 40/kg
	- Furodan	Rs. 12/kg
	- Peranox	Rs. 23/kg
Farm power	- 2 wheel tractor	Rs. 20/hour (Rs.24.70/hour)
	- Pair of buffalo	Rs. 50/day
Farm Labour	- Hired	Rs. 16/day (Rs. 6/day)
	- On-farm	Rs. - (Rs. 6/day)
Agriculture Produce	- Paddy	Rs. 1900/tonne (Rs. 3500/ tonne)
	- Soybeans	Rs. 5100/tonne
	- Groundnuts	Rs. 5600/tonne
	- Pulses	Rs. 5300/tonne
	- Maize	Rs. 2000/tonne
	- Chillies	Rs.19,000/tonne
	- Cassava	Rs. 500/tonne
	- Vegetables	Rs. 1000/tonne
	- Bananas	Rs. 11/bunch
Livestock Products	- Milk	Rs. 1.31/litre (Rs. 2.21/litre)
	- Beef culls	Rs. 3.30/kg Live Weight (L.W.)
	- Beef Heifers	Rs. 6.60/kg L.W.
Forest Products	- Commercial Timber	Rs. 140/m^3
	- Firewood	Rs. 10.60/m^3
	- Poles and Posts	Rs. 3.00/each
Fish	- Tilapia	Rs. 4/kg

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

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 deducing 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 labour 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 produced 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.

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, may override the aggregate assessment. The reader is cautioned that the indicator is relative only and is based on an assessment of eight factors, each of which is extremely difficult to reduce to an ordinal 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.

The major areas where economic and financial prices differ are for fertiliser inputs and for paddy. At present, the cost of fertiliser to the farmer is heavily subsidised by the government, which provides fertiliser 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 world market price. One result of these differences is an economic return from paddy production which varies considerably from its financial return.

170

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 project" situation as well as the "with project" situation so that net benefits for the project can be determined.

Without Project

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

The economic return from paddy production is assumed to be similar to the return for the "with project" situation with comparable yields (see Table 7-4). Table 7-3 summarises the area cropped, the yields achieved in each season and estimated current economic returns per annum. The areas are taken from the present land use estimates.

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 project" situation, where net returns are assumed to remain unchanged once the target yields have been achieved.

TABLE 7-3

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

AREA	NET IRRIGABLE AREA(HA.)[1] MAHA	YALA	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

1. Areas estimated by referring to the map of present land use (Fig.4) and official statistics.

2. Estimated Crop cutting experiments by the consultants in Yala 1979 indicated yields of over 4.4tons/ha, but this figure was adopted to be consistent with "with Project" assumptions.

3. Latest 5 year "mean" - DCS - Batticaloa District Major Tanks.

4. Latest 5 year "mean" Polonnaruwa + Batticaloa Districts - Minor Tanks. DCS

5. Latest 5 year "mean" Polonnaruwa + Batticaloa Districts - Rainfed.DCS.

AB : 7-4

T CTED ECONOMIC CROP BUDGET SUMMARY
A PER HECTARE)

	RICE (MAHA)		RICE (YALA)		GROUNDNUTS(MAHA)		SOYBEANS(YALA)	
	1R	2R	1R	2R	1U	2U	1U	2U
;et Yield (t/ha)	4.4	3.6	4.6	3.8	1.7	1.5	2.0	1.6
onomic Price (Rs/t)	3467	3467	3467	3467	5572	5572	5143	5143
Gross Value of Production (Rs)	15255	12481	15948	13175	9472	8358	10286	8229
st of Production:(Rs)								
Fertilizer	1281	1281	1281	1281	1028	1028	882	882
op Protection	399	399	399	399	156	156	192	192
Farm Power	1800	1800	1800	1800	741	741	741	741
bour	1050	1050	1050	1050	678	678	774	774
Miscellaneous (seeds, bags etc.)	863	863	863	863	1045	1045	836	836
Total Cost of Production	5393	5393	5393	5393	3648	3648	3425	3425
t Value of Production/Crop(A-B)	9862	7088	10555	7782	5824	4710	6861	4804
t Value Year 1	5917	4253	6333	4669	3494	2826	4117	2882
2	6903	4962	7389	5447	3786	3062	4460	3123
3	7890	5670	8444	6226	4077	3297	4803	3363
4	8876	6379	9500	7004	4368	3533	5146	3603
5	9862	7088	10555	7782	4950	4004	5832	4083
6	9862	7088	10555	7782	5242	4239	6175	4324
7	9862	7088	10555	7782	5533	4475	6518	4564
8 - 00	9862	7088	10555	7782	5824	4710	6861	4804

173

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

With 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 about 10% of the total projected area under irrigated agriculture in System B. Chapter 6 has detailed those crops which can be grown successfully from an agronomic point of view on the upland soils. However, since 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 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 rice production in new areas have been calculated on the basis of rice yields (tonnes/ha) as follows :

	Maha	Yala
Land Class 1R	4.4	4.6
Land Class 2R	4.0	4.2

174

Maximum economic returns are not achieved in the first year of agricultural production. For paddy, a 5 year development period is used, while for upland crops, an 8 year development period is anticipated. Each begins with 60% 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 levelling of the land, water stress due to start-up problems with the delivery system, shortage of inputs, etc. The economic return for one hectare 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 rice prices or higher production costs. To calculate the annual economic return from each one hectare farm, a cropping intensity of 98% in Maha and 90% in Yala is used. This return is further reduced by 5% to account for bunds and other minor land losses on each farm.

Chapter 4 details the net irrigable areas which can be allocated to farms. Two development scenarios are considered and Table 7-5 indicates the rates at which different sectors and land classes in each sector come into production. The figures may differ slightly from those presented in other parts of the report but equal annual divisions of various soil classes in each phase have been assumed for calculation purposes. 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.

175

'ABLE 7-5

'ITIAL AGRICULTURAL PRODUCTION
1000 HECTARES)

SCENARIO A

SECTOR/LAND CLASS	1983 M	1983 Y	1984 M	1984 Y	1985 M	1985 Y	1986 M	1986 Y
Sector 1 - IR		2.55	2.55					
- 2R		2.15	2.15					
- 1U+2U					1.05			
;ector 2 - 1R				2.48	2.48			
- 2R				3.45	3.45			
- 1U+2U							1.80	
Sector 3 - 1R						1.83	1.83	
- 2R						3.49	3.49	
- 1U+2U								1.28

SCENARIO B

SECTOR/LAND CLASS	1983 Y	1984 M	1984 Y	1985 M	1985 Y	1986 M	1986 Y	1987 M	1987 Y	1988 M	1988 Y	1989 M	1989 Y
tor 1 - 1R	1.275	1.275	1.275	1.275									
- 2R	1.075	1.075	1.075	1.075									
- 1U+2U					.525	.525							
Sector 2 - 1R soil					1.250	1.250	1.250	1.250					
- 2R soil					1.725	1.725	1.725	1.725					
- 1U+2U									.900	.900			
;ector 3 - 1R soil									.910	.910	.910	.910	
- 2R soil									1.740	1.740	1.740	1.740	
- 1U+2U												.638	.638

Note : The Upland areas shown above do not include homestead allocation for Upland farms (1375 ha).

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 Yala 1983 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 (t/ha)	
		Maha	Yala
Pimburettewa	1,660	4.4	4.6
Vakaneri/Punanai	3,530	3.8*	4.0*

For Pimburettewa, Vakaneri and Punanai schemes, a similar five-year build-up from present yield levels to the above levels is assumed.

Using the areas in Table 7-5 and returns shown in Table 7-4, net economic returns from irrigated crop production in the "with project" situation are calculated and summarised in Table 7-6. Returns from small tank areas and rainfed rice 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.6,000 per productive hectare

---

* Weighted average of 25% R1 soil and 75% R2 soil.

TABLE 7-6

NET ECONOMIC RETURNS FROM IRRIGATED CROP PRODUCTION
(WITH PROJECT, MILLION RUPEES)

		SCENARIO A					SCENARIO B				
	YEAR	A	B	C	D	E	A	B	C	D	E
Year 1	(1980)	38	-	-	41	79	38	-	-	41	79
2		38	-	-	41	79	38	-	-	41	79
3		34	-	-	41	75	34	-	-	41	75
4		26	-	22	62	110	30	-	11	62	103
5		6	-	124	71	201	26	-	59	71	156
6		-	5	254	76	335	20	1	118	76	215
7		-	19	368	80	467	6	6	193	80	285
8		-	23	417	85	525	-	8	275	85	368
9		-	26	459	87	572	-	16	356	87	459
10		-	27	483	87	597	-	22	425	87	534
11		-	30	490	87	607	-	27	455	87	569
12		-	32	490	87	609	-	28	476	87	591
13		-	34	490	87	611	-	29	488	87	604
14		-	35	490	87	612	-	32	490	87	609
15		-	35	490	87	612	-	33	490	87	610
16		-	35	490	87	612	-	34	490	87	611
17		-	35	490	87	612	-	35	490	87	612

A - Small Tanks, Rainfed Areas

B - Upland Crops

C - New Areas (includes areas previously included under Category 'A' when additional irrigation water available)

D - Pimburettewa, Vakaneri, Punanai Schemes

E - Total

per annum. This is an implicit economic value for homestead production, irrespective of its final destination.

It is anticipated that a total of one-half hectare of land will be allocated for each homestead, but this land must also be used for a house and "living space". The potential cultivated area is therefore about 0.4 hectares. In turn, the 0.4 hectares must be allocated to livestock as well as food crops. The area deducted for "living space" and livestock is approximately 20 per cent and 17 per cent respectively. This reduces the effective homestead food crop revenue to :

Rs.6000 x .5 x .63 = Rs.1,900 / Yr./ family

Total benefits would be realised in either four or seven 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 was evaluated to determine the economic contribution of such a programme to total project benefits from agriculture. These buffalo would supply irrigation draft power and supplement farm incomes with milk and surplus stock disposal.

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 27,000 head. In total, about 8,000 buffalo cows would be assigned to approximately one out of every four settlers at the time of their arrival in the project area.

TABLE 7-7

PROJECTED HOMESTEAD BENEFITS FROM FOODCROPS
SCENARIO A

YEAR	CULTIVATED AREA[1] (1)	LIVESTOCK AREA[2] (2)	NET AREA[3] (3)	NET BENEFITS[4] (RS.MILLION) (4)
1	1,717	395	1,322	7.9
2	5,627	1,293	4,334	26.0
3	9,974	2,233	7,741	46.4
4	12,660	2,679	9,981	59.9

SCENARIO B

YEAR	CULTIVATED AREA[1] (1)	LIVESTOCK AREA[2] (2)	NET AREA[3] (3)	NET BENEFITS[4] (RS.MILLION) (4)
1	840	197	643	3.9
2	2,521	579	1,942	11.7
3	4,658	1,041	3,617	21.7
4	6,978	1,545	5,433	32.6
5	9,207	2,007	7,200	43.2
6	11,326	2,443	8,883	53.3
7	12,660	2,679	9,981	59.9

1. Number of new settlers X 0.4. New settler total is approx. 34,650-3,000 = 31,650.

2. Cumulative beef cow total divided by three. The rate at which multi-purpose beef cows are introduced into the project area is directly dependent on incremental settlement rates. A total of 8036 cows are required at project maturity (to obtain 27000 draft animals), each of which (with followers, excluding draft animals) requires 1/3 hectare, i.e. 2679 hectares. For further details, see Section 7.3.3 and Annex F.

3. Column (1) - Column (2).

4. Column (3) x Rs. 6,000 per hectare.

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 ; and
- 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 27,000 draft animals can eventually be generated.

The budget is summarised 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 sub-program were compil 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/annum was added as an additional net benefit via existing draft animals which will subsequently be used for two crops per year instead of one. 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 hectares of reservoir area as follows :

Maduru Oya Reservoir	3,900 ha
Pimburettewa Tank	580 ha
Vakaneri Tank	240 ha
Various Small Tanks	280 ha
Total	5,000 ha

TABLE 7-8

ANNUAL BUDGET FOR 1000 MURRAH BUFFALO COWS
(MILLION RUPEES)

YEAR	GROSS REVENUE (1)	TOTAL COSTS (2)	NET REVENUE (3)
1	1124	6511	(5387)
2	1124	603	521
3	1349	603	746
4	1679	603	1076
5	2003	603	1400
6	2321	603	1718
7	2632	603	2029
8	2938	603	2335
9	3240	603	2637
10	3533	603	2930
11	3929	603	3326
12	4211	603	3608
13	4486	603	3883
14-40	4846	603	4243

TABLE 7-9

ANNUAL BUFFALO COW PURCHASES DURING
PROJECT IMPLEMENTATION[1]

YEAR	SCENARIO A	SCENARIO B
1	1184	580
2	2695	1158
3	2821	1385
4	1336	1512
5	-	1385
6	-	1310
7	-	706
	8036	8036

1. Total allocated according to irrigation settlement rates.

TABLE 7-10

POTENTIAL LIVESTOCK BENEFITS WITH PROJECT
(MILLION RUPEES)

YEAR	SCENARIO A	SCENARIO B
1	(4.1)	(0.9)
2	(11.7)	(3.7)
3	(10.7)	(4.2)
4	(0.2)	(3.7)
5	9.6	(1.3)
6	12.1	1.1
7	14.7	6.9
8	17.2	13.3
9	19.7	15.8
10	22.1	18.3
11	24.6	20.8
12	27.3	23.3
13	29.9	25.9
14	32.4	28.4
15	34.5	30.8
16	35.9	32.8
17	36.3	34.4
18	36.3	35.4
19	36.3	36.1
20	36.3	36.3

With a yield of 150 kg/ha/year and a price of Rs.4/kg, the net economic return to the project is Rs. 2 million per annum. 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	(1)
2	(1)
3	(1)
4	1
5	1
6 - 00	2

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

At full development, the fisheries activity will yield 750,000 kg/annum, 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.

TABLE 7-11

FISHERIES ECONOMIC BENEFITS

Yield	150 kg/ha
Price	Rs. 4/kg
Gross Return	Rs. 600/ha
Recurring Costs	Rs. 75/ha
Labour Costs	Rs. 96/ha
Net economic Return	Rs. 429/ha
Annual Economic Return for Project at Full Development	Rs. 2 million

7.3.5 Forestry

Two types of forestry benefits have been identified :

- benefits from clearing forest
- benefits from reforestation

Benefits from Clearing Forest

As a basis for the clearing estimates it has been considered that the equivalent of 25,000 ha of medium forest would be cleared. Four classes of clearing benefits have been identified.

- Commercial timber
  The medium forest is estimated to yield some 5.1 m^3 per ha. The value of this wood resource is taken at Rs.140 per m^3. The area to be cleared would yield 130,000 m^3 with a resultant value of Rs.18 million.

- Poles and posts
  The yield per ha is expected to be some 200 poles and posts of average length of 2.4 m and average diameter of 5 cm. The value has been set at Rs.3 per post or pole, for a total of Rs.600 per ha and a total benefit of Rs.15 million.

- Firewood
  Some 14 m^3 of firewood can be extracted per ha. The economic value of firewood has been set at Rs.10.6 per m^3 for a production per ha of Rs.150 and a total benefit of Rs.4 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 per 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.

The total clearing benefits for 25,000 ha are as follows :

Commercial timber	Rs. 18 million
Poles and Posts	Rs. 15 million
Firewood	Rs. 4 million
Reduction in clearing cost	Rs. 13 million
Total	Rs. 50 million

Benefits of Rs.50 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

Reforestation in either plantation or intensification form is proposed for 7,500 ha. The species proposed is eucalyptus, with sawlogs and fuelwood the main products. Cost of reforestation is estimated at Rs.875/ha, resulting in a total cost of Rs.6.6 million. Forestry benefits would result from two cuttings* - the first in Year 15

---

* These assumptions have been made for simplicity in preparing a cash-flow summary. In practice, forestry benefits can be expected to be more evenly distributed over the life of the project.

187

with a yield of 85 m^3/ha and the second in Year 30 with a yield of 64 m^3/ha. Valued at Rs.350/m^3 ft. total forestry benefits are Rs.395 million over the project analysis period. In Scenario A, initial planting is spread over 5 years while in Scenario B, it is spread over 8 years.

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 - year cash flow considerations are usually ignored.

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

TABLE 7-12

NET CASH FLOW - FORESTRY

YEAR	SCENARIO A	SCENARIO B
1	-	-
2	10.	7
3	9	5
4	9	5
5	9	5
6	9	5
7	(1)	5
8	0	5
9	0	6
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	45	30
19	45	30
20	45	30
21	45	30
22	45	30
23	0	30
24	0	30
25	0	15
26-32	0	0
33	34	22
34	34	22
35	34	22
36	34	22
37	34	22
38	0	22
39	0	22
40	0	11

An annual farm budget* has therefore been prepared to anticipate actual farm conditions on two principal farm types considered here, as summarized in Table 7-13. This table indicates the net cash flow from crop production, as well as the projected net cash flow position of the farm family after a minimum monthly cost-of-living allowance has been deducted from the crop cash flow. The cost-of-living allowance is estimated at Rs.500 per month, less the value of food generated by homestead production (Rs.160/month) and (if applicable) rice (Rs.125/month) and livestock production (Rs.45/month). The estimate for August can be interpreted as his cash balance at the end of one crop year.

The relevant annual disposable income estimates are :

Paddy farmer (with buffalo)	1 ha	= Rs.8,400
Upland farmer	1.5 ha	= Rs.10,200

Table 7-13 also shows that when an adjustment is made for the value of home production, the remaining disposable income for both farm types is very similar.

7.4.2 Implications for Farmers

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

(1) It is highly desirable that the paddy farmer have his own draft buffalo. Buffalo ownership reduces his farm costs by 25 - 30 per cent <u>and</u> reduces his cash food outlay considerably. The saving is about

---

* Based on <u>existing</u> (1979) prices for inputs and paddy.

TABLE 7-13

FINANCIAL FARM CASH FLOW PROJECTIONS
AT PROJECT MATURITY
(RS)

	PADDY FARMER(WITH DRAFT)		UPLAND FARMER	
MONTH	CUMULATIVE FARM CASH FLOW	CUMULATIVE FAMILY CASH FLOW AFTER B.C.L.	CUMULATIVE FARM CASH FLOW	CUMULATIVE FAMILY CASH FLOW AFTER B.C.
Sept.	(800)	(970)	(1990)	(2330)
Oct.	(1170)	(1510)	(2575)	(3255)
Nov.	(1615)	(2125)	(2855)	(3875)
Dec.	(1655)	(2335)	(2895)	(4355)
Jan.	(1645)	(4240)	5500	3800
Feb.	4215	3195	5460	3420
March	3495	2305	5420	3040
April	3160	1800	3485	765
May	2750	1220	2870	(190)
June	2710	1010	2830	(570)
July	2525	655	2760	(980)
Aug.	8390	6350	10205	6125

Cumulative Farm Cash Flow = Net sales-less Costs of production. Sales exclude home consumption.

Cumulative Family Cash Flow = Cumulative Farm Cash Flow -less Basic Cost of Living (B.C.

Basic Cost of Living (B.C.L.) = Rs.500/mo.less homestead production (Rs.160/mo.), and (for paddy farmers) rice (Rs. 125/mo.) and livestock (Rs. 45/mo.)

Paddy Farmer = 43% R1 soil and 57% R2 soil.

Upland Farm Revenue = 75% of total projection, a risk index.

Rs.2,000 per annum, which is particularly beneficial just prior to harvest 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.

(2) 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.1,900 per annum, the ramifications of which are similar to that of buffalo ownership. This financial benefit also far exceeds the economic importance of homesteads to the project as a whole.

(3) Even with (1) and (2) above, the first few years may be difficult. For example if a farmer only obtains a yield of 60 per cent of that expected, the family disposable income level after basic necessities are secured would be approximately as follows :

Paddy Farmer	Rs.(100)
Upland Farmer	Rs.(600)

This reemphasises the need for good support services, particularly in the early years of project development, as discussed in Section 7.5 and in Chapter 8 following.

(4) The commercial character of the entire farm operation must be appreciated. Economic inter-dependence with the non-farm 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.

To pay out-of-pocket farm expenses alone, the following yields are required :

Paddy farmers,	w/o draft	2.9 tons
	with draft	1.9 tons
Upland farmers	- Groundnuts	0.6 tons
	- Soy beans	0.7 tons

(5) It might be suggested that farmers should eventually contribute to the operation and maintenance costs of the system. The issue is dependent upon what farm standard-of-living is acceptable to policy-makers. For illustrative purposes, however, consideration can be given to a water rate which is based on 10 per cent of the annual value of total crop production. If Rs.4,000/year is allowed for consumption and investment over-and-above the farmers' basic cost of living, the following figures emerge :

	Hypothetical Fee (Rs.)	Farm Liquidity (Rs.)	Repayment Capacity
Paddy Farmers	1,200	2,400	Yes
Upland Farmers	1,700	2,100	Yes

This suggests that after lowland farmers have their own farm power, all farmers have their own homestead production, and projected yields have been obtained, a water "tax" of this magnitude is potentially feasible.

(6) 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

Section 6.2 and 7.3 have both emphasised 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 labour, (b) farm power, (c) other farm inputs, (d) farm credit and (e) product markets. For illustrative purposes, only Scenario A is considered in the calculations which follow. All values are expressed in terms of mid-1979 Rupees and must be taken as being order of magnitude only. They are generally indicative of levels of input but cannot be used for purposes of detailed planning.

(a) Farm Labour

All farm labour 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 labour is inadequate and hired labour is required. This occurs during planting and, to

a lesser extent, during harvest. Labour requirements are particularly acute during the transplanting of rice, a highly desirable agronomic practice. If off-farm labour 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 labour shortages, particularly during the initial years of project development. The peak number off-farm labourers will be as much as one labourer per 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 Chapter 6 and 7.3.3 above). However, even with full implementation of this livestock programme, a farm power shortage could occur for at least three reasons :

- a delay because of the buffalo build-up period ;
- upland tractor requirements ; and
- 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. The number of

tractors which will have to be purchased is approximately as follows :

Period	Two Wheel	Four Wheel
Years 1 - 4	5,400	1,100
Years 5 - 9	3,900	150
Years 10 - 14	1,200	150
After Year 14	200/year	20/year

The tractors could be supplied to farmers via government tractor pools, co-operative ownership, or private ownership. Again, adequate credit and service facilities will be required.

(c) Other Farm Inputs

The timely provision of adequate farm supplies (especially fertiliser and chemicals) is also mandatory. Again, the general magnitude of this project area requirement per season is instructive.

Year	Fertiliser (tonnes)
1	1,400
2	4,600
3	8,400
4 onwards	11,200

By year 4, about 4,400 - 5 ton truckloads would thus be required per annum, or about 20 truckloads per working day per year. In addition, since demand is seasonal, ten or more 10 m x 10 m storage facilities will be required.

196

(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 years) credit must be available for capital purchases, and short-term (6 month) production credit will be required twice yearly. Initial and recurring capital costs include buffalo, tractors, and farm tools.

Total farm credit requirements are expected to be approximately as follows :

Year	Intermediate Term	Short Term	Average per Farm
	Million Rupees		Rs.
1	32	14	9,790
2	80	40	8,180
3	110	83	7,000
4	86	107	5,420
5 - 9	34	107	3,965
10 - 14	23	107	3,655
15 onwards	21	107	3,600

These estimates are made in 1979 currency and must be escalated to account for inflation. The establishment of some 40 local credit facilities in the project area may be called for.

(e) Product Markets

A product market delivery system, with spot payments, is also required. Looking solely at rice, sales levels

after prospect implementation could reach 112,000 tonnes per season. This will require Paddy Marketing Board (PMB) purchasing centres, storage facilities, and mills as well as private and"quota" mills. Again comprehensive government planning and private incentives must precede full-scale development.

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 non-technical, 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 Chapter 4 that these phases will overlap to a considerable degree in the course of developing the farming area of the project.

The Government is considering various approaches to the administration of the project, in both the construction and operation phases. At the time of writing no clear policy has emerged. The purpose of this chapter is therefore to discuss the factors involved and to highlight those aspects which will require particular attention.

8.1 Construction Phase

The general organization envisaged for the construction of the irrigation works is shown on Figure 16.

8.1.1 Irrigation Works - Expatriate Contractors

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

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 subject 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 labour ; and
- 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 6 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 non-irrigation aspects -- environment, settlement planning, operations and maintenance, etc., may also be required.

8.1.2 Irrigation Works - Local Forces

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

On the assumption that MDB would have responsibility for the execution of this work, four approaches may be considered :

- direct labour, engaged by MDB ;
- "settler/workers", organized in small groups ; their activities would normally be confined to on-farm works.
- small local contractors ; and
- medium to large local contractors.

It is evident that, except where large local contractors are employed, a considerable amount of technical input would be required on the part of MDB. The following figures indicate the approximate number of technical personnel who will be required to design and supervise construction :

	Scenario A		Scenario B	
	Engineers	Technical Assts.	Engineers	Technical Assistants
Average number of persons per year	80	260	55	180
Number of persons in peak year	160	520	100	320
Total man years	540	1,800	540	1,800

While the H area will provide a proportion of these, additional engineers will have to be trained and engaged to meet the peak demand, which is expected to occur in 1983 or 1985, depending on the adopted schedule. The total cost of these technical services has been allowed for in the estimates presented in Chapter 4.

8.1.3 Non-Irrigation Infrastructure

Roads

The primary roads and bridges that are under consideration for financing by MDB may be designed with the assistance of expatriate consultants. The actual construction may or may not be carried out by expatriate contractors, depending on the type of contract, the construction standards adopted, and the availability of local contractors for this type of work. It would be important that the primary roads be handed over to the Department of Highways soon after construction, so that maintenance could be planned and executed as part of existing road maintenance programmes.

Access Roads

These roads are of a relatively low standard. Construction will be a matter of high priority to facilitate the design and survey work on the main and branch canal system. Contractors should be engaged by MDB to make an early start on the access road network.

Irrigation System Roads

An early transportation planning study should be undertaken to indicate which canal maintenance roads should be upgraded to function as important links in the area's road network. If this is done, the extra work required to widen and otherwise improve the roads can be incorporated into the canal construction contracts.

Link Roads

These roads would be constructed by medium size contractors under contract to MDB.

Settlement Roads

These roads can be constructed by local (medium and petty) contractors. Petty contractors could be groups of settlers working on roads in their settlement area, once the basic road has been completed.

Settlements

The construction of settlements, especially the small low-density communities, can be a comparatively simple matter. Of primary importance are the selection of appropriate locations, and the provision of adequate linkages to other centres. Once the settlement locations have been established, and the linking road network planned, the homesteads can be surveyed and internal roads laid out. After the farmer settlers have been allocated their homesteads, they can begin work on their homes and do some work on internal roads. For the smaller settlements, little outside construction labour will be required.

For the larger centres local contractors supervised by MDB will be engaged on the construction of social and project management infrastructure. The construction of schools, health centres, stores, offices, co-operatives, staff housing etc., should take place with construction labour engaged locally if possible. For the larger more specialised buildings, design and supervision should be passed to local architectural firms, to be engaged by MDB. The engagement of local architectural firms to undertake the planning, design, implementation and supervision of complete communities should also receive consideration. The larger communities in particular could benefit from such an approach.

Experimental-Demonstration Farm

The development of the Experimental-Demonstration Farm (a matter of first priority) should be handled by a special project implementation group. This group would consist of crop and extension experts, irrigation and drainage engineers, and administrators. While overall construction supervision would be an MDB responsibility, the advice of this special project group would be required at all stages.

8.1.4 Construction Labour Force

The approximate size of the construction labour force required to implement the Maduru Oya Project has been estimated for Implementation Scenarios A and B. Tables 8-1 and 8-2 present the results of these estimates in summarised form. Further details, particularly for the headworks and main canals, can be found in Annex D.

Labour requirements for the develcpment of System B should be examined in the context of simultaneous requirements for other development projects. The supply of labour for headworks and main canal construction should be adequate, and some of the work for the tertiary irrigation system and for the non-irrigation infrastructure can be carried out by settlers. However, it is doubtful that any more than one third of the tertiary system labour requirements can be met by settler/workers unless such workers are required to work for several years before being allowed to settle. If it is assumed that each settler contributes one man-year of construction labour, some 85,000 man-years would be required from contractors or from labour directly hired by MDB.

8.2 Operational Phase

The organizational structure and major areas of emphasis for water management and other services to farmers are considered in the following sections. The rationale for the development of cost estimates is outlined, and reference is made to tabulations of estimated cost presented elsewhere in the text.

TABLE 8-1

LABOUR REQUIREMENTS FOR DEVELOPMENT SCENARIO 'A'

CONSTRUCTION ACTIVITIES	PERIOD OF CONSTRUCTION	PEAK YEAR	NUMBER OF SKILLED AND UNSKILLED WORKERS PEAK YEAR LEVEL	AVG YEAR LEVEL	TOTAL MAN YEARS
Dam & Tunnel[1]	1980 - 82	1981	1,600	1,000	3,000
Main & Branch Canals[1]	1981 - 85	1983	1,500	1,000	5,000
Tertiary Irrigation System[2]	1981 - 86	1983	36,000	24,000	120,000
Non-Irrigation Infrastructure	1980 - 86	1983	2,500	1,700	12,000
Overall Project	1980 - 86	1983	40,000	20,000[3]	140,000

1. Assuming machine-intensive construction by International Contractors.

2. Assuming labour-intensive construction methods.

3. Average over seven years.

TABLE 8-2

LABOUR REQUIREMENTS FOR DEVELOPMENT SCENARIO 'B'

CONSTRUCTION ACTIVITIES	PERIOD OF CONSTRUCTION	PEAK YEAR	NUMBER OF SKILLED AND UNSKILLED WORKERS		TOTAL MAN-YEARS
			PEAK YEAR LEVEL	AVG YEAR LEVEL	
Dam & Tunnel[1]	1980 - 82	1981	1,600	1,000	3,000
Main & Branch Canals[1]	1981 - 88	1985	1,000	625	5,000
Tertiary Irrigation System[2]	1981 - 89	1985	20,000	13,333	120,000
Non-Irrigation Infrastructure	1980 - 89	1985	1,800	1,200	12,000
Overall Project	1980 - 89	1985	22,800	14,000[3]	140,000

1. Assuming machine-intensive construction by International Contractors.

2. Assuming labour-intensive construction methods.

3. Average over ten years.

8.2.1 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 outside* the project boundaries. Water management organization and procedures can, therefore, be considered on two levels - the project level and the system level. The estimated cost of providing these services is summarised in Table 4-14, together with the cost of maintaining the irrigation system.

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 associations.

The project water management organization will have as its prime responsibility the co-ordination of water deliveries to the distributary and sub-distributary 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 sub-distributaries ;
- crop status, based on monitoring of planting dates ;
- recent rainfall, based on a network of rain gauges ;

---

* The interaction of water demands in System B and C, discussed in Section 4.2.4, is one example of the effect that water management in one component project can have on the performance of another.

- field water conditions, based on farmer and staff reports and possibly a network of representative field plots ;
- theoretical water requirements, based on regularly updated calculations ; and
- 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 co-ordinate 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 sub-distributary) 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.

A project water management organization which is based on one water liaison officer per 80 farmers* is proposed. These officers would be responsible for liaison with the

---

* About four to five turnout areas per officer. Each turnout area would have its own water user association.

water user associations formed in their areas of responsibility, implementing operational policies, organizing cultivation meetings, etc. They would report to officers in charge of zones who would report to an overall project manager.

System Water Management

System-level water management will call for water use monitoring and operational decisions at monthly 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 programme 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 programme. Once reservoir operating policies are fixed, a modified programme 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.

8.2.2 Extension Services

Organizational Structure and Purpose

An Agrarian Development Service (ADS) is proposed. This service would integrate the two existing types of agricultural support services, and would be a three-level organization that closely corresponds to the system by which agricultural production and groups of farmers can be organized. At the lowest level, the ADS provides Farm Guidance Workers (FGW), approximately one for every 125 ha. The actual contact with farmers would take place through the FGW, whose guidance function is intended to be more intensive than that provided by the present KVS (village extension worker). In addition to being knowledgeable on the subject of paddy cultivation, he should be capable of advising on homestead crops and livestock.

At the next level would be the Agrarian Service Team (AST), which would not operate on an individual farmer contact basis but would provide specialist advice to the Farm Guidance Workers. Each AST (one is proposed for every 3,000 ha) would contain at least six specialists.

For System B there should also be an Agrarian Development Service Centre. Adaptive research, extension worker and farmer training and the co-ordination of all types of agricultural development services would be its key function. This centre should be established in conjunction with the Experimental-Demonstration Farm.

Cost of Extension Services

To achieve the agricultural production potential of the project area, the farmers will require a high level of practical support from the Agrarian Development Service. A total staff of about 500 is proposed for this service, of which some 340 would be Farm Guidance Workers, 140 would work within or support the Agrarian Service Teams, and 20 would work at the Agrarian Development Centre.

The total annual operating cost, including staff salaries, supplies, travel, maintenance and support help, would be about Rs.9.4 million. Under Scenario A, this level should be reached by 1986, whereas under Scenario B, it would be reached by 1989. It is anticipated that extension services would be maintained at a high level for ten years, at a somewhat lower level for the next ten years, and that they could be further reduced over the following decade.

The annual cost of extension services is estimated to be Rs.250 per ha or between one and five per cent of gross farmer revenue.

Other services to farmers, including credit, marketing and inputs, are discussed in Chapter 7.

8.2.3 Settlement - Related Services

Services to settlers would include assistance with :

- land administration matters (boundary disputes, allocation of land and suitability of land to family) ;

- food problems (where food aid may not be timely or sufficient) ;
- health problems (to advise on preventive 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 making supplies of building materials available); and
- general problems of adjustment to a new environment.

Settler services would be performed by community development workers whose scope of work should be structured to allow them to develop guidance skills for a range of services. A degree of responsibility should be accorded to the community workers to make their function significant in the eyes of the settlers. The present role of the development assistants should be re-structured into that of the all-round community development worker. This worker should be allowed to operate with a reasonable degree of independence, within a properly organised and communicated framework of settler assistance measures.

Cost of Settler Services

An average of one community development worker for every one hundred families is proposed. In the second and third

decade of the project's life, fewer workers will be required. In the first year of settlement, as many as one worker per 50 families may well be required. The total cost of providing these services is estimated to be Rs.7.3 million per year, or about Rs.200 per family per year.

The services that are to be provided to the farmer/ settler are threefold :

- Water Management,
- Agricultural Extension,
- Settler Assistance.

It has been proposed that two or all three of these functions might be combined, at the lowest level, to be the responsibility of a single person who would be the only contact with the farmer and his family. In preference to this approach, a more familiar multi-departmental approach is proposed. This would involve three distinct individuals, each with different skills and responsibilities, working at the grass roots level to provide the intensity and range of services required. This "army" of almost 2,000 persons will be of paramount importance in helping the farmer attain his potential.

For strong decentralized project management, an allowance has been made of ten per cent of the total cost of all previously discussed categories of management services. The following tabulation summarises the estimated operation and maintenance costs, in million Rupees (1979 prices).

Irrigation Works (from Table 4-14)	Rs.34.6
Agricultural Extension	9.4
Settlers Assistance, Community Development, etc.	7.3
General Project Management	5.1
Total	Rs. 56.4

8.3 Project Management Infrastructure

Project management infrastructure refers to the capital expenditure that must be made to support those engaged in operations and maintenance*. For the most part, this includes homes for Organisation and Management staff, offices, and equipment, transportation, and meeting places.

The infrastructure required and its cost reflects the specific needs of the three types of service that will be provided to settlers - water and irrigation management, agricultural extension, and settlers' assistance. Each of these services requires approximately the same amount of infrastructure.

In total, the estimates provide for some 1,400 houses of different grades, 600 bicycles, 200 motorcycles, 100 jeeps, 20,000 m^2 office and community centre space, and associated equipment. The total estimated cost of Rs.110 million is broken down as follows :

---

* As well as for project management during construction where such capital items are not included as part of irrigation system costs. Conversely, project management infrastructure costs can be reduced by utilising construction management infrastructure which is suitable for conversion.

- Dwellings (single and multiple occupancy)	Rs. 77 million
- Offices and other buildings	Rs. 13 million
- Transportation and other equipment	Rs. 20 million
Total	Rs.110 million

9. ENVIRONMENTAL ASPECTS

Annex J presents details on the existing environment in the project area and an overall assessment of the potential environmental impacts arising from the proposed project. The following paragraphs emphasise 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 Chapters 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.

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 per cent 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 20-22 per cent of the total land area, well below a generally accepted minimum desirable level of 25 per cent. Even more serious, forest cover in the Wet Zone has decreased to

8 per cent. 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 per cent, excluding forest plantations. Most of this forest is of poor quality - extensive areas have been "high graded" or 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, 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 Elephant Corridor).

Of the 427 species listed in Phillip's "Checklist of the Birds of Ceylon"[13], 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 six endangered species and two 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.

Aquatic

Because of their seasonal nature, the Maduru Oya and smaller streams show little evidence of phytoplankton, zooplankton, benthic invertebrates or aquatic vegetation. This is probably a reflection of low nutrient loads, especially during the dry season. 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 centres of aquatic and terrestrial life, particularly in the dry season.

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.

A summary of these major environmental issues, and the associated causes, effects and mitigating measures, is presented in Table 9-1.

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 gastro-enteritis, cholera, enteric fever, hepatitis, amoebic dysentery and polio should be prevented from becoming major problems.

Forest Conservation

Although clearing of over 25,000 ha of forest will take place, preservation of adequate natural forested areas as well as reforestation programmes for fuel wood supplies, watershed protection, wildlife habitat protection and

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 should not be ruled out Construction and farm labor productivity will suffer from exposure to malaria Many deaths due to snake bites will occur during land clearing and settlement	Vector control programs Issue of malaria pills Prepare malaria epidemic emergency contingency plan Make sufficient quantity of anti-venom medicine available at appropriate locations
Water-borne 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 Ecological balance and stability are upset	Design irrigation system according to WHO specifications to ensure proper sanitation and safe water supplies Presettlement check-ups 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

ENVIRONMENTAL COMPONENT	CAUSES	EFFECTS-DIRECT AND INDIRECT	MITIGATING MEASURES
Forest conservation (continued)		Catchment areas are deforested leading to reservoir siltation, loss of valuable soil, reduction of moisture storage capacity etc. Diversity of plant and animal life declines	Reduce width of forest clearing beyond canals and roads to 5 m Reforestation programs including canal banks, river banks, plantations, archaeological reserves Use of indigenous trees in Maduru Oya 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 Wildlife leaves the area (to where?) Wildlife conflicts with man, cause damage to property, crops, etc Wildlife is shot by man for food and other reasons	Plan wildlife/forested areas along rivers and streams and upland areas (in addition to Maduru Oya National Park) Plan corridor relocation routes Capture and sell or transport to suitable areas
Birds	Loss of habitat for forest-dependent birds	Predator-prey-parasite balance is upset leading to pest proliferation	Monitor pest populations, adopt scientific control methods
Aquatic Environment	Reservoir and irrigation system is constructed. Area is settled with complete infrastructure	Terrestrial, aquatic and estuarine ecosystems drastically modified Flora and fauna species composition and numbers will be altered	Leave adequate forest cover in the project area and especially in the catchment areas (25 percent minimum)

123

ENVIRONMENTAL COMPONENT	CAUSES	EFFECTS-DIRECT AND INDIRECT	MITIGATING MEASURES
Aquatic Environment (continued)		Erosion risk increased (loss of soil fertility, siltation of reservoirs) Water quality problems (pesticides, agricultural runoff, eutrophication, leaching etc) Aquatic weed infestation Change of wet-dry cycle encourages proliferation of water-dependent insect pests and diseases	Practice recommended water management and farm management techniques Use biodegradable pesticides and integrated pest control techniques Deal with water quality problems and aquatic weed infestations before the problem becomes too widespread
Long-Term Energy Supplies	Ongoing requirement of over 100 ft^3 of firewood per family per year	Cost and transportation difficulties will escalate Shortages of firewood may develop Cost of family firewood will increase with collection distance Removal of natural forest for firewood, resulting in a long-term decline in forest cover	Plan for firewood yielding forests within walking distance Plant fast-growing tree species Charcoal excess wood from clearing program Promote manufacture of inexpensive domestic charcoal burners Promote manufacture of inexpensive but efficient firewood burners Promote use of appropriate technology Investigate Windmills for pumps and the use of solar energy to conserve fuel wood and electricity Investigate the use of biogas

224

erosion control should reduce the magnitude of this impact. Forest clearing programmes must be carefully controlled and monitored to minimise 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 programme.

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 forests, 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 animals 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 accomodation of the animals' needs or removal of the animals to more suitable habitat. The emphasis should be on the provision of escape routes (see Figure 15) for the sensitive wildlife

species to move to parks, reserves, etc. The proposed Maduru Oya Park is intended to serve this purpose. A system of wildlife corridors will be needed, at least in the early stages of the project development period, to allow reasonable freedom of movement for the animals.

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 programmes can keep these negative aspects under control.

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, the use of charcoal, the use of solar and wind energy, the use of biogas) will help to preserve fuel-wood supplies and diversify the energy base.

226

It is technically feasibile to solve many of the potential environmental problems expected to arise from this development provided adequate staff, budgets and time are made available.

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[12] are employed to determine economic farm-gate prices on the basis of import substitution or export. For those products which are not internationally traded, local prices are used. The IBRD commodity forecasts are also used to calculate the economic prices for a number of farm inputs as well. 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 foreign exchange costs are converted to local currency using the following exchange rates :

$ 1 U.S. = Rs.16
$ 1 CAN = Rs.13

228

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 labour :

Cement (delivered)	..	Rs.1,220/tonne
Diesel Fuel	..	Rs. 21.50/gallon
Farm Labour (incl.hired)	..	Rs. 6/day

For the economic analysis, all construction and operational labour 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 1986. For the second - Senario B - this occurs in Yala 1989. The schedules are detailed in Section 4.5.1, and the land areas developed under each schedule are summarised in Table 7-5.

10.2 Scenario A

10.2.1 Direct 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 price of cement and for the cost of diesel fuel when it

is a significant component of the total cost. Other costs which are chargeable to the project include those associated with the Experimental-Demonstration Farm, primary and access roads, settlement 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 summarised 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, has been estimated by the System C team to be Rs.1,267 million. Of this total an amount of Rs.854 million represents the estimated cost of those parts of the works (the canal itself plus the level crossings) 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 System C is considdsred. It is estimated that 75% of the cost of the flow-related works

TABLE 10-1

PROJECT COSTS FOR ECONOMIC ANALYSIS
(MID 1979 PRICES)

CAPITAL COSTS	
IRRIGATION WORKS	RS. MILLION
Dam and miscellaneous reservoir works	882
Link Tunnel	269
Main and Branch Canals	1032
Teritiary System, Drainage, Land Development	609
Contingencies	361
Engineering and Construction Supervision	250
Sub-total Irrigation Works	3404
Other Costs	
Experimental-Demonstration Farm	13
Roads (including access roads)	270
Settlement	187
Project Management Infrastructure	110
Upstream costs	214
Sub-total Other Costs	794
Total Capital Costs	4198
ANNUAL OPERATING EXPENSES	
Dam and Tunnel	6
Irrigation System	28
Agricultural Extension	9
Settler Assistance, Community Development etc.	7
General Project Management	6
Total Annual Operating Expenses	56

TABLE 10-2

SCENARIO A
CAPITAL AND OPERATING COSTS FOR ECONOMIC ANALYSIS
(MILLION RUPEES)

YEAR	IRRIGATION SYSTEM	UPSTREAM COSTS	EXPERI-MENTAL FARM	ROADS INCL. ACCESS ROADS	SETTLE-MENT	PROJECT MGT. INFRA-STRUCTURE	O&M	TOTAL
1	351	64	6	15	-	15	-	451
2	800	107	7	45	-	15	-	974
3	837	43	-	45	-	15	-	940
4	716	-	-	50	41	15	12	834
5	452	-	-	50	68	15	25	610
6	243	-	-	50	64	15	38	410
7	5	-	-	15	14	15	49	98
8	-	-	-	-	-	5	56	61
9-16	-	-	-	-	-	-	56	56
17-26	-	-	-	-	-	-	50	50
27-40	-	-	-	-	-	-	44	44

(Rs. 854 million), would be incurred if the canal were sized only for System C. Thus 25% or Rs.214 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 basic analysis.

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.684 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 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 benefitting 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.

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 project" and "with project" scenarios. In the latter, the benefits begin in Project Year 4 and reach a maximum in Project Year 14. Thus incremental benefits attributable to the project reach a maximum in Project Year 14 as well. 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 4, when the first farmers are settled, and reach their maximum level in Project Year 7, 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 8. They reach their maximum level in Project Year 19.

Benefits from fisheries and forestry have been developed in Section 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\power-houses is 31 Gwh and is classed as secondary energy. NEDECO has indicated the necessity for thermal capacity in the system by 1983 and thus this secondary energy has been assumed to be 100% useable 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. .61/Kwh, or an annual benefit of Rs.19 million over the life of the project, beginning in Project Year 4.

234

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 with some additional engineering costs (on the Main and Branch Canals) relating to the longer development period. Total costs are spread out over the years 1980 - 88. The cost schedule for the Right Bank Canal from Minipe to Ratkinda is comparable to Scenario A. A summary of the annual phasing of the capital costs used in the economic analysis is shown in Table 10-5.

10.3.2 Project Benefits

The delayed benefits from the project for Scenario B have been developed in Chapter 7. As in Scenario A, power benefits are included in the total project benefits at Rs.19 million beginning in Project Year 4. A summary of the project benefits for Scenario B is provided in Table 10-6.

TABLE 10-3

SCENARIO A
SUMMARY OF NET PROJECTED BENEFITS
(MILLION RUPEES)

YEAR	IRRIGATED CROPS WITHOUT	IRRIGATED CROPS WITH	IRRIGATED CROPS NET	HOMESTEAD	LIVESTOCK	FISHERIES	FORESTRY	POWER	TOTAL
1	79	79	-	-	-	-	-	-	-
2	79	79	-	-	-	-	10	-	10
3	79	75	(4)	-	-	-	9	-	5
4	79	110	31	8	(4)	(1)	9	19	62
5	79	201	122	26	(12)	(1)	9	19	163
6	79	335	256	46	(11)	(1)	9	19	318
7	79	467	388	60	-	1	(1)	19	467
8	79	525	446	60	10	1	-	19	536
9	79	572	493	60	12	2	-	19	586
10	79	597	518	60	15	2	-	19	614
11	79	607	528	60	17	2	-	19	626
12	79	609	530	60	20	2	-	19	631
13	79	611	532	60	22	2	-	19	635
14	79	612	533	60	25	2	-	19	639
15	79	612	533	60	27	2	-	19	641
16	79	612	533	60	30	2	-	19	644
17	79	612	533	60	32	2	-	19	646
18	79	612	533	60	35	2	45	19	694
19-22	79	612	533	60	36	2	45	19	695
23-32	79	612	533	60	36	2	-	19	650
33-37	79	612	533	60	36	2	34	19	684
38-40	79	612	533	60	36	2	-	19	650

TABLE 10-4

SCENARIO A
NET CASH FLOW SUMMARY
(MILLION RUPEES)

YEAR	CAPITAL AND OPERATING COSTS	TOTAL PROJECT BENEFITS	NET CASH FLOW
1	451	-	(451)
2	974	10	(964)
3	940	5	(935)
4	834	62	(772)
5	610	163	(447)
6	410	318	(92)
7	98	467	369
8	61	536	475
9	56	586	530
10	56	614	558
11	56	626	570
12	56	631	575
13	56	635	579
14	56	639	583
15	56	641	585
16	56	644	588
17	50	646	596
18	50	694	644
19-22	50	695	645
23-26	50	650	600
27-32	44	650	606
33-37	44	684	640
38-40	44	650	606

sources : Tables 10-2 and 10-3

TABLE 10-5

SCENARIO B

CAPITAL AND OPERATING COSTS FOR ECONOMIC ANALYSIS
(MILLION RUPEES)

YEAR	IRRI-GATION SYSTEM	ALLOCATED COSTS	EXPERI-MENTAL FARM	ROADS INCL. ACCESS ROADS	SETTLE-MENT	PROJECT MGT. INFRA-STRUCTURE	O&M	TOTAL
1	350	64	6	15	-	10	-	445
2	735	107	7	30	-	10	-	889
3	592	43		30	-	10	-	675
4	401	-	-	30	15	10	11	467
5	293			30	26	10	17	376
6	357			30	36	10	23	456
7	313			30	32	10	30	415
8	227			30	35	10	38	340
9	160			30	29	10	45	274
10	5			15	14	10	52	96
11						10	56	66
12-19							56	56
20-29							50	50
30-40							44	44

TABLE 10-6

SCENARIO B

SUMMARY OF NET PROJECT BENEFITS
(MILLION RUPEES)

YEAR	IRRIGATED CROPS WITHOUT	IRRIGATED CROPS WITH	IRRIGATED CROPS NET	HOMESTEAD	LIVESTOCK	FISHERIES	FORESTRY	POWER	TOTAL
1	79	79	-	-	-	-	-	-	-
2	79	79	-	-	-	-	7	-	7
3	79	75	(4)	-	-	-	5	-	1
4	79	103	24	4	(1)	(1)	5	19	50
5	79	156	77	12	(4)	(1)	5	19	108
6	79	215	136	22	(4)	(1)	5	19	177
7	79	285	206	33	(4)	1	5	19	260
8	79	368	289	43	(1)	1	5	19	356
9	79	459	380	53	1	2	6	19	461
10	79	534	455	60	7	2	-	19	543
11	79	569	490	60	13	2	-	19	584
12	79	591	512	60	16	2	-	19	609
13	79	604	525	60	18	2	-	19	624
14	79	609	530	60	21	2	-	19	632
15	79	610	531	60	23	2	-	19	635
16	79	611	532	60	26	2	-	19	639
17	79	612	533	60	28	2	-	19	642
18	79	612	533	60	31	2	30	19	675
19	79	612	533	60	33	2	30	19	677
20	79	612	533	60	34	2	30	19	678
21	79	612	533	60	35	2	30	19	679
22-24	79	612	533	60	36	2	30	19	680
25	79	612	533	60	36	2	15	19	665
26-32	79	612	533	60	36	2	-	19	650
33-39	79	612	533	60	36	2	22	19	672
40	79	612	533	60	36	2	11	19	661

The net cash flow for determining the economic internal rate of return for the project for Scenario B is provided in Table 10-7.

10.4 Benefit-Cost Assessment

10.4.1 Base Case Results

For Scenario A the Base Case, analysis is conducted with paddy yields (t/ha) at the following levels :

	Maha	Yala
Land Class 1R	4.4	4.6
Land Class 2R	3.6	3.8

The net cash flow for this scenario is shown in Table 10-4 and the resulting economic IRR is 10.7 per cent per annum. Using the same yield levels for Scenario B (Table 10-7) results in a project economic IRR of 10.2 per cent per annum. Thus the slower development schedule results in about a 0.5 per cent decline in the project IRR.

10.4.2 Sensitivity Analyses

A number of sensitivity tests have been undertaken on the Base Case . In addition, the sensitivity of the IRR with respect to a number of different paddy yield levels has been conducted for both Scenarios A and B. With reference to the Base Case paddy yields discussed above, project benefits were recalculated on the basis of higher and lower paddy yields (t/ha) in Maha/Yala as follows :

240

TABLE 10-7

SCENARIO B

NET CASH FLOW
(MILLION RUPEES)

YEAR	CAPITAL AND OPERATING COSTS	TOTAL PROJECT BENEFITS	NET CASH FLOW
1	445	-	(445)
2	889	7	(882)
3	675	1	(674)
4	467	50	(417)
5	376	108	(268)
6	456	177	(279)
7	415	260	(155)
8	340	356	16
9	274	461	187
10	96	543	447
11	66	584	518
12	56	609	553
13	56	624	568
14	56	632	576
15	56	635	579
16	56	639	583
17	56	642	586
18	56	675	619
19	56	677	621
20	50	678	628
21	50	679	629
22-24	50	680	630
25	50	665	615
26-29	50	650	600
30-32	44	650	606
33-39	44	672	628
40	44	661	617

Source : Tables 10-5 and 10-6

	Lower Yields		Higher Yields	
	Maha	Yala	Maha	Yala
Land Class 1R	4.0	4.2	4.9	5.1
Land Class 2R	3.2	3.4	4.0	4.2

An eight year period to realise the maximum economic benefit from paddy production (versus 5 years) was also tested for both development scenarios. The results of the yield sensitivity calculations are shown below :

	Scenario A	Scenario B
Base Case	10.7 %	10.2 %
Higher Yields	12.3 %	11.6 %
Lower Yields	9.2 %	8.8 %
Eight years to Maximum Paddy benefit (base case yields)	10.4 %	9.8 %

In short, the IRR estimate is very sensitive to yield levels. A 10 per cent change in yields would change the IRR by about 1.4 per cent. 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 years has a relatively minor impact on the resulting IRR.

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 to 9.6 per cent per annum.

A number of sensitivity tests were also undertaken to determine the impact of increases in capital costs on

TABLE 10-8

SUMMARY OF IRR ESTIMATES

		SCENARIO A	SCENARIO B
Base Case		10.7%	10.2%
Higher Yields		12.3%	11.6%
Lower Yields		9.2%	8.8%
Eight years to maximum Paddy Benefits		10.4%	9.8%
Scenario A with			
50% share of Right Bank Canal Costs		9.6%	
Capital costs up	5%	10.3%	
	10%	9.9%	
	15%	9.5%	
	20%	9.1%	
Project Benefits down	5%	10.1%	
	10%	9.4%	
	15%	8.8%	
	20%	8.1%	
Unplanned Delay in Implementation Schedule		9.5%	

the project IRR. The results indicated an approximately linear relationship in which the project IRR falls 0.8 per cent for every 10 per cent increase in capital costs. Thus a 10 % increase in capital costs for the Base Case in Scenario A would result in an IRR of about 9.9 per cent per annum.

In addition, the impact of a decline in overall project benefits was examined. Again, an approximately linear relationship was established where the project IRR would fall by 1.3 per cent for every 10 per cent decline in project benefits. Thus if total project benefits are actually overestimated by 10% in the Base Case, the IRR would drop to 9.4 per cent per annum.

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 9.5 %. Clearly a planned re-scheduling of project implementation yields more attractive economic results than does an unplanned delay.
The results of the Base Case analysis and various sensitivity tests are summarised in Table 10-8.

10.4.3 Other Evaluation Criteria

Decision makers may actually want to analyse 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 ; and
- long-term regional growth of the secondary and tertiary sectors which is directly dependent on the agricultural population in the project area.

The implications of these investigations with respect to the basic economic analysis conducted are summarised below :

Consideration	Impact on Basic IRR
The net social benefit of assistance to relatively low income families	Add from 1.2% to 2.5% to basic IRR
The regional impact of construction worker expenditure in the area	Add 1.6% to basic IRR
The net socio-economic benefits of long-term regional spin-offs	Add 2.1% to basic IRR

short term + long-term spin-offs

10.5 Summary

In this chapter an economic cash flow analysis has been conducted to determine the most likely internal rate of return (IRR) for the Maduru Oya Project. The key IRR estimates are :

Scenario A - 10.7 %
Scenario B - 10.2 %

Acknowledging that some risk and uncertainty is inherent in any project of this nature, a number of sensitivity tests were conducted. Using either higher or lower level yields for both Scenarios A and B resulted in either a 14 % increase or a 14 % decrease in the IRR. The impact of higher capital cost charges, different project benefits, or a different cost sharing formula for the Right Bank Canal was also considered. With respect to Scenario A, the principal results are as follows :

	IRR Range
Yields ± 10 %*	9.2% - 12.3% (± 14% of 10.7%)
Project Benefits ±10%	9.4% - 12.1% (± 13% of 10.7%)
Capital Costs ± 10%	9.9% - 11.5% (± 8% of 10.7%)
Shared Cost of RBC	9.6 % (- 16% of 10.7%)

In short, the economic internal rate of return is estimated to be about 10 to 11 per cent per annum. Allowing for risk and uncertainty the IRR actually achieved could range from a low of 8% per annum to a high of 12% per annum.

At the same time, it must be acknowledged that if a slightly different methodological approach is employed, a significant upward adjustment in the economic IRR is warranted. In total an increase in the order of 50% in the basic IRR is possible if less quantifiable factors are incorporated into the analysis.

---

* Because of two crops of paddy per annum, a 10% yield change will result in a disportionate change in paddy benefits which is more than a 10% change in total project benefits.

LIST OF REFERENCES

1. Food and Agriculture Organization of the United Nations (FAO)"Mahaweli Ganga Irrigation and Hydropower Survey".

   FAO, 1963 - Reports.

   Volume 1 - Water Resources Administration & Legislation in Ceylon.
   2 - Climate & Hydrology
   3 - Soils
   4 - Engineering Geology
   5 - Water Management
   6 - Parts 1, 2 and 3 } Irrigation
   Parts 4 and 5 }
   7 - Dams and Hydro Electric Stations
   8 - Part 1 } Agricultural Economics
   Part 2 }
   9 - Hydropower
   11 - Sociological Aspects
   12 - Forestry & Forest Land Use
   14 - Agricultural Aspects

2. CECB/SOGREAH. "Maduru Oya Reservoir - Project Report" Colombo, July 1973.

3. NEDECO "Revised - Mahaweli Ganga Development Program Implementation Strategy Study". Colombo, July 1979.

   Annex A - Hydrology
   B - Irrigation and Drainage Requirements
   C - Unit Costs and Unit Resource Requirements
   D - Market Prospects for Agricultural Commodities
   E - Economic Prices
   F - Land Resources and Agricultural Benefits
   G - Power Planning Aspects

247

H - Future Demand for Electricity
I - Part B - Transbasin Canals
Part C - Main Irrigation Systems
Part D - Minor Irrigation System & Settlement
J - Geology
K - Environmental Aspects
L - Social Aspects
M - Physical Constraints
N - Macro-Economic Aspects
O - Part B - Preliminary Water Balance Studies.

4. CECB/SOGREAH "Maduru Oya Reservoir, Revised Project Report". Colombo, February 1979.

Volume 1 - Main Report
2. - Drawings

5. Food and Agriculture Organization of the United Nations. "Guidelines for Predicting Crop Water Requirements". FAO Irrigation and Drainage Paper 24. Rome, 1977.

6. United States Government. Department of Agriculture. "Quality of Irrigation Water". Agriculture Handbook No.60, Washington, 1954.

7. Food and Agriculture Organization of the United Nations. "Water Quality for Agriculture". FAO Irrigation and Drainage Paper No. 29. Rome, 1976.

8. Baghirathan Vanniasinghan, R. and Show, E.M. "Rainfall Depth - Duration -Frequency Studies for Sri Lanka". Journal of Hydrology, Volume 37. Amsterdam, 1978

248

9. Hunting Technical Services Ltd., Sir Alexander Gibb and Partners Ltd., and Preece, Cardew and Rider. "Victoria Scheme - Mahaweli Development Project- Phase I - Preliminary Feasibility Report". Borehamwood, 1970.

10. Mahaweli Development Board. "Basic Socio-Economic Data of Maduru Oya (System B)". Colombo, 1979.

11. Joshua, W. "Soils, Land Classification and Crop Water Requirements of Systems B and C - Mahaweli Development Project". Land Use Division, Irrigation Department., 1978.

12. International Bank for Reconstruction and Development. "Commodity Price Forecasts", Commodities and Export Projections Division, Washington, 1979.

13. Phillips, W.W.A. "Checklist of the Birds of Ceylon". Colombo, 1952 - 1966.

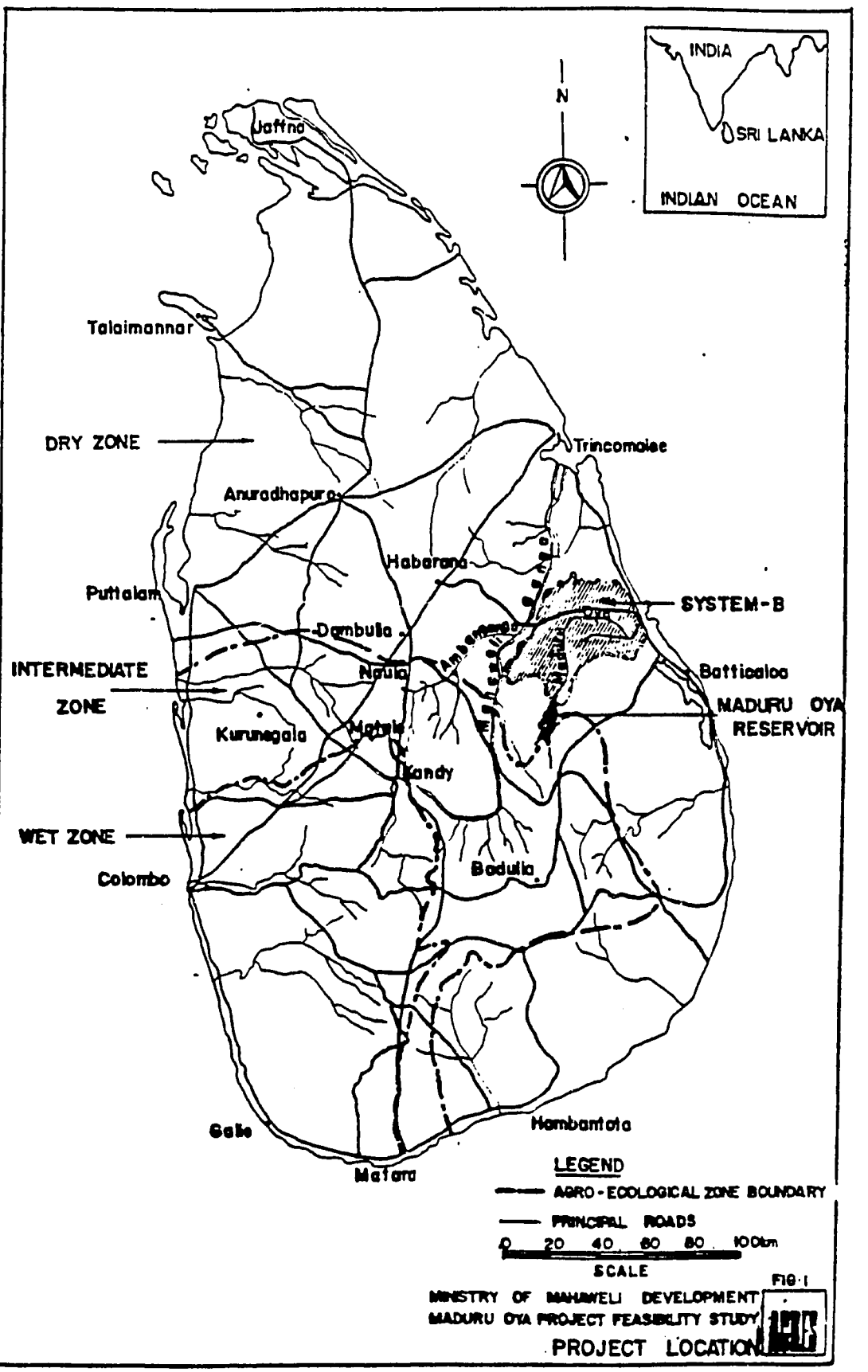


FIG-1

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

PROJECT LOCATION

250

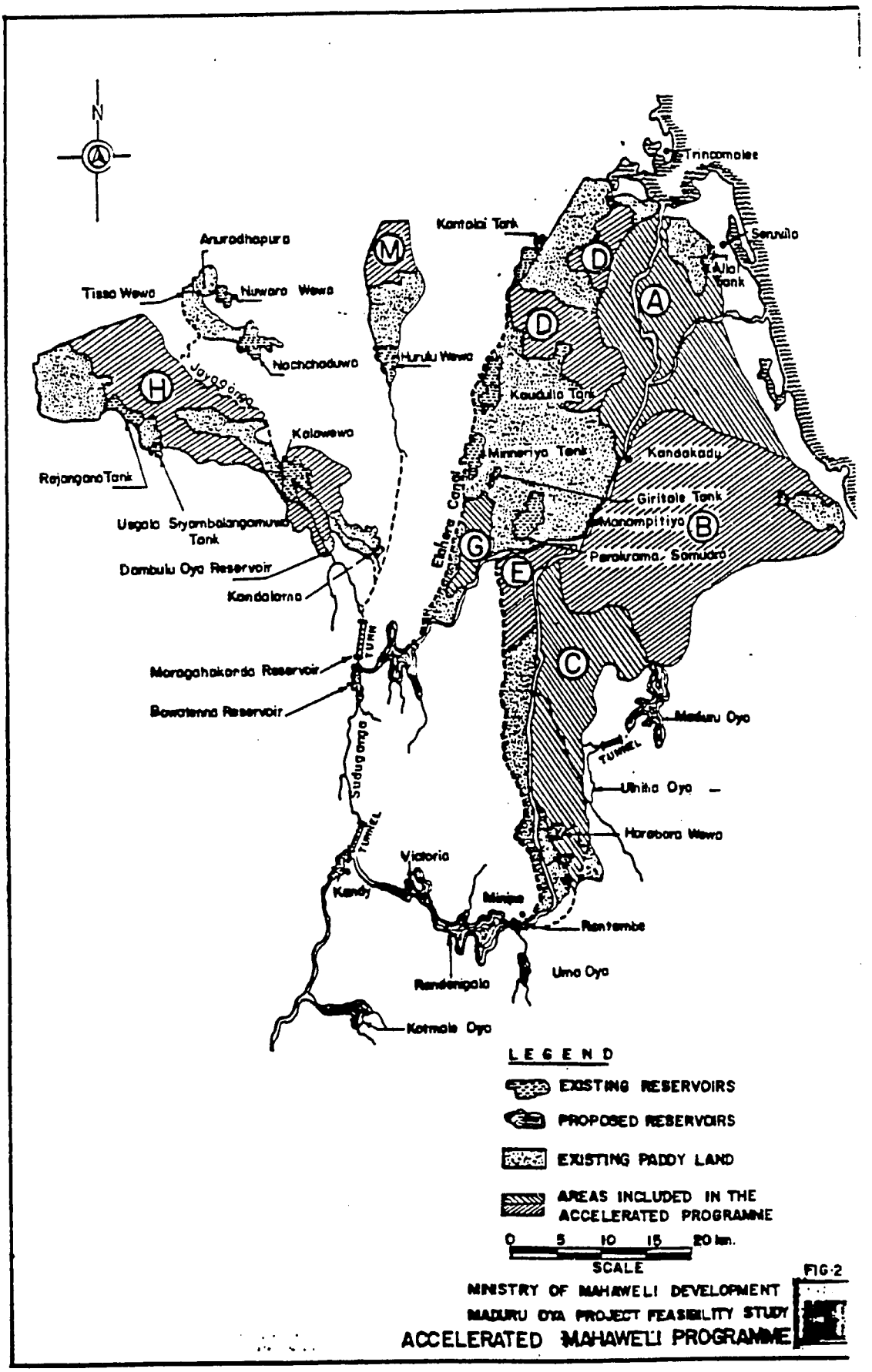


FIG-2

MINISTRY OF MAHAWELI DEVELOPMENT

MADURU OYA PROJECT FEASIBILITY STUDY

ACCELERATED MAHAWELI PROGRAMME

251

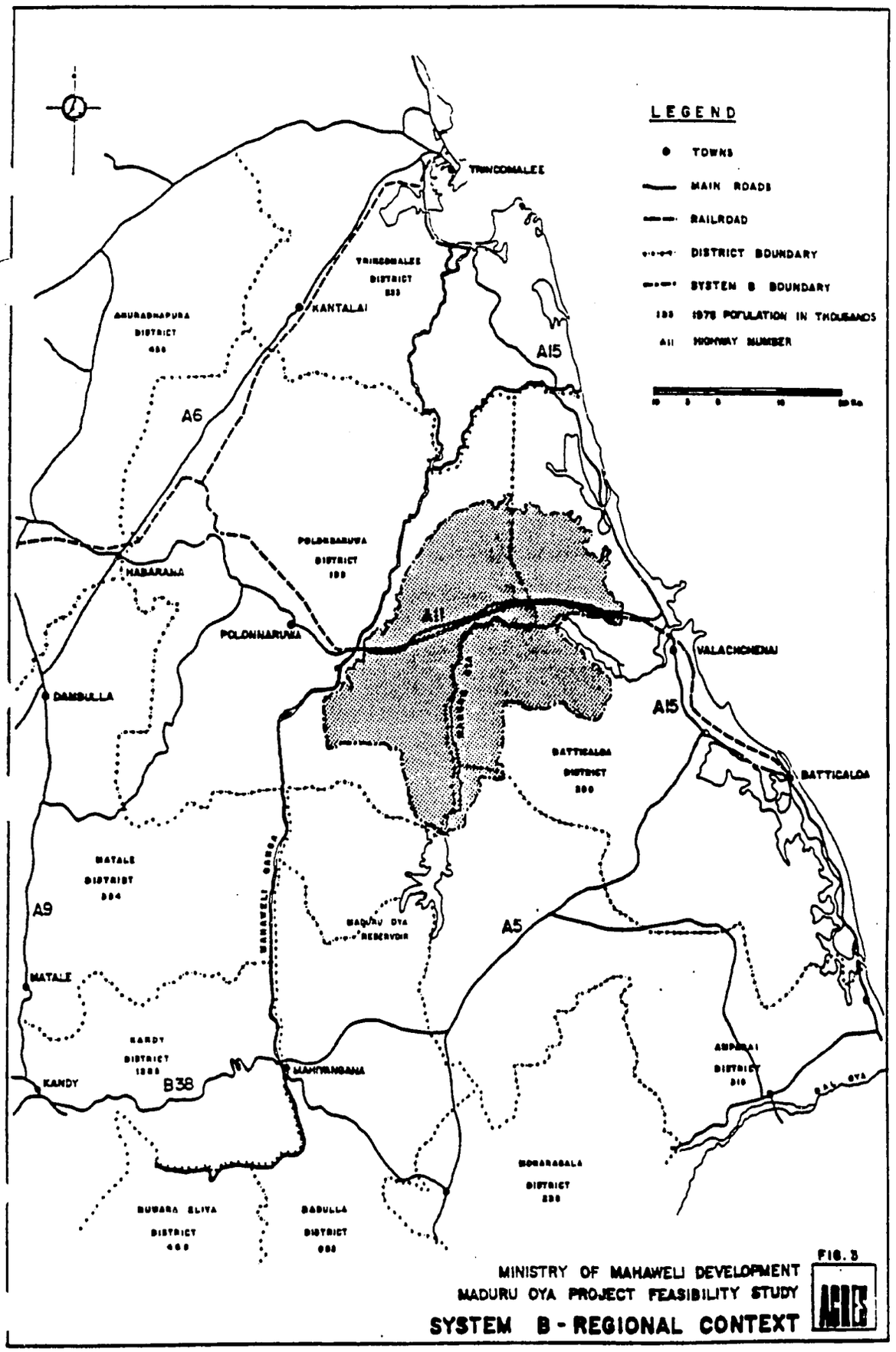
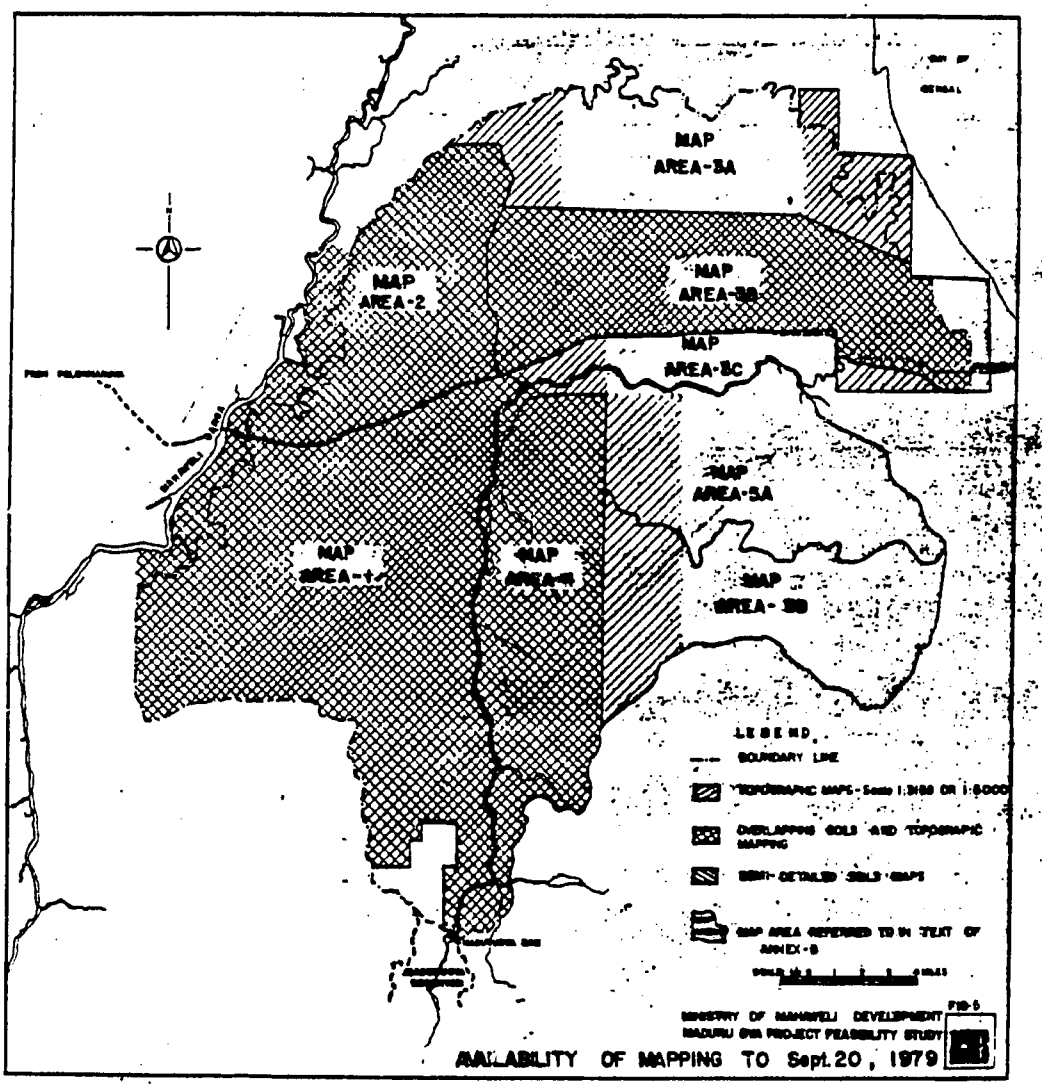


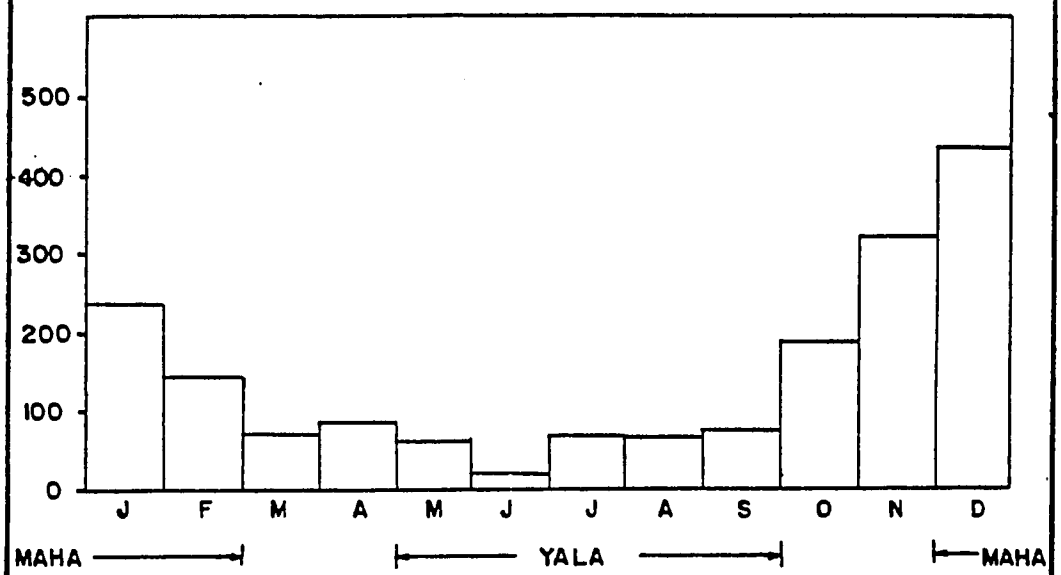
FIG. 3

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

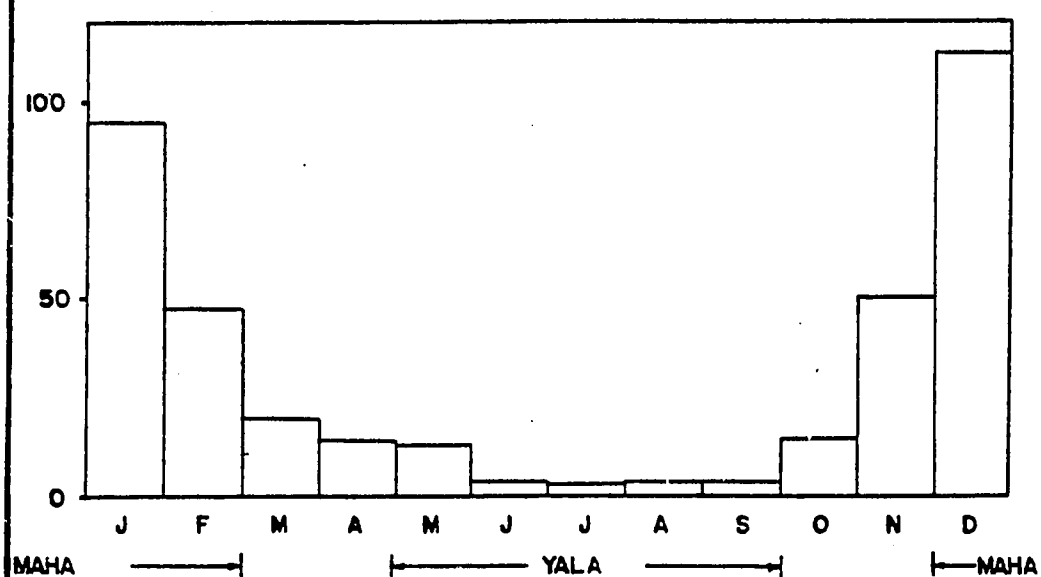
SYSTEM B - REGIONAL CONTEXT

256


MAP
AREA-3A
MAP
AREA-2
MAP
AREA-3B
MAP
AREA-3C
MAP
AREA-5A
MAP
AREA-1
MAP
AREA-4
MAP
AREA-5B
LEGEND
BOUNDARY LINE
OVERLAPPING SOILS AND TOPOGRAPHIC MAPPING
SEMI-DETAILED SOILS MAPS
MAP AREA REFERRED TO IN TEXT OF ANNEX-B
MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
AVAILABILITY OF MAPPING TO Sept.20, 1979



MEAN RAINFALL (mm)$_1$



MEAN RUNOFF (10^6 m^3/mo)$_2$

NOTES

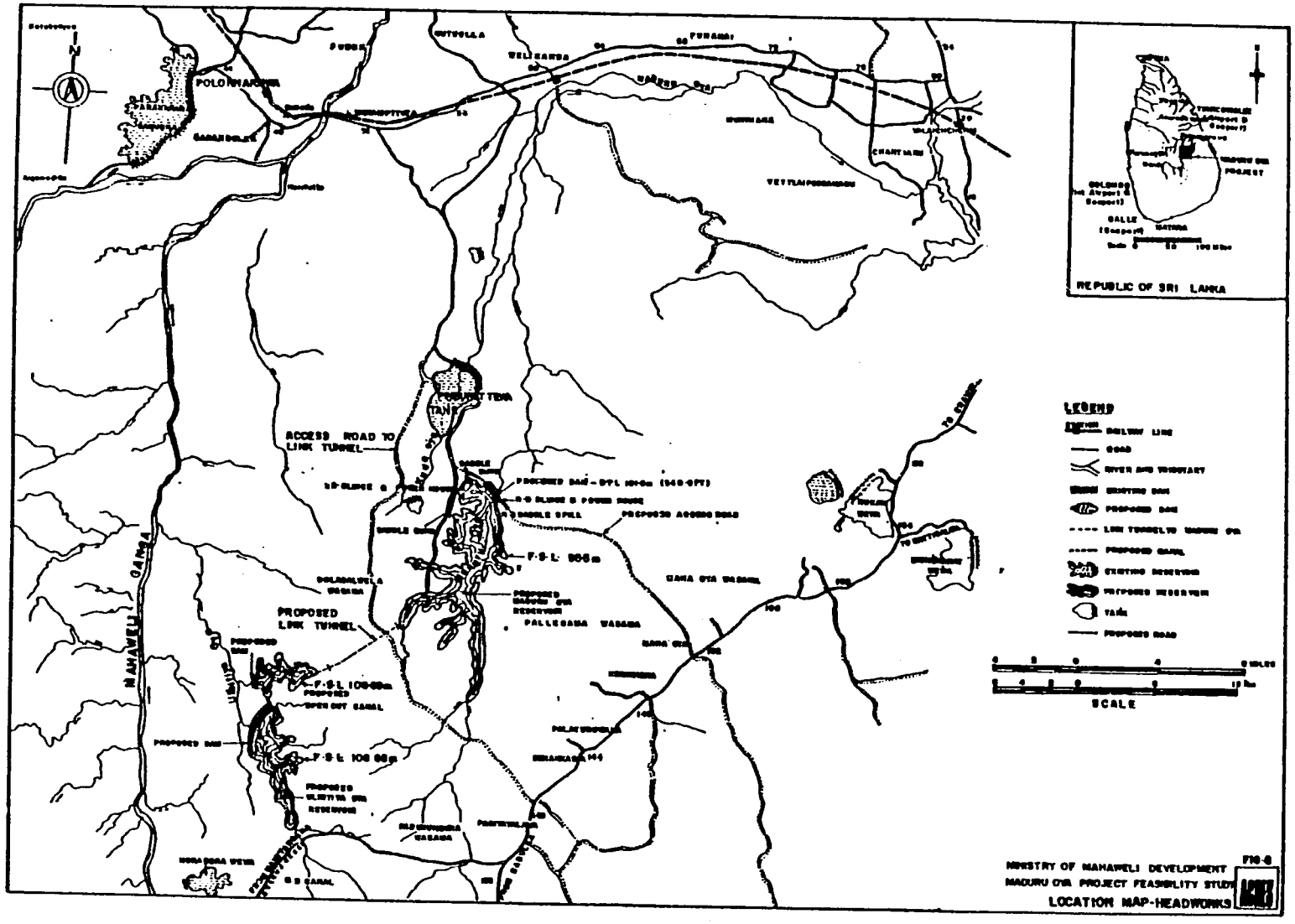
1. MEAN RAINFALL AT WELIKANDA.
2. MEAN RUNOFF AT MADURU OYA DAM SITE.

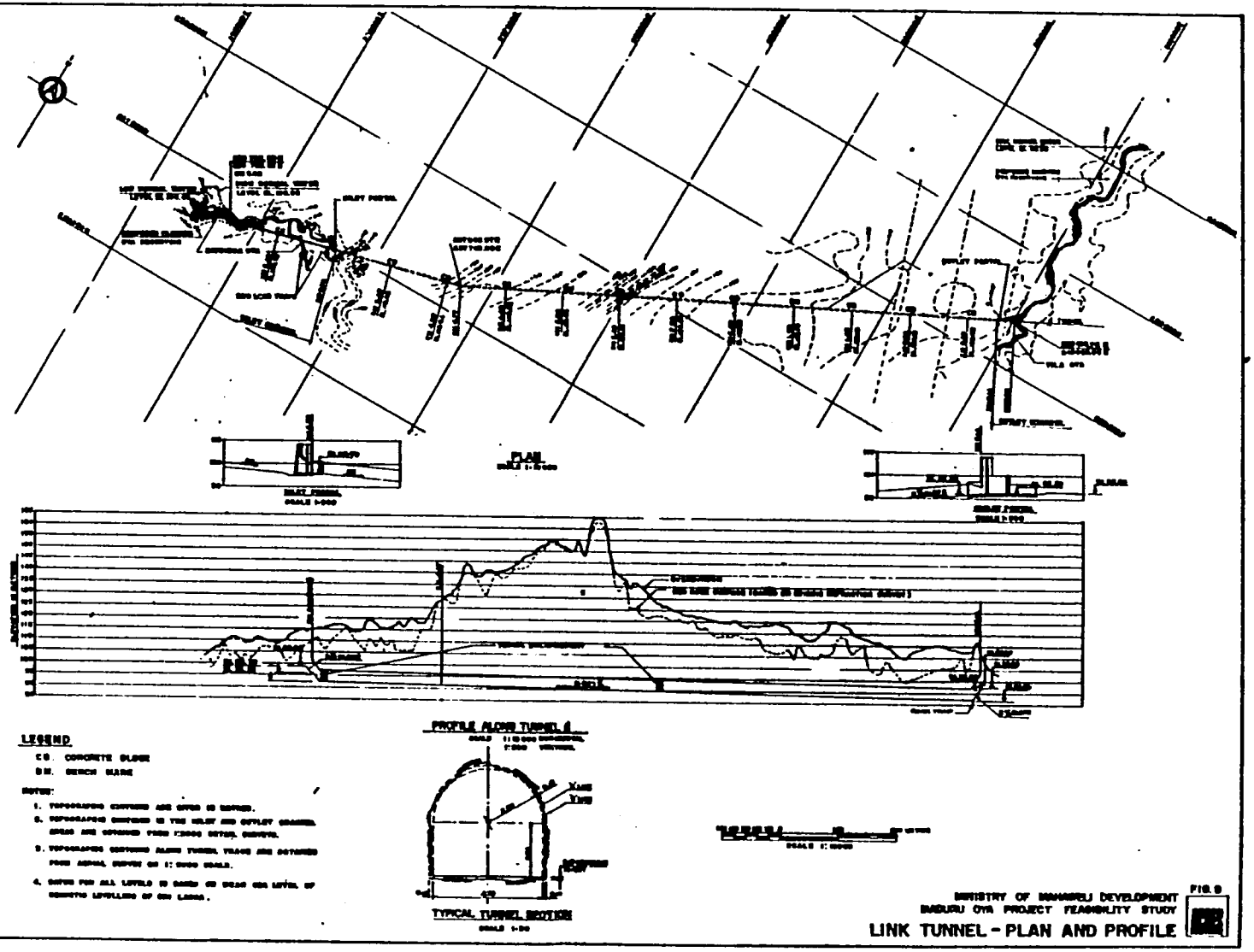
FIG 7

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

PATTERN OF RAINFALL AND RUNOFF

254

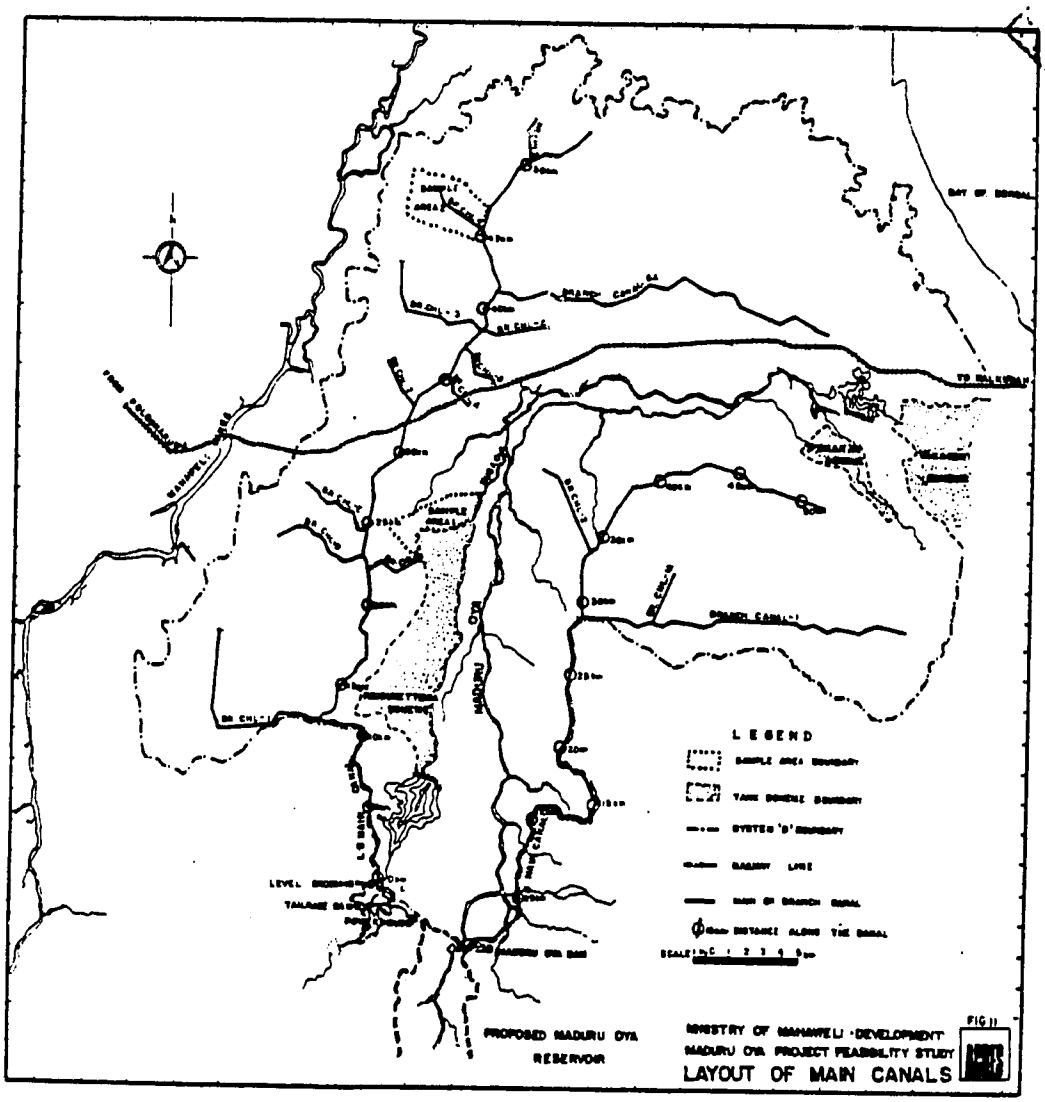

POLONNARUWA
ACCESS ROAD TO LINK TUNNEL
PROPOSED LINK TUNNEL
MAHAWELI GANGA
F.S.L. 106.68m
REPUBLIC OF SRI LANKA
LEGEND
SCALE
MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
LOCATION MAP-HEADWORKS

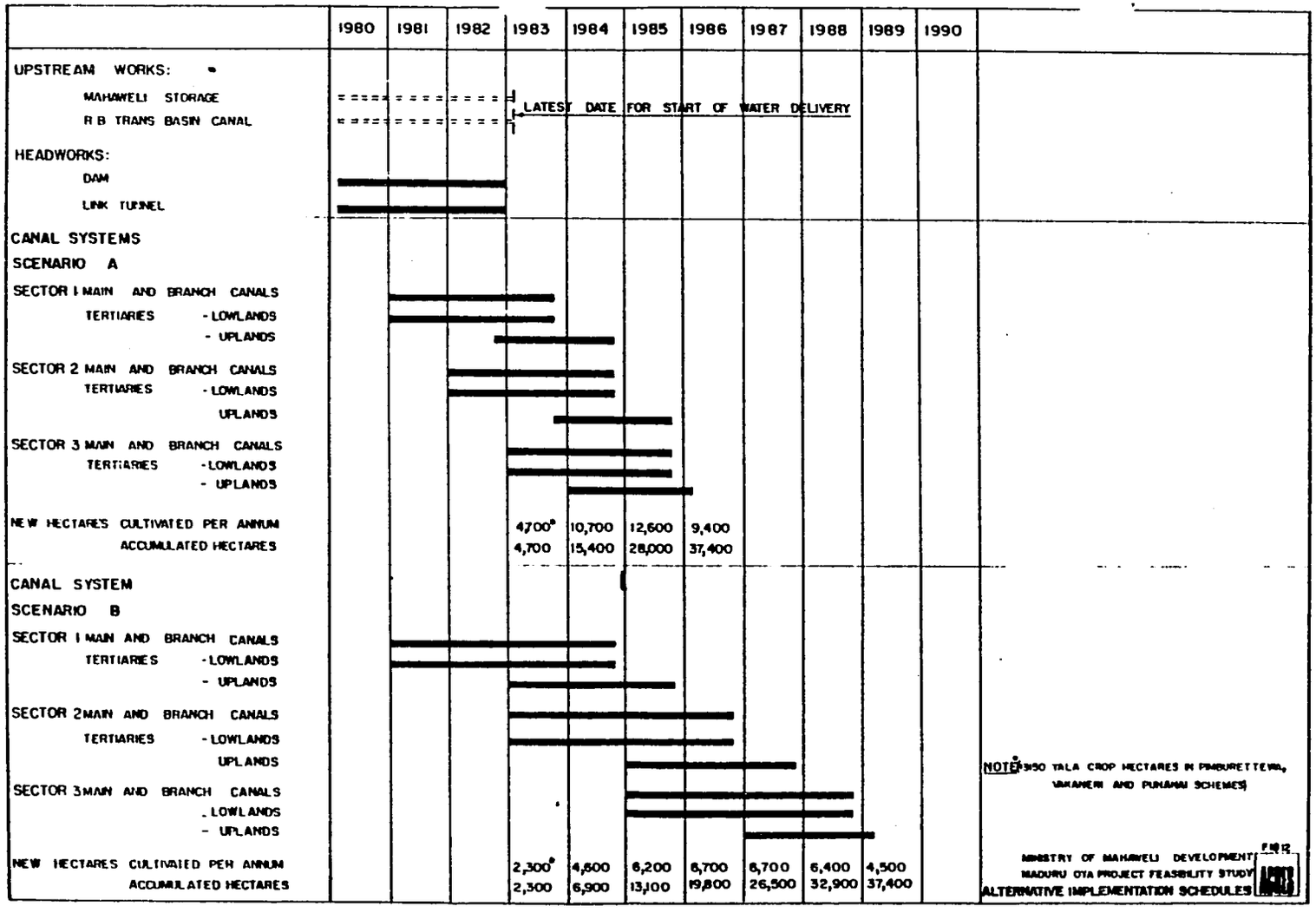


MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

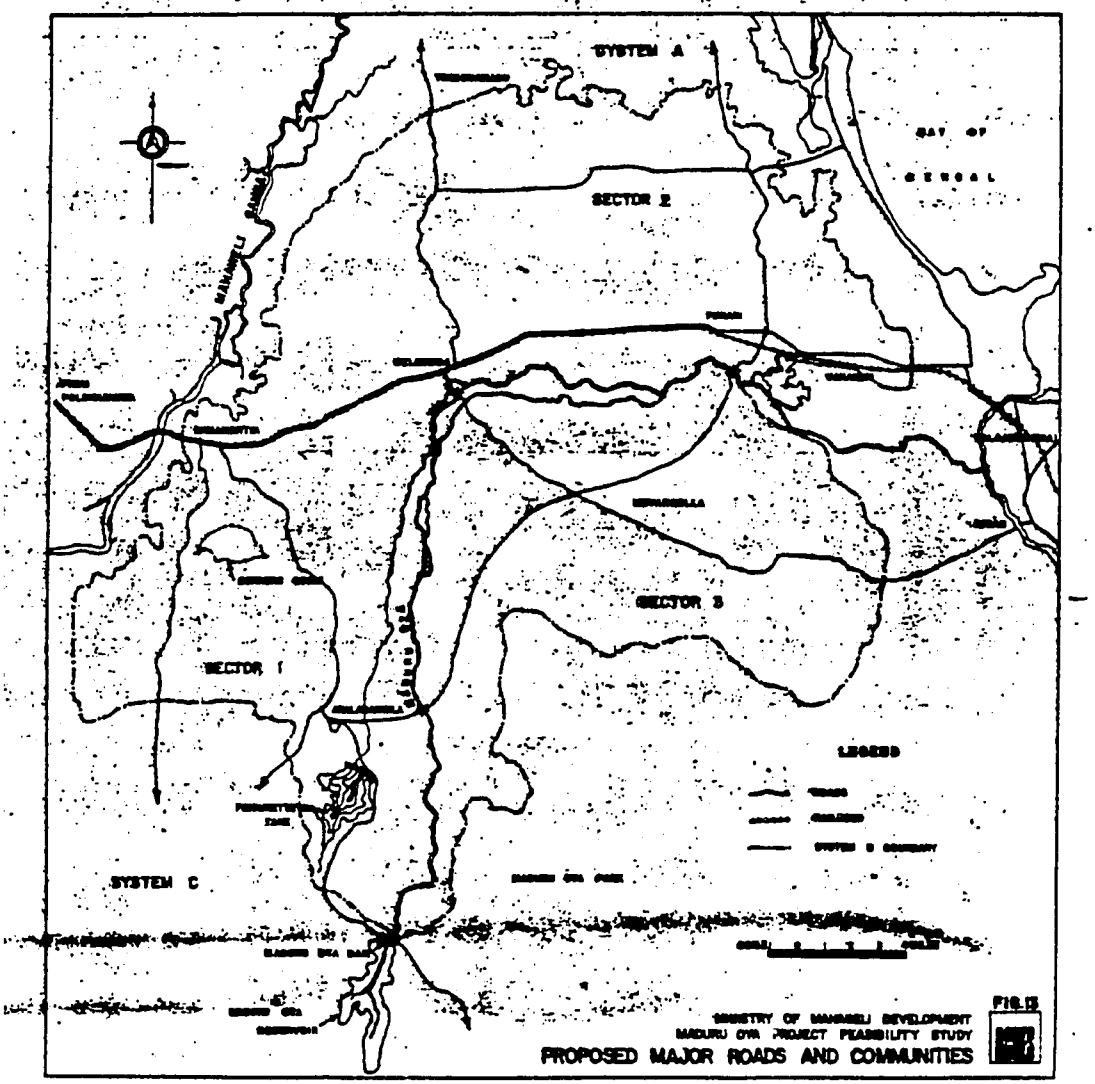
FIG. 8

LINK TUNNEL - PLAN AND PROFILE


LEGEND
PROPOSED MADURU OYA RESERVOIR
MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
LAYOUT OF MAIN CANALS
FIG 11


1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
UPSTREAM WORKS:
MAHAWELI STORAGE
R B TRANS BASIN CANAL
LATEST DATE FOR START OF WATER DELIVERY
HEADWORKS:
DAM
LINK TUNNEL
CANAL SYSTEMS
SCENARIO A
SECTOR 1 MAIN AND BRANCH CANALS
TERTIARIES - LOWLANDS
- UPLANDS
SECTOR 2 MAIN AND BRANCH CANALS
TERTIARIES - LOWLANDS
UPLANDS
SECTOR 3 MAIN AND BRANCH CANALS
TERTIARIES - LOWLANDS
- UPLANDS
NEW HECTARES CULTIVATED PER ANNUM
4,700* 10,700 12,600 9,400
ACCUMULATED HECTARES
4,700 15,400 28,000 37,400
CANAL SYSTEM
SCENARIO B
SECTOR 1 MAIN AND BRANCH CANALS
TERTIARIES - LOWLANDS
- UPLANDS
SECTOR 2 MAIN AND BRANCH CANALS
TERTIARIES - LOWLANDS
UPLANDS
SECTOR 3 MAIN AND BRANCH CANALS
- LOWLANDS
- UPLANDS
NEW HECTARES CULTIVATED PER ANNUM
2,300* 4,600 6,200 6,700 6,700 6,400 4,500
ACCUMULATED HECTARES
2,300 6,900 13,100 19,800 26,500 32,900 37,400
NOTE: *950 TALA CROP HECTARES IN PIMBURETTEWA, VAKAMERI AND PUNAMAI SCHEMES
MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
ALTERNATIVE IMPLEMENTATION SCHEDULES

258


SYSTEM A
SECTOR 2
SECTOR 3
SECTOR 1
SYSTEM C
LEGEND
FIG.13
MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
PROPOSED MAJOR ROADS AND COMMUNITIES

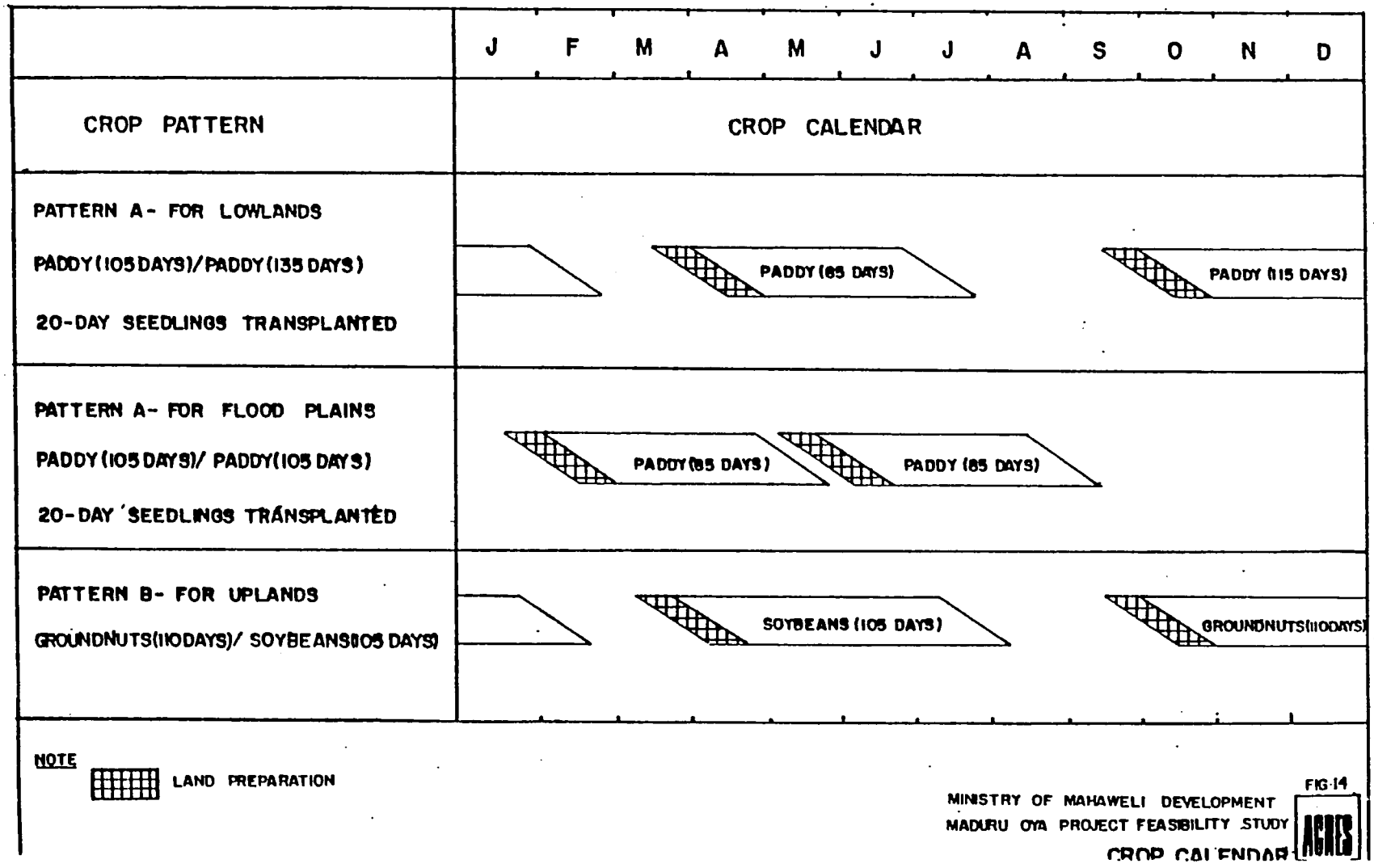
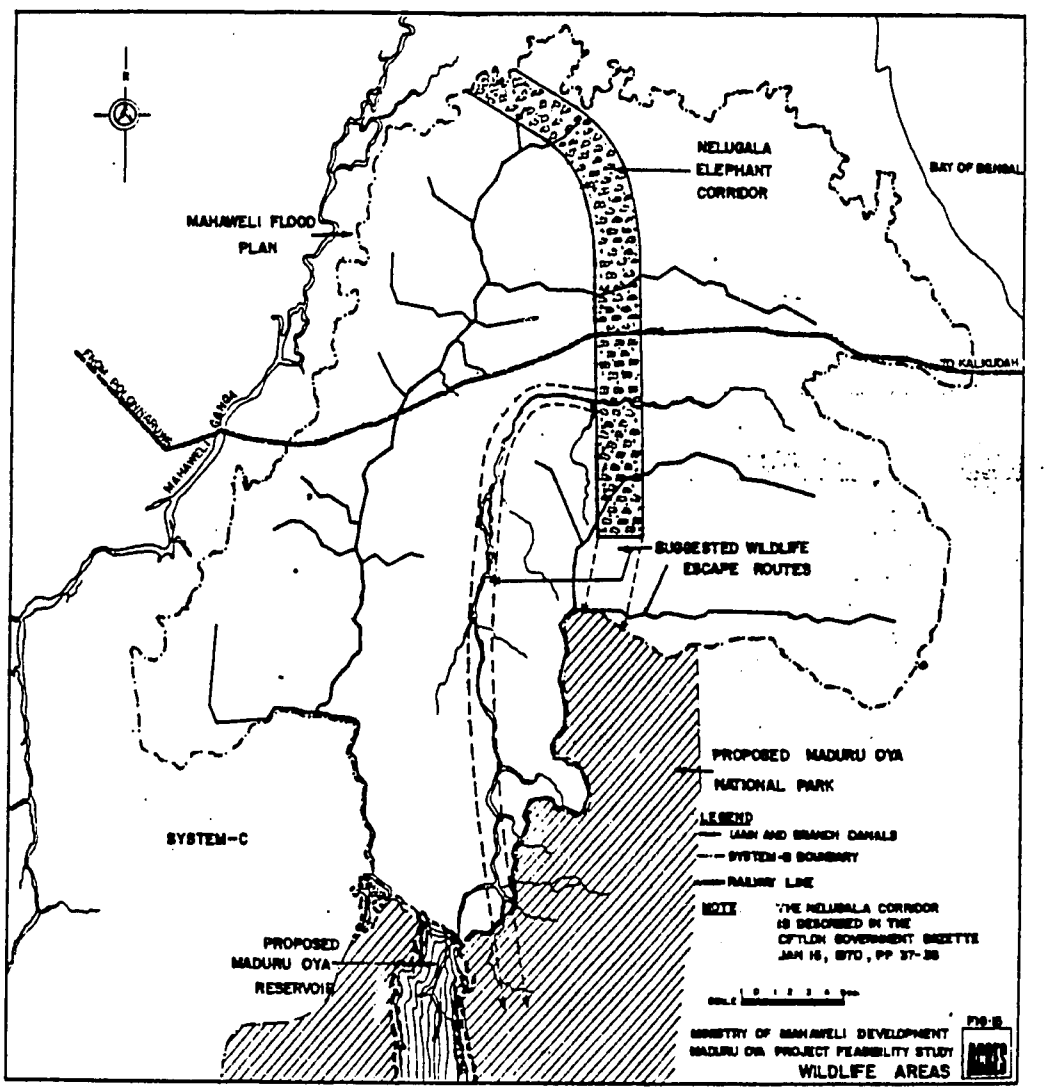


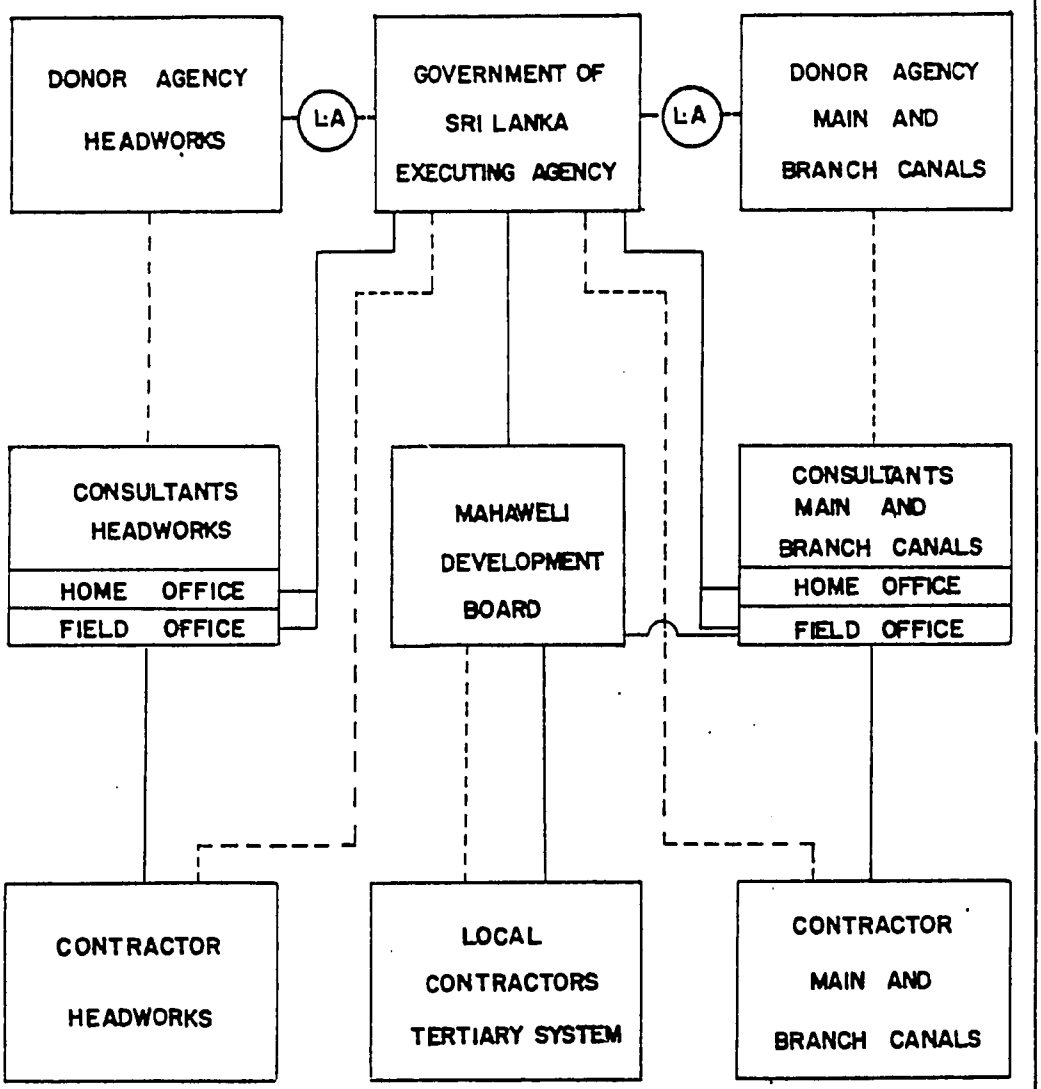
FIG-14

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
CROP CALENDAR

ACRES

260


NELUGALA
ELEPHANT
CORRIDOR
BAY OF BENGAL
MAHAWELI FLOOD
PLAN
TO KALKUDAH
MAHAWELI GANGA
SUGGESTED WILDLIFE
ESCAPE ROUTES
PROPOSED MADURU OYA
NATIONAL PARK
SYSTEM-C
LEGEND
MAIN AND BRANCH CANALS
SYSTEM-C BOUNDARY
RAILWAY LINE
NOTE
THE NELUGALA CORRIDOR
IS DESCRIBED IN THE
CEYLON GOVERNMENT GAZETTE
JAN 15, 1970, PP 37-38
PROPOSED
MADURU OYA
RESERVOIR
MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
WILDLIFE AREAS



LEGEND

------ ASSUMED CONTRACTUAL LINKS

--(L.A)-- LOAN AGREEMENT

——— WORKING COMMUNICATIONS

FIG 16

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

CONSTRUCTION PHASE - GENERAL ORGANIZATION CHART

ACRES

262

55

Democratic Socialist Republic of Sri Lanka

Ministry of Mahaweli Development

Maduru Oya Project

Feasibility Report

Annex A
The Project Area

Acres International Limited, Niagara Falls, Canada

August 1980

2677

FOREWORD

The Feasibility Report on the Maduru Oya Project, of which this Annex forms a part, is made up as follows:

Main Report

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

Annex F - Livestock

Annex G - Agroeconomic Studies

Annex H - Forestry

Annex I - Settlement Planning

Annex J - Environmental Aspects

Annex K - Implementation, Organization and Management

Annex L - Economic and Financial Analysis

TABLE OF CONTENTS

LIST OF TABLES
LIST OF FIGURES

	Page
1 - INTRODUCTION	1
2 - PHYSICAL AND BIOLOGICAL FEATURES	3
2.1 - Introduction	3
2.2 - Physiography and Geology	4
2.3 - Climate	7
2.4 - Forests	8
2.5 - Floodplains	10
2.6 - Wildlife	15
2.7 - Archaeological Sites	16
3 - PRESENT LAND USE	19
3.1 - The Map of Present Land Use	19
3.2 - Irrigated Agriculture Under Tank Schemes	20
3.3 - Rainfed Paddy Cultivation	28
3.4 - Chena Cultivation	30
3.5 - Livestock	31
3.6 - Industrial Development	38
4 - COMMUNITIES AND SERVICES	41
4.1 - Population and Land Ownership	41
4.2 - Communications and Access	64
4.3 - Infrastructure	69

APPENDIX I - PREVIOUS STUDIES OF THE MADURU OYA PROJECT
APPENDIX II - FOOD STAMPS AND WORLD FOOD AID
APPENDIX III - RURAL HOUSING IN SRI LANKA

REFERENCES

FIGURES

265

LIST OF TABLES

Number	Title
A-2.1	Summary of Climatic Means and Extremes
A-2.2	Forest and Chena Lands in the Project Area
A-2.3	Principal Tree Species
A-3.1	Summary of Present Land Use in System B
A-3.2	Characteristics of Major Tank Schemes
A-3.3	Small Tank Schemes in the Project Area
A-3.4	Comparison of Data Related to Areas Cultivated in Paddy
A-3.5	Rainfed Paddy Cultivation Averaged 1973 to 1979
A-3.6	Livestock Numbers - 1979
A-3.7	Estimated Herd Composition in the Maduru Oya Project Area, 1979
A-4.1	Population of Maduru Oya Region
A-4.2	System B Population - 1979
A-4.3	Village Populations in System B - 1979
A-4.4	Project Area Population According to Age Group - 1979
A-4.5	Families and Households in System B - 1979
A-4.6	Birth and Death Rates in Maduru Oya Region - 1977
A-4.7	Ethnic Origin and Religion of Families in the Project Area
A-4.8	Occupations of Families in the Project Area
A-4.9	Family Incomes in System B
A-4.10	Legitimate Land Ownership in the Project Area
A-4.11	Lands Allocated Under the Land Development Ordinance
A-4.12	Encroachment in the Project Area

List of Tables - 2

Number	Title
A-4.13	Highway Traffic Volumes in the Maduru Oya Region
A-4.14	Airfields in the Maduru Oya Region
A-4.15	Schools in the Project Area
A-4.16	Hospital Beds
A-4.17	Infant Mortality Rate by Districts - 1976
A-4.18	Causes of Hospitalization - 1977

Appendix

Table 1	Qualifications for Receiving Food Stamps
Table 2	World Food Aid Program

LIST OF FIGURES

Number	Title
A-1	National Context
A-2	Regional Context
A-3	Pattern of Rainfall and Runoff
A-4	Present Land Use
A-5	Present Population System B
A-6	Existing Infrastructure

1 - INTRODUCTION

The Maduru Oya project is located in the eastern part of the Dry Zone of Sri Lanka, as shown in Figure A-1. Its overall area of some 130 000 ha (1,300 km^2) is located primarily within the Polonnaruwa and Batticaloa Districts. The former falls within the North Central Province, and the latter is in the Eastern Province.

This annex presents a picture of the project area as it is now. Section 2 contains physical data and descriptions, drawn primarily from other annexes to this report. The most important of these, in which further details can be found, are

- Annex B - Soils and Land Classification
- Annex C - Hydrology and Water Balance
- Annex E - Agronomic Studies
- Annex F - Livestock
- Annex H - Forestry
- Annex J - Environmental Aspects.

Section 3 presents information on present land use. Since this is dominated by agriculture, emphasis is on tank schemes of various sizes which have been established in parts of the project area. March 1979 aerial photographs form the basis for a map of present land use. Communities of significant size are identified, and the level of services provided to the residents of the area is discussed and compared to national norms in Section 4. A brief outline of studies of the proposed project which preceded this feasibility study is included as Appendix I.

Especially with respect to the subject of human activities and infrastructure development, a survey conducted by MDB in early 1979, "Basic Socioeconomic Data of Maduru Oya (System B)"[1], was an extremely valuable source of data and is used extensively herein.

2 - PHYSICAL AND BIOLOGICAL FEATURES

2.1 - Introduction

Figure A-2 shows the location of the project area 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 of the Mahaweli Scheme, and falls within Polonnaruwa District (the Left Bank of the west of Kadawathamadu) and Batticaloa District (the Right Bank and the eastern Left Bank). A small part of the southern Right Bank area falls within Amparai District.

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. 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, which is located approximately 32 km south of Welikanda. 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.

2.2 - Physiography and Geology

Physiographically, the project area is a peneplain--an old erosional surface with generally subdued topography broken by outcrops of rock ridges or isolated knobs. These outcrops become less frequent toward the northern boundary of the project area.

The geology of the project area is characterized by Precambrian rock which can be separated into two groups.

- The Vijayan series of hornblende gneiss, biotite gneiss and hornblende biotite gneiss with associated pegmatites and migmatites. This group dominates the project area.

- The transitional zone of rocks between the Vijayan series and the Khondalite series. This group is made up of hornblende biotite gneiss, charnokites, biotite gneiss and thin calcic silicate lenses. This rock group is found mainly in the southwest part of the project area.

These ancient rocks have given rise to a mature, mantled and undulating peneplain which merges to the north with 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. Because of the relatively impermeable nature of the parent rock, groundwater is generally confined to localized joint concentrations, and the solid and associated weathered rock.

272

Two very different soils have developed on the Precambrian rocks. On those rich in ferromagnesian minerals belonging to the Vijayan series and especially to the transitional zone, moderately deep to shallow (less than 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 greater than 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 bottom land and old alluvial soils of variable but usually sandy texture. These old alluvial soils, although showing a dendritic pattern and for the most part occupying relatively low land, 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.

During the wet season, known as the Maha (see Section 2.4), the imperfectly draining recent and old alluvial soils become saturated, partly because of indeterminate drainage. The elevated quartz-rich soils, which are in many cases underlain at depths of 1 m or less by impermeable rock, also quickly reach saturation and remain waterlogged throughout the wet season. These same soils, because of their coarse texture, dry out quickly during the dry season.

The reddish to brown sandy clay loams, usually associated with the steeper slopes, can shed water, not only due to their slopes, but also due to their lower infiltration rates. Because of their composition, especially the nature of the clay fraction, they also dry out quickly in the dry season. Unlike their grey-brown sandy counterparts, which remain friable, they become hard and difficult to cultivate.

Fifteen great soil groups have been indentified in Sri Lanka, six of which occur in the project area. These are as follows.

Reddish Brown Earths (RBE)

Four well drained and four imperfectly drained series of this group have been identified within the project area. About 24 percent of the soils of the project area fall into this group. In the upland (well drained) areas, many of the RBE soils are shallow, steeply sloping or gravelly. The better quality soils tend to occur in small (under 100 ha) blocks.

Noncalcic Brown Soils (NCB)

Two sell drained and two imperfectly to poorly drained series of this group have been identified. For each drainage type, the two series are differentiated by clay content. About 34 percent of the soils in the project area fall within this group.

Low Humic Gley Soils (LHG)

Three poorly drained series of this group have been identified in the project area, and together they constitute about 3 percent of the total project area.

Recent Alluvial Soils (RAL)
of the Maduru Oya

Four series of recent alluvials have been identified, three of which are poorly drained and one of which is a moderately well drained levee soil. About 7 percent of the soils in the project area fall within this group.

Old Alluvial Soils (OAL)

These soils, which occur in old tributary valleys, are variable in texture, but drainage is normally imperfect to poor. Soils of this group constitute about 21 percent of the project area. The group is subdivided into four series.

Solodized Solonetz Soils (SS)

These soils, which occupy less than 1 percent of the project area, are imperfectly drained and alkaline at depth. Two series have been identified.

As discussed in Section 3, agriculture in the project area is dominated by lowland paddy cultivation. This type of agriculture is carried out successfully on LHG, RAL and OAL soils, on the imperfectly drained RBE's and on the finer textured, poorly drained NCB's. Some homestead and shifting cultivation takes place on the upland soils.

2.3 - Climate

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 A-3). 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. Table A-2.1 summarizes mean and extreme values of three key hydrometeorological indicators--temperature, precipitation and streamflow. These figures illustrate the relatively minor temperature fluctuations which are normally experienced, compared with wider fluctuations in precipitation and streamflow.

2.4 - Forests

The forests of the project area appear to have been heavily exploited in one manner or another over a long period. Evidence of ancient settlements is found throughout in the form of abandoned bunds, tanks and ruins. More recent selective commercial logging has depleted much of the area of material for railway sleepers and timber logs. There has also been widespread exploitation of the forests for building materials and fuel wood by the local population, and chena (shifting) cultivation has left significant scars on the landscape.

These activities have turned the originally lush Dry Zone forest into badly degenerated scrub jungle, characterized by scattered, short, limby mature trees of many species, with an understory of shrubs and pole-sized material. Some replanting to teak or eucalyptus of clear-cut chena lands has been carried out, either by the Forest Department (in the Korale Forest Reserve) or under agreements between chena farmers and the Forest Department. Large park-like areas

TABLE A-2.1

SUMMARY OF CLIMATIC MEANS AND EXTREMES

	Maximum, Minimum or Average	Month Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (^{o}C)*	Maximum	31.4	33.6	35.4	36.6	37.4	38.2	37.4	37.8	37.6	36.2	33.3	32.1	38.2
	Average	25.4	25.7	26.8	28.0	29.0	29.5	29.1	28.6	28.4	27.3	26.3	25.5	27.5
	Minimum	17.1	17.4	19.1	21.7	20.9	21.2	21.1	20.6	20.4	20.4	18.0	19.0	17.1
Rainfall (mm)**	Maximum Year	152	402	0	0	10[illegible]	0	28	7	38	173	579	1,465	2,946
	Average	236	147	65	87	62	22	65	64	75	192	319	432	1,765
	Minimum	128	0	116	0	0	0	0	0	18	26	269	315	871
Streamflow ($10^6 m^3$)***	Maximum Year	59	107	14	2	4	0	0	0	0	0	81	630	897
	Average	95	48	20	14	13	4	3	4	4	15	50	112	381
	Minimum	36	9	6	14	0	1	0	1	0	9	25	53	154

* Data for Batticaloa. Maxima and minima are extremes recorded over the period of record.

** Data for Welikanda. Maximum year - 1957, minimum year - 1968.

***Data for Maduru Oya at damsite. Maximum year - 1957, minimum year - 1956.

have developed as a result of soil and moisture conditions, plus the long-term use by human (chena cultivation) and animal (grazing) populations.

Five classes of forest or recently forested land have been identified from the recent aerial photographs

- Dense Forest (Type 1)
- Medium Forest (Type 2)
- Light Forest or Parkland (Type 3)
- Forest Plantations
- Chena (active or recent).

Conclusions regarding areas and timber volumes drawn from these photographs are more reliable than any available official forest inventories because of the continuing activities of chena farmers. The locations of the various classes of forest are shown in Figure A-4, the preparation of which is discussed in Section 3.1. Areas and estimated timber volumes are summarized in Table A-2.2, while the principal tree species occurring within the project area are summarized in Table A-2.3. These exhibits indicate the degree of influence that exploitation by chena cultivation has had on the forests of the project area. Only 2 percent of the forested area is classed as Type 1 (dense forest), while an area equal to almost half of the total forested area has been subject to recent chena cultivation.

2.5 - Floodplains

2.5.1 - Mahaweli Ganga Floodplain

The western boundary of the project area can be considered to be the edge of the Mahaweli floodplain or the Right Bank

278

TABLE A-2.2

FOREST AND CHENA LANDS IN THE PROJECT AREA

	Estimated Yield* (m^3/ha)	Area in ha: Left Bank	Area in ha: Right Bank	Area in ha: Total	Percent of: Total Forest	Percent of: Total Project Area
Type 1 - Dense Forest	6	1 000	300	1 300	1.9	1.1
Type 2 - Medium Forest	5	31 800	18 000	49 800	74.7	40.2
Type 3 - Parkland	Nil	9 200	2 000	11 200	16.8	9.0
Plantation	-**	4 200	200	4 400	6.6	3.6
Subtotal Forests	-	46 200	20 500	66 700	100.0	53.9
Chena	Nil	22 700	10 100	32 800	-	26.5
Total Forest and Chena	-	68 900	30 600	99 500	-	80.4

* Merchantable timber.

**No yield estimate available. Plantations in the project area are under 15 yr old.

219

TABLE A-2.3

PRINCIPAL TREE SPECIES

Botanical Name	Local Name	Potential Uses
Drypetes sepiaria	Wira	Fuel and charcoal
Manilkara hexandra	Palu	Sawlogs--less valuable
Hotoptelea intigrifolia	Godakirilla	Sawlogs--less valuable
Euphoria longana	Mora	Sawlogs--less valuable
Berrya cordifolia	Halmilla	Sawlogs--valuable
Bauhinia racemosa	Mayila	Sawlogs
Pterospermum canescens	Velang	Sawlogs
Spyzygium cimini	Nadung	Sawlogs

Note - All species can be used for fuelwood and charcoal. Wira is only suited to this use, due to the poor shape of its trunk.

of the Mahaweli Ganga, depending on the plans for development of the floodplain. Elsewhere in this feasibility study, the boundary is considered to be the edge of the floodplain due to the difficulties associated with agricultural development under continued flooding conditions, and the importance of the area to wildlife, fish and grazing domestic animals. The following description is intended to complete the picture of the project area, as bounded by the Mahaweli.

The portion of the floodplain of the Mahaweli Ganga which is adjacent to System B covers an area of over 10 000 ha. The levees of the Mahaweli are at a relatively high level and consist of generally well drained soils. A considerable amount of tobacco cultivation is carried on in these areas, often with supplementary irrigation water lifted from the river. Moving inland, the level drops to that of the floodplain proper, which is subject to widespread inundation. Flooding typically begins in late October and often lasts until late January. The main Polonnaruwa-Manampitiya road is occasionally impassable during this period. In 1978, it was impassable from November 24 until December 8.* At the lowest elevation are permanent wet areas or swamps, known as "villus". These areas receive water when the river level is high and discharge it slowly through connecting channels when the river level is low. They do not dry out in most years, and are therefore important dry season concentrating points for wild animals, birds, fish and grazing domesticated animals. The major villus adjacent to the project area, beginning at the northern boundary, are

- Vandevetiena Villu
- Kokku Villu

*The floods caused by the 1978 cyclone were fairly serious, and are estimated to correspond to a return period on once in 3 to 5 yr.

- Kanavadi Villu/Katuwanwila Villu
- Mutugalla Villu
- Hewampitiya Villu/Karapola Villu
- Tamdra Villu
- Gengala Villu
- Bendiya Villu/Handipan Villu.

Because of the opportunity presented by nature for grazing, water supply and fishing during the dry season, villages have become established over the years on the high land adjacent to the floodplain. Small tanks have also been established to permit a late wet season crop of paddy to be grown in some areas.

2.5.2 - Maduru Oya Floodplain

The floodplain of the Maduru Oya is subject to shorter duration, more intense flooding than that of the Mahaweli. The period of serious flooding typically lasts from mid December to early January, although once in 5 yr such flooding can begin as early as October 30 or end as late as February 4. The median duration of serious flooding is 2 days, but durations of 0 to 14 days have been recorded.

The floodplain of the Maduru Oya has fewer swamp areas (villus) than does that of the Mahaweli, and has been cultivated to a greater degree by the residents of the area. Parts of the area downstream from Welikanda are cultivated in "rainfed" paddy (see Figure A-4 for locations) by farmers who accommodate the risk of flood damage by planting in early October, thereby ensuring that the long-stemmed variety which they plant will have grown tall enough by mid December to resist flood damage. The need to use long-stemmed varieties does limit yield potential, however.

2.6 - Wildlife

As discussed in Annex J, the project area is inhabited by a wide variety of wildlife, six species of which have been included in the U.S. Government's most recent (1979) endangered species list.

Of the 115 mammalian species and subspecies found in Sri Lanka, 58 are likely to be found in the project area. Species observed or detected by signs during field trips associated with this feasibility study included

- *Presbytis entellus thersites*	- Grey Langur (Monkey)
- *Macaca sinica sinica*	- Toque Macaque (Monkey)
- *Hystrix indica*	- Old-World Porcupine
- *Lepus nigricollis singhala*	- Black-Naped Hare
- *Canis aureus lanka*	- Jackal
- *Herpestes edwardsi lanka*	- Grey Mongoose
- *Herpestes smithi zeylanicus*	- Ruddy Mongoose
- *Panthera pardus fusca*	- Leopard
- *Elephas maximum maximus*	- Ceylon Elephant
- *Axis axis ceylonensis*	- Spotted Deer
- *Rusa unicolor*	- Sambhur.

Of the mammals present in the project area, two (leopard and elephant) are listed as endangered species, while the purple-faced langur and toque macaque, both endemic to Sri Lanka, are considered to be threatened.

There are 2 amphibian and 18 reptilian species endemic to Sri Lanka, and found within the project area. Three of these, the mugger crocodile (*Crocodylus palustis*), Bengal monitor (*Veranus bengalensis*) and the python (*Python molurus molurus*) are listed as endangered and many others have shown a decline as a result of habitat destruction.

There is little information relating to the fish of the project area specifically. There are about 60 species of freshwater fish on the island, at least 15 of which have been introduced. Of the eight endemic fish species found within the area affected by the Accelerated Mahaweli Programme, at least four are known to occur in the project area. These are the two-spotted barb (Barbus bimaculatus), leaf lates (Belontia signata), stone sucker (Garra lamta) and the mountain labeo (Labeo fisheri).

The avian fauna of the project area is very diverse, including both resident and migrant populations. Well over 100 species are expected to occur within the project area and, in fact, 50 were observed during a single 9-day field trip in September 1979. About half of these were species dependent, in whole or part, on forest habitat.

Among the birds of Sri Lanka, eight species are endemic and one of these, the red-faced malkoha (Phaenicophaeus pyrrohocephalus) is endangered*. Others, such as the rose-ringed parakeet (Psittacula krameri) and two species of munia (Lonchura malabarica malabarica, Lonchura malacca malacca) are agricultural pests of economic significance, likely to have a negative impact on agricultural development within System B.

2.7 - Archaeological Sites[4]

The Maduru Oya project area was once the scene of intensive paddy cultivation and associated settlement, as evidenced by the large number of abandoned tank bunds (including a large bund at the Maduru Oya damsite), temples and other places of

*This species is, however, unlikely to occur within the project area.

religious significance. There are several purana* villages within the project area which are associated with still-active ancient tanks. Yakkure village, which is located in System C near the Mahaweli Ganga on the boundary with System B, has been identified as one purana village which has attributes which are particularly worthy of preservation. The ruins of an ancient monastery, now used as a cemetery, are located there.

Twenty-eight archaeological sites have been identified to date by MDB within the project area. The most important of these, which are located in Figure A-6, are as follows.

Kandegama

This major site, which is located on a large rock outcrop near the Maduru Oya damsite, has been set aside by MDB as an Archaeological Reserve. The overall reserve is 1,200 ha in extent, while the area immediately surrounding the caves, dagoba,** and other ruins is about 36 ha.

Aralaganwila Vihare***

This site, which is located within the boundaries of the Pimburettewa Scheme, contains a small dagoba. It can be considered to be one of the earlier dagobas, as it has a chatra (a stone umbrella). The ruins of the sacred quadrangle are still visible.

---

* Purana - traditional.
** Dagoba - monument shaped like a hemisphere surmounted by a spire.
***Vihare - temple building.

Dimbulagala

This site, (Gunner's Quoin), consists of a vihare with several buildings enclosed within a sacred quadrangle. The Archaeological Department has excavated and conserved the site which has been "identified as a typical monastery found in several parts of the island"[2].

Nelugala

This site is located on a large rock outcrop to the south of Welikanda, on the Right Bank of the proposed project. An Archaeological Reserve covering the entire outcrop has been set aside.

Annex J contains an outline of the measures to be employed by MDB[4] to preserve the above major sites, catalogue additional sites, and preserve those which may be threatened by the proposed development.

3 - PRESENT LAND USE

3.1 - The Map of Present Land Use

High quality aerial photographs flown by Hunting Technical Services Ltd. in March 1979 and printed at a scale of approximately 1:20 000 were interpreted to form the basis for the map of present land use, Figure A-4. This map distinguishes the following categories of land use

- Forest
  - Type 1 - dense forest
  - Type 2 - medium forest
  - Type 3 - light forest ("parkland")
  - plantation

- Rock Outcrops

- Water
  - tanks
  - major rivers
  - smaller rivers and streams

- Agriculture
  - areas under paddy cultivation
  - areas recently subject to chena cultivation
  - large farms (government-owned livestock farms and fiber plantations)

- Settlements
  - groups of homesteads

- Transportation
  - roads
  - railroad.

Table A-3.1 summarizes the areas which are devoted to the above land uses.

Areas of human activity are scattered, with concentrations in the Pimburettewa, Vakaneri and Punanai schemes, and in settlements and minor tank schemes associated with the lower lying areas. Over 50 percent of the project area remains in forest (Section 2.5), and only 16 percent of the total area can be considered to be associated with concentrated human activity. The remainder is either subject to limited human activity (chena farming, forest exploitation, grazing of domestic animals) or is uninhabited. The majority of the population is engaged in agricultural activity of some type, with some additional employment provided in the service and government sectors. Communities in the area provide basic services, but the standard of most services is below national norms.

3.2 - Irrigated Agriculture Under Tank Schemes

The traditional form of paddy cultivation in the Dry Zone of Sri Lanka, which has been followed for over 2,000 yr, involves the construction of a small reservoir or "tank" to provide security of water supply for a wet season (Maha) crop. Secondary benefits of tanks have included their function as sources of water for a small Yala crop, for domestic water, and for domestic animal and wildlife grazing during the dry season. Because of the typically open nature of the damsites and the low height of the dams, a considerable area of land is inundated relative to the area irrigated--typically 3 to 4 ha of Maha cultivation per hectare flooded by the tank.

TABLE A-3.1

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 A-4 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.

3.2.1 - Major Irrigation Schemes

There are three "major" (over 500 ha gross area) irrigation schemes which fall within the overall boundaries of the project area, although some surveys of the area have deliberately excluded them. For purposes of completeness, they are included here. These schemes are the Vakaneri and Punanai schemes, which are located in Batticaloa District, and the Pimburettewa Scheme, which is located in Polonnaruwa District. The present human activity in the project area is concentrated around these three schemes. Table A-3.2 summarizes their characteristics.

The Vakaneri Scheme depends on the Vakaneri Tank, which was restored in 1910. It has been upgraded several times since then, and now serves an area of some 3,100 ha in the Maha and provides a Yala water supply which is sufficient to cultivate about 800 ha. Runoff from the tank's small natural drainage area (only 10 km^2) is supplemented by water which can be diverted from the Maduru Oya. The Punanai Anicut (diversion structure), which is located to the south of the village of Punanai on the Maduru Oya, was rebuilt in 1966-67. It permits full control of the main (north) channel of the Maduru Oya, diverting water to the north into Vakaneri Tank and to the south to the Punanai Scheme.

Normal operating procedure for the Vakaneri Scheme is to retain the tank level at full supply level (FSL) as long as possible into the dry season, using a combination of natural and diverted inflows. As flows in the Maduru Oya reduce in May and approach zero in June, July and August, the water stored in the tank must be withdrawn to "finish off" the Yala crop.

TABLE A-3.2

CHARACTERISTICS OF MAJOR TANK SCHEMES

Tank Characteristics	Scheme Name		
	Pimburettewa	Vakaneri	Punanai
Gross Storage ($10^6 m^3$)	49	17	
Live Storage ($10^6 m^3$)	42	16	
Full Supply Level (m)	71.3	16.3	
Minimum Operating Level (m)	64.0	10.5	
Irrigated Area			
Nominal Area (ha)	1 660[1]	3 400	510[2]
Normal Maha crop (ha)	1 260	3 120	410
Normal Yala crop (ha)	1 160	800	80

Notes: [1]Includes Tract 9, which is not irrigated at present.
[2]Estimated from map of present land use. Area quoted by officials is 620 ha.

In addition, some 1.4 million m^3 of water is required per year by the National Paper Corporation's Valaichchenai mill (Section 3.6), which obtains its water supply by pumping directly from the tank. Problems are frequently experienced late in the Yala season when shortages occur because the planted area is greater than that authorized by the Irrigation Department.* Officials estimate that about one-third of the Yala crop is damaged by water stress.

As noted above, the Punanai Scheme receives water diverted from the Maduru Oya at the Punanai Anicut. Due to the absence of storage, the Maha crop of some 400 ha and Yala crop of about 80 ha are subject to the uncertainty of the unregulated flows of the Maduru Oya. Crop yields suffer accordingly.

The Pimburettewa Scheme is located on the Kuda Oya, a left bank tributary of the Maduru Oya which enters the latter near Welikanda. The scheme was constructed over the period 1969 to 1978, with the first crop grown in the 1974 to 1975 Maha season. The bund (dam) for the tank was built at the site of an ancient bund and impounds a total of 49 million m^3 of water, 39 million m^3 of which can be considered to be usable live storage. The natural water supply, as regulated by the tank, is adequate to irrigate about 1,260 ha of land in the Maha season, and an average of 1,160 ha in the Yala. The northernmost tract (Tract 9) of this scheme has never received water due to limitations in the natural water supply and losses from the unlined canal system.

*The Yala crop is planted as early as possible to try and minimize this problem. The crop is harvested in August rather than in September, which is more typical for the Dry Zone.

3.2.2 - Minor Tank Schemes

The Irrigation Department, through its offices at Manampitiya (covering Polonnaruwa District) and at Chenkaladi (covering Batticaloa District), keeps statistics for the numerous small tank schemes falling within System B. However, since the Department plays a limited (sometimes no) part in the operation of these schemes, the statistical data must be used with some reservations. Fortunately, the map of present land use (Figure A-4) provides a means of checking the statistics, at least for the total areas quoted as being irrigated from tanks or being cultivated under rainfed conditions.

The Manampitiya Irrigation Engineer's (IE) office lists 35 small tanks under its jurisdiction, while the Chenkaladi IE's office lists 15. Twenty-nine of these 50 tanks are located on Figure A-4, and the statistics relating to them and other small tanks are summarized in Table A-3.3.

The operating policy followed at most of the minor tanks is to give priority to the supply of water to the Maha crop, with the result that there is little water left for a Yala crop. Much of the water that is left is used for stock watering or is lost to evaporation during the dry season.

Table A-3.4 allows a comparison to be made between the cropped areas measured from the map of present land use and the official statistics provided by the Department of Census and Statistics and quoted extensively in Annex E. The data in the table show that, in spite of the difficulties inherent in obtaining meaningful statistics for scattered small developments which are independently administered, the derived indicators of present agricultural activity are reliable.

TABLE A-3.3

SMALL TANK SCHEMES
IN THE PROJECT AREA

Sector[1]	Tank Number[2]	Tank Name	Gross Storage in Tank ($10^6 m^3$)	Areas in ha: Gross Irrigable[3]	Net Cropped: Maha[4]	Net Cropped: Yala[5]	Remarks
1	9	Ambalana Kulam	N.R.[6]	40			
	10	Kolakanaweli Kulam	1.0	70			
	11	Maha Wewa	N.R.[6]	20			
	12	Dalukana Wewa	0.6	70			
	13	Gal Wewa	6.8	260			
	15	Iddepichcha Wewa	0.2	20			
	16	Ella Wewa	N.R.[6]	80			
	17	Ettapolankadawela Wewa	0.5	40			
	18	Aralaganwila Wewa	N.R.[6]	-	-	-	(Included in Pimburettewa Scheme (18)
		Miscellaneous	N.R.[6]	240			
		Subtotal Sector 1		840	660	130	
2	1	Rottuwa Wewa	1.3	90			
	2	Mawa Kulam	1.1	90			
	3	Moonamadu Kulam	0.6	40			
	4	Mutugalla Kulam	N.R.[6]	-	-	-	(In Mahaweli floodplain (4)
	5	Puduveli Kulam	0.1	-	-	-	
	6	Talemende Ode Kulam	0.4	40			(In Mahaweli floodplain (5)
	7	Madiran Kulam	0.5	40			
	8	Kottukerner Kulam	0.2	20			
	14	Gamunu Wewa	0.1	10			
	25	Singara Kulam	0.3	40			
	26	Attikattu Kulam	N.R.[6]	60			Estimate.
	27	Mathurawerni Kulam	2.7	160			Tank under construction (26)
	28	Kunchan Kulam	N.R.[6]	40			
	29	Kirimechchi Ode Kulam	1.5	100			
	30	Kadawatamadu Kulam	N.R.[6]	80			
	31	Annasuddakattu Kulam	1.2	120			
		Miscellaneous	N.R.[6]	370			
		Subtotal Sector 2		1,300	1,040	210	
3	20	Meeyankolla Kulam	N.R.	580			
	21	Tharavai Kulam	0.5	80			
	22	Wadamunne Wewa	4.5	150			
	23	Harakagala Wewa	N.R.[6]	40			
	24	Kalichchai Tank	N.R.[6]	40			
		Miscellaneous	N.R.[6]	360			
		Subtotal Sector 3		1,250	1,000	200	
		Grand Total		3,390	2,700	540	

Notes:
[1] Sector 1 - Left Bank as supplied by Main Canal to Railroad
Sector 2 - Balance of Left Bank
Sector 3 - Right Bank
[2] See Figure A-4 for locations of tanks
[3] Taken from Irrigation Department statistics
[4] Estimated to be 80 percent of gross area
[5] Estimated to be 20 percent of Maha area
[6] N.R. - Not Recorded

TABLE A-3.4

COMPARISON OF DATA RELATED TO AREAS CULTIVATED IN PADDY

	Total Areas in Hectares for Project Area			
	Source			
	Dept of Census & Statistics	Irrigation Dept	Present Land Use Map	Adopted for Study[1]
Small Tank Schemes				
Gross Area	2 300	3 390	3 590	3 400
Maha Crop Area	1 920	-	-	2 700
Yala Crop Area	550	-	-	540
Rainfed Areas				
Gross Area	6 360	-	5 190	5 000
Maha Crop Area	4 790	-	-	4 000
Small Tank Schemes and Rainfed				
Gross Area	8 660	-	8 780	8 400
Maha Crop Area	6 710	-	-	6 700
Yala Crop Area	550	-	-	540
Major Schemes				
Gross Area	5 020	5 680	4 900	5 170
Maha Crop Area	4 060[2]	4 880	-	4 790
Yala Crop Area	1 620[2]	1 860	-	2 040

Notes:

[1] Adopted for calculating "Future Without the Project" returns.

[2] DCS data not representative, as build up of cropped area in Pimburettewa Scheme took place 1973-1978, for which period averages have been computed.

3.3 - Rainfed Paddy Cultivation

In those areas which have imperfectly to poorly drained lowland soils but which have no suitable site for a tank, paddy can still be grown on bunded fields in the Maha season. It is estimated that some 5,000 ha of land in the project area are bunded and suitable for "rainfed" paddy cultivation, and that about 4,000 ha are cropped in the average Maha season.

The rainfed paddy areas are usually in the lower reaches of tributary streams or the Maduru Oya. Thus, the term "rainfed" is somewhat misleading, since some of each field's water supply is derived from upstream runoff. However, since the natural storage capacity of the watersheds is limited, there is little insurance against dry periods during the wet season. This form of paddy cultivation is, therefore, the least secure--a fact which is reflected in lower yields (Annex E). Due to the higher risk of crop failure, farmers with rainfed lands tend to invest as little as possible in their crop and devote a minimum of labor to it. They typically live far away (often over 5 km) from the cropped area, seeking supplementary employment during periods of low labor requirement for the paddy crop.

Extensive rainfed paddy areas can be identified in Figure A-4 in the floodplain of the Maduru Oya, on the eastern boundary of the Pimburettewa Scheme, and in the valley bottoms of the Right Bank tributary streams. Rainfed areas recorded by the Department of Census and Statistics over the past several years are summarized in Table A-3.5, while the resolution of these areas against the areas computed from the map of present land use is shown in Table A-3.4.

TABLE A-3.5

RAINFED PADDY CULTIVATION
AVERAGED 1973 TO 1979

	District			
	Polonnaruwa	Batticaloa	Amparai	Total
Gross area (ha)	674	5 615	66	6 355
Area sown-Maha (ha)	643	4 119	26	4 788
Cropping intensity (percent)	95	73	39	75

3.4 - Chena Cultivation

Chena (slash and burn) agriculture is the oldest form of rainfed cultivation in the Dry Zone. Although in some areas it is the only form of agriculture practised, it is more often practised in association with paddy cultivation under a tank of upland/rainfed paddy. Within the project area, chena cultivation can be categorized as follows

- Type 1 - Virgin Jungle - maximum cropping period 3 yr

- Type 2 - Scrub Jungle - (10- to 15-yr chena) - cropping period 2 yr

- Type 3 - Short Cycle Chena - fallow period of 2 to 3 yr. If grasses dominate the fallow vegetation, livestock grazing may be practised as a "Maha crop" in association with the grazing of the villus in the river floodplains during Yala - cropping period 2 yr

- Type 4 - "Permanent" Cultivation - subsistence food crops and cash crops in Maha; fallow or very short duration crops (60 days) in Yala.

The total area of land devoted to existing or recent chena cultivation has been estimated from the 1979 aerial photographs to be 32 800 ha. It is estimated that about 20 percent of the area (6,600 ha) is under cultivation in a given year.

Several cropping patterns can be distinguished.

- A mixture of two or more crops, broadcast, e.g. kurankkan and mustard; cassava, maize and cucurbits; or bananas and papaw. Planting starts in Maha with the onset of the rains

and continues as far as possible into the Yala (Type 1 and 2 chena).

- Monoculture blocks or interplanting with a total of 5 to 6 crops in one field, for instance, chillies, cowpeas, maize, tomato, and ladies' finger (Type 2 and 3 chena).

- A great variety of crops for subsistence and for local markets may be grown. In such cases, there is some specialization in cash crops like tobacco, chillies, or soybean, for which fertilizers might be used. During Yala sometimes a short duration crop like sesame or pulses is also grown. The success of the latter depends on adequate rainfall (Type 4 chena).

- When the permanently cultivated land becomes a homestead (even of 1 to 2 ha) more perennial crops are grown, such as coconut, fruit trees, hedges, and different types of useful trees and plants for fodder, firewood, medicinal purposes, etc.

On fertile soils the final stage of chena may be the homestead, on infertile soils it may be man-made "parkland". The natural vegetation, even on the shallow (sand) soils is forest and scrub. For the most part chena cultivation results in the long-term degradation of forest and soil resources.

3.5 - Livestock

One of the more important activities in the project area, affecting a large proportion of the land, is livestock grazing. While productivity rates per unit area are low due to the poor nutritional value of natural pastures and

other environmental factors, the livestock population is nevertheless large.

Cattle graze the villus during the 9-month period when they are not flooded; it is estimated that about 10 000 ha of villus land which is usable for grazing lies adjacent to the project area, along the Mahaweli. During the 3 wettest months of the Maha, the cattle are moved to the "damana" or parkland areas, which are then usable to a limited extent. Other suitable grazing lands are the verges of the flooded areas of the numerous small tanks, and the crop stubble and other material which are available in the irrigated lands below the tanks.

3.5.1 - Livestock Numbers

Data on cattle and buffalo numbers were collected during MDB's 1979 Socioeconomic Survey.[1] The estimated total number of livestock was 49 200, with the distribution between Polonnaruwa and Batticaloa Districts and among livestock types as shown in Table A-3.6. Furthermore, the survey estimated there were about 5,000 goats in the area. It said nothing about poultry, but most villagers keep a few chickens for domestic use.*

---

*Independent data on bovine numbers in the Batticaloa System B area are consistent with these estimates, nearly identical. (Data collected by the Batticaloa District Administration according to GSO Division, 1979.) The Socioeconomic Survey may, however, have grossly underestimated the number of goats in the region. The BDA data indicate a total in excess of 7,000 for the System B Batticaloa area alone. This same source indicates that the System B Batticaloa area has a poultry population of some 6,000 birds.

TABLE A-3.6

LIVESTOCK NUMBERS - 1979

District	Neat Cattle		Buffalo		Total	
	Number	Percent	Number	Percent	Number	Percent
Polonnaruwa	9 650	44	12 150	56	21 800	44
Batticaloa	19 050	70	8 350	30	27 400	56
	28 700	58	20 500	42	49 200	100

Source: MDB Socioeconomic Survey- System B (1979)

Note: The above areas exclude the Korale Forest Reserve and the Pimburettewa and Vakaneri Tank Schemes.

Most of the bovine animals were in the Batticaloa District with a particular concentration in the Vakaneri area. Buffalo represented 42 percent of bovine animals and were more important in the Polonnaruwa District. The MDB data are very sketchy, and no information on herd composition was collected. Nevertheless, the herd composition postulated in Table A-3.7 has been estimated in Annex F based on the MDB and other related data.

3.5.2 - Breeds of Livestock

The vast majority of the cattle and buffalo within the area are of the indigenous type. Indigenous neat cattle (*Zebu* or *Bos indicus*) are referred to as Sinhala breed; these are small with a mature live weight of 160 to 200 kg reached after about 4 yr of age.

Indigenous buffalo (*Bubalus bubalis*) average over 270 kg at maturity (over 4 yr of age). The crosses between indigenous buffalo and exotic Indian breeds, such as the Murrah, grow to mature weights of around 320 to 370 kg. Surti (the other main Indian breed) crosses are smaller.

3.5.3 - Livestock Production and Ownership

In the project area, neat cattle and buffalo are essentially multipurpose animals which can produce milk, meat, hides, draft power and manure. When surplus animals are sold for any of the above purposes, they can also provide a source of cash income for an individual farmer.

Ownership is mainly private although, as described below, there are some large government farms within or just outside

TABLE A-3.7

ESTIMATED HERD COMPOSITION IN THE MADURU OYA PROJECT AREA, 1979

Class	Type: Neat Cattle	Buffalo	Total
Subsistence or Traditional Sector			
Cows	6 000	4 000	10 000
Breeding Bulls	600	400	1 000
Draft Bulls	1 000	4 000	5 000
Calves	8 000	6 000	14 000
Replacements	3 000	2 000	5 000
Private Subtotal	24 600	20 400	45 000
Government			
Commercial Milking Cows	1 300	340	1 640
Draft Breeding Cows	300	-	300
Breeding Bulls	120	30	150
Calves	600	140	740
Replacements	680	490	1 170
Government Subtotal	3 000	1 000	4 000
GRAND TOTAL	27 600	21 400	49 000

the area. Most of the private large herd owners reside outside the area, and stock are tended by herdsmen.*

3.5.4 - Grazing and Management Systems

"Villu/Damana" Association

Herd size in the private sector tends to be larger than in other areas of Sri Lanka, especially on the "Villu/Damana" association--individual farmers may own over 300 cattle. At the "purana" (traditional) village, a common occurrence is for an individual to own 10 to 15 cattle with perhaps 3 in milk at any particular time of the year. If the cows are milked at all, it is once a day in the morning before they are sent out to graze collectively on public land. There are large herds of cattle which provide only subsistence milk production because of a lack of marketing outlets. These may move many kilometres in search of grazing and to respond to villu floods. In some areas, herds of 20 to 30 goats are run in conjunction with cattle and provide meat as well as milk.

There are two types of large government farms within or adjacent to the project area. On the northwest "Villu/Damana" association at Kandakadu and Trikonamadu** lie the Department of Animal Production and Health's two mainly dairy farms.

---

* The Socioeconomic Survey revealed that, of the 17 800 private cattle and buffalo in the Polonnaruwa District, only 4,274 were owned by 1,323 resident families. Of the 27 400 in the Batticaloa District, only 1,397 were owned by 396 resident families.

**Now excluded from the project area and included in System A.

Their areas total 4,700 ha, and they run 3,500 neat cattle as well as 1,060 buffalo for milk production and multiplication and distribution of breeding animals. Within the project area proper, near Welikanda, the National Livestock Development Board (NLDB) is establishing a 2,400-ha draft breeding station.

Tank or Colonization Schemes

Around existing and disused tanks and associated arable areas (e.g. Vakaneri, Pimburettewa, Wadamunne and Punanai), cattle and buffalo are integrated into irrigated agriculture. They may utilize paddy stubble, other crop residues and may graze on bunds or fallow areas. They also utilize the tank catchment areas.

Bovine animals may be for milk/meat or draft production. If draft power is used for irrigated and dryland farming, the animal can be regarded as an outlay or a receipt--if not owned, it has to be hired.

The MDB Socioeconomic Survey estimates that buffalo are used for land preparation for 70 percent of the cultivated area in Polonnaruwa District and 20 percent in Batticaloa. In each district, the remaining area is cultivated using tractors or mamoties. For road transport, male cattle are generally used in preference to buffalo. In some areas the buffalo is not considered suitable for dry land cultivation because of its fewer sweat glands and wallowing habit--therefore cattle are used.

305

3.6 - Industrial Development

The only industrial development of any significance in the project area is the National Paper Corporation's mill at Valaichchenai. This mill, which uses a mixture of local fiber and imported long fiber pulp as furnish, has a rated pulp capacity of 16 000 tonnes/yr (7,300 actual), and produces about 22 000 tonnes of paper and linerboard/box-board per year. Present practice is to use rice straw purchased from local farmers* and waste paper as sources of local fiber, which together make up about 60 percent** of the mill's furnish. Attempts are being made to produce other types of fiber in the project area, using either kenaf of sunnhemp. These two crops are being grown under rainfed conditions on a farm (the "Kenaf Farm" in Figure A-4) located near Punanai and belonging to the Paper Corporation, and kenaf is being grown on a farm located north of Welikanda and belonging to the Sri Lanka Cashew Corporation. The results of these tests have not been encouraging so far. Problems have included low yields under rainfed conditions and difficulties in handling the plants and processing the pulp.

The water supply for the paper mill is taken from Vakaneri Tank, via a pumping station which is located over the water and close to the bund. The pumping station is capable of pumping water when the tank level is below that of the irrigation sluices. However, when water levels are low, production problems are experienced in the mill due to algae growth which appears to coincide with the low tank levels.

* About 16 tonnes of rice straw were purchased in 1978, at Rs 80/tonne.
**The balance is made up of imported softwood pulp.

306

Production problems at the mill are currently being examined, and the feasibility of increasing the local fiber content of the mill's output is also receiving attention. It is likely that rice straw will continue to be the dominant source of new local fiber, with a change in product mix to emphasize corrugated cardboard and coarse papers and the most probable means of increasing local fiber content.

307

4 - COMMUNITIES AND SERVICES

The project area, since it is underdeveloped relative to most of the country, has a lower population density and lower level of services available to its inhabitants. This section presents data on population and services, together with comments where applicable. Population and settlement data are presented first, followed by information on communications and access. Information on infrastructure covers the areas of housing, schools, health, electricity and agricultural support infrastructure.

4.1 - Population and Land Ownership

4.1.1 - Population Centers

Table A-4.1 shows the population of the region which includes the project area, and national figures. Population densities in the area are well below those of the nation as a whole. The population growth rate from 1968 to 1978 was significantly above the national average. This reflects not only high natural growth but also migration into the region. Table A-4.2 presents data specific to the project area itself, and shows that population density within the project area is substantially lower still--only 20 persons per km^2. The population is concentrated in the western part (Polonnaruwa District), mostly associated with the Pimburettewa Tank Scheme and numerous small tank schemes.

Population data for the project area were collected by MDB by Grama Sevaka Division (GSD); these are the administrative units into which each district is subdivided. The boundaries

TABLE A-4.1

POPULATION OF MADURU OYA REGION[1]
(in thousands)

District	1968	Density[2]	1978	Density[2]	Increase 1968-78 Number	Percent
Trincomalee	165	63	223	85	58	35
Polonnaruwa	134	39	190	56	56	42
Batticaloa	233	95	300	122	67	29
Amparai	251	84	316	106	65	26
Total	783	68	1 029	90	246	31[3]
Sri Lanka	11 992	185	14 184	219	2 198	18[4]
Population Maduru Oya region as percent of Sri Lanka	6.5		7.3			

Notes:

[1]Matale and Badulla districts not included due to their Intermediate Zone orientation.
[2]Persons per square km
[3]Corresponds to an annual growth rate of 2.8 percent
[4]Corresponds to an annual growth rate of 1.7 percent

Source: Department of Census and Statistics

TABLE A-4.2

SYSTEM B POPULATION - 1979

District	Number of Persons	Percent	Density[1]
Polonnaruwa[2]	20 930	81.3	28.8
Batticaloa[3]	4 255	16.5	7.8
Amparai	572	2.2	22.0
Totals	25 757	100.0	19.8

Notes:

[1]Persons per km^2.

[2]Population includes 6,780 persons in the Pimburettewa Colonization Scheme who were not surveyed. It also includes 1,208 encroachers (275 families) in the Pimburettewa area who were included in the field survey. According to the MDB survey the existing settlements in Yakkure (four villages) are outside the project area. Air-photo interpretation, (see Figure A-6) however, shows the location of two of these villages - Ellawewa and Etapollangoda - to be within System B. No adjustment to the MDB survey data has been made.

[3]This includes 175 persons in GSD 211A-Kayankerni, for which no details were included in the survey report.

Source: MDB Socioeconomic Survey - System B (1979); densities calculated based on following areas - Polonnaruwa 730 km^2; Batticaloa 540 km^2; Amparai 26 km^2. Total area - 1,300 km^2.

and total population of the GSD's in the project area are shown in Figure A-5, and the population data for villages are presented in Table A-4.3. This table lists a total of 82 villages or areas of settlement. Forty-five of the larger settlements are located on Figure A-6. Twenty-five percent of the population is concentrated in nine of the villages.* These villages are

Name of Village	GSD Number	Population
Manampitiya	84	1,494
Katuwanwila	81	1,076
Kadawathamadu	82	775
Marawila	144 B	572
Horiwila	84 A	563
Karapola	83	505
Wallidda	83	485
Mutugalla	81	454
Uthuchenai	210 A	402
		6,326

The population data show that there are more males than females in all GSD's within the area, with an average of 118 males per 100 females. The national average is 106 males for every 100 females. The higher male/female ratio is probably the result of recent migration into the area.

4.1.2 - Population Characteristics

The age distribution of the project area population (see Table A-4.4) is "younger" than the national distribution.

*The Pimburettewa area, including encroachers, accounts for about one-third of the project area population.

TABLE A-4.3

VILLAGE POPULATIONS IN SYSTEM B 1979

G.S. Division Number	Grama Sevaka Division	Name of Villages	Population Male	Population Female	Total
POLONNARUWA DISTRICT					
80	Kandakadu	Kandakadu	84	64	148
		Rottuwa Wewa	49	46	95
			133	110	243
81	Mutugalla	Mutugalla	262	192	454
		Alinchipotana	188	164	352
		Katuwanwila	536	540	1 076
			986	896	1 882
82	Makuppe	Kuruntandamana	78	56	134
		Kumarapura	84	87	171
		Welikanda	88	61	149
		Suryoodaya	44	41	85
		Singarakulam	51	40	91
		Pulleyaradi	24	21	45
		Kadawathamadu	422	353	775
		Galmaduwa	31	20	51
			822	679	1 501
83	Karapola	Karapola	246	259	505
		Wallidda	263	222	485
		Hewampitiya	71	90	161
		Kolakanaweli	175	152	327
		Ginidamana	123	106	229
		Borawewa	61	55	116
		Galwewa	200	154	354
		Mahawewa	18	16	34
			1 157	1 054	2 211
84	Manampitiya	Manampitiya Bazaar	798	696	1 494
		Manampitiya	36	30	66
		Mahagantota	75	62	137
		Maha Wewa Scheme	144	113	257
			1 053	901	1 954
84A	Dimbulagala	Dimbulagala	41	26	67
		Millana	139	106	245
		Horiwila	311	252	563
		Puduveli	109	94	203
		Getamune	172	134	306
		Dalukana	142	120	262
		Seelapura	161	114	275
			1 075	846	1 921

Table A-4.3 (cont'd)
Village Populations in System B 1979 - 2

G.S. Division Number	Grama Sevaka Division	Name of Villages	Population Male	Population Female	Total
85	Alawakumbura	Alawakumbura	49	43	92
		Madurankulama	168	159	327
		Damminna	34	12	46
		Paranagama	18	14	32
		Ulpothawewa	149	189	338
		Wilayaya	222	69	291
		Veheragala	12	8	20
		Kandegama	25	14	39
		Kanichchegala	131	103	234
		Pimburettewa Tracts 1 and 2	24	12	36
		Aralaganwila	27	27	54
			859	650	1 509
85A	Yakkure*				
85B	Aralaganwila	Pimburettewa Tracts 3,4, and 5	135	129	264
		Kudawewa	111	97	208
		Bimpokna	94	80	174
		Kudaella	105	93	198
		Bamunakotuwa	184	161	345
			629	560	1 189
85C	Dewagala	Pimburettewa Tracts 6,7, 8 and 9	64	56	120
		Katupitiya	56	24	60
		Higuruwewa	92	30	122
		Divuldamana	132	98	230
			324	208	532
Subtotal Polonnaruwa District			7,038	5,904	12,942
BATTICALOA DISTRICT					
209	Perillaveli	Perillaveli	25	20	45
		Murutanai	79	55	134
		Pallathuchenai	25	12	37
		Miranakadawai	94	74	168
		Taravavi	25	17	42
		Kakilacholai	39	36	75
		Akkuranai	18	15	33
		Meeyankolla	112	93	205
		Kudumpimalai	25	20	45
			442	342	784
210	Vakaneri	Vakaneri	103	112	215
		Mulliwatawan	79	50	129
		Kudanunaikal	25	16	41
		Kulathumadu	107	98	205
		Soodupathinasenai	69	45	114
		Madurangani	61	47	108
		Mylanthanai	109	100	209
		Meeyankulam	29	21	50
		Vahulavalai	26	32	58
		Punanai	106	101	207
		Kooladchenai	55	56	111
			769	678	1 447

313

Table A-4.3 (cont'd)
Village Populations in System B 1979 - 3

G.S. Division Number	Grama Sevaka Division	Name of Villages	Population Male	Population Female	Total
210A	Kallichchai	Kallichchai	178	143	321
		Wadamunne	206	135	341
		Uthuchenai	181	221	402
		Meerandavil	122	62	184
			687	561	1,248
211	Makerni	Maturankernikulan	181	129	310
		Kirimicchai	24	43	67
		Madiyamadu	20	15	35
			225	187	412
212	Vakarai	Oddamaddu	105	84	189
Subtotal Batticaloa District			2 228	1 852	4 080
AMPARAI DISTRICT					
144B	Unuwaturabubula	Marawila	299	274	572
Subtotal - Surveyed Villages in 3 districts -			9 504	8 030	17 594
Pimburettewa encroachers (MDB Survey)			629	579	1 208
Subtotal - Population surveyed by MDB			10 193	8 609	18 802
Additional Population					
GSD 211A - Kayankerny - Alan Kulam Village			90	85	175
Pimburettewa Scheme					6 780
Grand Total - Project Area					25 757

* According to the MDB survey, the existing settlements in Yakkure (four villages) are outside the project area. Air photo interpretation (see Fig. A-6), however, shows the location of two of these villages - Ellawewa and Etapollangoda - to be within System B. No adjustment to the MDB survey data has been made.

Source: MDB Socioeconomic Survey - System B (1979) and unpublished survey information compiled by L. Gunasekera. See also Figure A-5.

TABLE A-4.4

PROJECT AREA POPULATION
ACCORDING TO AGE GROUP - 1979

Age	Male	Female	Total	Percentage
Below 6	1 791	1 650	3 441	18.3
6 - 18	3 314	2 918	6 232	33.2
19 - 30	2 474	2 212	4 686	24.9
31 - 40	1 062	931	1 993	10.6
41 - 50	776	546	1 322	7.0
51 - 60	492	233	725	3.9
Over 60	284	119	403	2.1
Totals	10 193	8 609	18 802*	100.0
Percent	54.2	45.8	100.0	

*Excludes populations of GSD 85A-Yakkure, Pimburettewa Scheme (6,780 persons as per Kachcheri), and GSD 211A - Kayankerny (175 persons).

Source: MDB Socioeconomic Survey - System B (1979)

Fewer people (6 vs 12 percent) are over 50 yr of age, and more people (87 vs 79 percent) are under 40. Over half of the project area population is under 18; consequently the provision of job opportunities within the project area for these people will be an important planning consideration.

Table A-4.5 summarizes MDB data on families and households. A total of 4,094 families living in 3,824 houses were recorded by the survey. This makes for an average family size of 4.6 persons and an average household size (number of persons per dwelling) of 4.9.

If the populations of the Pimburettewa Scheme and GSD 211A are included, the total number of families in the System B area is about 5,600 and the total number of houses is 5,240.

The birth, death and natural increase rates in the region are shown in Table A-4.6. Birth rates are generally higher and death rates lower than the national figures, resulting in a greater rate of natural increase. This is consistent with the population data presented in Table A-4.1.

Table A-4.7 summarizes the ethnic and religious makeup of the population which will be directly affected by the proposed project.* The Sinhalese population is concentrated in that portion of Polonnaruwa District lying to the south of the railroad line, while the Tamil population predominates elsewhere.

*The population of the major schemes will be affected only indirectly.

TABLE A-4.5

FAMILIES AND HOUSEHOLDS IN SYSTEM B - 1979

	District			
	Polonnaruwa	Batticaloa	Amparai	Total
Population	14 150	4 080	572	18 802[1]
Number of families	3 108	876	110	4 094[2]
Average family size	4.6	4.7	5.2	4.6
Number of houses	2 871	843	110	3 824[2]
Average household size	4.9	4.8	5.2	4.9

Notes:

[1]The population for which detailed data are available excludes the registered population of the Pimburettewa Scheme (6,780 persons) and the population at GSD 211A, neither of which were surveyed by MDB.

[2]There are 270 families who do not have their own houses and who live with other families.

Source: MDB Socioeconomic Survey - System B (1979)

TABLE A-4.6

BIRTH AND DEATH RATES*
IN MADURU OYA REGION - 1977

	Birth Rate	Death Rate	Rate of Natural Increase
Trincomalee	39.6	5.2	34.4
Polonnaruwa	32.1	5.8	26.3
Batticaloa	35.0	9.0	26.0
Sri Lanka (1976)	28.0	8.0	20.0

*Number per 1,000 population

Source: Ministry of Health

TABLE A-4.7

ETHNIC ORIGIN AND RELIGION
OF FAMILIES IN THE PROJECT AREA

	District				Percentages	
	Polonnaruwa	Batticaloa	Amparai	Total	Project Area	National
Ethnic Origin						
Sinhala	2 022[1]	22	110	2 154	52	72
Tamil	692	720[2]	-	1 412	34	20
Muslim	327	153	-	480	12	8[3]
Mixed	67	18	-	85	2	-
Total	3,108	913	110	4 131	100	100
Religion						
Buddhist	2 080[1]	36	110	2 226	54	67
Hindu	688	721[2]	-	1 409	34	18
Muslim	327	153	-	480	12	7
Christian	13	3	-	16	-	8
Total	3 108	913	110	4 131	100	100

Notes:

[1]Data for Polonnaruwa District exclude the registered population of Pimburettewa Scheme - 6,780 persons at 4.6 per family = 1,474 families, presumably all Sinhala and Buddhist.

[2]Data for Batticaloa District include the population of GSD 211A (Kayankerni) 175 persons at 4.7 per family = 37 families, presumably all Tamil and Hindu.

[3]National figures include "others" with Muslim category.

Source: MDB Socio Economic Survey - System B (1979)

Some 83 percent of the families surveyed reported agriculture as their prime occupation. Of the 83 percent, less than half are described as farm laborers (Table A-4.8). The overall total is higher than the national average, and reflects the rural nature of the project area. Just over 10 percent of occupations can be considered to be nonfarm employment. The figures do not indicate the extent of underemployment; presumably the farm and farm labor sectors do not operate at full capacity or full productivity, considering income levels in the area.

Cash income data as summarized in Table A-4.9 show that 45 percent of the families earn less than Rs 2,000/yr, while another 45 percent earn between Rs 2,000 and Rs 5,000. Nine out of every 10 families earn a cash income of less than Rs 5,000. The average annual cash family income is about Rs 2,800 or Rs 600 per capita. The total area income (excluding Pimburettewa) is estimated to be Rs 12 million/yr.

Agricultural laborers are reported to earn between Rs 8 and Rs 10/day (March, 1979)*. During paddy harvesting periods, farm labor migrates to the more developed parts of Polonnaruwa District, where they can earn higher wages.

Most families in the project area receive government food stamps to supplement their income. The value of the food stamps ranges between Rs 15 and Rs 25/person/month, depending on age. Details of the stamp scheme are contained in Appendix II.

4.1.3 - Land Ownership and Tenure

Most of the lands in the project area are owned by the Government of Sri Lanka. However, some of these lands have

*In Yala 1980 the wage rate for daily workers was in the order of Rs 15.

TABLE A-4.8

OCCUPATIONS OF FAMILIES
IN THE PROJECT AREA

	Polonnaruwa	Batticaloa	Amparai	Total	Percent
Farming	1 581	463	97	2 141	52.3
Farm Labor	909	320	7	1 236	30.2
Government Service	180	22	-	202	4.9
Cooperatives	33	3	1	37	0.9
Selfemployed	21	3	-	24	0.6
Business	121	34	1	156	3.8
Unemployed	110	23	1	134	3.3
Unclassified	153	8	3	164	4.0
Totals	3 108	876	110	4 094	100.0

Source: MDB Socioeconomic Survey - System B (1979)

TABLE A-4.9

FAMILY INCOMES IN SYSTEM B

Annual (1979) Cash Income (Rs)	Families	Percent
Less than 1,200	751	18.3
1,200 - 2,000	1 118	27.4
2,001 - 3,000	954	23.3
3,001 - 4,000	537	13.1
4,001 - 5,000	291	7.1
5,001 - 6,000	144	3.5
More than 6,000	299	7.3
Totals	4 094	100.0

Note: Current data on national incomes are not available for comparison.

Source: MDB Socioeconomic Survey - System B (1979)

been encroached upon over time by farm families seeking lands to cultivate, either in rainfed paddy or chena crops. Encroachment on government land has in some cases been regularized after the fact, by giving the encroachers a lease to occupy and farm the lands under the Land Development Ordinance (LDO) of 1935. In other cases, encroachment has been condoned in that no actions have been taken to move the encroachers, realizing that they were in need of a place to live and farm.

Some encroachers have been in the area for decades, while substantial numbers have come recently.

Encroaching, unlike urban squatting*, is an activity that in effect is spontaneous settlement--a family takes possession of a piece of land on which it hopes to make a living. Under the Mahaweli Scheme, settlement will be more organized and will bring greater rewards to the settlers from irrigated agricultural production. The MDB Socioeconomic Survey of System B has recorded the following situation for families living in the project area.

Legitimate land holders	1,148	28 percent
Encroachers	2,736	67 percent
Landless families	210	5 percent
Total number of families (excluding Pimburettewa)	4,094	100 percent

*which often takes place on private lands.

Legitimate Residents
of Project Area

The legitimate landowners and occupiers consist of free-holders, food production permit holders and some regularized encroachers. The free holders are few; mostly they own "praveni" (ancestral) lands in purana (traditional) villages.

The total extent of freehold land is 143 ha of paddy land and 59 ha of highland. The size of these holdings varies from 0.2 to 2 ha. The largest group of legitimate land occupiers consists of those who have been given permits to lands under the LDO of 1935, and those who obtained leased land under the Crown Lands Ordinance (CLO). Including the freeholders, the legitimate land occupiers have

Paddy lands	- 1,001 ha	at an average of 1.3 ha/holding
Highlands	- 603 ha	at an average of 0.6 ha/holding
Total	1,604 ha	

There are more parcels of highland (1,075) than of paddy land (779), although the average paddy holding is more than double the size of a highland holding. Most owners, however, have both highland and paddy land, considering that all of the above lands are held by only 1,148 families. There are only 126 families with individual holdings which exceed 2 ha.

The legitimately held lands (1,600 ha or 4,000 acres) are scattered throughout the project area; there are seven Grama Sevaka divisions in which the extent of legitimate land holdings exceeds 40 ha for either highlands or paddy, as shown in Table A-4.10. The legitimate land holdings

TABLE A-4.10

LEGITIMATE LAND OWNERSHIP
IN THE PROJECT AREA

GS Division		Highlands		Paddy	
		No. of Owners	Total Land (ha)	No. of Owners	Total Land (ha)
81	Mutugalla	204	100	109	149
83	Karapola	226	140	172	182
84	Manampitiya	171	87	57	48
84A	Dimbulagala	125	72	59	44
209	Perillaveli	52	33	57	104
210	Vakaneri	59	31	98	201
210A	Kallichchai	112	56	112	143
Other GS divisions		126	84	115	130
Totals		1 075	603	779	1 001

Source: MDB Socioeconomic Survey - System B (1979)

(1,600 ha) account for less than 5 percent of the total lands that are to be developed for agricultural production in System B. The disruption to legitimate land holdings and owners can be kept to a minimum, considering that most of these lands are irrigated from existing small tanks that will continue to function with supplemented water supplies.

Absentee Landowners

The above paragraphs have described the situation with respect to legitimate owners and occupiers of land who reside on their land within the project area. However, an additional large area of land has been alienated under the LDO and in addition some permits have been issued under the CLO to persons not currently residing in the project area. Under a previous government's food production drive, individuals as well as groups of applicants were leased land for cultivation. They were given the task of renovating abandoned small tanks and developing adjacent lands. Leased areas ranged from 2 to 20 ha. Many have discontinued cultivation.

According to official sources, 2,285 families living outside the project area hold government leases on lands exceeding 2 ha. Since these families were not covered by the MDB survey, little is known about their characteristics, the extent to which they utilize their leased land, and the extent of their holdings elsewhere. Neither is it known what the precise total extent of nonresident leased land is within the project boundaries. The MDB survey indicates that the total Crown land disposed of by the Crown (LDO and CLO) is 6,140 ha of paddy land and 58 ha of highland. However, the statistics also suggest that a number of Batticaloa District leases relate to lands in the Punanai and Vakaneri Schemes, which were excluded from the MDB survey (see Table A-4.11). Because of the flooding of the Madura Oya, settlement is

TABLE A-4.11

LANDS ALLOCATED UNDER
THE LAND DEVELOPMENT ORDINANCE[1]

District	Highlands		Paddy Lands	
	No. of Parcels	Area (ha)	No. of Parcels	Area (ha)
Polonnaruwa	1 027	460	1 224	717
Pimburettewa Scheme[2]		(1 150)		(1 725)
Batticaloa[3]	401	120	1 549	4 965
Totals	1 428	580	2 773	5 682

Notes:

[1]Does not include lands allocated under the Crown Lands Ordinance

[2]The Pimburettewa Scheme contains 1,464 parcels which are likely to include both highlands and paddy.

[3]Lands listed under Batticaloa District include some lands within the Punanai and Vakaneri Schemes.

Source: MDB Socioeconomic Survey - System B (1979)

impractical for many holders of floodplain lands, and they prefer to live outside the project area, mostly in the coastal area.

As pointed out in the MDB survey document, a major problem in the settlement program will be the treatment of absentee leaseholders. It would not be in the best interest of the agricultural objectives of the project to continue the practice of absentee ownership on a large scale. At the same time, it is not certain whether leaseholders can be required to take up residence in the area.

Encroachers

The number of encroachments which have taken place up to March 1979 within the project area is recorded by the MDB survey to be 2,736. Of this number, 685 families (25 percent) arrived in the 3 yr preceding the survey (see Table A-4.12). The increasing encroachment activity can be attributed in part to the publicity surrounding the Accelerated Mahaweli Programme.

Most encroachers occupy less than 2 ha. Preferred locations for this spontaneous settlement are along the main roads, especially the road from Manampitiya to the Maduru Oya damsite, the vicinity of the Maduru Oya, and around the Pimburettewa Scheme.

In many cases, the encroachers are relatives of legitimate landholders and farm laborers who settle in the hope of being allocated "Mahaweli land". Their enterprise is commendable considering the years of subsistence farming they will have to carry out before the proposed project becomes operational. In the meantime, encroachers can augment the area's construction labor force. It has been suggested that the announcement of a "cut-off" date by the Government might reduce the

TABLE A-4.12

ENCROACHMENT IN THE PROJECT AREA

District		Number of Families 1976	1977	1978
84A	Dimbulagala	23	14	37
85	Alawakumbura	25	18	13
85B	Aralaganwila	21	22	17
	Pimburettewa	19	13	15
210	Vakaneri	18	29	28
210A	Kallichchai	14	48	30
	Other GSD's	74	64	99
	Totals	194	208	239

Note: 44 families encroached in the first 3 months of 1979.

Source: MDB Socioeconomic Survey - System B (1979)

inflow of encroachers--those that settled in the area before a certain date would receive serious consideration for legitimate settlement, while those who settle after that date would not.

Consideration should be given at the policy level to the expected net effect on the project of the present influx of encroachers, in terms of the project's implementation and ultimate objectives. Considering the large number of settler families that must be attracted to the area, the present amount of voluntary settlement by encroachers may be consistent with the settlement policies that in time will be worked out for the project, provided that encroachers are willing to relocate within the area if required.

"Ande"

Ande cultivation refers to the practice of either

- subleasing one's leased land to a farmer; in return the owner will receive a proportion of the agricultural production, or

- agreeing to share in some form the agricultural production with the supplier of one's farm inputs (i.e. fertilizer, tractor, seed, credit).

The practice as far as government leased land is concerned is illegal. Although it is prevalent in some parts of the country, this is not the case in the project area, with the exception of the Pimburettewa Scheme where some Ande is taking place.

4.2 - Communications and Access

Access to the project area region is possible by road, rail, air and sea. Access to the project area itself, however, is only possible by road and rail. Postal and telephone service is available at regional centers and to a limited extent in the project area.

4.2.1 - Roads

The principal roads of the region are shown in Figure A-2. Roads designated "A" are major national roads, while those designated "B" are regional roads. Table A-4.13 summarizes recent traffic counts, which indicate the magnitude of road use throughout the region. The figures illustrate the role of Highway A-11, which traverses the project area, as an access route to the east coast. Most of the traffic on the road does not stop in the project area.

The principal point of entry into the project area is via Highway A-11, which crosses the Mahaweli on a bridge shared with the railway. This highway* and an all-weather road which runs south from Manampitiya to the Pimburettewa Scheme are the major roads which are the responsibility of the Department of Highways (see Figure A-6). The condition of the Highways Department roads is generally poorer than that of roads elsewhere in the country, reflecting the modest traffic volumes and low maintenance priority. Travel time by

*Where it crosses the floodplain, this highway is subject to closure due to floods in the Maha (see Section 2.6.1).

TABLE A-4.13

HIGHWAY TRAFFIC VOLUMES
IN THE MADURU OYA REGION

Name of Road	Location	Year	Average Daily Traffic Flow (both directions)
A-5 Badulla-Chenkaladi Rd	140th mile Padiyatalawa	1979	486
A-6 Habarana-Dambulla Rd	106th mile Habarana	1978	800
A-6 Trincomalee-Kanatalai Rd	136th mile Kantalai	1978	378
A-9 Kandy-Jaffna Rd	30th mile Nalanda	1979	1 462
A-9 Kandy-Jaffna Rd	65th mile Huradankadawela	1979	398
A-6 and A-9 Kandy-Jaffna Rd	93rd and 46th mile Dambulla	1978	1 433
A-11 Habarana-Polonnaruwa Rd	16th mile Habarana	1978	613
A-11 Habarana-Anuradhapura Rd	14th mile Habarana	1978	186
A-11 Habarana-Polonnaruwa Rd	40th mile Polonnaruwa	1979	1 280
A-11 Habarana-Valaichchenai Rd	53rd mile Manampitiya	1979	753*
A-11 Habarana-Valaichchenai Rd	70th mile Welikanda	1979	648
A-12 Trincomalee-Anuradhapura Rd	82nd mile Horawapothana	1978	170
A-12 Puttalam-Trincomalee Rd (Prana Medawachchiya)	100th mile	1979	170
B-38 Kandy-Weragantota Rd	43rd mile Pallewatta	1979	729
B-46 Bibile-Aluthnuwara Rd	15th mile Andaulpota	1979	243

*Representative of traffic volume on shared road/railroad bridge.

Source: Department of Highways

jeep from Manampitiya to Colombo is about 5 hours. Other roads in the project area are indicated in Figure A-6. Many of these roads are maintained by the Irrigation Department. Generally, road access to the existing villages on the Mahaweli floodplain is adequate, via all-weather roads which are in reasonable condition. Access to parts of the Left Bank and most of the Right Bank is difficult, with jeep access only reliable during the dry season. One all-weather road traverses the Right Bank area, reaching a point opposite Welikanda. The ford across the Maduru Oya at this location is only passable in the dry season.

Limited public bus service is available in the project area. Basic service is available via the Polonnaruwa-Batticaloa run, but the frequency of service was reported by MDB to be inadequate. Private van services operate sporadically to "augment to some extent the poor transport service in the area".[1] A twice daily bus service from Polonnaruwa to the Maduru Oya damsite is of importance to transient workers and Pimburettewa settlers.

4.2.2 - Railroads

The main line of the Ceylon Government Railroad's Colombo-Batticaloa line traverses the project area from west to east, in parallel with Highway A-11. There are 4 stations in the project area, at Manampitiya, Welikanda, Punanai and Vakaneri. Slow passenger trains will also stop at a halting place at Kolakanaweli. Freight facilities and sidings at the above stations are underdeveloped but those at Manampitiya and Welikanda are being upgraded in anticipation

of the increased traffic to be expected from the project. Service is provided by two Colombo-Batticaloa passenger trains and by one or two slow freight trains per day. The 6:00 a.m. train from Colombo arrives at Manampitiya in the early afternoon.

4.2.3 - Air

While it is possible to land a helicopter at many locations within the project area, the only government-operated airfields are located outside. Figure A-2 shows the locations of four airfields which are reasonably close, while Table A-4.14 sumarizes the facilities available at each. The airfield at Hingurakgoda is the most convenient to the project area, and offers a relatively long (2,000 m) runway and refueling facilities.

4.2.4 - Sea

The natural harbor at Trincomalee is located close to the project area. However, it is underutilized due to its inadequate docking facilities and its location away from the country's population and activity centers. With the development of the Mahaweli Scheme, the importance of the Trincomalee harbor will increase.

4.2.5 - Post and Telecommunications

There are four sub post offices in the project area which have limited delivery services. These are located at Manampitiya, Welikanda, Aralaganwila and Mutugalla. Villagers normally go to the sub post office or some preselected drop-off point to collect their mail.

TABLE A-4.14

AIRFIELDS IN THE MADURU OYA REGION

Name	Runway	Authority
Hingurakgoda	2,000 x 46 m bitumen	Department of Civil Aviation (DCA), day only
Batticaloa	1,070 x 46 m bitumen	DCA, day only
Gal Oya/Amparai	1,100 x 46 m bitumen	DCA, day only
Trincomalee (China Bay)	2,150 x 46 m bitumen	Sri Lanka Air Force; Portable lighting equipment on request

Source: DCA Aerodrome Directory 1975

Telephone service is only available along the main road/railroad, and is associated with post offices and a few government offices. Better service, including fairly reliable trunk service to other points on the island, is available at Polonnaruwa and at Valaichchenai/Kalkudah, to the west and east respectively.

4.3 - Infrastructure

The village statistics presented in Section 4.1 indicate that the residents of the project area live in some 80 villages or settlements which vary in population from about 20 (really a small group of houses) to over 1,500 (Manampitiya). The quality of housing in these settlements is low, and the level of services provided is also low. Only Manampitiya and Aralaganwila can be considered to have reasonably complete services available.

4.3.1 - Housing

The MDB Socioeconomic Survey shows a total of 3,824 housing units in the project area (outside Pimburettewa Scheme), with an average of 4.9 occupants per dwelling (see Table A-4.5). Figure A-6 shows the location of major settlements and the number of dwellings in groups of five or more which were counted from air photos. The latter should be taken as indicative of major concentrations only, since some houses surveyed by MDB could not be counted.

Most of the houses surveyed by MDB (95 percent or 3,624) can be classed as semipermanent or temporary huts. Most are built of wattle and daub*, with a cadjan or straw roof. The

*Appendix III contains a description of this type of construction and presents suggestions for improvements in simple rural house construction techniques.

few permanent houses are generally built with brick or rubble walls, with roofing of tiles or galvanized steel or asbestos sheeting. Most houses (93 percent) do not have pit latrines, and only 8 percent of the houses have wells of some type.

These are hand dug, usually unprotected wells, and are typically 1.5 to 2 m in diameter and 2 to 5 m deep. Families which have neither a well nor access to one obtain their water from nearby tanks or streams.

The cyclone of November 1978 caused considerable damage to houses within the project area. Most commonly, the roofs were blown away, although there were instances of fallen trees causing damage to the walls and interiors as well. Affected families received assistance from the Government and relief organizations to repair their homes.

4.3.2 - Schools

A total of 32 schools, all but one of which are junior schools, are located in the project area (see Figure A-6 and Table A-4.15). Only the schools associated with the Pimburettewa Scheme have more than 100 students, and some of the schools have fewer than 50. While the overall number and location of schools relative to the school age population appears to be adequate, the schools suffer from poor attendance and a lack of teachers. The former is partly attributable to the scattered nature of the settlements and associated travel distances for the students, while the latter is largely due to a lack of accommodation for teachers from outside the project area.

TABLE A-4.15

SCHOOLS IN THE PROJECT AREA

District	Grama Sevaka Division	Village	School Type	Instruction Medium
Polonnaruwa	Kandakadu	Kandakadu	Junior	Tamil
		Rottuwa Wewa	Junior	Tamil
	Mutugalla	Mutugalla	Junior	Tamil
		Katuwanwila	Junior	Tamil
		Alinchipotana	Junior	Tamil
	Makuppe	Welikanda	Junior	Sinhala
		Kadawathamadu	Junior	Sinhala
	Karapola	Karapola	Junior	Tamil
		Hewampitiya	Junior	Tamil
		Ginidamana	Junior	Sinhala
		Borawewa	Junior	Sinhala
		Borawewa	Junior	Tamil
	Manampitiya	Manampitiya	Junior	Sinhala
		Manampitiya	Junior	Tamil
		Maha Wewa Scheme	Junior	Sinhala
	Dimbulagala	Dimbulagala	Junior	Sinhala
		Horiwila	Junior	Tamil
		Dalukana	Junior	Sinhala
	Alawakumbura	Alawakumbura	Junior	Sinhala
		Wilayaya	Maha Vidyalaya	Sinhala
		Aralaganwila	Junior	Sinhala
Batticaloa	Perillaveli	Pallathuchenai	Junior	Tamil
		Meeyankolla	Junior	Tamil
	Vakaneri	Vakaneri	Junior	Tamil
		Meeyankulam	Junior	Tamil
		Punanai	Junior	Tamil
		Punanai	Junior	Sinhala
		Mulliwatawan	Junior	Tamil
	Kalichchai	Wadamunne	Junior	Tamil
	Vakarai	Oddamaddu	Junior	Tamil
	Kayankerni	Alan Kulam	Junior	Tamil
Amparai	Unuwaturabubula	Marawila	Junior	Sinhala

Total Number of Schools -

Polonnaruwa District	- Sinhala	11	
	- Tamil	10	
	Total	21	21
Batticaloa District	- Sinhala	1	
	Tamil	9	
	Total	10	10
Amparai District	- Sinhala	1	1
			32

4.3.3 - Health Facilities[3]

There is one rural hospital at Aralaganwila (24 beds) and a maternity home at Manampitiya (12 beds) to serve the entire project area. Nearby, there is a base hospital at Polonnaruwa (184 beds) and peripheral units at Vakarai (24 beds) and Valaichchenai (52 beds). The nearest general hospital is located at Batticaloa. Four central dispensaries are located within the project area at Aralaganwila, Manampitiya, Mutugalla and Kandakadu.

In spite of the low level of medical services in the project area proper, data for the three Superintendent of Health Services Divisions into which System B falls (Table A-4.16) indicate that the overall number of hospital beds per capita is not far below the national average. Infant mortality statistics for districts in the region (Table A-4.17) are below or near the national average.

Table A-4.18 summarizes hospital admission statistics for the two hospitals closest to the project area--the base hospital at Polonnaruwa and the peripheral unit at Valaichchenai. Malaria consistently accounts for about 20 percent of admissions - more than three times the national average. Malaria and intestinal disorders related to water supplies and waste disposal are the most important health problems in the project area.

4.3.4 - Agricultural Support Infrastructure

Support facilities provided by the Government are oriented to paddy and milk production. Paddy Marketing Board (PMB) stores located at Manampitiya and in the Pimburettewa Scheme handle much of the production of the Polonnaruwa District, while the output of the Batticaloa District is channelled eastwards, mainly to private traders.

TABLE A-4.16

HOSPITAL BEDS

Superintendent of Health Services Division	Beds per 1,000 Population
Batticaloa	2.17
Badulla	2.37
Matale	2.72
Sri Lanka	2.63

Note: SHS Divisions Batticaloa and Matale cover most of the System B area.

Source: Ministry of Health

TABLE A-4.17

INFANT MORTALITY RATE*
BY DISTRICTS 1976

District	Rate
Polonnaruwa	24
Batticaloa	49
Amparai	39
Trincomalee	25
Badulla	51
Matale	53
Sri Lanka (1974)	44

*Per 1,000 live births.

Source: Ministry of Health

TABLE A-4.18

CAUSES OF HOSPITALIZATION 1977

	Polonnaruwa Base Hospital (184 beds)	Percent	Valaichchenai Peripheral Unit (52 beds)	Percent	National Percentages
Respiratory	2 168	13.5	212	4.7	14.2
Accidents	1 623	10.1	1 374	30.4	10.7
Deliveries	1 629	10.1	754	16.7	11.2
Intestinal Disorders	1 886	11.8	160	3.5	9.7
Malaria	2 988	18.6	973	21.5	5.9
Other	5 775	35.9	1 054	23.2	48.3
Totals	16 069	100.0	4 527	100.0	100.0

Source: Ministry of Health

Cooperatives, which are mainly developed in Polonnaruwa District, are engaged in the purchase of paddy from farmers, as agents of the PMB. MDB estimates that, overall, two-thirds of the present production in the project area is purchased by the cooperatives, with the balance purchased by PMB authorized dealers and private traders.* Cooperatives also distribute food stamp rice and consumer goods, sell fertilizers, and administer Cultivation Loans.

Milk collection is organized by the Milk Board at Collecting Centers at Manampitiya, Mutugalla (Polonnaruwa District) and at Chittandi (Batticaloa District). Milk collecting co-operatives organize milk collection at seven locations in Polonnaruwa District, while collection is mainly in the hands of private traders in Batticaloa District. Most of the milk is transported to the condensed milk factory at Polonnaruwa, with the balance being consumed fresh in nearby villages.

4.3.5 - Electrical Service

A 33-kV power transmission line traverses the project area, in parallel with the railroad and Highway A-11. Domestic service is confined to this corridor at the present time, with Manampitiya, Welikanda and Valaichchenai (just to the east of the project area) the only settlements with significant electrification.

*Further research carried out by the consultants in May 1980 indicates that an increasing proportion of paddy is being purchased by Mudalalila (private traders) from Batticaloa.

APPENDIX I

PREVIOUS STUDIES OF THE MADURU OYA PROJECT

APPENDIX I

PREVIOUS STUDIES OF THE MADURU OYA PROJECT

The idea of large scale irrigation in the Maduru Oya basin has been considered for centuries, as evidenced by the stub of an ancient dam at the present Maduru Oya damsite.

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, constituted the first detailed assessment of the potential of the 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 stem 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

studies began. These were undertaken almost simultaneously by the Dutch firm of NEDECO and the Sri Lanka government-run Central Engineering Consultancy Bureau (CECB). NEDECO's studies covered all of the component projects of the Mahaweli Scheme, with emphasis on the projects selected for early development, known as the Accelerated Mahaweli Scheme.

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 Tender 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 dams 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	NEDECO[1]	CECB[2]
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[3]
Live Storage Capacity ($10^6 m^3$)	344	429	467
Irrigated Area (ha)	44 000	50 500	50 000

Notes: 1 - 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.

2 - As of February 1979.

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

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.

APPENDIX II

FOOD STAMPS AND WORLD FOOD AID

APPENDIX II

FOOD STAMPS AND WORLD FOOD AID*

1 - Origin

Distribution of food under a rationing scheme was first started in Berlin, Germany in 1914 to distribute bread under a "Bread Cards System". There was a shortage of sugar in England in 1917 and sugar was distributed under a rationing scheme.

A general shortage of food was experienced throughout the world during World War II and Sri Lanka too was affected by this. A committee, led by the then food commissioner Mr. R.S.D. Polier, recommended that essential and basic food items should be distributed under a rationing scheme. Accordingly, the distribution of rice under ration books was started on February 2, 1942 in Sri Lanka, for the first time. These ration books were issued to all the people in the country. In the first instance about 4 million ration books were printed.

The rice ration book scheme which was introduced in 1942 remained until September 1, 1979. On that date the food stamp scheme was introduced; it replaced the rice ration books.

*This appendix was prepared by L. Gunasekera in October 1979.

2 - The Food Stamp Scheme

Conditions for Receiving Food Stamps

All families earning a gross monthly income of Rs 300 or less are eligible for food stamps. However, this income varies depending on the number of members in the family (see Table 1).

Value of Food Stamps According to Age

Age groups		Value of Food Stamps per month
Children below 8 yr	=	Rs 25.00 each
Children over 8 yr and below 12 yr	=	Rs 20.00 each
Those over 12 yr	=	Rs 15.00 each

What a Family Can Get for Food Stamps

- rice
- bread
- dhall (Lanka parippu)
- paddy
- sugar
- milk powder (Lakspray, Vita-milk)
- flour
- dry fish
- condensed milk (Parakum)

TABLE 1

QUALIFICATIONS FOR
RECEIVING FOOD STAMPS

Number of Persons in Household	5	6	7	8	9	10	11	12	13
Annual Income of Household (Rs)	Persons Qualifying for Receiving Food Stamps								
Below 3,600	Up to 5	6	7	8	9	10	11	12	13
3,601 to 4,320	No	1	2	3	4	5	6	7	8
4,321 to 5,040	No	No	1	2	3	4	5	6	7
5,041 to 5,760	No	No	No	1	2	3	4	5	6
5,761 to 6,480	No	No	No	No	1	2	3	4	5
6,481 to 7,200	No	No	No	No	No	1	2	3	4
7,201 to 7,920	No	No	No	No	No	No	1	2	3
7,921 to 8,640	No	No	No	No	No	No	No	1	2
8,641 to 9,000	No	No	No	No	No	No	No	No	1

There is a separate set of stamps for kerosene. If one wishes, kerosene stamps can be used to obtain other items mentioned above, but food stamps cannot be used to obtain kerosene.

Food items and kerosene under the stamp scheme are valued at subsidized prices. Thus, the food stamp holders get a double subsidy, i.e. free goods at subsidized prices, not open market prices.

Stamps not redeemed can be placed as cash in savings accounts.

Total Number of
Persons Benefitting

At present about 7 million people out of 7.5 million who had rice ration books before September 1, 1979 receive food stamps. The food commissioner is taking action to issue food stamps to the remaining half million also. Accordingly, 7.5 million people will benefit from the food stamp scheme. This is about half of the total population of Sri Lanka.

3 - World Food Aid to
Mahaweli Settlers

A Mahaweli settler receives World Food Aid for 15 months from the date that he is given land. This is the situation in System H which would hopefully continue in System B. The Mahaweli Authority has to make a request for food aid in System B to the World Food Programme of the FAO.

The amount of food aid varies according to the number of dependents in the familty (see Table 2). A family with five members (father, mother and three children, aged 13, 10 and 7) would receive the following quantities of food under the aid program. In terms of current market value, the aid is the equivalent of Rs 220/month.

World Food Aid for
a Family of Five

	Quantity Per Person Per Day	Quantity Per Month		Retail Price Per lb	Value of Food Aid	
	g	lb	oz	Rs Cts	Rs	Cts
Flour	300	98	07	1.30	127	96
Pulses (dhall etc)	25	08	02	4.00	32	50
Dry fish or or canned fish	20	06	04	8.00	50	00
Sugar	10	03	02	3.00	9	37
Total Value					219	83

World Food Aid is given for 15 months. Therefore, the typical Mahaweli family would receive World Food Aid to a total value of Rs 3,300. This aid is intended as subsistence allowance until the settlers develop their land. It is expected that the settlers would spend their working time on the development of their land.

4 - Food Stamps to Mahaweli Settlers

The total value of food stamps that the above family would receive per month is as follows, provided the monthly income is less than Rs 300.

TABLE 2

WORLD FOOD AID PROGRAM

Item	Flour lb	Flour oz	Pulses lb	Pulses oz	Dry Fish or Tin Fish lb	Dry Fish or Tin Fish oz	Sugar lb	Sugar oz
Per Person Per Month								
1 person	19	11	01	10	01	04	-	10
2 persons	39	06	03	04	02	08	01	04
3 persons	59	01	04	14	03	12	01	14
4 persons	78	12	06	08	05	00	02	08
5 persons (maximum)	98	07	08	02	06	04	03	02
Per Person Per Day	300 g		25 g		20 g		10 g	

Child - 7 yr of age	=	Rs 25.00
Child - 10 yr of age	=	Rs 20.00
Three persons over 12 yr of age	=	Rs 45.00
		Rs 90.00
Value of kerosene stamps	=	Rs 9.50
Total value of food stamps		Rs 99.50

Combining food stamps and World Food Aid, the typical Mahaweli family would get aid valued at about Rs 320/month for the first 15 months. Thereafter the family would continue to qualify for food stamps, if the Rs 300/month income level is not exceeded.

APPENDIX III

RURAL HOUSING IN SRI LANKA

APPENDIX III

RURAL HOUSING IN SRI LANKA*

In the rural areas, the quality of housing of low income households is poor. The "wattle and daub" house is the simplest housing type which offers shelter to rural households with low incomes. This type of house is not a permanent structure because the thatched roof needs replacement every year and the mud walls need occasional replastering. The timber framework used either partially or totally buried in the wall is subjected to attack of dry rot and termite. The rot first starts at the bottom of the posts and gradually spreads to the top. If these houses could be built of more durable materials, then the rural low-cost housing problem could be solved to a great extent. One of the ways of improving these houses is by the introduction of earth walling, without the use of a timber frame. "Rammed earth" construction could be encouraged in rural areas and the techniques could be taught to rural folk through the village community center, priest or headman. This is an inexpensive and sound method of small-house construction. Moist earth is rammed between boards or planks laid on both sides of the wall. The success of this construction lies in quick and hard beating of the earth in molds. It is necessary to protect this type of wall from rainwater dropping from eaves, or streams of rainwater scouring the bottom. It is better to use brick or stone in lime mortar up to the plinth. This will ensure a dry bottom for the earth wall in addition to increasing its strength and durability.

*From "Housing in Sri Lanka", Marga Institute, Colombo 1976 (pp 234 to 236).

Stabilized earth construction is another method which could be used in rural house building. This type of construction can compete with the conventional building materials like stone and brick. It is cheap and most suitable for low-cost housing in rural areas since different types of earth found in different parts of the country can be used for earth walling. In a tropical country where there is bright sunshine, stabilized earth is a good building material. The techniques are so simple that ordinary rural folk without any special training can build their houses themselves and build them quite economically.

Soil stabilization is that process where the natural soil is mixed with a stabilizing agent in certain proportions. This would render it more suitable as a construction material like burnt brick or stone. The addition of the stabilizing agent or binding material not only enhances the properties of the soil but imparts to it other valuable properties. The stabilizing agents that could be used are

- cement
- asphalt, bitumen or pitch
- lime
- molasses
- silicates of sodium or calcium.

Of these, cement, though relatively costly, is the most suitable material as it is easily available. It is easy to mix cement with soil, and it gives good strength. Other materials like bitumen, molasses, and silicates cannot be mixed well except in a mechanical mixer, and would therefore be costly.

Earth wall construction could be encouraged in rural areas if brick or block making machines are made available to builders

through village welfare societies or cooperative societies. Well-designated simple machines could be operated by unskilled hands. Simple machines, like the "Sinwa-Ram" could be locally designed and manufactured. Such a machine should conform to the following principles.

- It should be light and portable on wheels, preferably made of steel plates joined by bolts and nuts.

- There should be two rigid plates or either wood, cast iron or steel, one at the top and the other at the bottom, of the exact length and width of the mold on the inside, so that they will just fit into the mold.

- The arrangement for applying pressure at the center of the mold from the top should be made by means of a long lever which presses down.

- There should be an arrangement of another lever at the bottom of the mold, which when cranked or pressed should lift the molded block together with the bottom and top plates, just above the top of the mold, so that the block can be removed by hand, and kept slightly inclined in a row on edge and the plates used again for molding the new block.

In rural housing the roof is often the most expensive item of construction, whether it is a thatched roof or tiled roof or a roof of sheeting.

Research is in progress on the feasibility of using locally made half-round tiles without elaborate roofing frames made of sawn timber. Such frames add so much to the cost of roofing that it is beyond the reach of most rural households. The technical feasibility of the use of paddy straw, which is

available freely and in abundance in rural areas as a roofing component is under investigation.

It has been suggested by researchers on low-cost building techniques that roof-frames could be assembled with round poles which are available in rural areas. On this frame, pads of straw treated with chemical preservatives could be laid 4 to 6 in. thick so as to give an even surface to the rough timber frame. On this even surface, the half round tiles could be laid so as to make a tiled roof.

The objection to the use of a straw padding between the timber frame and the tiles is that the straw can accumulate dust and be a breeding place for insects. This objection could be leveled against cadjan roofs as well. It is expected that further research will help builders to surmount these weaknesses of straw and tile roofing.

Once the technological problems of rural low-cost housing are resolved, the way will be open to the development of rural housing of improved standards. Here again the principles of collective or individual self-help housing could be applied as in urban areas. A Housing Authority should plan economical land use in rural areas, housing densities, layouts, access roads, size of plots and communal spaces and amenities. Rural households could then embark on projects of redevelopment and reconstruction of rural areas on the principles of self-help, provided they are backed by adequate long-term finance.

LIST OF REFERENCES

LIST OF REFERENCES

[1]Mahaweli Development Board
"Basic Socioeconomic Data of Maduru Oya System B"
Colombo, 1979

[2]Mahaweli Development Board
"Mahaweli Archaeological Survey - Exploration of Sites in System C between Mahiyangana and Maduru Oya"
Internal memorandum, Colombo 1979

[3]Ministry of Health
"A proposal for Health Services in the Operational and Accelerated Mahaweli Development Areas"
Dr. N. G. Wijesooriya
Colombo, 1979

[4]L. K. Karunaratne
"Conservation and Development of Historic Sites and Monuments Under the Accelerated Mahaweli Development Scheme"
Colombo, 1979

FIGURES

362

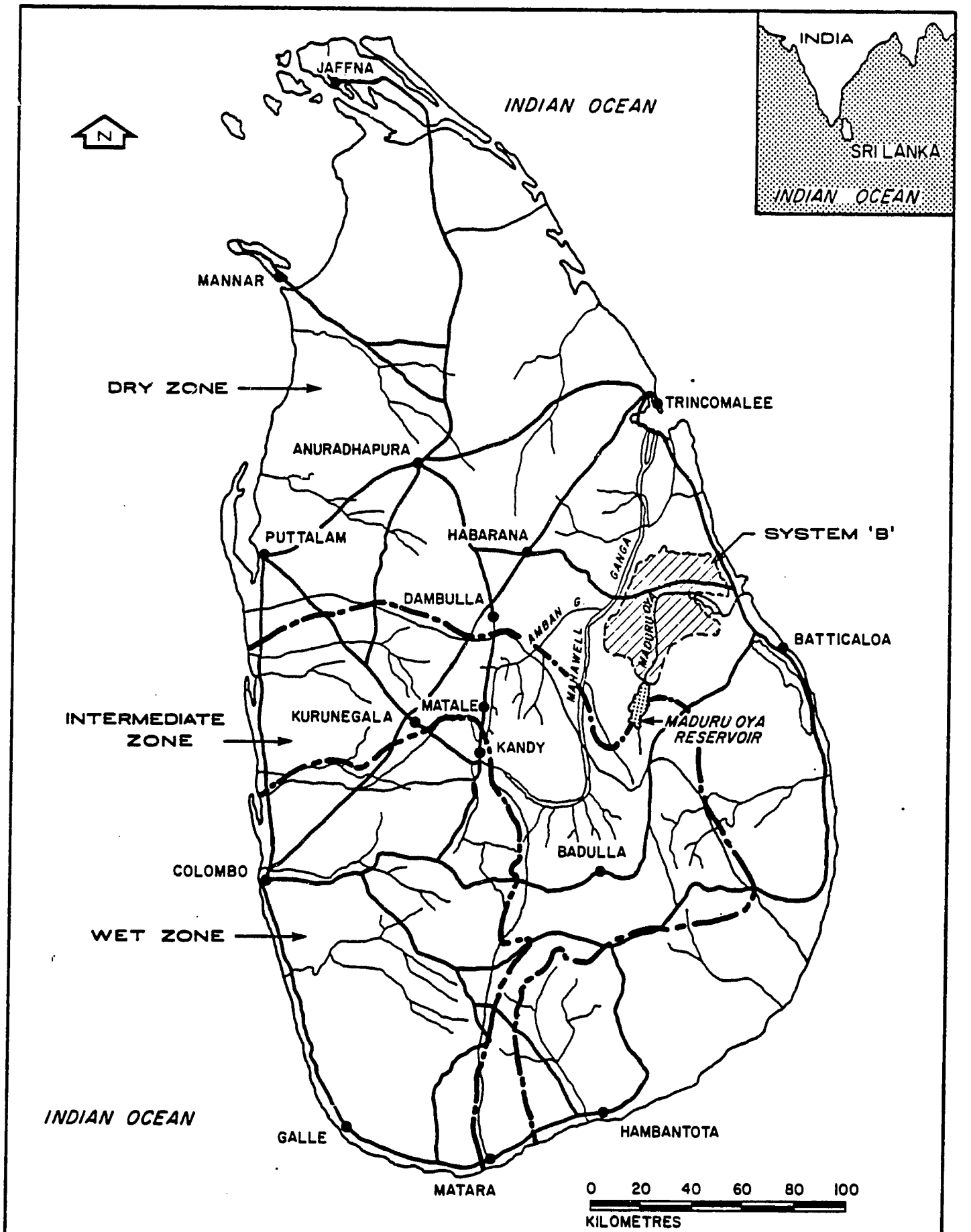


FIG. A-1

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

NATIONAL CONTEXT

ACRES

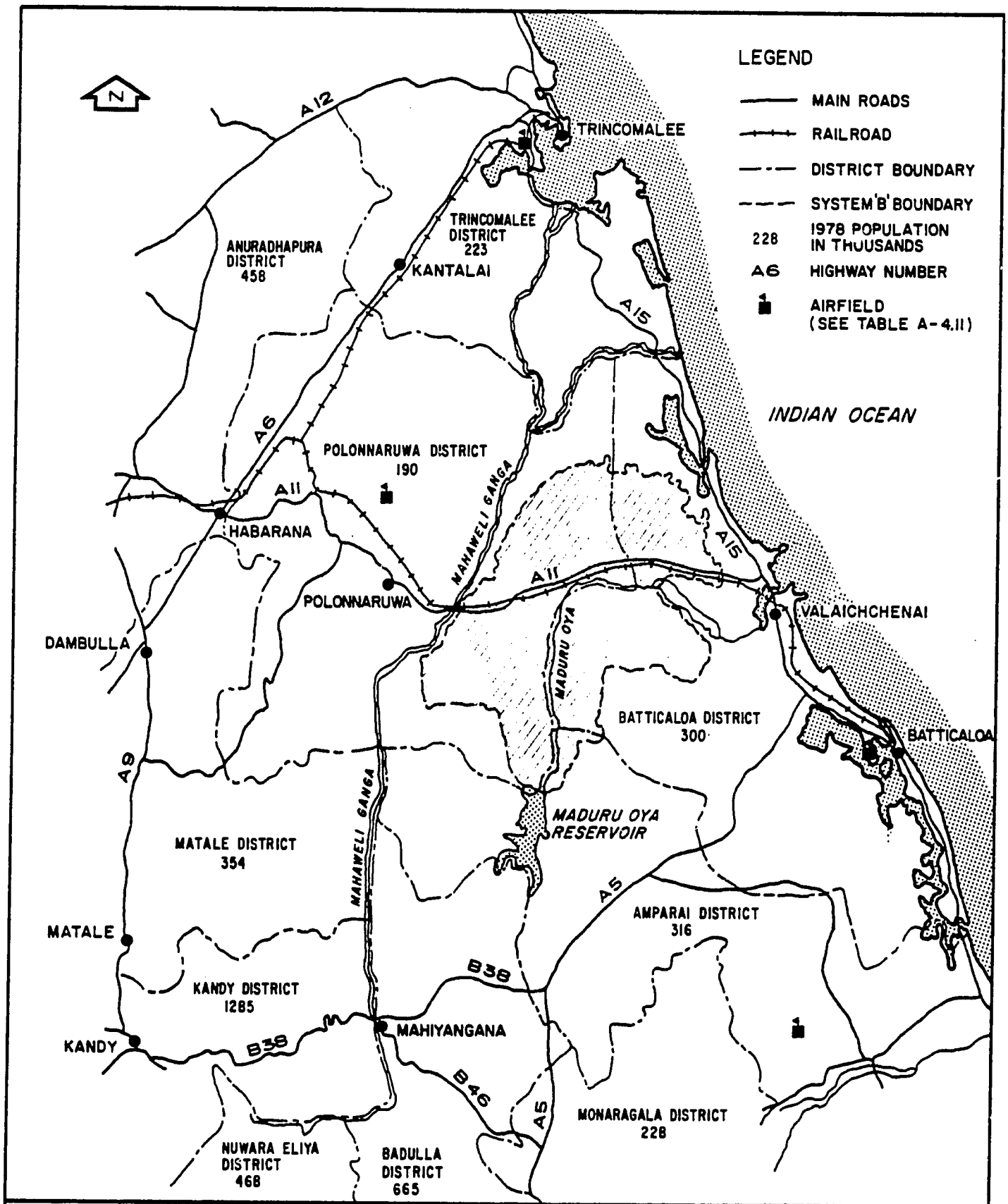
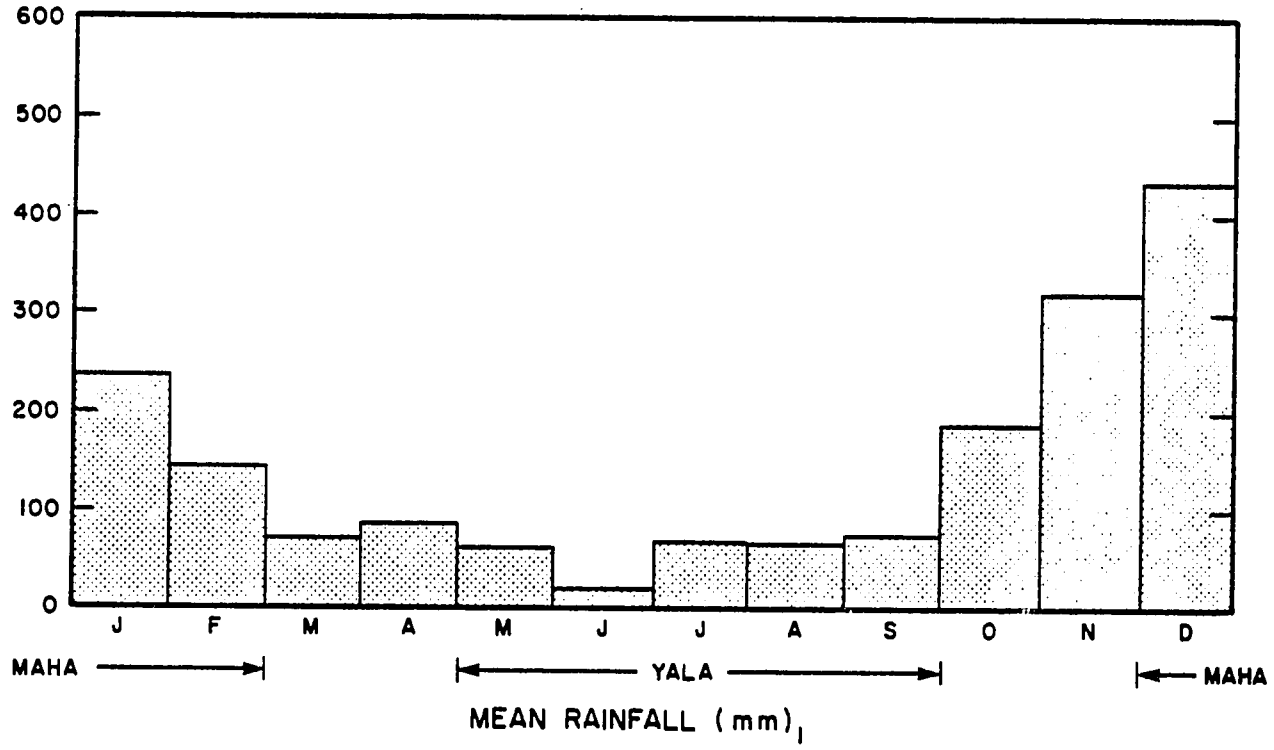


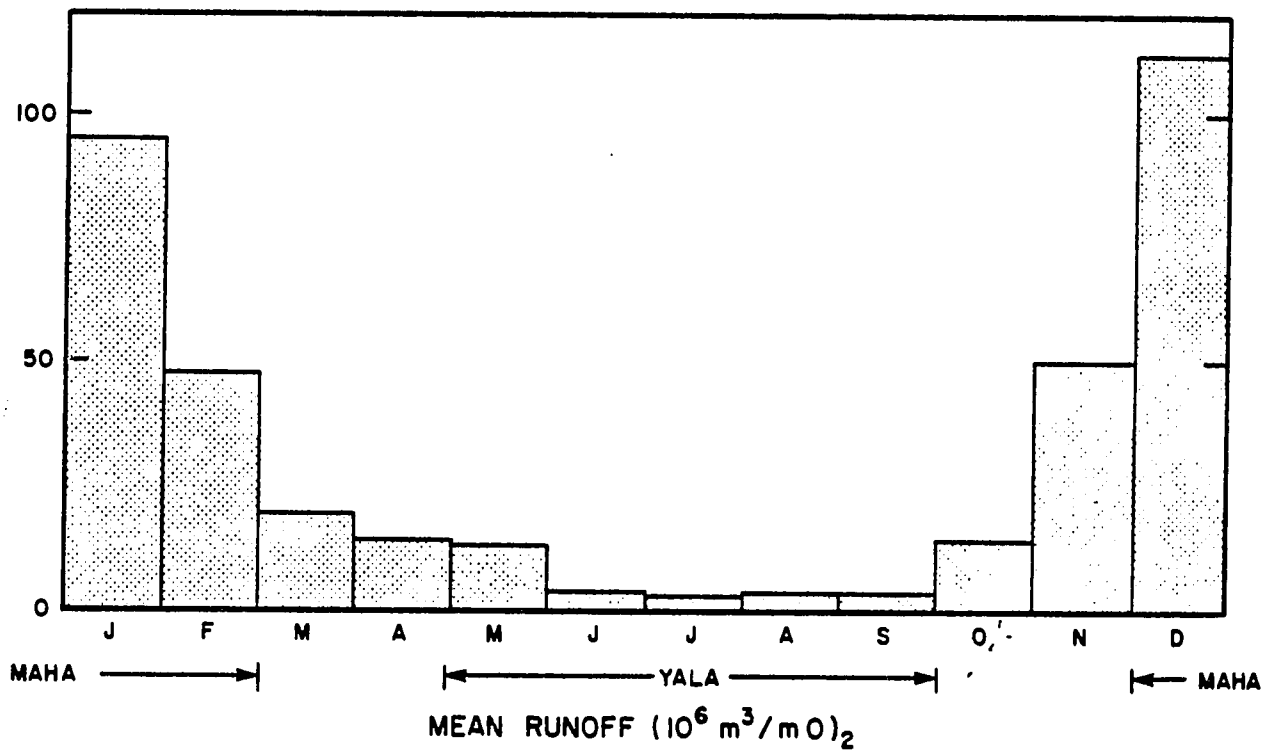
FIG. A-2

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY
REGIONAL CONTEXT

ACRES

364





NOTES

1 MEAN RAINFALL AT WELIKANDA

2 MEAN RUNOFF AT MADURU OYA DAM SITE

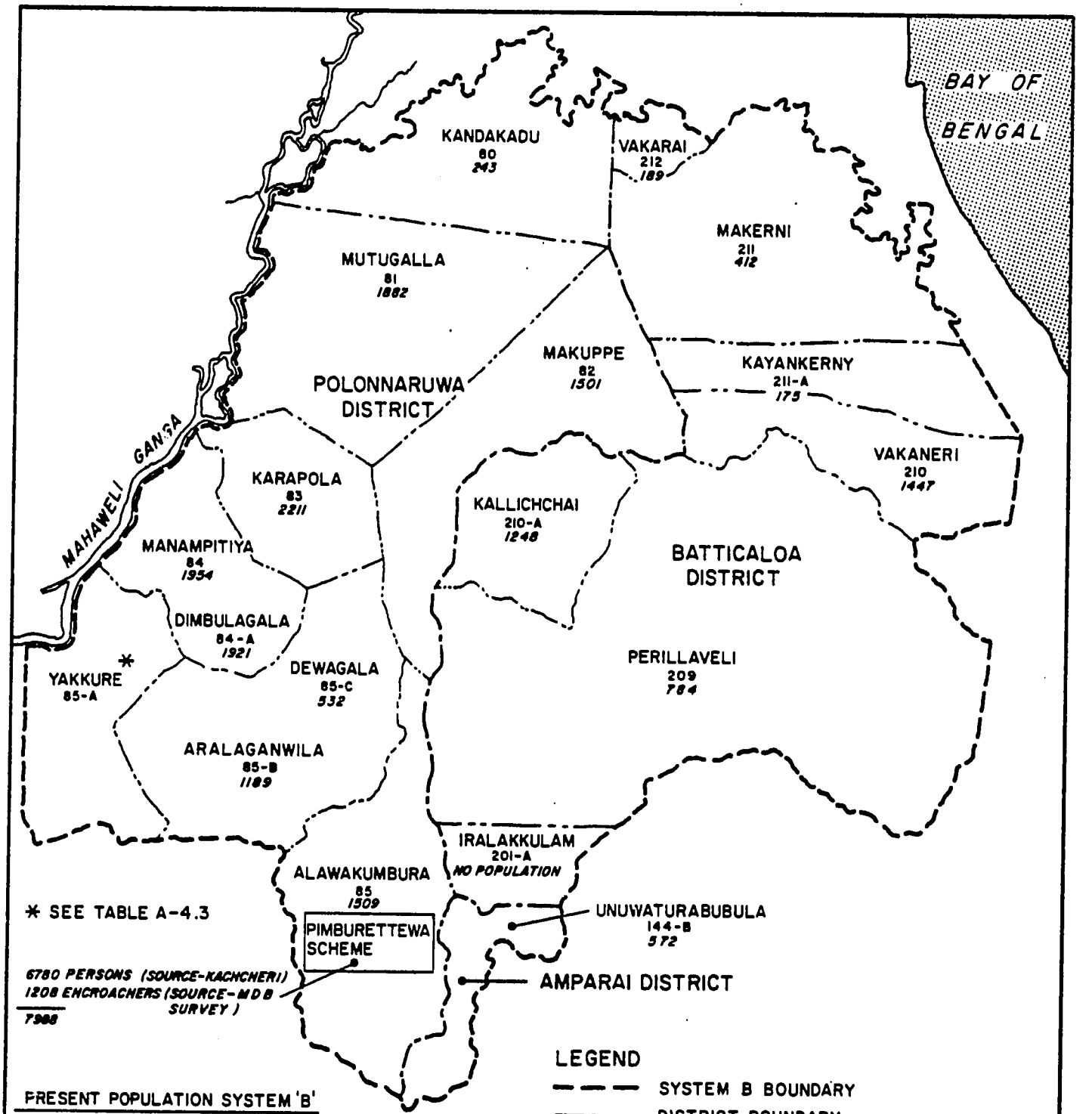
FIG. A-3

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

PATTERN OF RAINFALL AND RUNOFF

ACRES

365



* SEE TABLE A-4.3

PRESENT POPULATION SYSTEM 'B'

POLONNARUWA	DISTRICT	20930
BATTICALOA	DISTRICT	4255
AMPARAI	DISTRICT	572
	TOTAL	25757

SOURCE:

POPULATION COUNTS ARE FROM MDB SOCIO-ECONOMIC SURVEY CONDUCTED MARCH-APRIL 1979

FIG. A-5

MINISTRY OF MAHAWELI DEVELOPMENT
MADURU OYA PROJECT FEASIBILITY STUDY

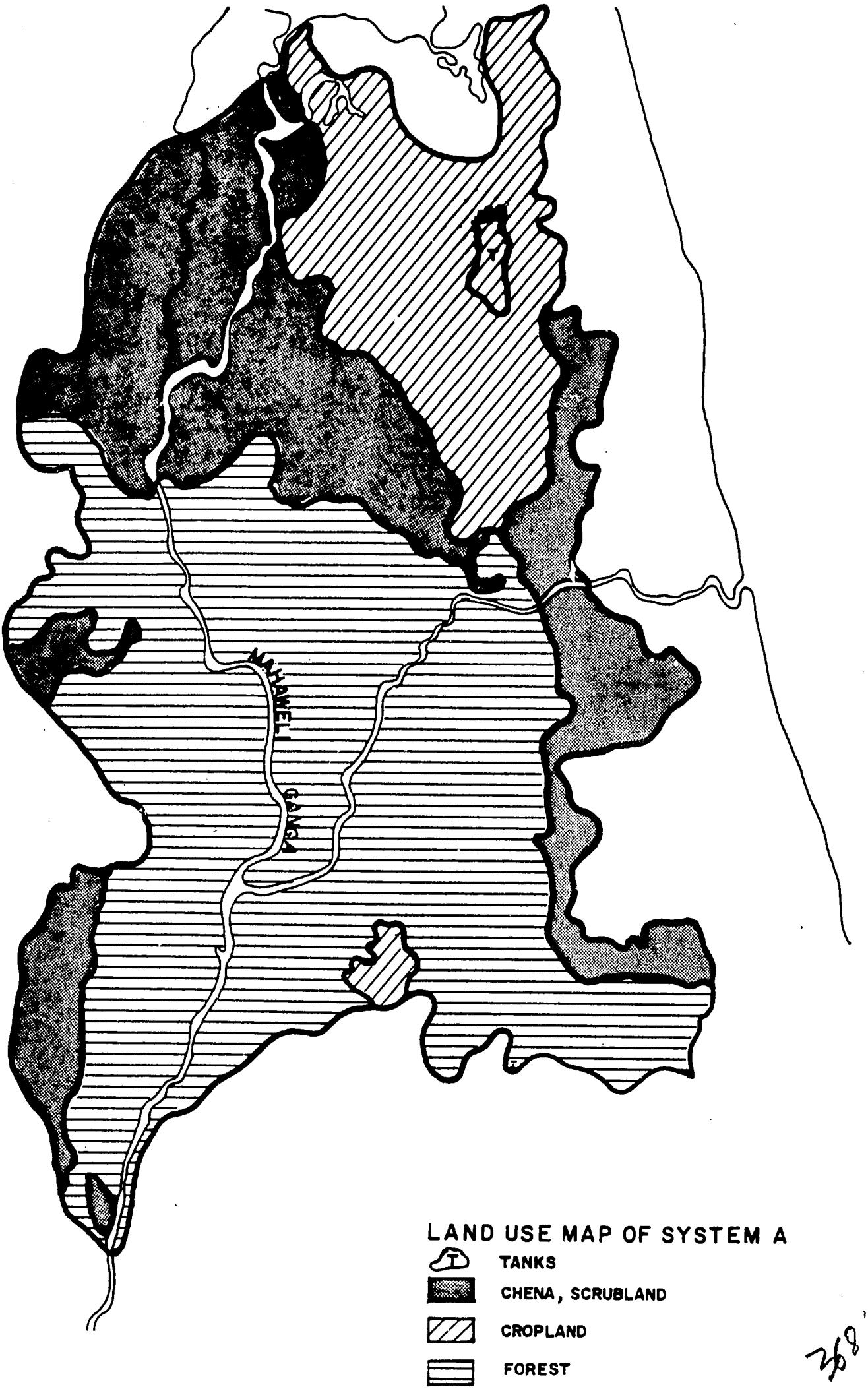
PRESENT POPULATION SYSTEM 'B'

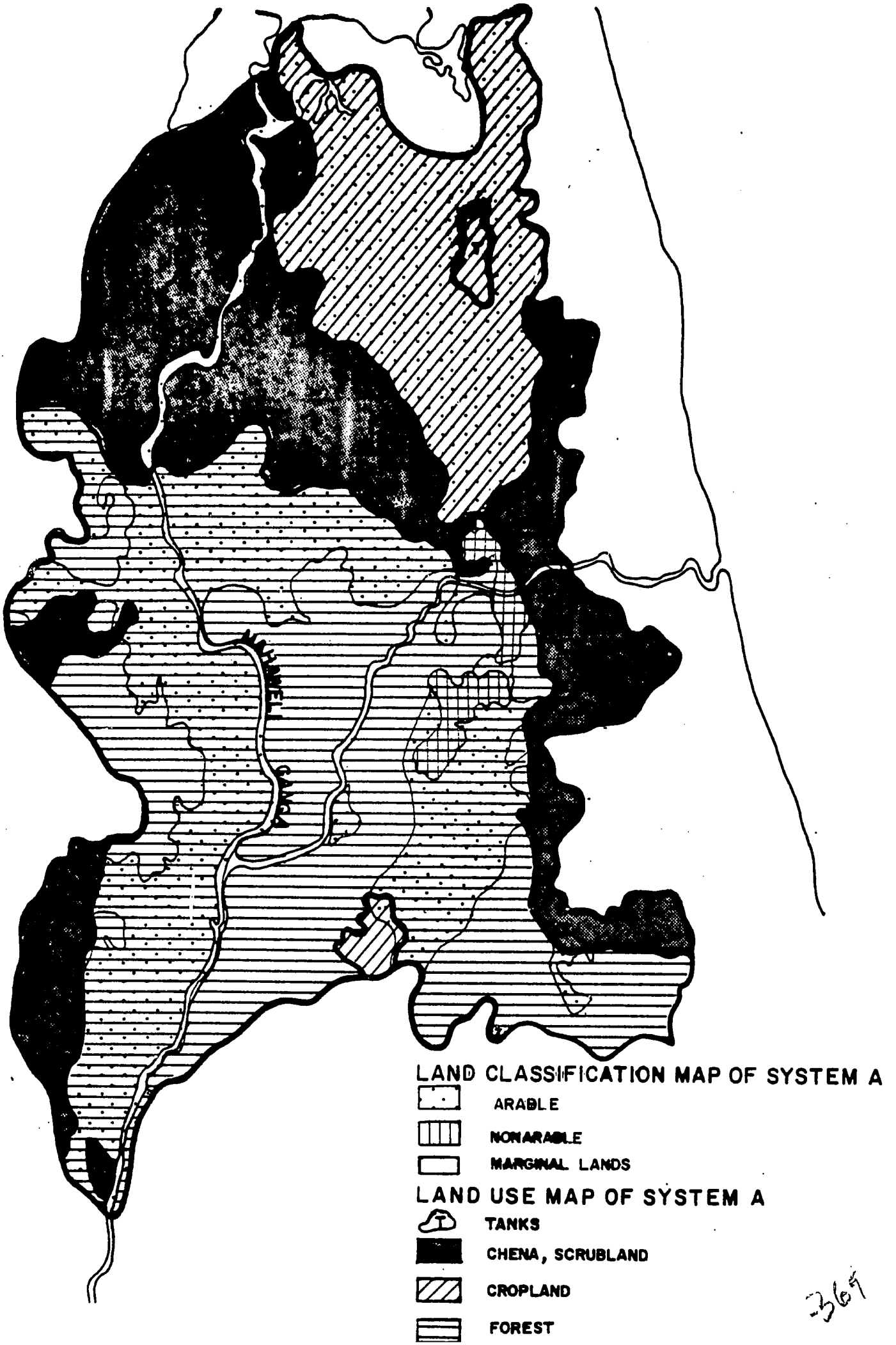
ACRES

366

D. Hertzmark

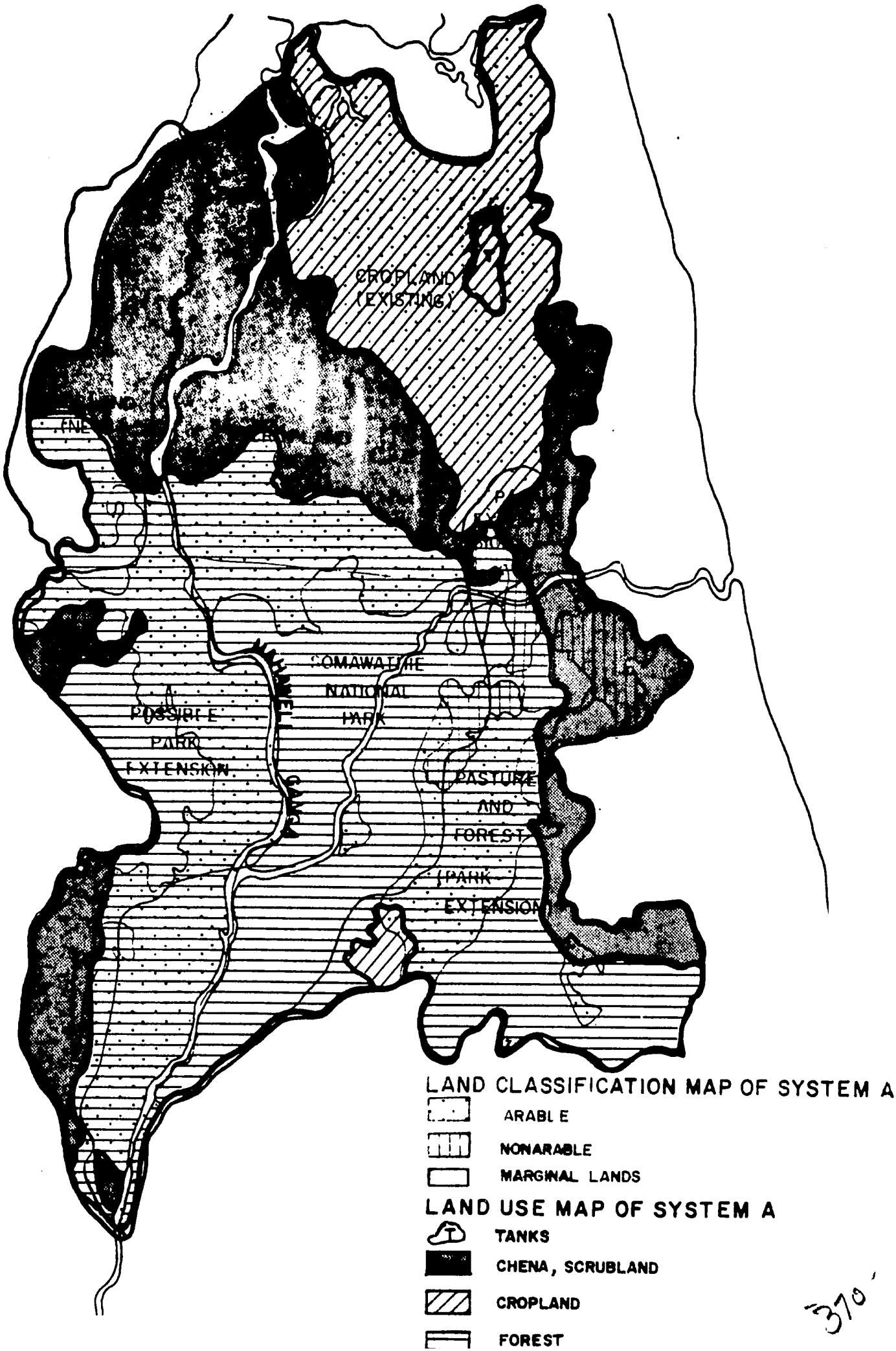
SYSTEM MAPS


MAHAWELI GANGA
LAND USE MAP OF SYSTEM A
TANKS
CHENA, SCRUBLAND
CROPLAND
FOREST

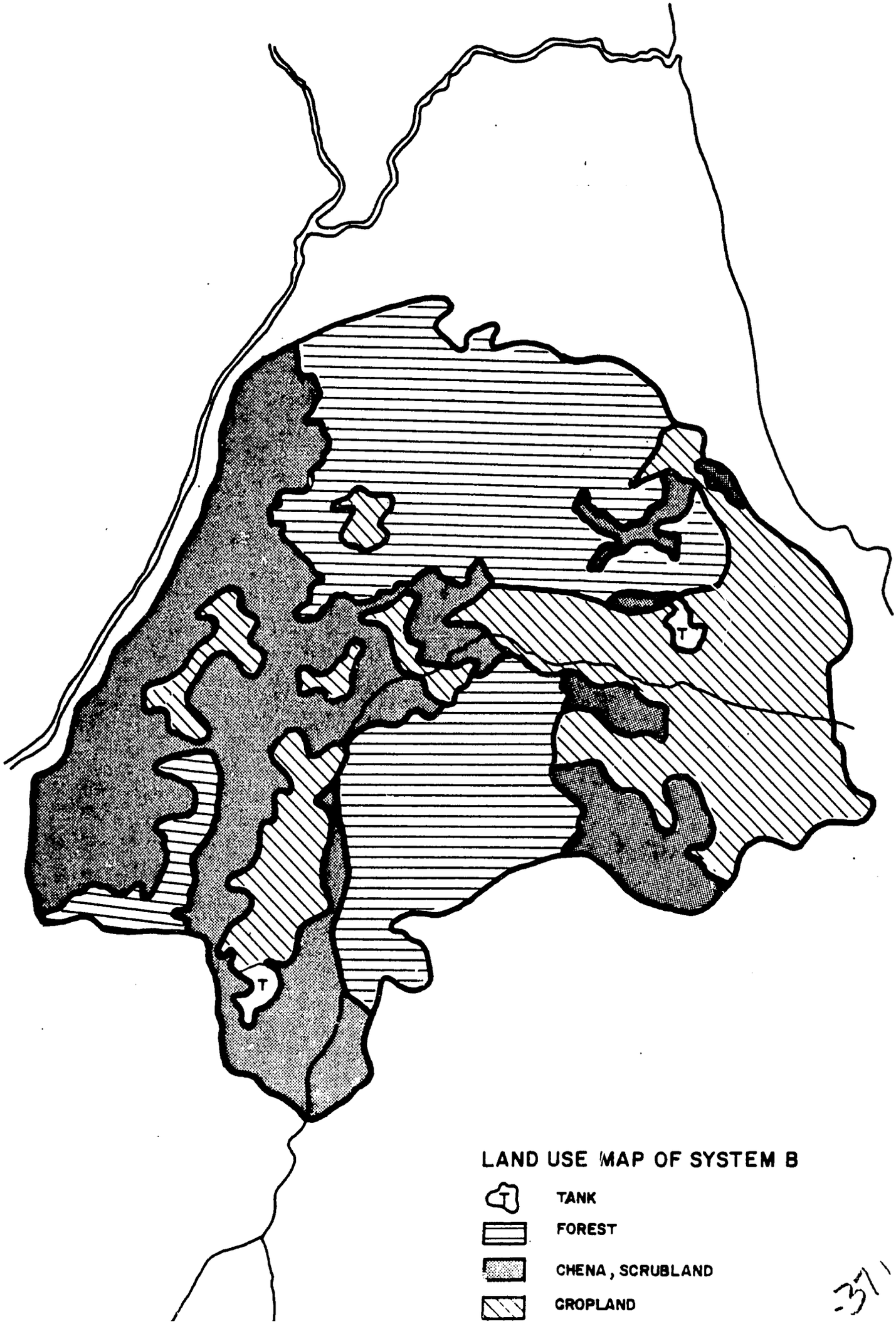

MAHAWELI GANGA
LAND CLASSIFICATION MAP OF SYSTEM A
ARABLE
NONARABLE
MARGINAL LANDS
LAND USE MAP OF SYSTEM A
TANKS
CHENA, SCRUBLAND
CROPLAND
FOREST

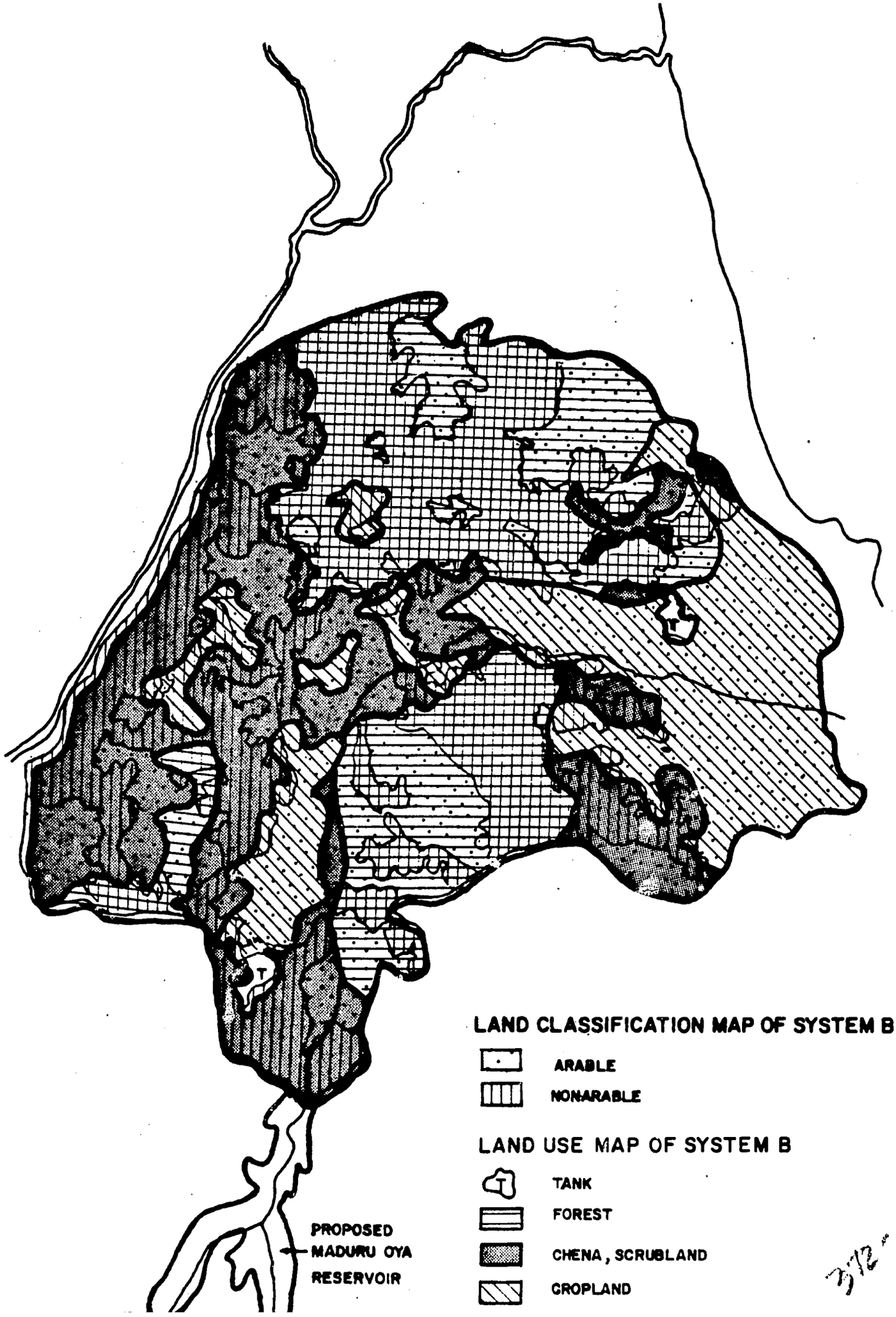
369

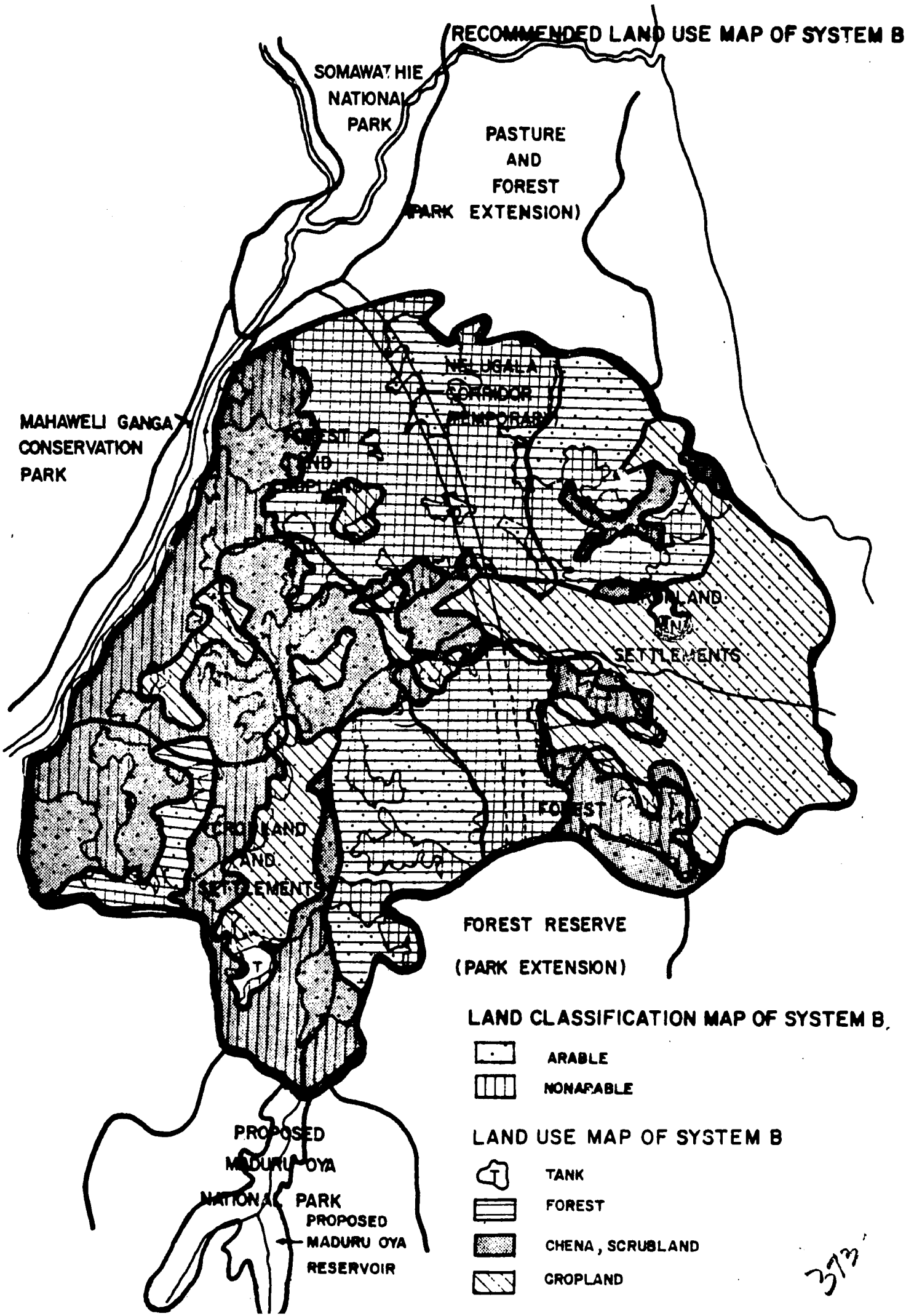
RECOMMENDED LAND USE MAP OF SYSTEM A



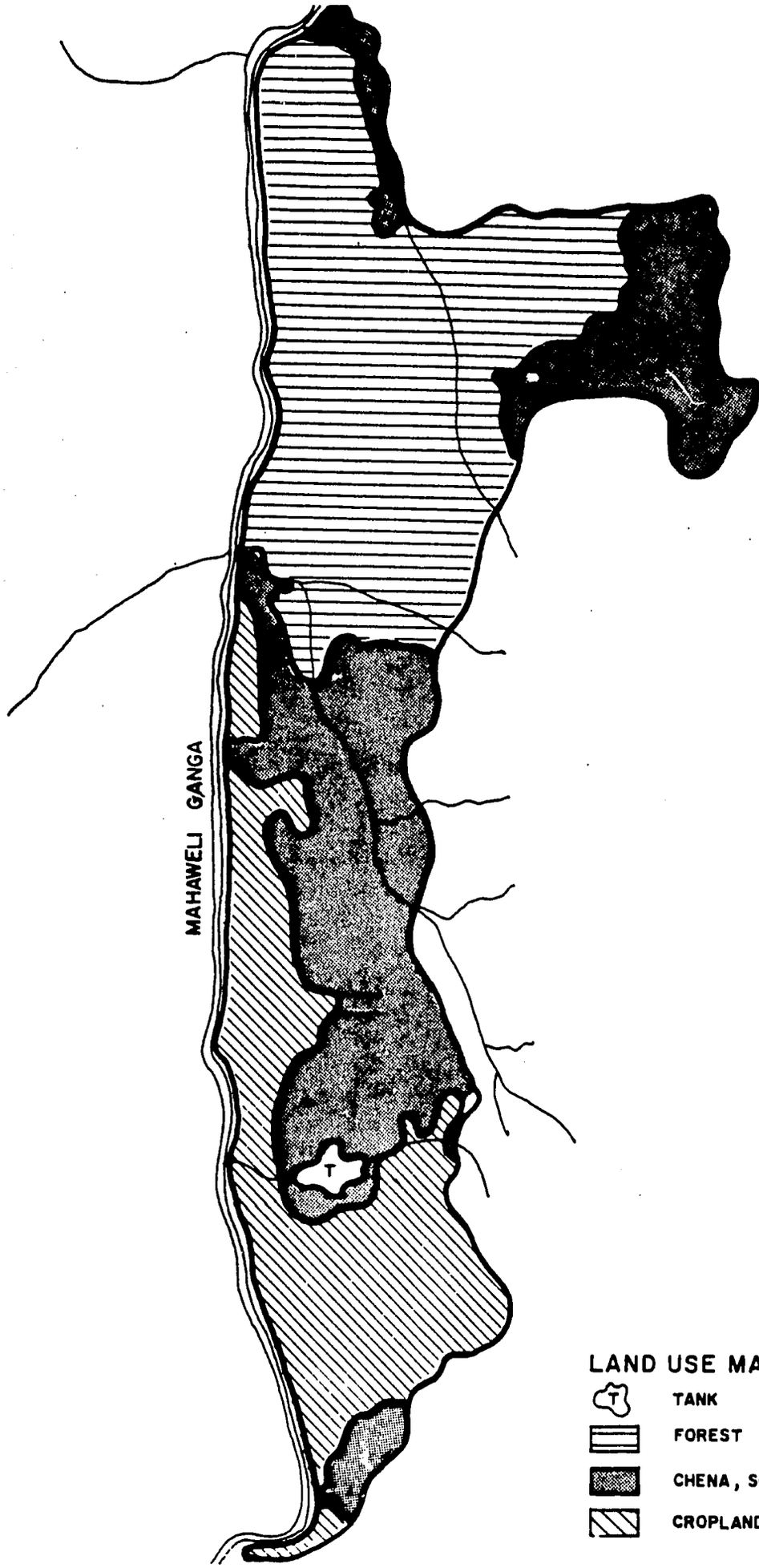
370'


T
T
LAND USE MAP OF SYSTEM B
T
TANK
FOREST
CHENA, SCRUBLAND
CROPLAND


LAND CLASSIFICATION MAP OF SYSTEM B
ARABLE
NONARABLE
LAND USE MAP OF SYSTEM B
TANK
FOREST
CHENA, SCRUBLAND
CROPLAND
PROPOSED
MADURU OYA
RESERVOIR


RECOMMENDED LAND USE MAP OF SYSTEM B
SOMAWATHIE NATIONAL PARK
PASTURE AND FOREST EXTENSION)
MAHAWELI GANGA CONSERVATION PARK
NEUGALA CORRIDOR
SETTLEMENTS
FOREST
CROPLAND AND SETTLEMENTS
FOREST RESERVE
(PARK EXTENSION)
LAND CLASSIFICATION MAP OF SYSTEM B
ARABLE
NONARABLE
LAND USE MAP OF SYSTEM B
TANK
FOREST
CHENA, SCRUBLAND
CROPLAND
PROPOSED MADURU OYA NATIONAL PARK
PROPOSED MADURU OYA RESERVOIR

373



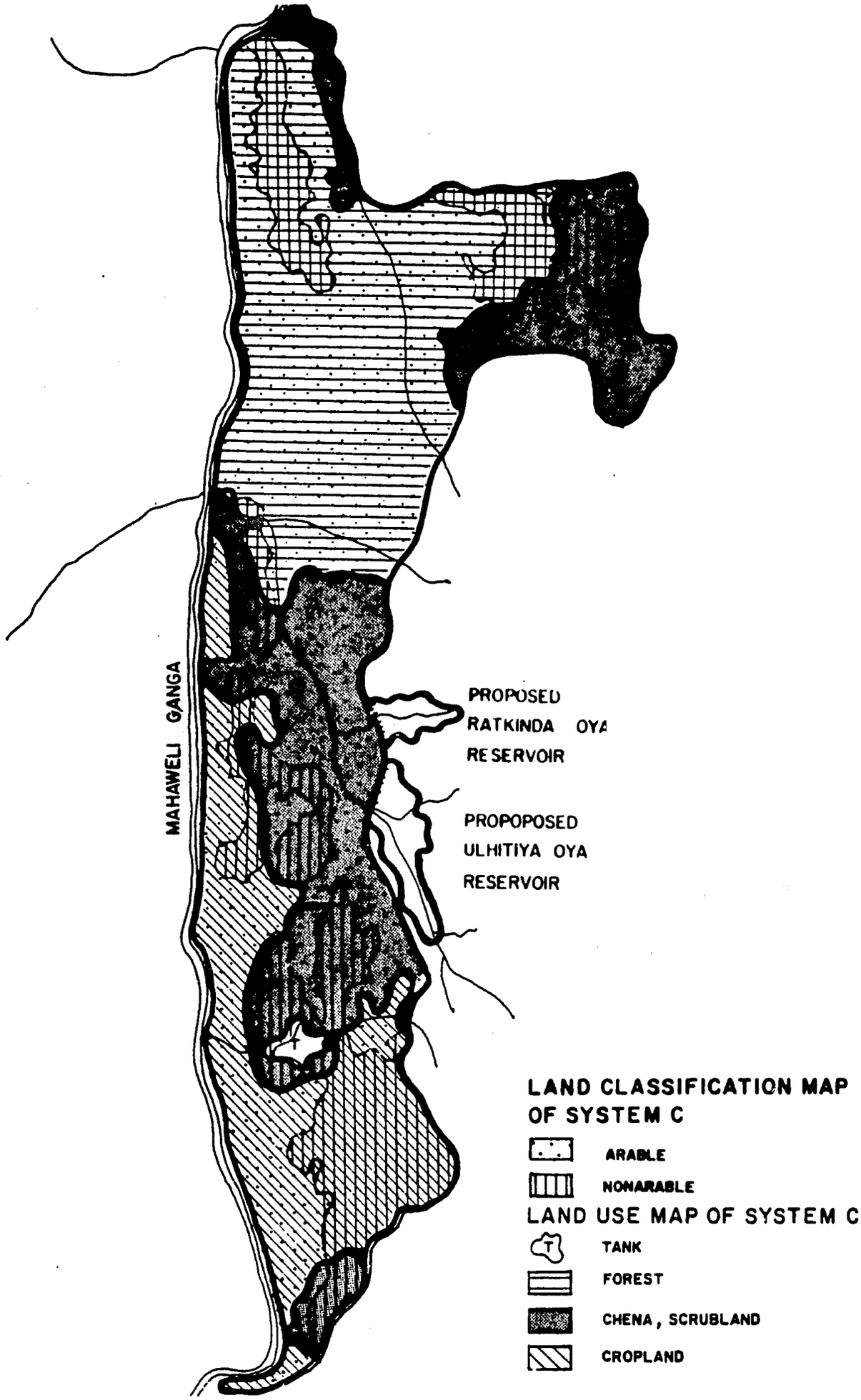
LAND USE MAP OF SYSTEM C

T TANK

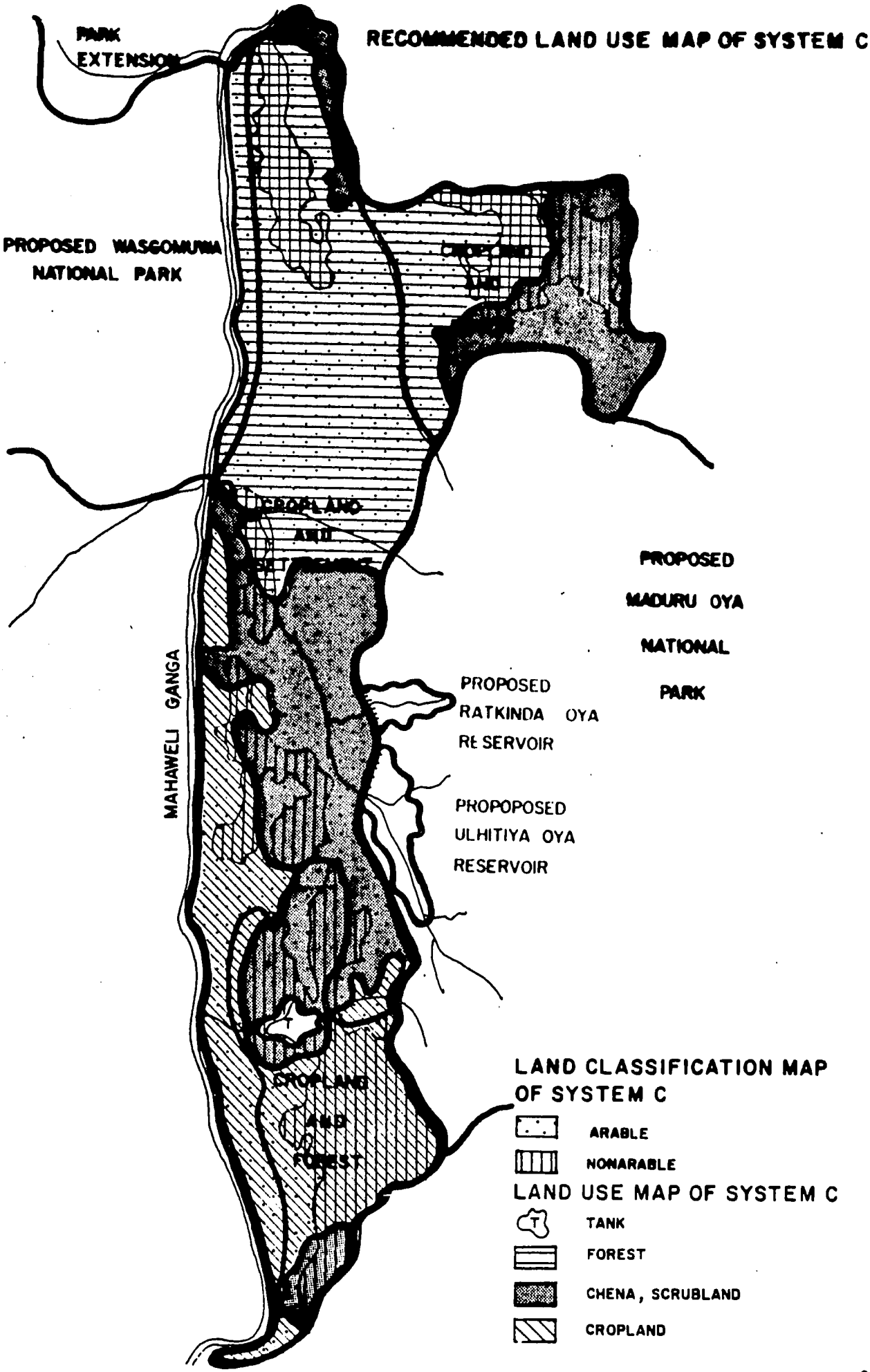
FOREST

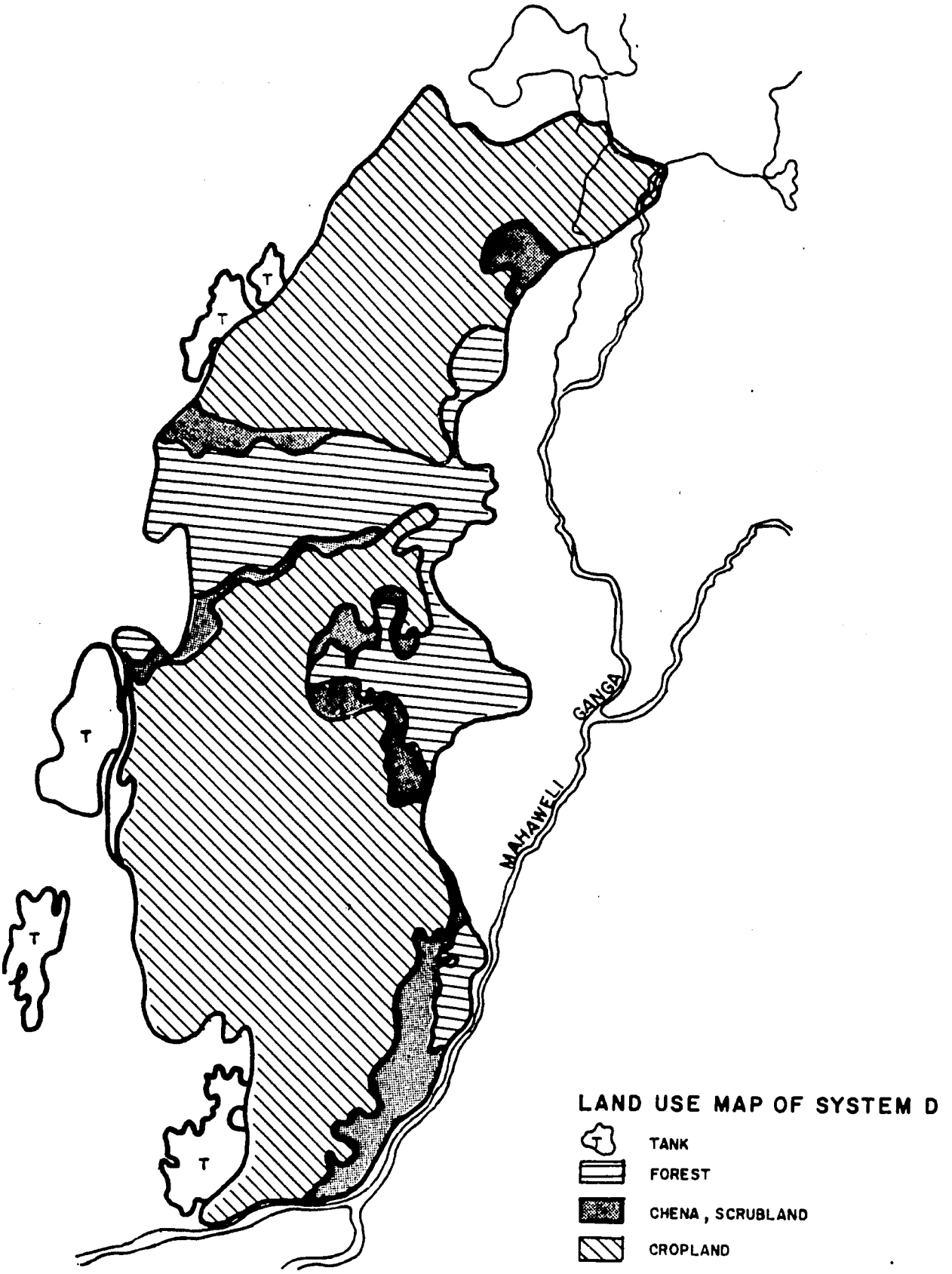
CHENA, SCRUBLAND

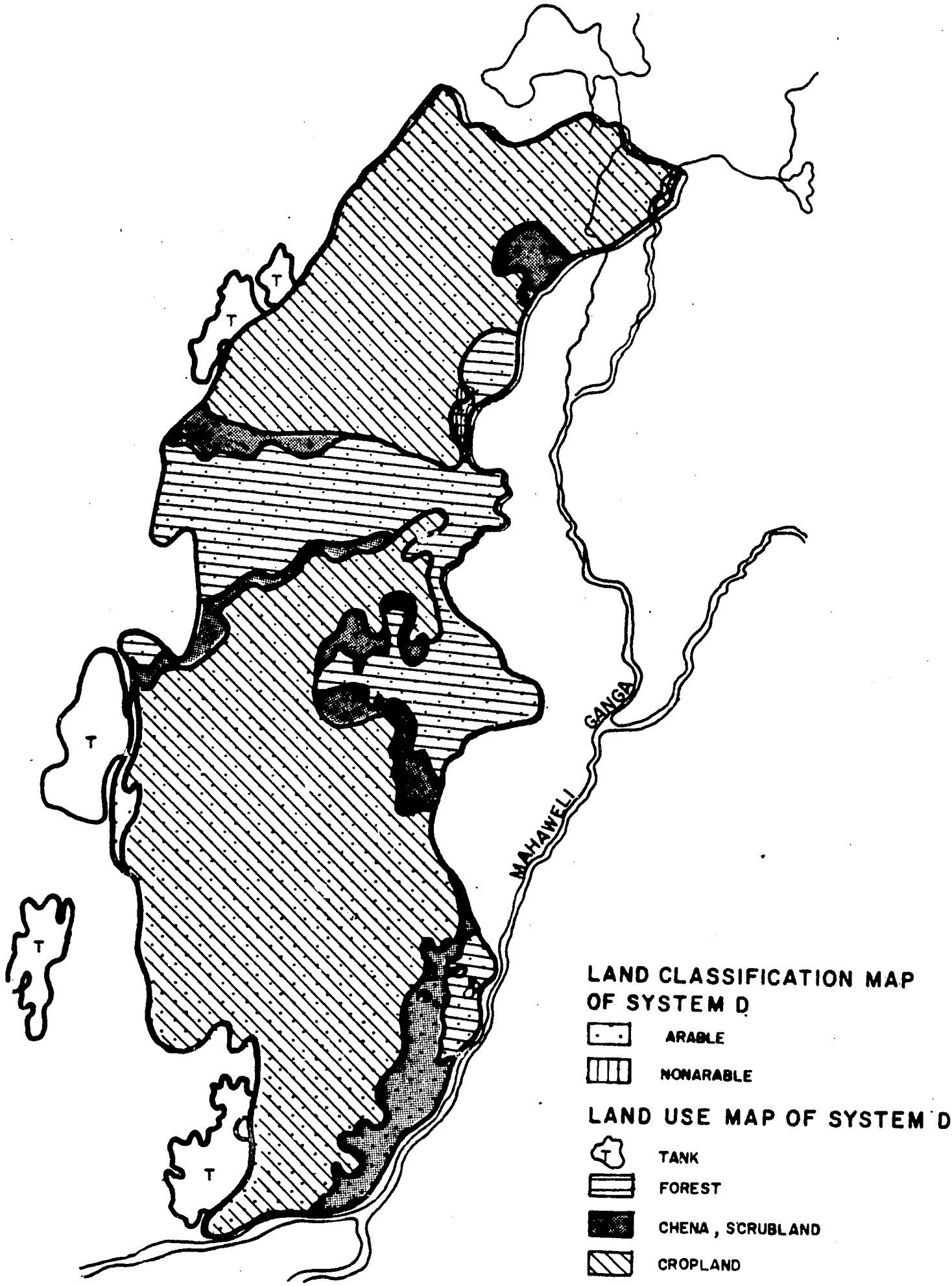
CROPLAND


MAHAWELI GANGA
PROPOSED
RATKINDA OYA
RESERVOIR
PROPOPOSED
ULHITIYA OYA
RESERVOIR
LAND CLASSIFICATION MAP
OF SYSTEM C
ARABLE
NONARABLE
LAND USE MAP OF SYSTEM C
TANK
FOREST
CHENA, SCRUBLAND
CROPLAND

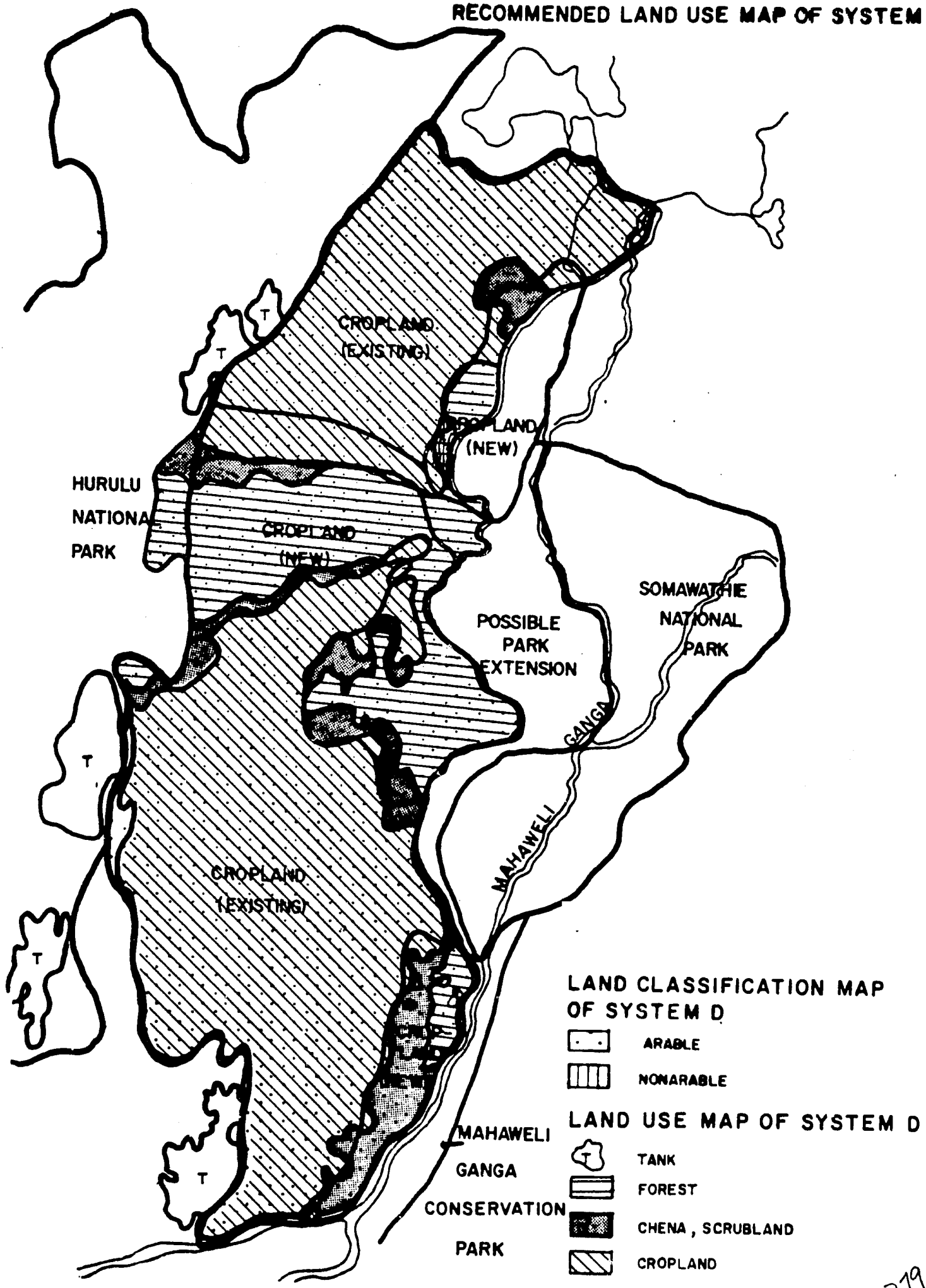
2575


RECOMMENDED LAND USE MAP OF SYSTEM C
PARK EXTENSION
PROPOSED WASGOMUWA NATIONAL PARK
CROPLAND
PROPOSED MADURU OYA NATIONAL PARK
MAHAWELI GANGA
PROPOSED RATKINDA OYA RESERVOIR
PROPOPOSED ULHITIYA OYA RESERVOIR
CROPLAND
LAND CLASSIFICATION MAP OF SYSTEM C
ARABLE
NONARABLE
LAND USE MAP OF SYSTEM C
TANK
FOREST
CHENA, SCRUBLAND
CROPLAND


T
T
T
T
T
MAHAWELI GANGA
LAND USE MAP OF SYSTEM D
TANK
FOREST
CHENA , SCRUBLAND
CROPLAND


T
T
T
T
T
MAHAWELI GANGA
LAND CLASSIFICATION MAP OF SYSTEM D
ARABLE
NONARABLE
LAND USE MAP OF SYSTEM D
TANK
FOREST
CHENA , SCRUBLAND
CROPLAND

RECOMMENDED LAND USE MAP OF SYSTEM D



379

D. Hertzmark

DRAFT

BIORESOURCE SYSTEMS DEVELOPMENT PROJECT WORKSHOP

INTRODUCTION

The Asia Bureau is supporting the International Institute for Environment and Development in the development of Mission level planning and policy enhancement tools through the Environmental Planning and Management Project (EPM). This phase of the Bioresource Systems Project development will utilize the inventory and annotation of thousands of natural resource-related models conducted for IIED as a job for the Environmental Planning and Management Project (number 5). The model inventory can be looked upon as an initial phase in the development of the Bioresource Systems Approach. The next phase which is described herein will consist of the development of a system model of a current A.I.D. project which will generate such products as

- the creation of a check list of the major variables (e.g. strains of rice or large wild ungulates) to be considered in this watershed-level project,

- the inputs and outputs which link each variable

- the temporal relationship of inputs and outputs so that sequencing of tasks and products in a milestone structure be identified through logic and critical path diagrams

- the construction of a simple integrated system model and its testing in simulation runs using several project alternatives. The approach is designed to assist in such decisions as siting of project elements and/or identifying counter-intuitive causes and effects.

- a model skeleton for refining and further fleshing out with additional sectoral elements to enhance its capability for assisting in planning or managing those project variables not considered in the initial workshop (e.g. other development projects).

- the production of an educational video tape for Mission and host environmental officers which can document and detail the efficacy of the systems analytic approach, how a model is constructed and can be used and resources necessary and available to employ this tool.

- a comparison of insights with those derived from the existing formal environmental impact analysis of the same project. This should help identify systematic strengths or weaknesses in each type of process.

This analytical approach and preliminary computer model will be developed through the vehicle of a workshop to be held near but outside of Washington, DC, primarily during the week of April 2, 1984. A pre-workshop meeting of several principals and programmers will be held in late January 1984 to define goals, bound the effort and assign tasks.

SPECIFIC OBJECTIVES OF WORKSHOP

- Design a heuristic agricultural-forestry-energy planning system that
  - demonstrates interdependence of sectors
  - demonstrates system-wide effects of alternative agricultural plans with enough reality to provide basis for validation and testing in future work
  - addresses current needs and problems of the A.I.D. Mission.
- Develop videotape documentation of modeling process, review process and model results and projections
  - educational and training of US/AID personnel
  - education and training of host country personnel

PRODUCTS OF MODEL

o Graphics

- maps of watershed categorized by potential agricultural productivity (color CRT)

- maps of watershed forests and wildlife range, and hydro dams and reservoirs

- maps of rigid constraints on agricultural area (include water, swamps, roads, cities, excluded forest and habitat, etc.)

- maps of available agricultural land, categorized by production potential

- graphics of comparable production of food stuffs by BYU small e.g. garden-model vs. traditional model and effects of differing agricultural systems on forests and wildland resources.

- temporal demographic changes and population dispersal as related to resource use limitations and assumptions

383

LIMITATIONS AND ASSUMPTIONS

- bounded by watershed boundary
- this is an initial phase of model development to be followed by integration of appropriate sectors in later phases
- data constraints

STRATEGY

- Define agricultural/vegetation/cultural sites by image processing for automatic entry and processing.
- Compute futures given carrying capacity and population models.
- Develop models driven by climate and climate-related pest impacts to incorporate stochastic climatic events and worst case analyses.
- Develop output equations relating water availability with irrigation requirements and hydroelectric power generation.
- Use data-rich but typical watershed-level AID project, e.g. a watershed of the Mahaweli in Sri Lanka.

CONDUCT OF WORKSHOP

The workshop will bring together several modeling and sectoral experts for varying periods of time over the course of a week. To facilitate rapid programming of the model, the simulation language DYNAMO will be used and two resource scientists experienced in coding DYNAMO will be employed (Faeth for agriculture and Van Wie for forest/energy systems). A total of nine participants are formally involved, although it is estimated that no more than seven will be present at a single time. Important but episodic contributions will be made by non-resident, short-term participants such as Anholz, Philley, and McNamara, and Ichord.

The initial morning will be devoted to describing the resources available, the limits of responsibility for each participant, and their tasks. The efficiency of this workshop and generation of products will strongly rely upon the distribution of materials to participants well in advance of the workshop. These materials include

- o digitized resource maps
- o listing of major state variables, inputs and outputs for an initial set of modules by the participants
- o copies of the Mahaweli data base

- original literature describing some models of choice, etc.

The next three days will be devoted to communally and individually building the individual conceptual models on a modular basis detailing flows of inputs and outputs. The afternoon of the fourth day will be devoted to merging the modules. The fifth day will be devoted to simulation runs and reviewing model behavior.

Most participants will disperse on Friday, April 6 after work. Reed, Faeth and one of the scientists will continue to build and refine the model for an additional week.

Generally it is envisioned that DYNAMO coding will occur throughout the workshop although the first few days will involve some foraging for the model documentation retrieving output and materials, etc. The last half of the workshop will reflect the "intensive" programming needs attendant to model development.

D. Hertzmark

BIORESOURCE SYSTEMS DEVELOPMENT PROJECT
PREWORKSHOP PLANNING MEETING
24-25 JANUARY 1984

FINAL REPORT
TO THE INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT - EPM PROJECT

INTRODUCTION

Many projects planned by donor agencies in LDC's could benefit from multi-sector integration and the use of systems analysis as a planning and analytic tool. Use of spatial analysis in conjunction with the systems approach provides an additional graphic tool useful in integrated assessments of interactions among the various sectors and disciplines.

In an effort to provide USAID with an example of an approach to demonstrate the applicability of systems analysis to project planning, the documented construction of a systems analysis of a" real world" project is proposed. The uses of such a policy determination tool are many and varied. Two major uses of the documented construction of the currently proposed systems model will be:

- as an educational tool for Mission administrators, project planners and managers, and
- as a prototype for further development in the Bioresource Systems Project which will generate an interactive planning tool for use in project design and adaptable to any systems project at any site.

287

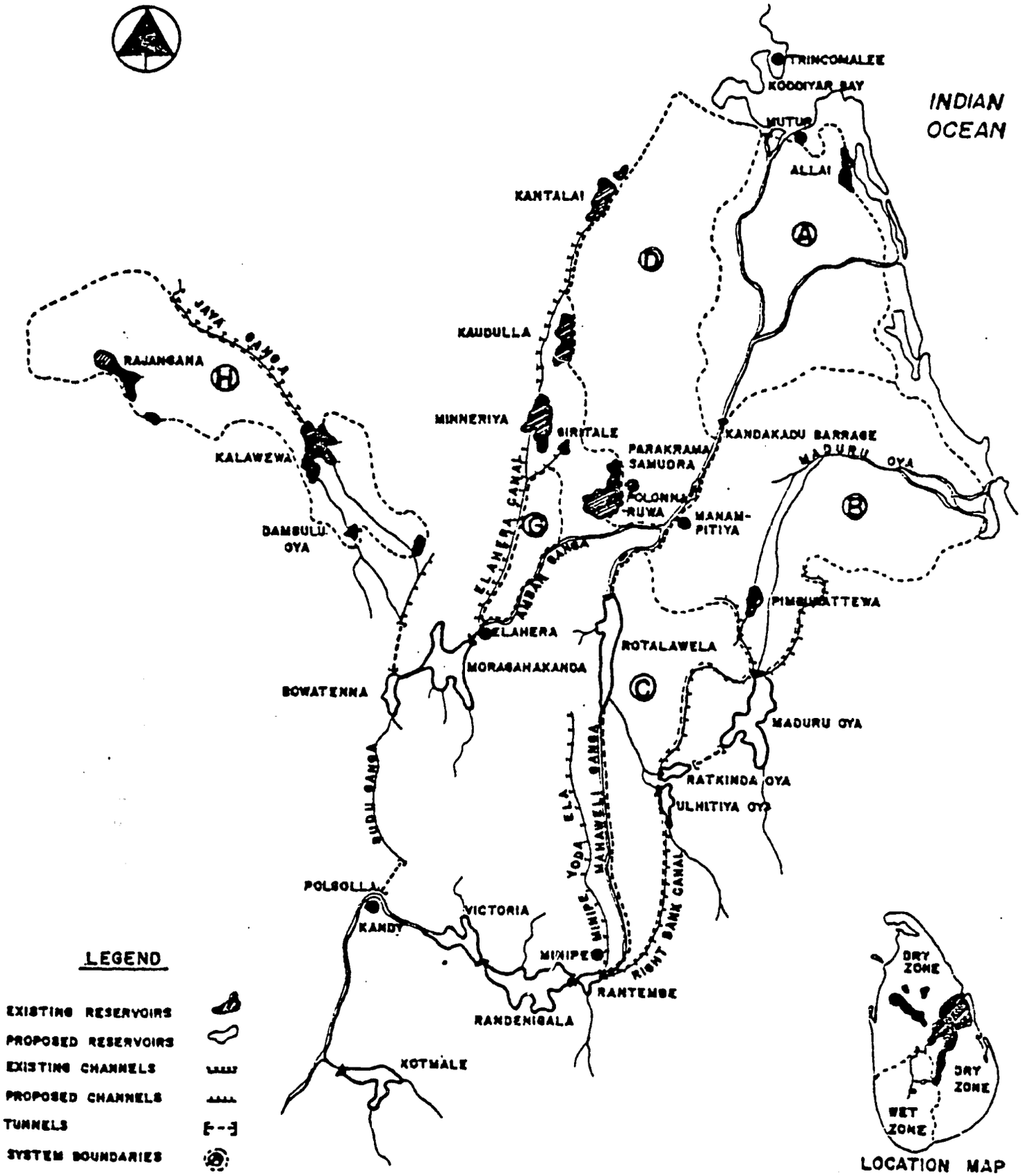
The Mahaweli Development project in Sri Lanka (Figure 1) is an excellent choice for such an example. It is well studied, an excellent environmental assessment is available, and the project is otherwise well suited for an interesting and challenging analysis.

The overall approach is similar to the Adaptive Environmental Assessment approach developed by Holling (1978) and his colleagues. A team of modelers and disciplinary scientists are assembled in a workshop format with the intent of building a heuristic systems dynamics model of the project. The entire modeling process of the currently proposed workshop will be documented by videotape.

A preliminary planning meeting was held on 24-25 January 1984 to define the scope, methodology, and objectives of the model and the workshop. These determinations, a conceptual model, a task breakdown, and a proposed budjet are presented below.

GOALS/OBJECTIVES: The primary goal of the Bioresource Systems Development Project Modeling Workshop is to develop a heuristic model that would serve as an educational tool to demonstrate the applicability of the systems approach to project planning, and introduce "systems thinking" to land management decision-makers. Systems models can provide an

388



ACCELERATED MAHAWELI DEVELOPMENT PROGRAM

insight as to the dynamics of interactive processes and allow focusing of resources on "sensitive" variables in feasibility planning. Thus, in addition to providing an educational tool for USAID and host country personnel, the model developed may also be viewed as a prototype or plan of reference to be used in designing project feasibility studies.

APPROACH: The overall strategy in devising the methodology is to interface systems modeling and spatial analysis. The general approach is to (1) locate a site; (2) build a land use map data base; (3) identify the major subsystems or sectors, their linkages and dynamics; and (4) address the human carrying capacity by comparing, for example, traditional vs. the small-scale approach to agriculture as described by Johnston et al. (1982). The systems approach allows identification od important variables and for manipulation of the most sensitive variables involved in the following questions. Will X hectares of land support X number of people? What is the long term carrying capacity of "System B"? Can one augment that carrying capacity by changing agricultural land use practices? How should population growth be taken into account? Assuming a given life of the project to be 50 years, how many people should be moved into the project at the outset in order to reach, but not exceed

350

carrying capacity by the end of the planning horizon? What are the effects of water diversion to systems and uses? What are the effects of a rice surplus and a corresponding lowering of prices? What are the effects of grazing and use of draft animals vs. mechanized agricultural practices? What are the effects of buffer zones? Varying grazing systems? Fuelwood plantations? etc.?

PROBLEM STATEMENT: Conceptual models are based on an initial "problem statement" which acts as the driving force for defining the components of the sectors and state variables to be addressed in the subsequent model development. The problem statement for this particular modeling effort is as follows: Is the Mahaweli System B Project sustainable? "Substatements" or questions to be addressed within the primary problem statement include project sustainability at what levels of population, at what levels of economic input, and for how long?

THE CONCEPTUAL MODEL: It is necessary and critical to define the system to be analyzed carefully in the context of the problem to be addressed. Discussion at the pre-planning meeting of the goals and objectives of the workshop effort has resulted in the model proposed below and illustrated in Figure 2.

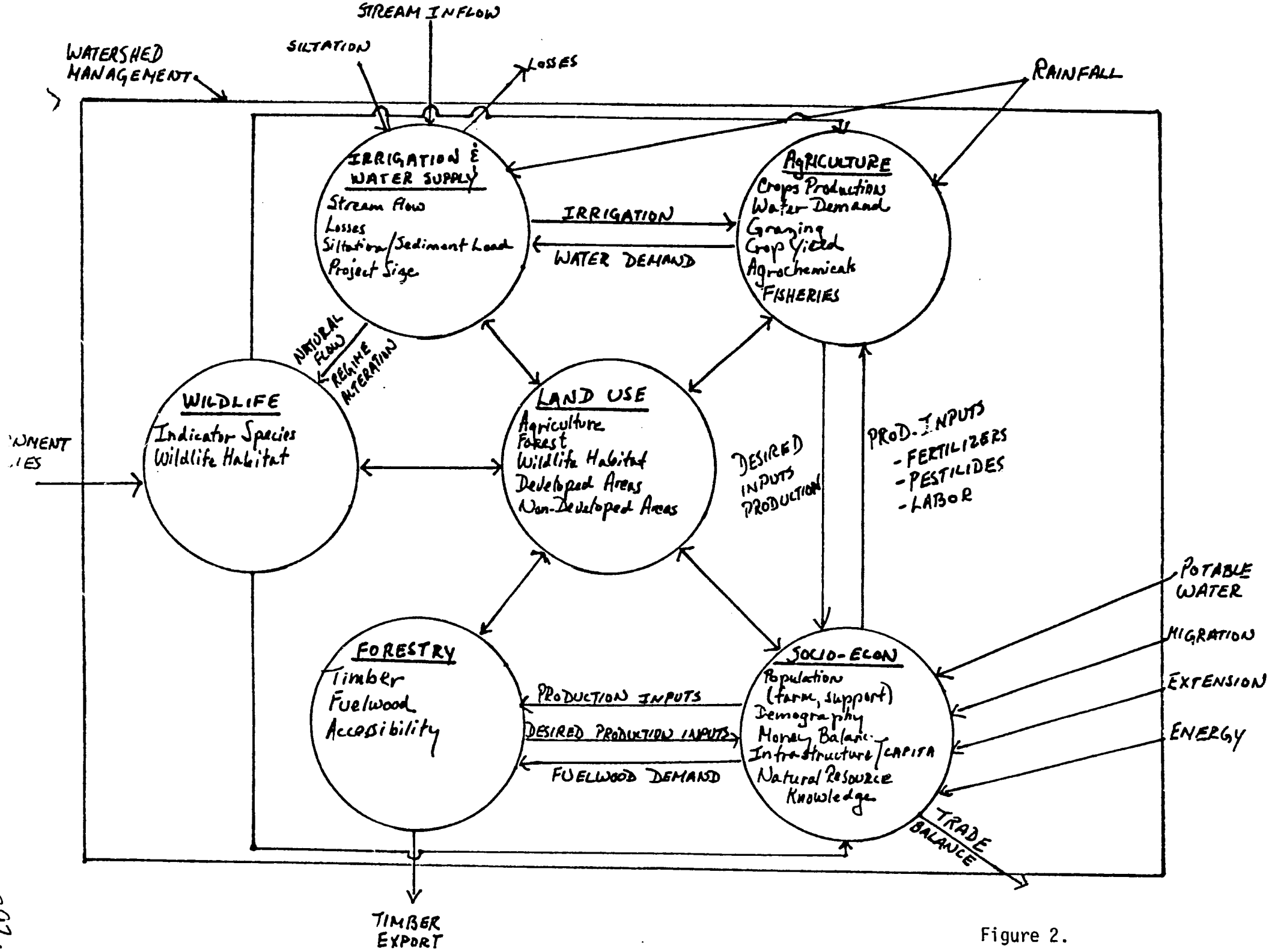

STREAM INFLOW
SILTATION
LOSSES
WATERSHED MANAGEMENT
RAINFALL
IRRIGATION & WATER SUPPLY
Stream Flow
Losses
Siltation/Sediment Load
Project Size
IRRIGATION
WATER DEMAND
AGRICULTURE
Crops Production
Water Demand
Grazing
Crop Yield
Agrochemicals
FISHERIES
NATURAL FLOW
REGIME ALTERATION
WILDLIFE
Indicator Species
Wildlife Habitat
LAND USE
Agriculture
Forest
Wildlife Habitat
Developed Areas
Non-Developed Areas
DESIRED INPUTS PRODUCTION
PROD. INPUTS
- FERTILIZERS
- PESTILIDES
- LABOR
POTABLE WATER
MIGRATION
EXTENSION
ENERGY
FORESTRY
Timber
Fuelwood
Accessibility
PRODUCTION INPUTS
DESIRED PRODUCTION INPUTS
FUELWOOD DEMAND
SOCIO-ECON
Population
(farm, support)
Demography
Money Balance
Infrastructure/CAPITA
Natural Resource
Knowledge
TRADE BALANCE
TIMBER EXPORT

Figure 2.

The spatial boundaries for the model development encompass the Mahaweli System B Project, include the bordering forest reserves and proposed National Parks (Figure 3), and extend to the coast to include the Valaichchenai Aru estuary at the mouth of the Maduru Oya (Figure 4). The upland "watershed" boundary was determined to start at the Maduru Oya reservoir and not at the headland waters. The primary factors driving this decision were two-fold: (1) System B is an irrigation system, and (2) accessibility of USAID data for the "left bank".

The decision on model boundary is critical as this is what defines the limits of the system to be analyzed. Quantities and control factors entering the system from outside are termed exogenous variables. These are considered to be inputs to the system and include, for example, government policies, watershed management, stream inflow, siltation, rainfall, potable water, migration, extension (education), energy, etc. (Figure 2). Additional exogenous variables will be identified during the course of the April workshop.

The circles represent the major modules (sectors) of the model: land use, agriculture, irrigation and water supply, socioeconomics, forestry, and wildlife. Listed within each circle are examples of the variables to be modeled or addressed. Arrows represent interactions between the modules.

393

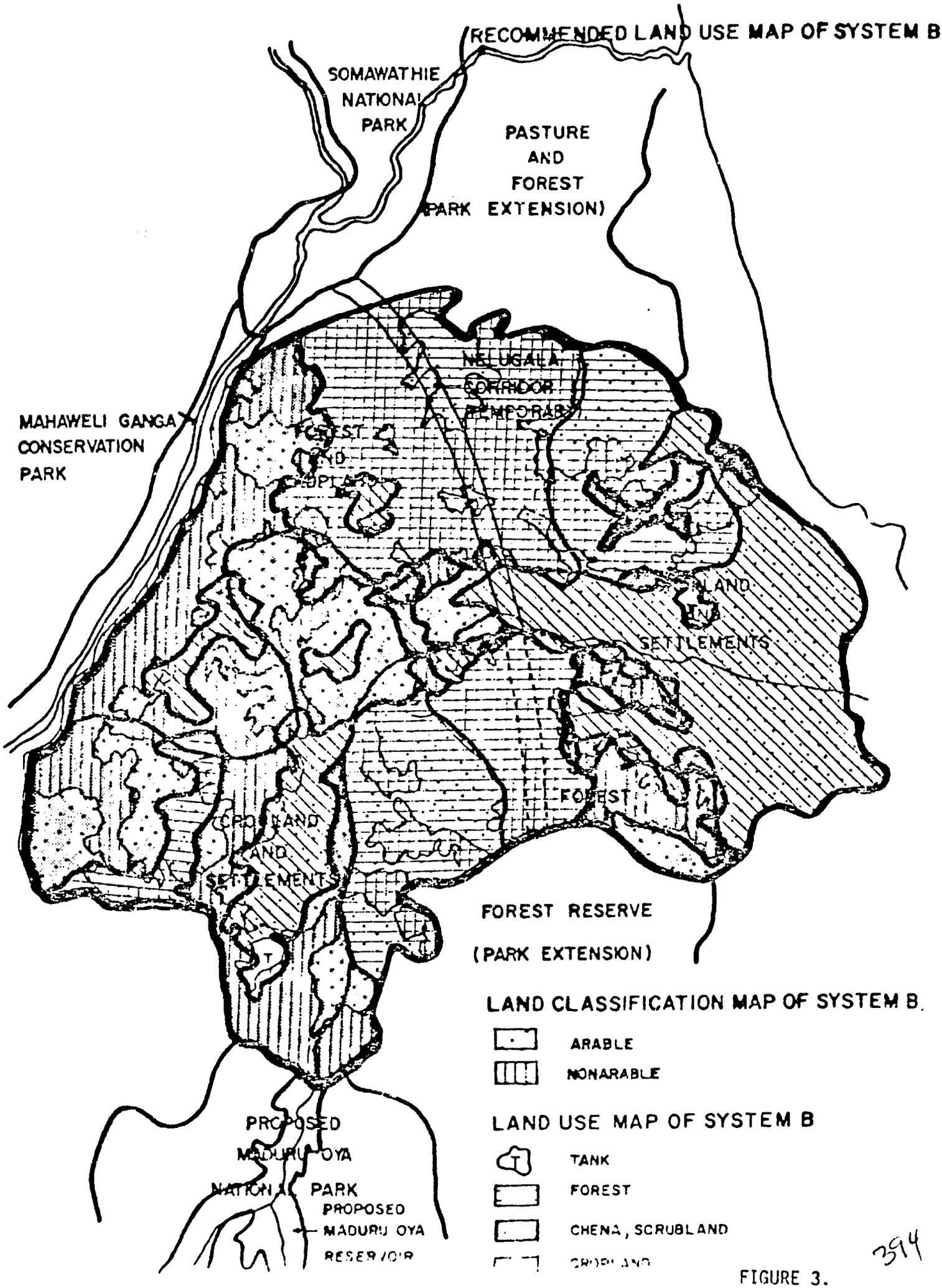
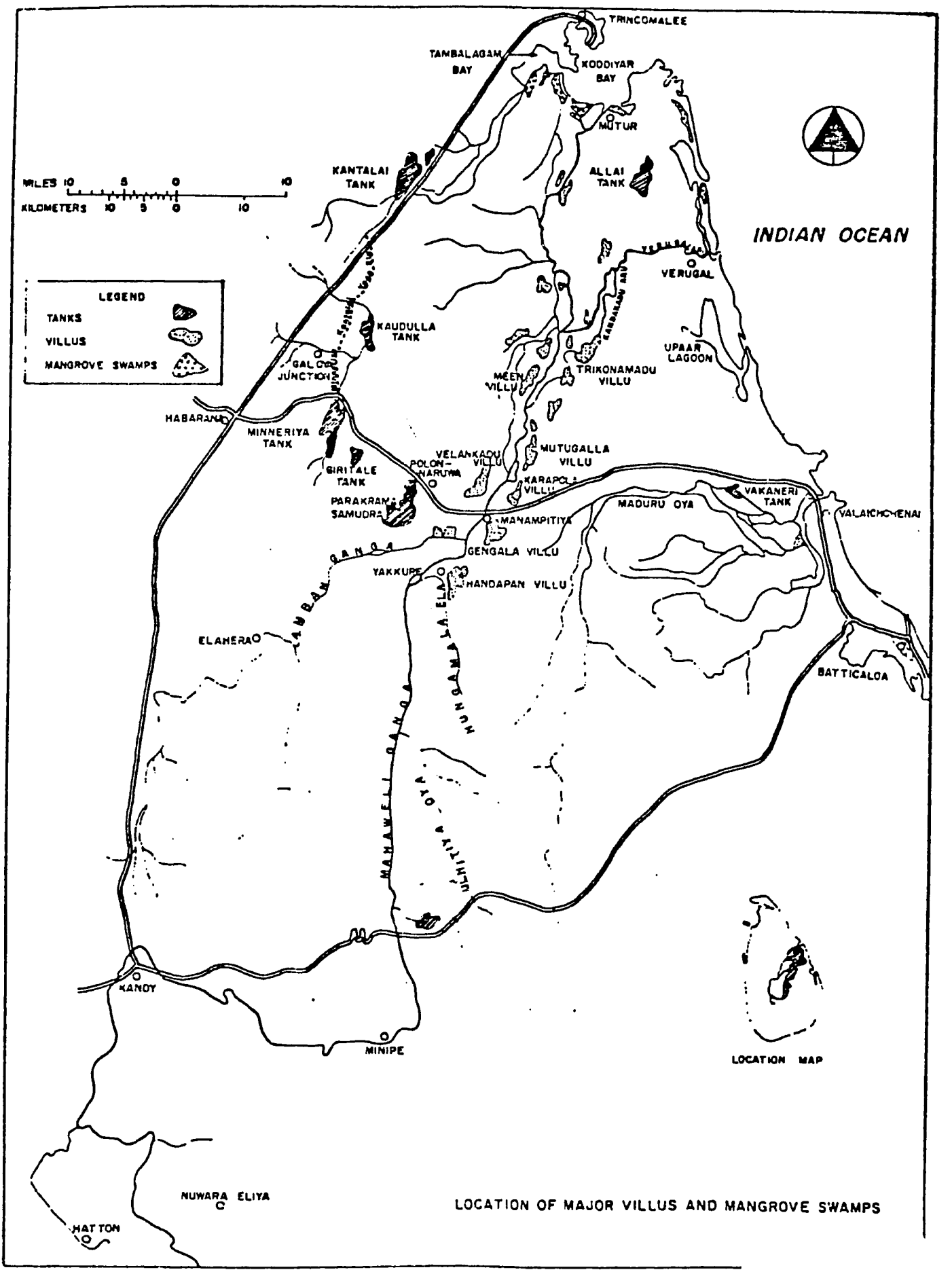

RECOMMENDED LAND USE MAP OF SYSTEM B
SOMAWATHIE NATIONAL PARK
PASTURE AND FOREST (PARK EXTENSION)
MAHAWELI GANGA CONSERVATION PARK
NELUGALA CORRIDOR TEMPORARY
FOREST AND CROPLAND
LAND AND SETTLEMENTS
FOREST
CROPLAND AND SETTLEMENTS
FOREST RESERVE (PARK EXTENSION)
PROPOSED MADURU OYA NATIONAL PARK
PROPOSED MADURU OYA RESERVOIR
LAND CLASSIFICATION MAP OF SYSTEM B.
ARABLE
NONARABLE
LAND USE MAP OF SYSTEM B
TANK
FOREST
CHENA, SCRUBLAND
CROPLAND

FIGURE 3.

394



LOCATION OF MAJOR VILLUS AND MANGROVE SWAMPS

FIGURE 4.

The model to be developed, evaluated, tested and tuned in the April workshop will consist of an elaboration of the modules as determined during the January planning meeting. Each module will be developed prior to the April workshop by the assigned participants identified below. The participants will utilize the appropriate "module-specific" data provided by three major sources:

- TAMS Environmental Assessment of the "Accelerated Mahaweli Development Program (1980),
- ACRES Maduru Oya Project Feasibility Report (1980), and
- USAID Project Paper: Mahaweli Environment Project (#383-0075).

Dr. Reed will provide the assigned team leaders with the necessary "sector-specific" bibliographic information on the appropriate modules from his 1983 report: Bibliography of Models Applicable to USAID Missions.

396

PERSONNEL ASSIGNMENT BY TASK

LAND USE SECTOR
- Reed, K.
- Van Wie, D.
- Star, J.

AGRICULTURE SECTOR
- Stinner, R.
- Robison, L.
- Anholt, C.
- Berwick, N.

IRRIGATION AND WATER SUPPLY SECTOR
- Faeth, P.

SOCIO-ECONOMIC SECTOR
- Faeth, P.
- Hertzmark, D.

FORESTRY SECTOR
- Van Wie, D.
- Tropical forestry expert

WILDLIFE SECTOR
- Van Wie, D.
- Reed, K.
- Berwick, N.
- Berwick, S.

PROGRAMMER/ANALYST
- Chamberlin, R.

VIDEOTAPE DOCUMENTATION
- Staniski, S.

PARTICIPANTS/OBSERVERS AT LARGE
- Sobczak, M.
- Ichord, R.
- Philley, M.
- McNamara, K.
- Greenberg, R.
- Collins, R.
- Kux, M.
- Dubois, R.

397

SECTOR MODELS

LAND USE: The land use module is a simple accounting of hectares in the various land use categories defined for the system. Some of these categories will be determined as a result of McHarg overlay techniques, others will be *a priori* land classifications. Spatial analysis will be used to make these classifications.

Map analysis assisted by the computer program "MAP" will be used to generate maps and compute category area. These categories and areas will be provided as input to the system. Categories will be defined in terms of requirements by other modules. These categories will include hectares of arable land, both potential and under cultivation, area of forest/woodlot/plantation, national parks, estuaries, wetlands, grazing lands, developed lands, etc.

Inputs from other modules will be expressed as requirements for reclassification of land use categories. For example, the agriculture sector may require conversion of forest land to rice paddy. Demands for this land will be met by a proirity scheme as long as sufficient potential rice paddy land is available. In a similar manner, conversion of agriculture or grazing land to forest or woodlot will be tracked.

798

Periodic snapshots of this compartment will be output and used to reclassify land in the maps contained in the MAP data base. This cannot be done dynamically at this time. These maps will be useful display devices. The map analysis step will be used to allocate initial land use hectarages as well as to define some of the categories such as potential crop land or village sites. Animal habitat will of course be tracked in the modules and in the MAP data base. Map categories can also represent habitat quality, productivity potential, etc.

AGRICULTURE SECTOR: The agriculture (or food production) sector will include crop growth, grazing, and fisheries including aquaculture. Crop growth will include the effects of irrigation and potential pests (at least one insect and one pathogen). Necessary inputs will include: irrigation water, rainfall, large vertebrate damage, and hectares involved. Amounts of irrigation water will come from the water supply sector, rainfall as generated input, hectares from the land use sector, and large vertebrate impact from the wildlife sector.

Outputs will include yearly biomass accumulation (yield and crop residue), water use, physical requirements such as agro-chemicals (fertilizers, pesticides,etc.) as well as labor and draft animal requirements. Yield, crop residue (for energy and/or soil amendment), and physical requirements will be passed to the socio-economic sector, and water use to the water supply sector.

The agricultural sector component will be developed using a more detailed model with a smaller time step and variable pest control strategies. A response surface will be fit for each output variable as a function of the input variables.

For grazing, simple calculations of pasture needs (hectares) and breeding herd needs (hectares) will be made

-400

based on the projected draft animal requirements an forage productivities from above. These land requirements will be passed to the land use sector.

In dealing with fisheries a time step of one year appears to be sufficiently small. Inputs for aquaculture are analogous to the crop section: fingerlings, water, food, fertilizer, and labor. Output is kilograms of fish/hectare of water. Water use will pass to the water supply sector. Fingerling numbers, food, fertilizer, labor requirements, and yield will pass to the socio-economic sector. Inputs to estuarine and nearshore capture fisheries include water supply, nutrient loading, downstream accumulation of agrochemical, silt, etc. Yield outputs will pass to the socio-economic sector.

401

IRRIGATION AND WATER SUPPLY SECTOR: The irrigation water supply sector will be a relatively simple module of the model. The major state variable will be the volume of water stored for irrigation - the water held by the System B reservoir. The single inflow rate to the volume of stored irrigation water would require information concerning the river flow including the average annual river flow, interannual high and low flow, and historical highs and lows. There would be two outflows from the volume of stored irrigation water: the rate of water usage for irrigation, and the rate of water loss from seepage, evaporation, and diversion to other projects. The rate of water usage for irrigation would be a function of the water stored and the water demanded. The water demanded for irrigation depends upon agronomic variables including the crop mix and number of seasons, the amount of land under cultivation, and the water supplied by rainfall.

The total amount of water stored is a function of the capacity of the reservoir in addition to the river flow. The reservoir capacity is a function of the initial construction volume and rate of siltation. Outputs such as the effects of water diversion to to crop and estuarine fisheries productivity will also be assessed.

.402

SOCIO-ECONOMIC SECTOR: The socio-economic sector would include three major state variables: human population, farm family money balance, and farmer natural resource knowledge. The human population variable would include inflows from immigration and births and outflows to emigration and death. Migration rates would require information from the land use sector on the proportion of developed land as well as from the agriculture sector by type of food produced in order to calculate a quality of life indicator. Birth and death rates would be constants. Population and settlement patterns will spontaneously respond to rural and road development as will planned dispersals.

The money balance would be a function of income and expenditures. The only variable income rate would be the income from crop sales. This income rate would require production (crop yields and land use) as well as price information. The rate of money expenditure would depend upon the desired rate of expenditures and would require information on optimal levels of production inputs and the farmer's willingness and ability to invest, which would depend upon farmer knowledge and liquidity, respectively. Other expenditures would simply be moderated by liquidity such as family support and energy expenditures.

403

Farmer natural resource knowledge would be fairly simple - basically a "learning by doing" feedback loop moderated by the level of extension support.

FORESTRY SECTOR: The forestry sector provides three main "products" to the project system: fuelwood, timber, and wildlife habitat. Large sections of the native forest are being cleared to convert land to agriculture, leaving only a limited supply of wood for timber products and fuelwood in the "System B" area. Significant quantities of native forest will be protected in the forest reserves and national parks. Therefore, much of the future demand for furlwood and timber is expected to come from plantations. For this reason, three types of forest land will be distinguished in the land use accounting module: native forest, fuelwood plantations, and timber plantations.

In the forestry module, inventory of wood biomass available for fuel or timber will be state variables measured in cubic meters. Forest "biomass" will "grow" annually through two or more age/size classes. Forest growth and productivity will be influenced by the availability and use of production inputs: labor, seedlings, equipment, etc. which will be provided by the indigenous population or by external support.

Fuelwood can be can be harvested from any size/age class, while sawtimber can only be harvested from the mature age class. Timber demand will be exogenous (determined by

405

State Timber Corporation), while most, or all timber will be exported from the region. It will be important to determine if export timber yields an income to the local region, or if revenues from timber are accounted for separately.

Fuelwood demand will be based on the total population in the region (socio-economic sector). A system dynamics model of fuelwood production and demand in developing countries (Kirchner, 1982) will be a good resource. However, our version will be less detailed than that effort. Fuelwood demand will also be determined by the price and availability of substitute fuels such as kerosene as well as the average money balance (wealth) of the population.

Another important element of fuelwood use is the relative accessibility of the fuelwood resources. The time spent to gather a family's fuel needs must be balanced against the cost of substitute fuels.

The role of forests in providing wildlife habitat will be determined in the wildlife sector.

WILDLIFE SECTOR: A habitat quality/quantity index will be developed for each indicator species as well as those of legal or religious significance. This index will depend on the amount and distribution of habitat components, as well as the density factor for each habitat area.

Wildlife impacts are important for several reasons. Preserving wildlife species is a clear social goal in the country. Secondly some species of wildlife, such as elephants, will cause significant economic damage if not enough habitat is available, or if the populations are not managed properly. Crop damage is a critical element in the model, as is the cost of controlling wildlife, or mitigating wildlife impacts. Another project-related impact is the physical constraint and cost of maintaining buffer zones, corridors, or other wildlife preserves in the project area.inally alteration of natural flow regimes coupled with downstream accumulation of agrochemicals affects wetland avifauna habitat as well as the estuarine fishery resources at the mouth of the Maduru Oya.

The basic components of the wildlife sector include: habitat type suitability indices (HSI), density of featured species for each habitat type, area of habitat types (from the land use sector), and multipliers to account for the

407

proximity of each discrete habitat patch to habitation or other anthropogenic features, and the linear distance of edge between types for appropriate sized areas (e.g. 25 square km). Twelve likely types would include scrub forest, mangroves and estuaries, inland wetland, riparian, seral forest and grassland, farm, urban , power corridors, roads, reservoirs, canals and tanks, and plantation forest. Fourteen likely species would include elephant, leopard, sambar, spotted deer, langur, certain waterfowl, certain wading birds, boar, carp, tilapia, shrimp, squirrel, parakeet, and munia. Representative indicator species will be chosen.

Inputs necessary for the HSI include natural history facts for the featured species (including seasonal occurrence) and distribution maps. The areal extent of types will be derived from the land use sector as will the multiplier for the edge. Density will be determined from EIS and research data, exploitation multipliers based upon distance from farm and labor sources (e.g. farm density, construction/forest camps, towns, etc.) which will come from the forestry and socio-economic sectors, and from mapped protected areas (forest reserves, national parks, etc.).

Outputs will go to such sectors as forestry and agriculture for crop/regeneration damage estimates, tourism,

408

land use (park and reserve projections) socioeconomic (e.g. sales of animals and their products such as birds, aquaculture and shrimp fisheries), and health (mosquitos, rodents, etc.).

409

D. Hertzmark

GIR3: A FOREST ECOSYSTEM MODEL OF THE GIR FOREST, INDIA

David Van Wie[1]

Stephen Berwick[2]

Kenneth L. Reed[3]

[1]Maine Audubon Society, Falmouth, Maine, USA

[2]IIED, 1319 F St NW, Washington, DC USA

[3]HDR Systems, Santa Barbara, California, USA

HP

INTRODUCTION

This paper is a non-technical, rather informal presentation of a working version of GIR3--an ecosystem model of the Gir Forest Preserve in India. The model is written in the DYNAMO compiler language using System Dynamics, a policy analysis technique developed at Massachusetts Institute of Technology. DYNAMO allows the succinct expression of complex systems that are characterized by nonlinear relationships and are capable of being represented in a differential equation format. System Dynamics is especially applicable to simulating complex systematic behavior over time and to testing policy options which can be expressed through relatively simple structural and numerical changes in the model. GIR3 is a rough, incomplete model which is presented here to illustrate the study of the dynamics of an existing complex problem structure, the Gir Forest Ecosystem, through the modeling process as well as some of the applications for managers of such an ecosystem.

THE PROBLEM

The Gir Forest, 1200 square kilometers of forest and savanna in northwest India, is among the largest nature preserves in the subcontinent. It contains remnant populations of a variety of wild ruminant species "that once constituted the magnificent faunal wealth of India" (Berwick 1974). The Gir also harbors the last 180 or so remaining Asiatic lions (Panthera leo persica), a subspecies that has been reduced to a minute fraction of its original range and numbers. The Gir also supports a healthy leopard population.

Unlike most Western nature preserves, the Gir Forest Preserve is the home of a number of native tribal people who practice a traditional pastoral economy and associated culture. The Maldhari tribesmen keep about 25,000 resident domestic cattle and buffalo that graze in the forest. During the monsoon, another 25,000 nonresident cattle are brought into the Forest to graze. In drought years (the monsoon fails about every 5 years), an additional 10,000 to 25,000 head are driven into the Gir in search of food. These domestic livestock cause severe local impacts on the forest vegetation through overgrazing and soil compaction, thus threatening the health of the entire forest ecosystem and the lions therein. Ironically, the stock animals also provide 75% of the lions' diet (Joslin 1973). The Indian government is faced with the task of managing this--a last vestige of the Asian faunal heritage in the face of these endemic conflicts. A model, similar, but more sophisticated than the one presented here would be a great tool in determining the answers to these complex problems. For a thorough discussion of the Gir Forest situation, see Berwick 1976.

THE REFERENCE MODE AND TIME HORIZON

In this modeling discussion, we will be looking back five to ten years in an effort to reproduce historical behavior of the system over that period. We will also be looking ahead 40 to 45 years in our projections of the system behavior. The model is based on ecological and demographic data which were collected from 1969 through 1976. Aknowledgements would generate a list longer than

48

this paper although the contributions of M. Berwick, S. Chavan, R. Grubh, K.T.B. Hodd, P. Jordan and N. Sanyal were critical to "systems" view. No 'hard' historical trends can be readily gleaned from the available data, but some basic trends and assumptions about past behavior can be inferred. The lion population has been holding fairly steady since 1970, although population estimates have been too variable to project trends (Joslin 1973). As a reference mode for the model, we will try to reproduce a stable population of lions for the first five to ten years of the run.

Other important variables in the model include the relative quantities of both herbage and browse available to both wild and domestic ungulates. Much of the concern for the Gir has stemmed from a perceived decline in the quality and quantity of fodder. Thus, we will also try to reproduce in our 5- to 10-year reference interval a condition of slightly deteriorating herbaceous biomass and productivity.

THE MODEL

The current status of the model is a working version called GIR3. the model structure has evolved through two earlier stages, aptly called GIR1 and GIR2. GIR3 while not working to complete satisfaction exhibits fairly sound behavior; its major problem is that it has not been properly "tuned." Further structural revisions may be necessary to produce a model with proper behavior <u>and</u> numbers. For the present, GIR3 is a step in the right direction.

The question is the uses to which such a model should be put. What is expected from such a simulation? Briefly, the reasons for constructing and using such a model can be summed as enhancing the

- knowledge of the system by formally drawing a "conceptual model" with boxes representing the state variables and showing the inputs, outputs and other relationships (e.g. functional proximity). This exercise can be very revealing and, for example, when planning research, is essential to prioritizing, programming and sequencing tasks and devising milestones so that data necessary for an analysis are generated before rather than after that task is written up. In a word a check-list of "linkages" is revealed.

- construction of a simple integrated systems model and it's testing in simulation runs using several managerial interventions. This approach is designed to assist in such decisions as siting of structural elements, sequencing or choosing management options (e.g. burning, provisioning lions, etc.)

- comparison of insights with those derived from the existing system of data analysis and management. This should help reveal systematic strengths or weaknesses in each type of process.

414

- constructing and running the model can be expected to reveal several higher order unexpected relationships which may have been counter-intuitive, e.g. the effect of Maldhari translocation upon soil moisture, or of increases in ungulate prey densities upon lion social behavior. These can be provocative insights which stimulate further research.

It should be noted that even if numbers are not cranked out of such models, e.g. the number of chital to four decimal places, the general relationships can be revealed and this level of resolution provides enough information to the manager. For example, changes in densities can be simply and subjectively portrayed as high, moderate or low, positive or negative. Following is a presentation of the basics of GIR3.

GIR3 is divided into five sectors, each centered on a single state variable, or <u>level</u>, its associated <u>rate</u> equations, and the <u>auxiliaries</u> that define the rates. The five sectors are set up as shown in Figure 1. An elaboration is given in Figure 2 and the working elements are shown in Figure 3 which should be consulted in much of what is discussed below.

The arrows denote causal interactions between independent and dependent variables, pointing to the dependent sector. It is clear from the diagram that certain sectors are not causally linked, while others are only linked in one direction. In the "real" system, the

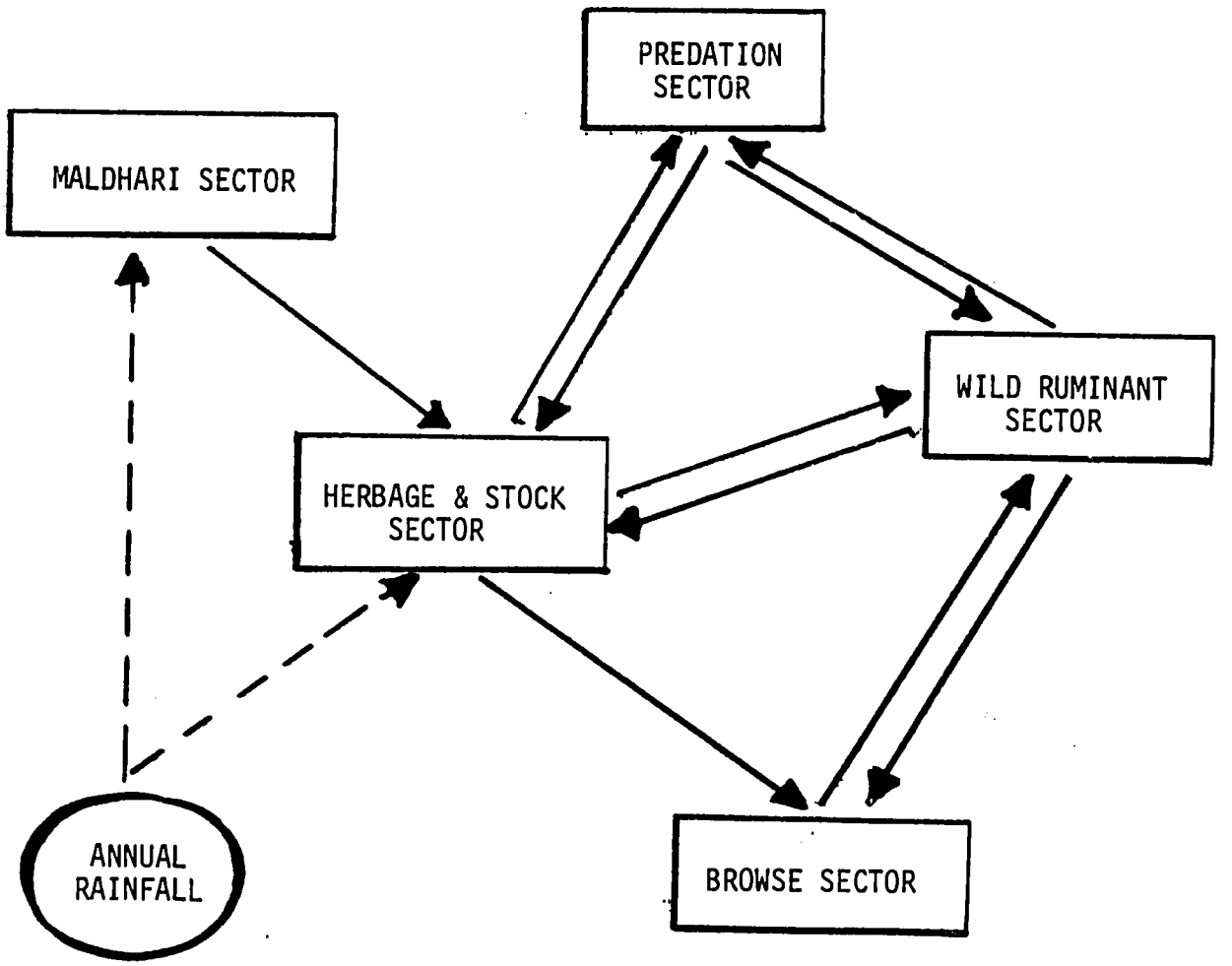


Figure 1. Major sectors of the Gir ecosystem.

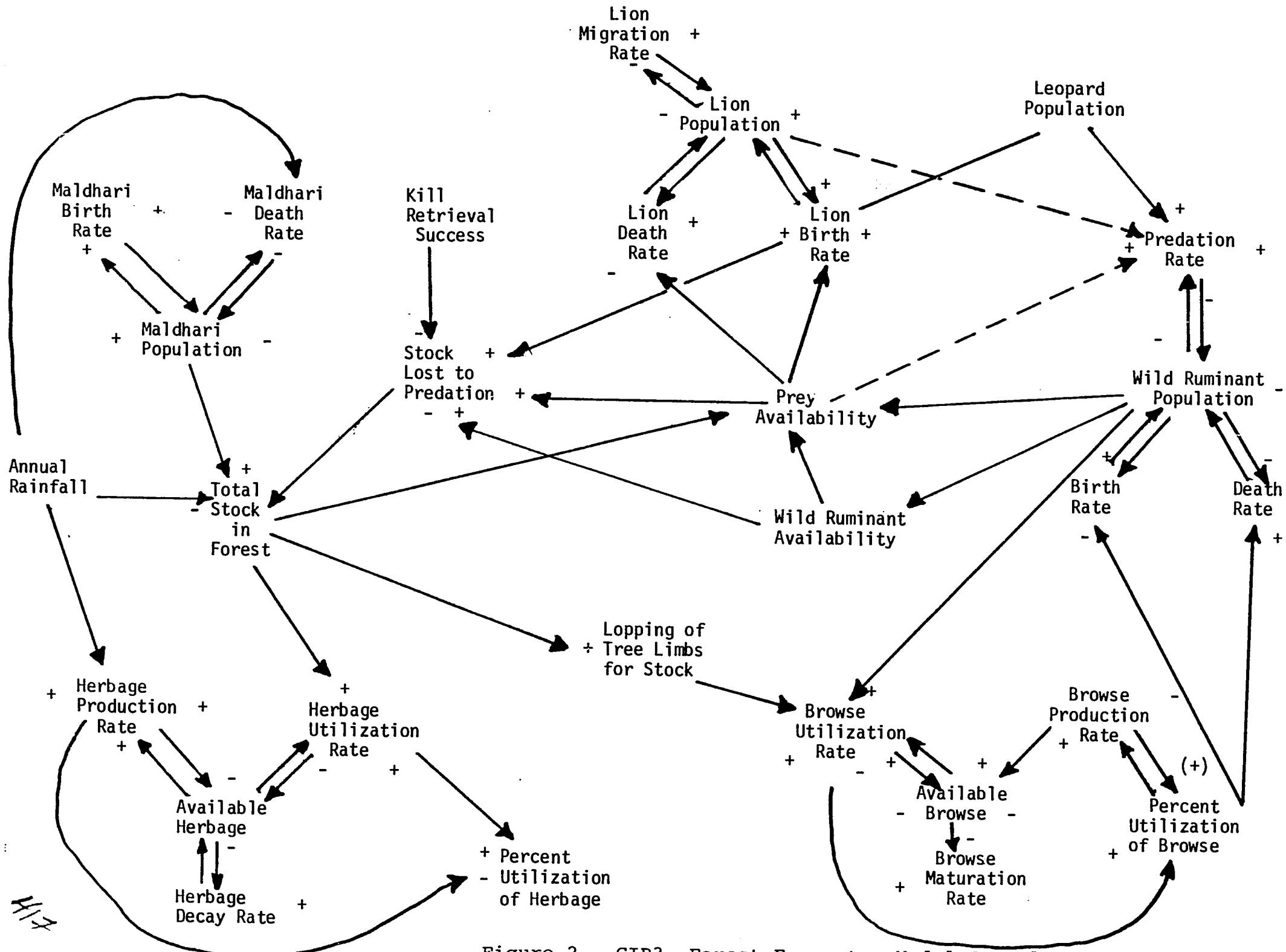


Figure 2. GIR3--Forest Ecosystem Model Causal Loop Diagram

Gir Forest itself, many relationships exist that have not been put into GIR3. Let it be clearly stated now that the purpose of this model is to capture a simplified representation of a particular perception of reality (ours) in an effort to reproduce a behavior analogous to the real system. Certain causal links are left out of the model as a result of a tradeoff decision between simplicity and behavior.

For example, the Maldhari people are obviously dependent on their stock for existence. In this model, it was assumed that the number of Maldharis will directly determine the number of resident stock, but the causal feedback was left out. The lack of a feedback making the Maldhari popuation dependent on the size of their herd would depend on an economic and demographic system that is tangential to, but not extremely relevant to the ecological system upon which we are focusing. Within the precision of the rest of the model, the exact number of Maldharis and the exact number of resident cattle is overshadowed in importance by the unpredictable numbers of non-resident cattle entering the forest. Therefore, such a causal feedback would add little to the behavior of the herbage sector, which is more responsive to the grosser changes in the total number of stock in the forest. This is not to say that such an additional structure is undesirable; rather, in this version of the model, it has been consciously left out.

The sector diagram above also indicates that the GIR3 model is a rainfall-driven system. In the Gir, the monsoon is a life-giving force which, to a large extent, determines the grass crop and the subsequent well-being of the Maldhari cattle. The monsoon also determines the annual number of nonresident stock entering the forest. In the model, the rainfall function is an exogenous force that drives the dynamics of many of the state variables in the system. A graphical representation of the rainfall function is presented in the Appendix.

Following on the next page is a very general and aggregated causal loop diagram of the GIR3 model as a whole. In the diagram, each linking arrow is marked with a polarity sign (+, -). A positive link is one in which an increase in one variable will cause an increase in the other; and, conversely, a decrease in one causes a decrease in the other. With a negative link, a change in the independent variable causes an opposite change in the dependent variable. Again, certain links have been left out by choice. This does not mean, of course, that the present links are the proper structure. Further scrutiny and experimentation are needed.

The remainder of this section of the paper will present a more detailed, yet brief discussion of the five sectors of the model. The data points, data collection methods and analyses are described in Berwick (1974). Please refer to the DYNAMO Flow Diagram and the model listing for a more detailed presentation of the schematic and mathematic structure of the model. No attempt is made here to

419

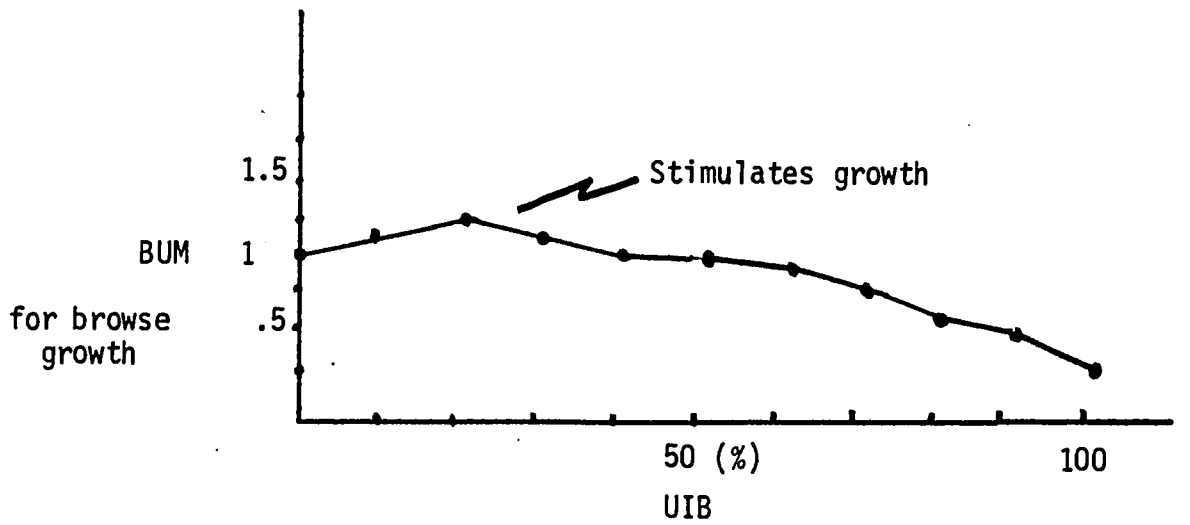
present a technical description of the equations and numbers used. Such an effort will be postponed until a more nearly final version of the model is completed.

THE BROWSE SECTOR

The state variable that is the heart of this sector is Available Browse (BROWSE), measured in kilograms. The change in BROWSE per year is equal to the yearly production of browse (BPR) less the yearly utilization (BUR) less the amount that matures annually to wood (BMR).

The Browse Production Rate is determined by multiplying a constant potential production rate (340 kg/ha-yr) times the total forest area (AREA) times a Browse Utilization Multiplier (BUM). The production of browse is largely a function of the previous year's utilization levels--very light browsing stimulates growth, while overbrowsing can eventually kill certain plants (Garrison, 1956 and others). BUM is based on the Percent Utilization of Browse (PUB) from the previous year. This is accomplished through a delay function (DLINF3), since back calculations are not possible in DYNAMO. Instead, "future" calculations are made by delaying present information until it is "needed" in the future (delays are very complex structures and cannot be adequately discussed here). The Percent Utilization of Browse (PUB) is determined by the ratio of consumption to production; this ratio is delayed for one year, becoming UIB, the Utilization Impact on Browse Growth. The Browse

Utilization Multiplier is then a non-linear function of UIB, the Utilization Impact on Browse Growth. The Browse Utilization Multiplier is then a non-linear function of UIB as shown below:



The annual Browse Utilization Rate is a function of the total wild ruminant population (in kilograms) times an annual Browse to Ruminant Ratio of 9.6 kg-browse/kg-ruminant per year, plus the amount of browse lopped for use by domestic stock (.11 kg/kg of domestic stock).

Finally, the Browse Maturation Rate (BMR) is determined by calculating the amount of unused browse each year and "dumping" it off as unusable wood the next year. Again, this accomplished through the use of a delay function in which the Browse Differentia (BD) is delayed for one year. BD is merely the difference between annual production and annual consumption.

121

RUMINANT SECTOR

The central level in this sector, Wild Ruminant Population (WRUM), is measured in total kilograms. There are four major wild ruminant species in the Gir; nilgai, sambar, chital, and the fourhorned antelope. These are aggregated into a single population in GIR3. In his thesis, Berwick used total wild ruminant biomass in his analysis of forest energetics, especially with regard to the predator/prey turnover.

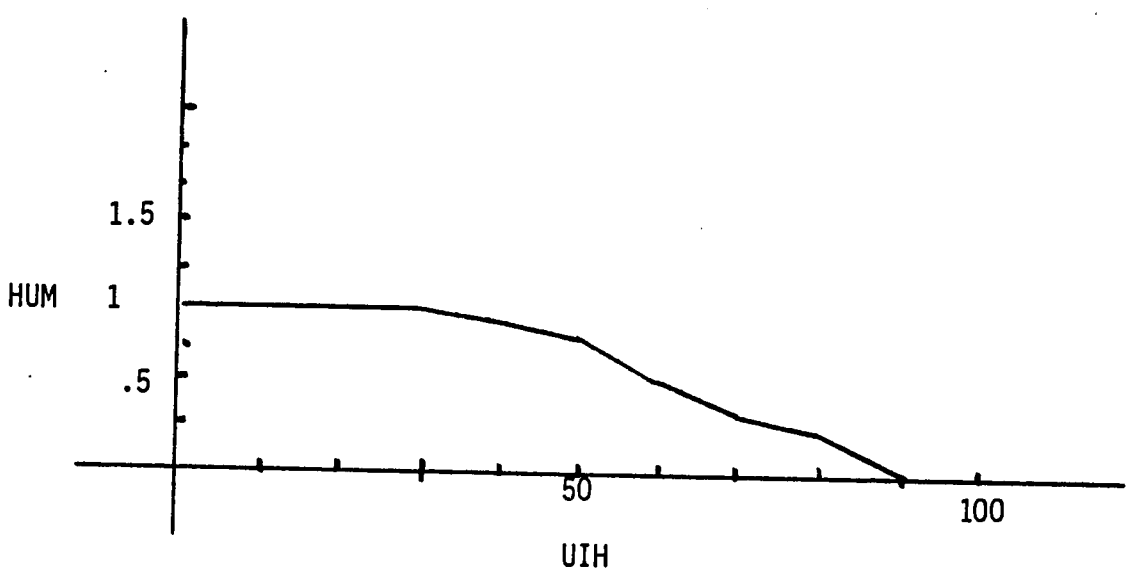
The dynamic changes in the WRUM population are accounted for through three rates: Ruminant Birth Rate (RBR), "Non-Predatory" Death Rate (NRDR), and Ruminant Predation Rate (RPR). The Birth and Non-Predatory Death rates are simple biological growth and decay functions based on constant fractions of the population entering and leaving each year. The source data can be found in the life table analyses of Berwick (1974). Each base fraction is modified by a Ruminant Nutrition Multiplier (RNM) which decreases the Birth Rate and increases the Death Rate when the browse resource is being overutilized. This Non-Predatory Death Rate accounts for deaths due to disease, accidents, and starvation.

The Predation Rate on Ruminants (RPR) is simply the sum of the total kill by lions and leopards (RLLI & RLLE). The calculation of these kill rates is quite complex and will be discussed in the Predation Sector.

422

HERBAGE AND STOCK SECTOR

The central dynamic structure of this sector is essentially identical to that of the BROWSE sector. Available Herbage (HERB) is increased by an Herbage Production Rate (HPR) and decreases by a stock Utilization Rate (HUR) and the decay of Unused Herbage (UHERB). The structure contains the same delays as in the Browse Sector. Like Browse Production, Herbage Production is a function of the previous season's use, according to the following relationship:



423

The Major difference between the Browse and Herbage Sectors is that the Potential Production Rate for Herbage (PHPR) is a function of annual rainfall, rather than a constant. A failure of the monsoon will significantly reduce the annual herbage production, but will not seriously affect the annual production of browse (Berwick, 1974).

This sector of the model also determines the yearly total of stock in the forest (TSTOCK), measured in kilograms. TSTOCK is the product of the average weight per animal (STOKWT) times the sum of the following:

Resident Stock + 1/4 (Non-resident Stock + Drought Stock) where each class (type) of stock is measured in individual animals. Resident Stock (RSTOCK) is the total number of animals, calculated on a per capita basis, belonging to the Maldhari people. Non-Resident Stock (NRSTOK) and Drought Stock (DRSTOK) only remain in the forest for one season of the year; hence, their "Animal Unit Year" value is reduced to 1/4 that of the permanent Resident Stock. The number of Drought Stock (DRSTOC) is determined as a function of annual rainfall. Since they only enter the forest when the monsoon fails, another function (SRSTOK) "decides" whether DRSTOC will enter the forest. A "CLIP" function, a type of IF...THEN function, is used to make the decision.

424

TSTOCK is used to calculate the Herbage Utilization Rate in this sector and the amount of browse lopped as supplementary feed for stock in the Browse Sector. In both cases, TSTOCK is multiplied by an annual food to stock ratio (HSR & LOPPC) measured in kg-food per kg-stock weight.

MALDHARI SECTOR

In this version of the model, the Maldhari Sector is quite simple and peripheral to the central ecological dynamics. The single link between the Madhari sector and the rest of the model is in the calculation of Resident Stock, where an exogenous input of Maldhari population could suffice. However, the current structure was built in anticipation of constructing a more complex dynamic sub-sector based on pastoral economics and tribal demographics. Both play an important role in how the forest is utilized. For example, in a subsequent version of GIR3, the total forest area could be broken down into areas within the area of villages and "ness" communities and areas outside a practical radius. Such a revision would mandate the addition of a community structure within the Maldhari Sector.

The Maldhari Population (MHARI) is measured in individuals. Constant fractions of the population are used as the bases for the Maldhari Birth and Death rates (MBR, MBRF & MDR, MDRF). Each of the

425

two rates is a function of the annual rainfall. When the monsoon fails, Maldhari Deaths increase as a result of lower nutrition (MNM). Likewise, when drought occurs, the Maldhari Birth Rate decreases subject to a one-year fertility delay (MFM).

PREDATION SECTOR

The most complex sector of GIR3 is by far the Predation Sector. This sector was modified extensively from the GIR2 version and has succeeded in imparting a much more acceptable behavior to the model as a whole. The central state variable is the Lion Population (LIONS) which is treated in terms of individual animals. The initial population used in the model is 137, Joslin's estimate of the number of lions within the Gir Preserve. The total lion population in the region has been estimated at about 200, but some of these occur outside the Preserve.

The basic dynamics of the lion population are quite straightforward; the Lion Birth Rate (LBR), Lion Death Rate (LDR), and the Lion Migration Rate (LMR) account for all changes in the population. For the first two rates, a constant fractional change per year is modified by a Prey Availability Multiplier (PM). This multiplier is a feedback mechanism from the overall availability of stock (SAM) and wild ruminants (WPAM), which prevents an unregulated overkill of the prey animals. PM will be discussed more thoroughly

424

below. The Lion Migration Rate is set up as a constant fraction of the lion population in this version of the model. Were the data available, a more realistic density dependent structure would have been more appropriate.

The leopard population is also included in this section, but, because its demographic composition was unknown, a static population was used. A table function is used in GIR3 so that the leopard population can be varied over time.

The total prey requirements of each predator population (LIPREY & LEPREY) are computed by multiplying an average prey per predator ratio (PLIR & PLER) by the number of individuals in the respective population. The ratio for each predator is computed by multiplying a "normal" value, estimated by Berwick, by the prey availability multiplier (PM). In GIR3, PM is the product of the relative abundance of stock (SAM) and the relative abundance of wild ruminants (WPAM). As a product of these two values, PM implies that the least available prey type will limit the total diet of the predators. Other possible formulations of PM, such as an average prey availability, could be substituted. The present formulation was chosen rather arbitrarily.

The diets of both predators are divided into two prey types as we have seen: stock and wild ruminants. Each type of prey comprises a given percentage of each predator's diet. The leopards' percentages are static, average figures. The lions' diet

composition is a function of the relative availability of wild prey (WPAM), assuming (correctly?) that its natural prey would be its first choice if sufficiently available. The percent of the Lions' Diet as (wild) Ruminants (PLIDR) is computed by multiplying a base figure of 25% by WPAM. The Percent of the Lions' Diet as Stock (PLIDS) makes up the difference.

For each predator there is a certain, constant Kill Retrieval Success factor (LIKRS & LEKRS). These pertain to the ability of the predator to consume a kill of domestic stock. In the Gir Forest, it is common for the Maldharis to chase a predator from its kill in order to sell the salvaged meat and hide to Harijans. Therefore, assuming the lions only keep 25% of their kills, they must kill four times as much meat than they require. These retrieval rates were calculated from data in Joslin's thesis.

All of the Predation Sector variables discussed so far are used to compute four important variables: the amount Stock Lost to Lions (SLLI), Stock Lost to Leopards (SLLE), Wild Ruminants Lost to Lions (RLLI), and Wild Ruminants Lost to Leopards (RLLE). Each of the four has nearly the same mathematical construction. For example, SLLI is the product of the total prey requirements of the lion population (LIPREY) times the percent of the lion's diet as stock (PLIDS), divided by the lions' kill retrieval success (LIKRS). For the (wild) ruminant kill variables, kill retrieval is assumed to be 100%.

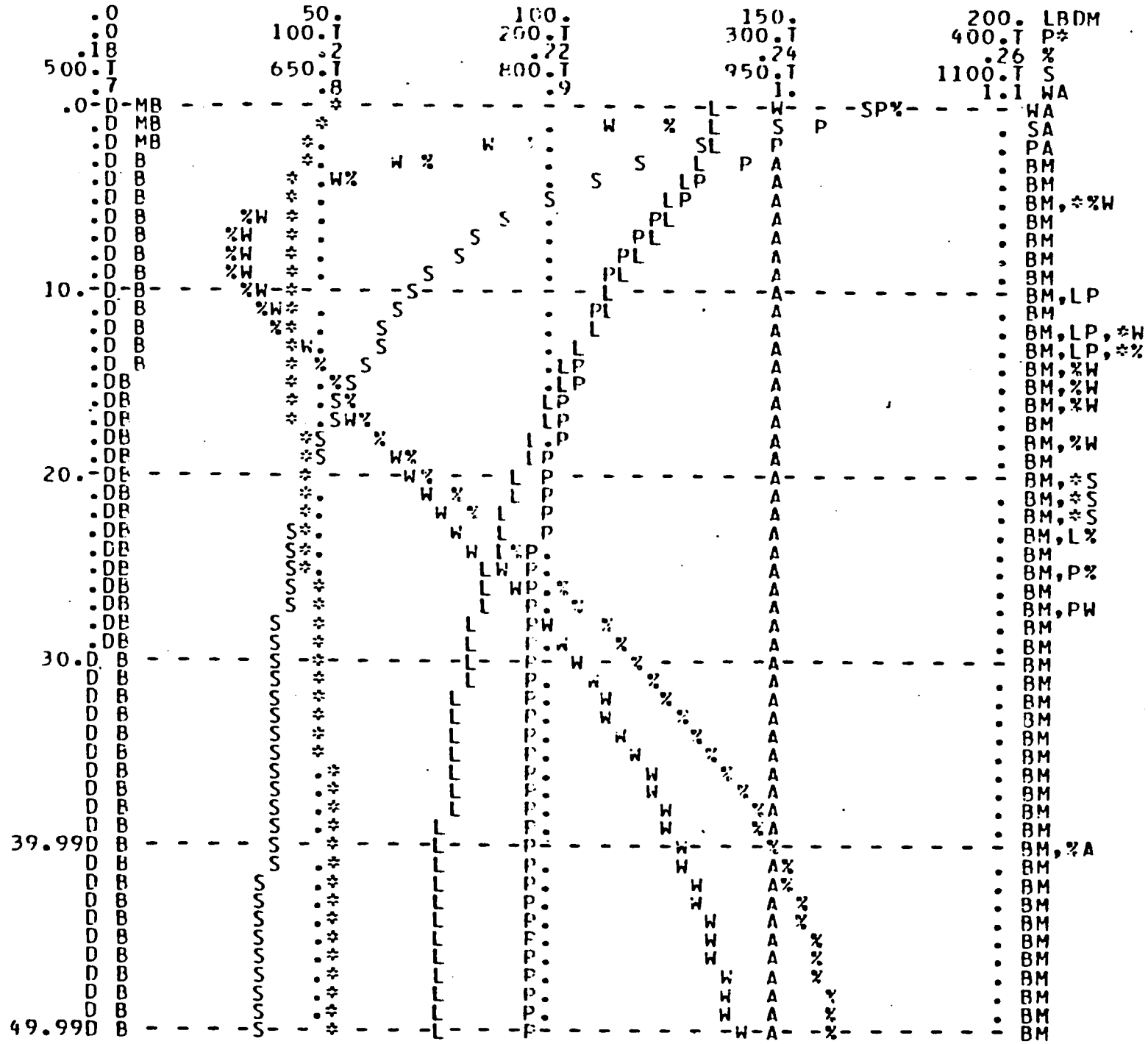
The Total Stock Lost to Predation (TSLP) is the sum of SLLI and SLLE. The units of TSLP are total kilograms of stock killed per year. To convert this to a more useful variable, the number of Resident Stock Killed (RSLOST), TSLP is divided by the average weight per stock animal (STOKWT) and multiplied by an average fraction of total kills inflicted upon resident stock (RSPF).

And finally, the sum of RLLI and RLLE is simply the annual Ruminant Predation Rate, as mentioned in the discussion of the Ruminant Sector. Note again the feedback loop from lion population through RLLI and back to the lion population through the Prey Availability Multiplier (PM). In the GIR2 version this feedback was absent, resulting in an extremely unstable system (either the ruminants were exterminated by the lions or increased exponentially, depending on relative recruitment rates).

DISCUSSION

The current structure of GIR3 is merely a working version. Rather extensive alterations may have to be made before the model is applicable to policy testing. Particular attention must be paid to the parameter values (our data) and table functions (non-linear relationships of dependent and independent variables such as plant productivity upon intensity of browsing). Those table functions used in GIR3 are nothing more than semi-educated guesses. A much

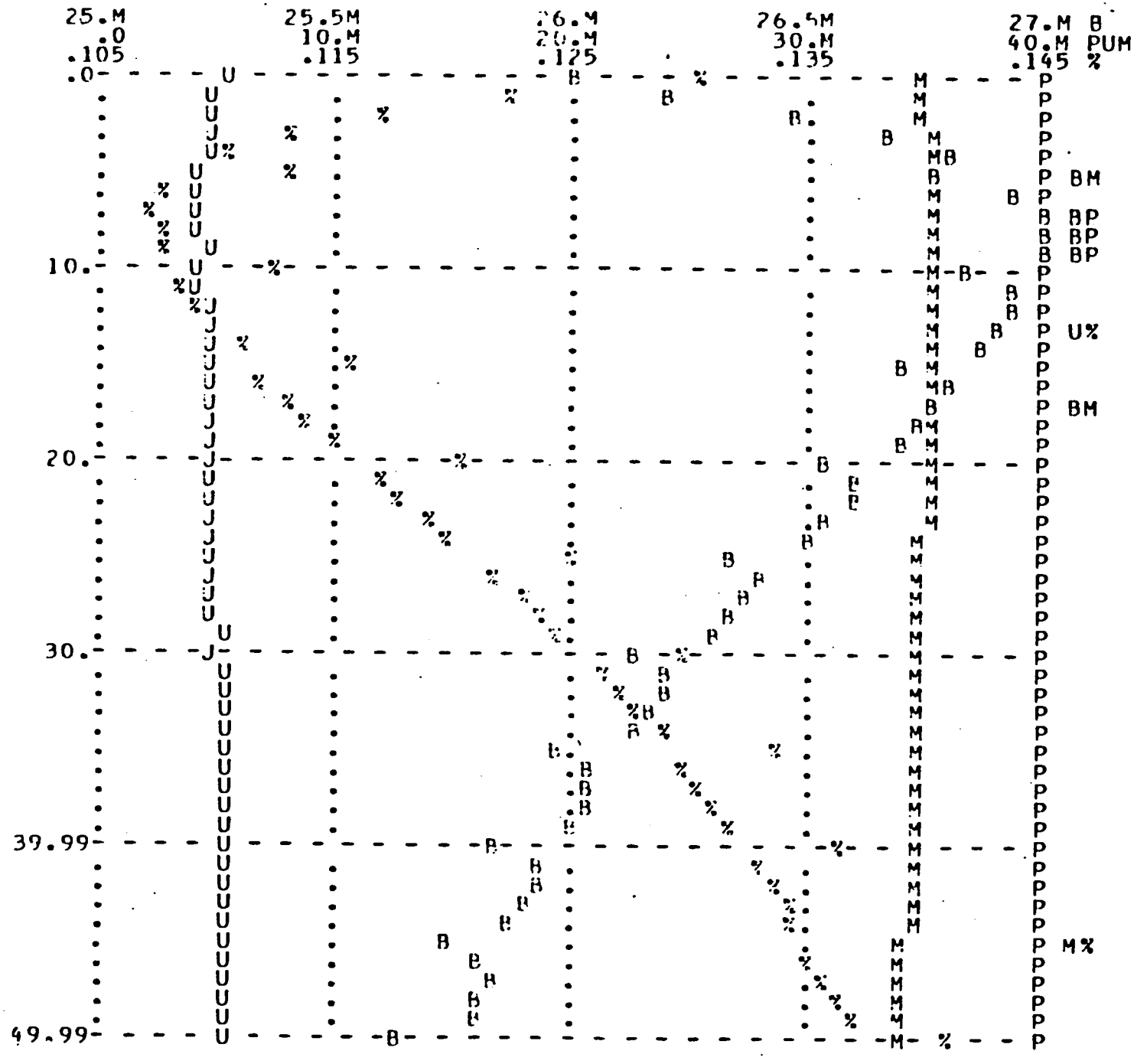
LIONS=L,LBR=B,LDR=D,LMR=M,LIPREY=P,LEPREY=*,PLIDR=%,TSLP=S,WPAM=W,SAM=A



BASE RUN: GIR3

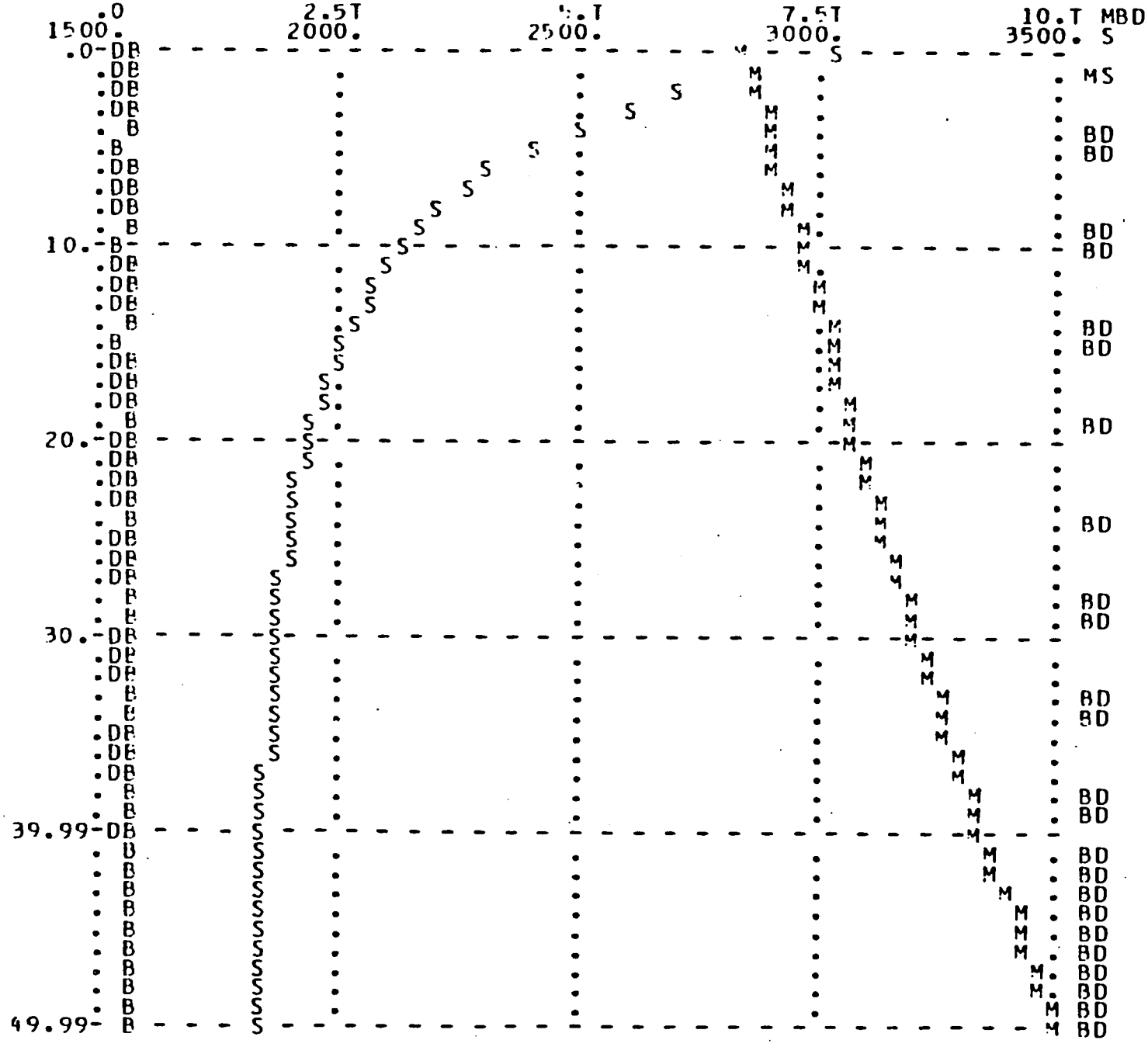
L = Lions = L
LBR = Lion Birth Rate = B
LDR = Lion Death Rate = D
LMR = Lion Migration Rate
LEPREY = Lion Prey Requirement = P
LEPREY = Leopard Prey Requirement = *
PLIDR = % Lion Diet Wild Rumenant = %
TSLP = Total Stock Lost to Predator = S
WPAM = Abundant Wild Ruminant = W
SAM = Abundant Stock = A

BROWSE=B,BPR=P,BUR=U,BMR=M,PUB=%



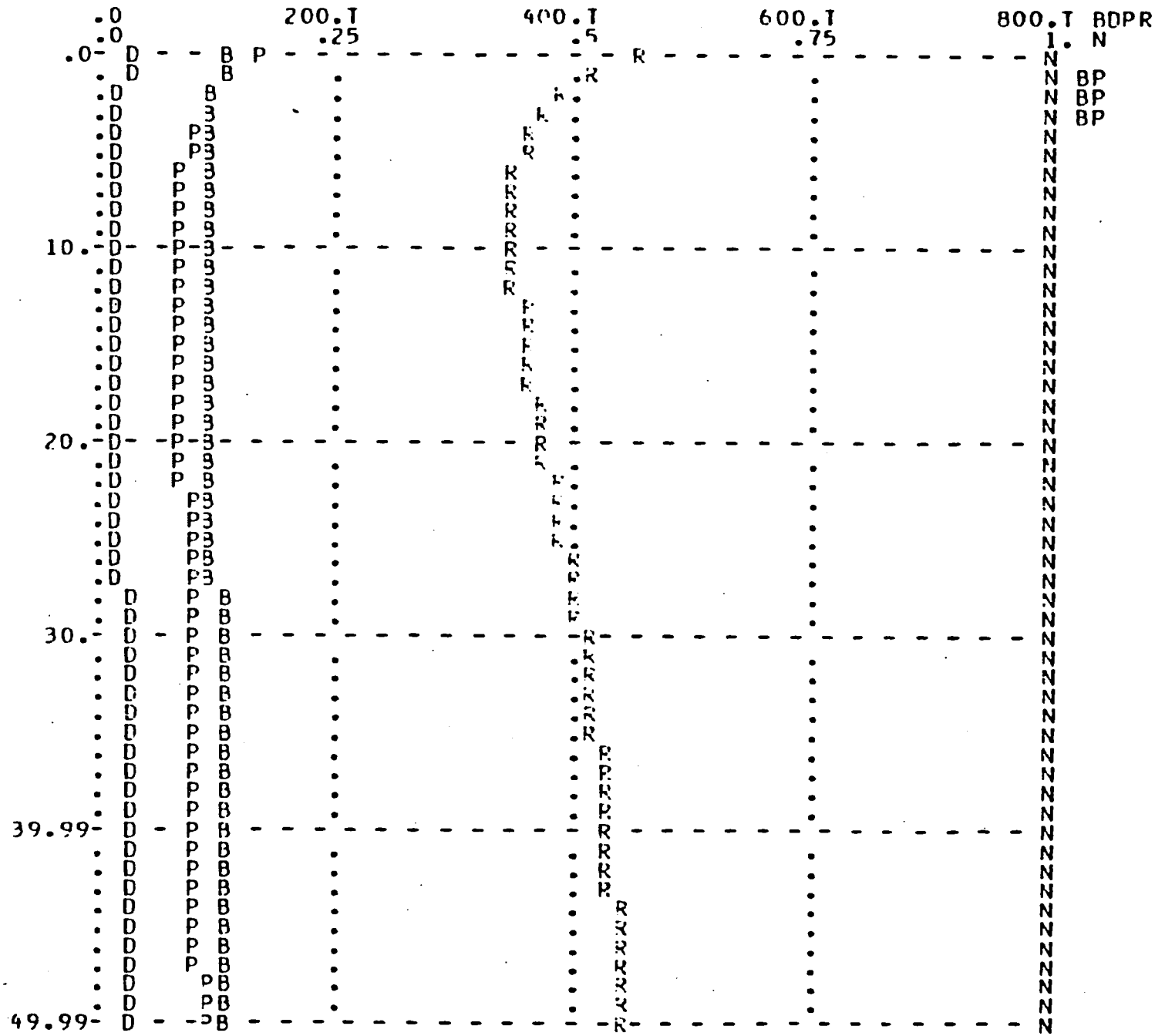
BASE RUN: GIR3

MHARI=M,MBR=B,MDR=D,RSLOST=S



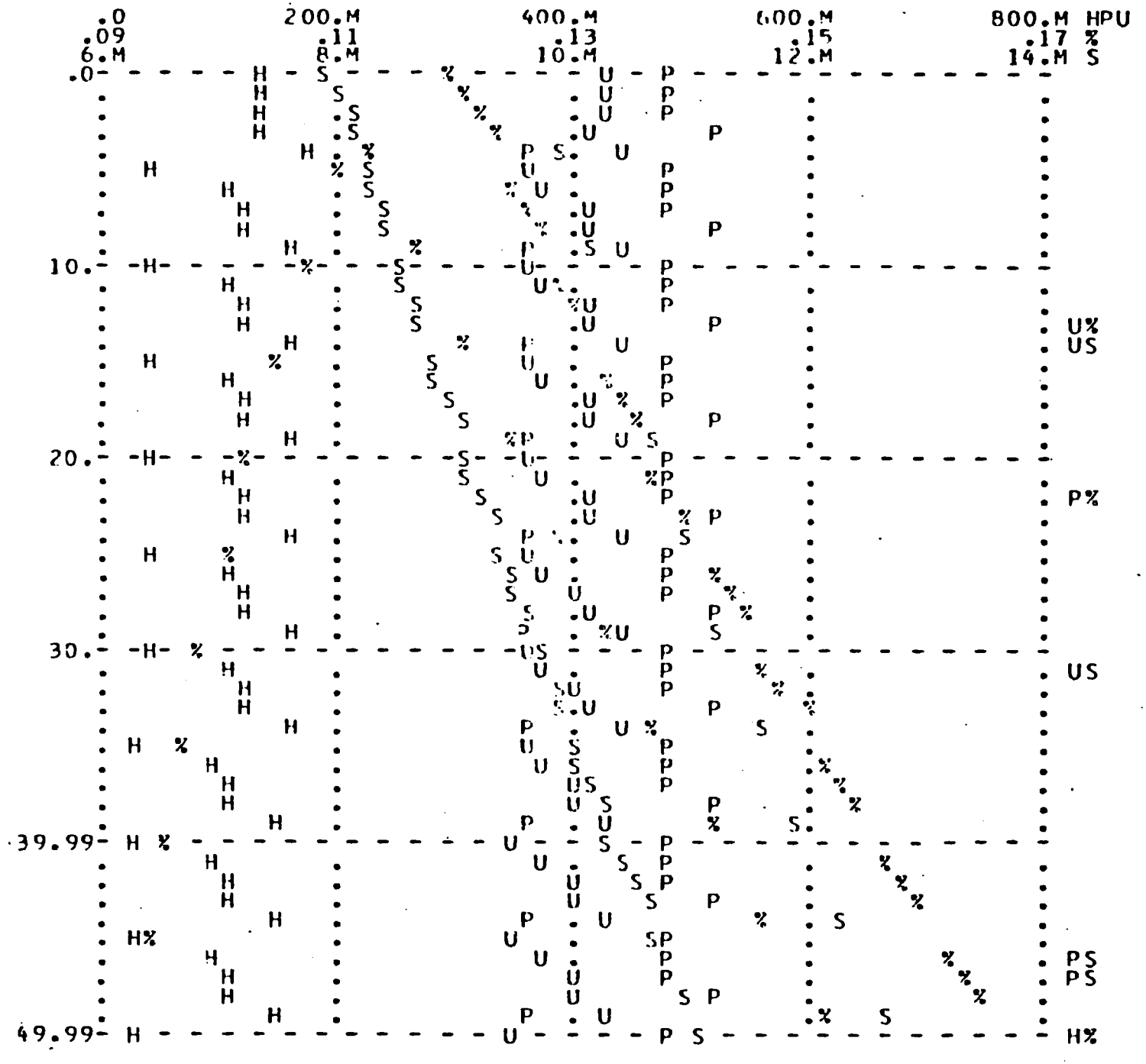
BASE RUN: GIR3

KBR=B,NRDR=D,RPR=P,WRUM=R,RNM=N



BASE RUN: GIR3

HERB=H,HPR=P,UHERB=U,PUH=%,TSTOCK=S



BASE RUN: GIR3

more extensive research effort is needed to determine better estimates of quantitative relationships although the model helps to pinpoint the types of data needed. The purpose of this model has been to create a "ballpark" prototype based upon extensive research which is useful in communicating the dynamics of an existing complex problem structure. In this respect, GIR3 is quite successful.

The base run of GIR3 follows in the next few pages. The dynamic behavior of this run seems plausible, but has not been satisfactorily verified through sensitivity analysis and fine tuning. Nevertheless, the base run is quite instructive.

In the DYNAMO plots, we can track the behavior of a large number of variables over time. In fact, there are about 36 variables and 102 linkages--more than the human mind can accomodate when an intervention causes changes throughout the system. By studying the individual behaviors of a number of complexly interrelated variables, we can get a better grasp of the dynamics of the model, and, if we are satisfied with the model, of the system itself. An example of the interactions might be the following: The predation pressure on wild ruminants by both predators initially decreases the wild ruminant population. This reduction in wild prey feeds back through the Prey Availability Multiplier to the lion population, reducing the birth rate and increasing the death rate. The lion population therefore decreases. Following this decrease in lions is a decrease in the resident stock lost to predation.

Other such dynamic relationships can be recognized through careful scrutiny of the model structure and printouts. Although it cannot be interpreted at face value, this base run can be used as a reference with which to compare the experimental policy option testing discussed in the next section.

POLICY OPTIONS

In the concluding section of his thesis, Berwick discusses a number of policy options which could be applied to the Gir Forest Preserve in an effort to maintain the health of the ecosystem and the lion population. GIR3 was designed to accommodate the testing of some of these policy options, including: reducing or eliminating non-resident stock from the Preserve, allowing a higher kill retrieval success for predators to reduce predation pressures on the resident herd, and reducing the leopard population to free up prey for use by the endangered lions. All three of these were tested using GIR3. The first two options failed to alter the behavior of the system significantly. This is probably a result of improper tuning and incongruities in the model. The third option, reducing the leopard population, did have a significant impact on the system's behavior. The policy option rerun is presented here as an illustration of the possible changes in dynamics that certain policies will impart on the model behavior. Again, the results of the option rerun demonstrate a plausible behavior, but have an uncertain applicability to reality.

We can see in the printouts on the following pages that the decrease in the leopard population after 10 years reduces the predation pressure on the wild ruminants. The increased availability of prey quickly checks the decrease in the lion population that we saw in the base run. The increase in prey availability increases PLIDR (percent lion diet ruminants), but the lions cannot take up all the slack in the ruminant population. An explosion of the wild ruminant population results in a concomitant decrease in available browse. (Notice that the limits on the graph differs from the base run.) The increase in ruminants reduces predation pressure on the domestic stock (RSLOST).

CONCLUSION

Berwick's conclusions in many of his papers imply that the Gir Forest is pesently at a stage of unstable equilibrium. The ecosystem operates on the margin of stability--any major perturbation, such as prolonged drought, may result in irreversible damage. We can see from the two model runs that such a system has been created in GIR3. Although the exact relationships between variables remain to be determined, the model is a big step in the right direction. Further refinements and improvements can make this a viable tool in analyzing management policies for the Gir Forest.

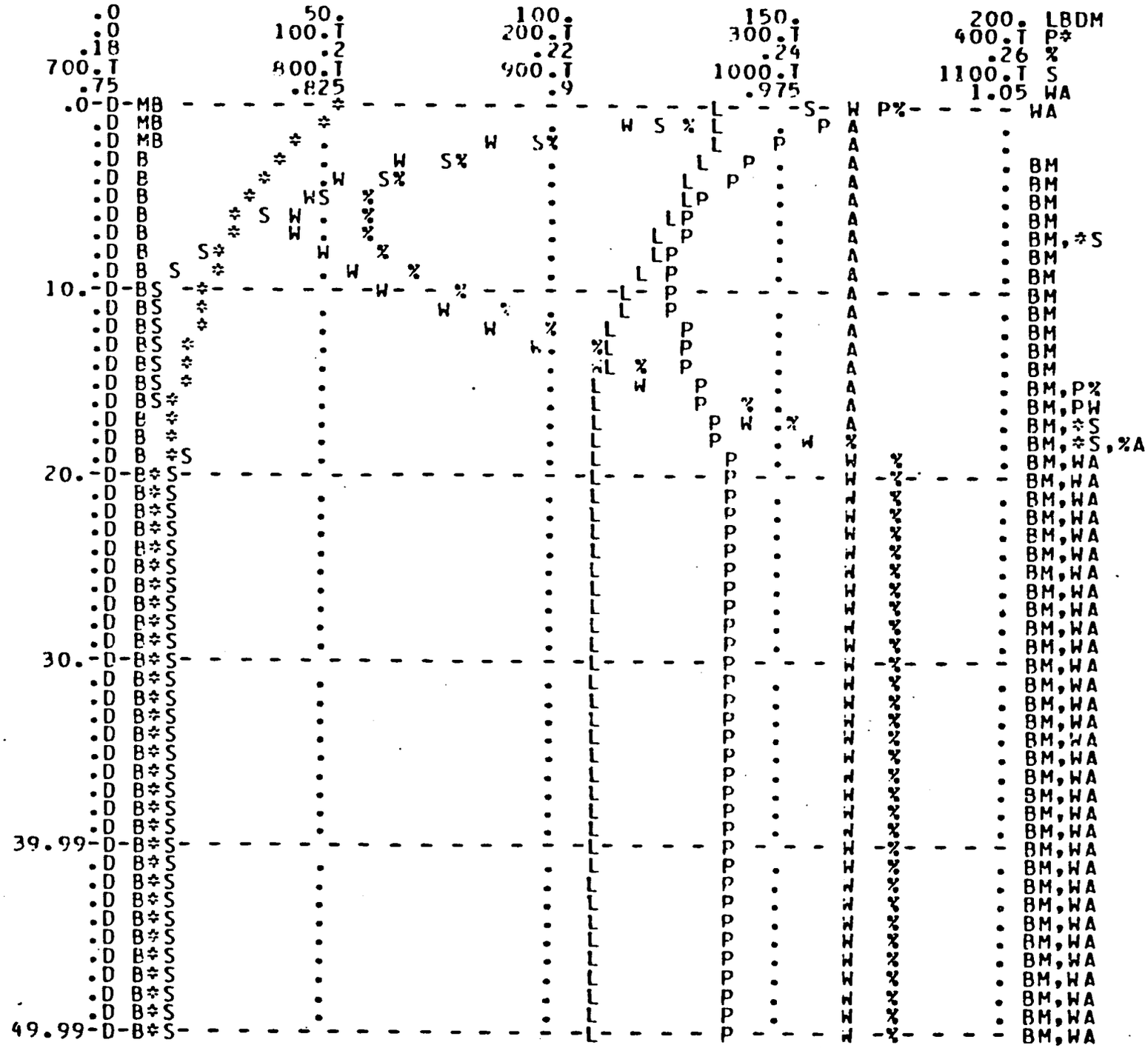
Particularly intriguing is the possibility of testing a refined incarnation of GIR3 against observed changes resulting from the management interventions of the past ten years. Our model was

431

constructed by biologists familiar with the system and employed an unusually robust data base. Model refinement and testing predictions attendant to management history against observed changes would constitute a significant and unusually powerful use of systems analysis for wildlife and wildland policy development and management.

438

LIONS=L,LBR=B,LDR=D,LMR=M,LIPREY=P,LEPREY=*,PLIOR=%,TSLP=S,WPAM=W,SAM=A

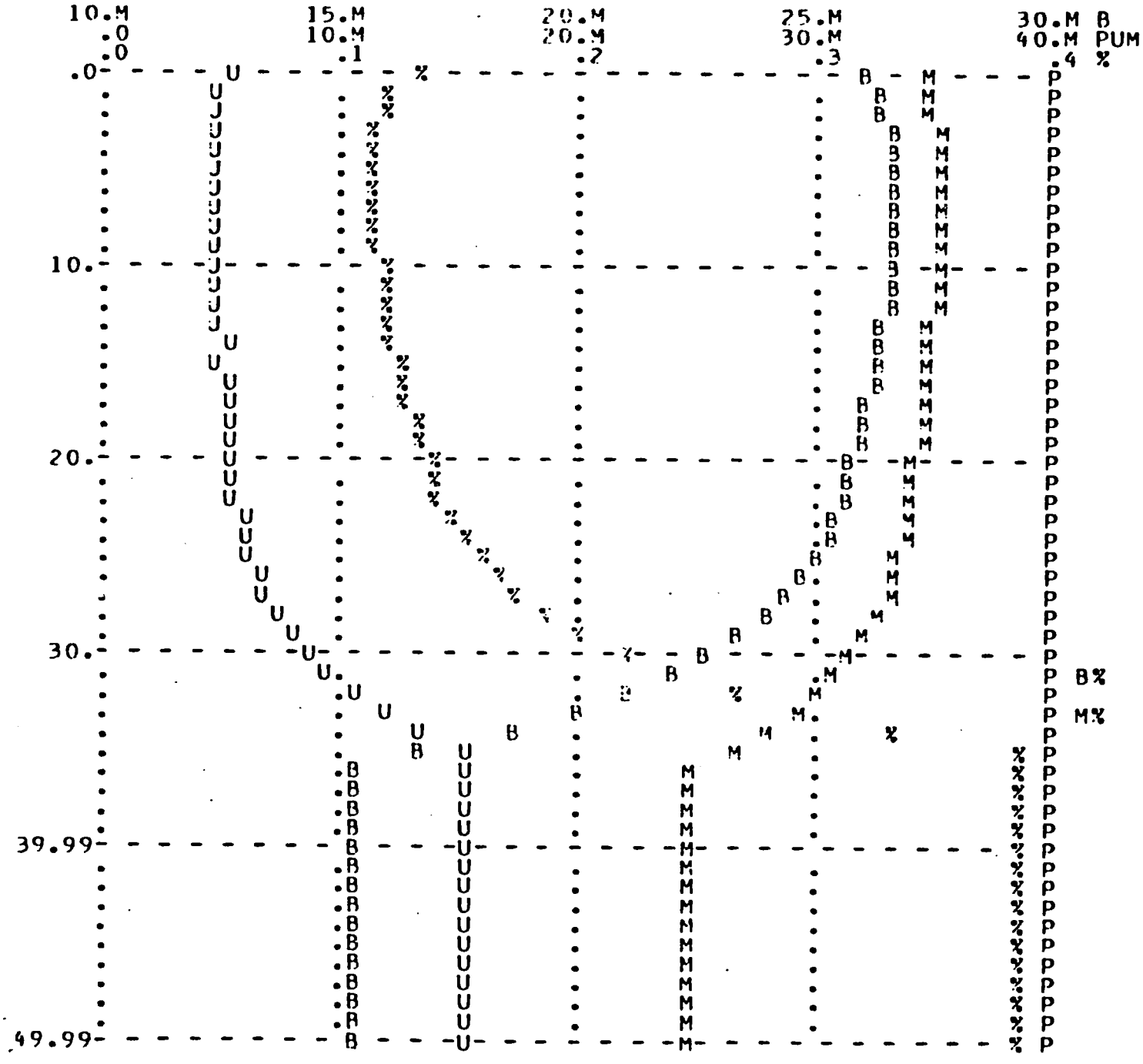


PAGE 29 GIR3 GIR FOREST ECOSYSTEM MODEL 5/06/80 11:57

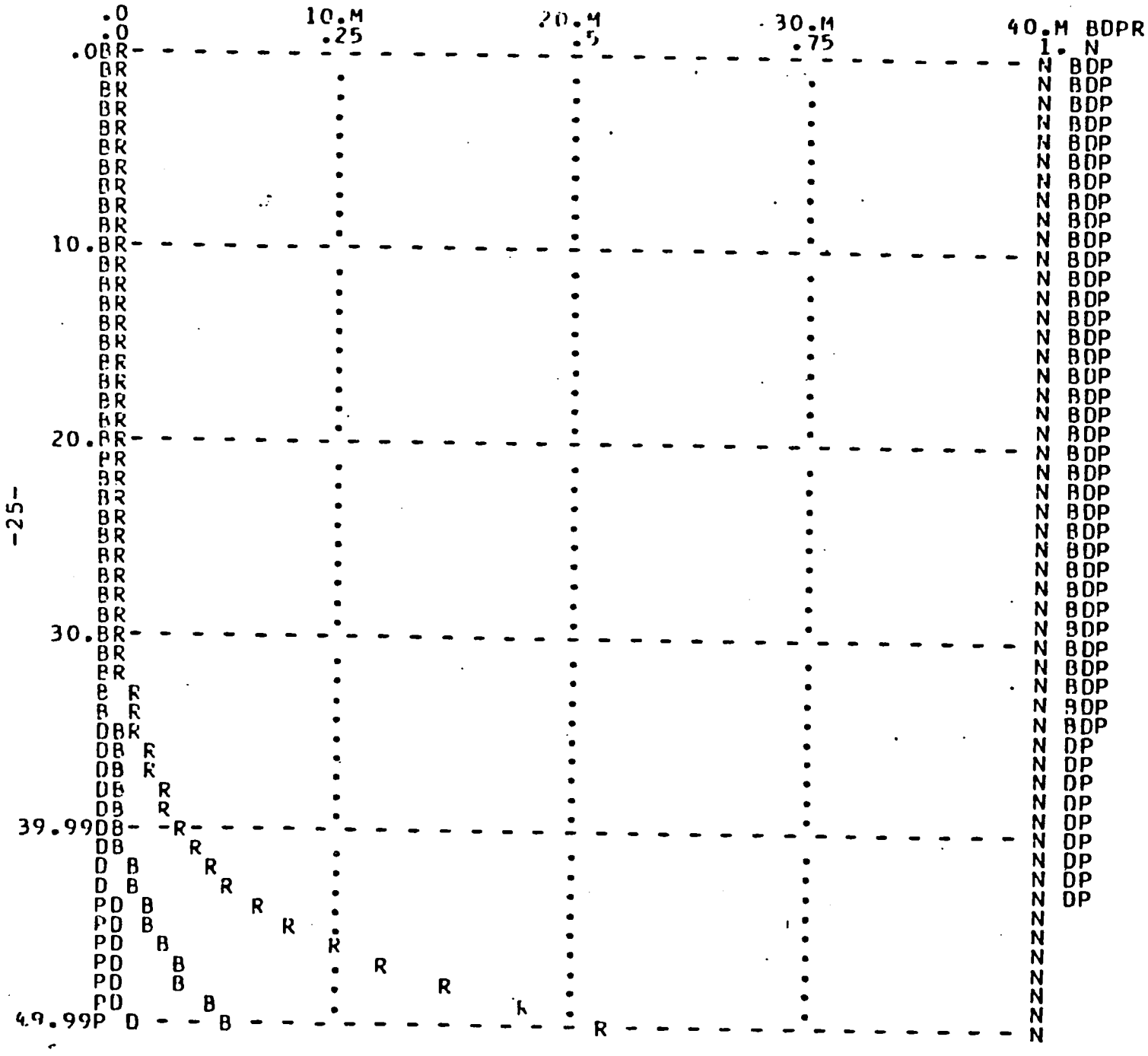
T LEOPT=100/50/25/25/25/25
RUN DECREASING LEOPARD POPULATION

	LEOPT				
PRESENT	100.0	50.00	25.00	25.00	25.00
ORIGINAL	100.0	100.0	100.0	100.0	100.0

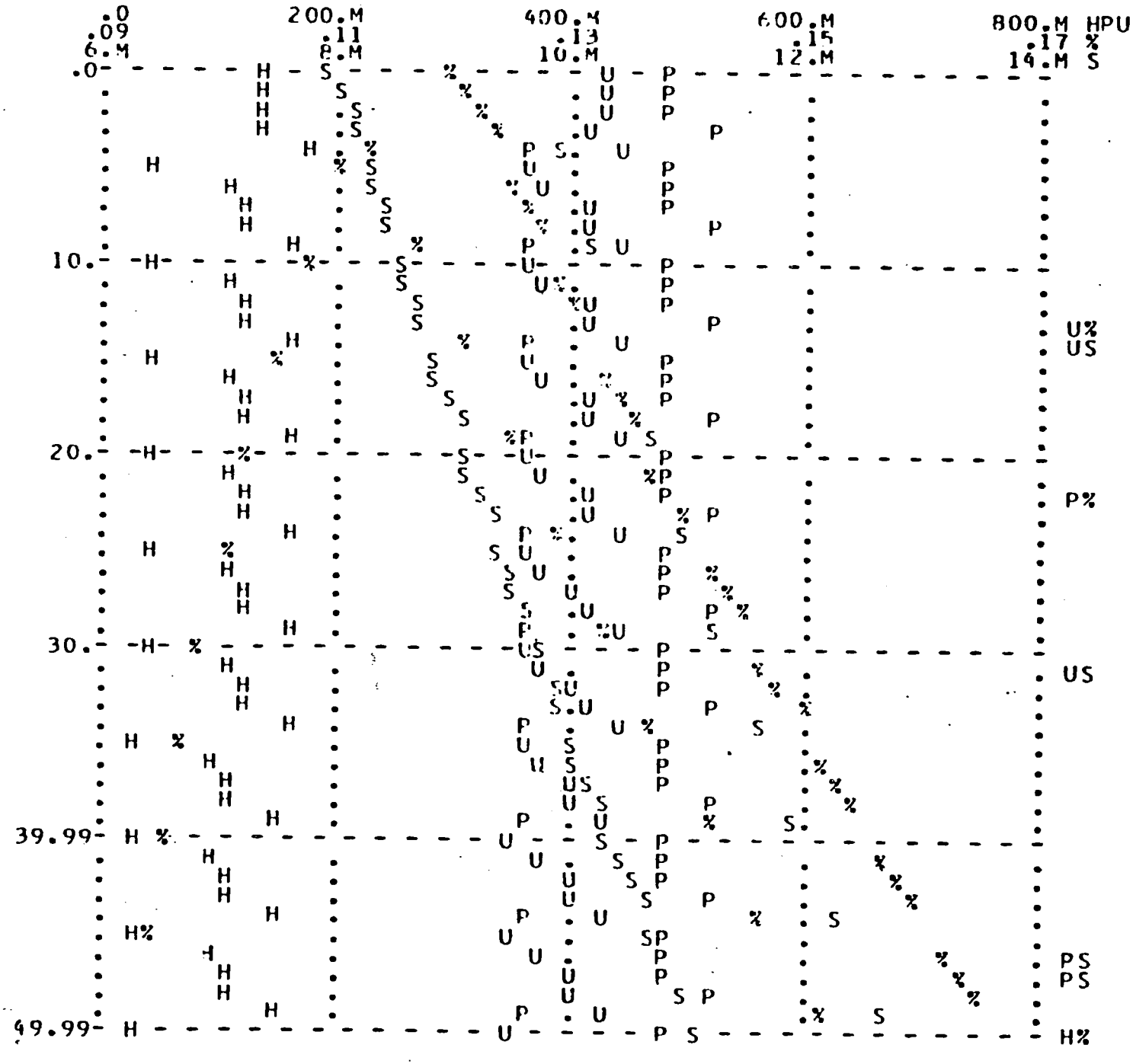
BROWSE=B,BPR=P,3UR=U,BMR=M,PUB=%



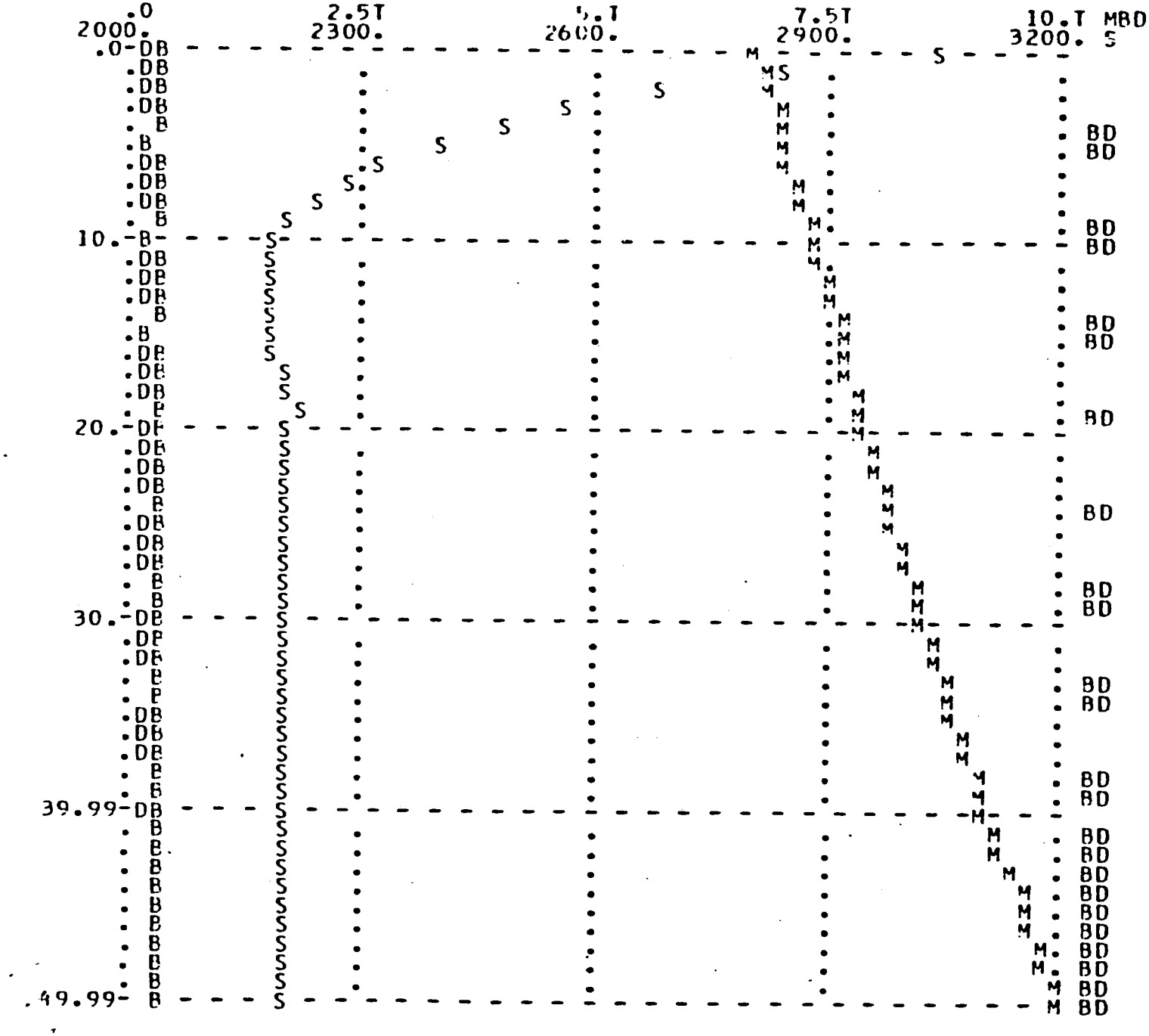
BR=B,NRDR=D,RPR=P,WRUM=R,RNM=N



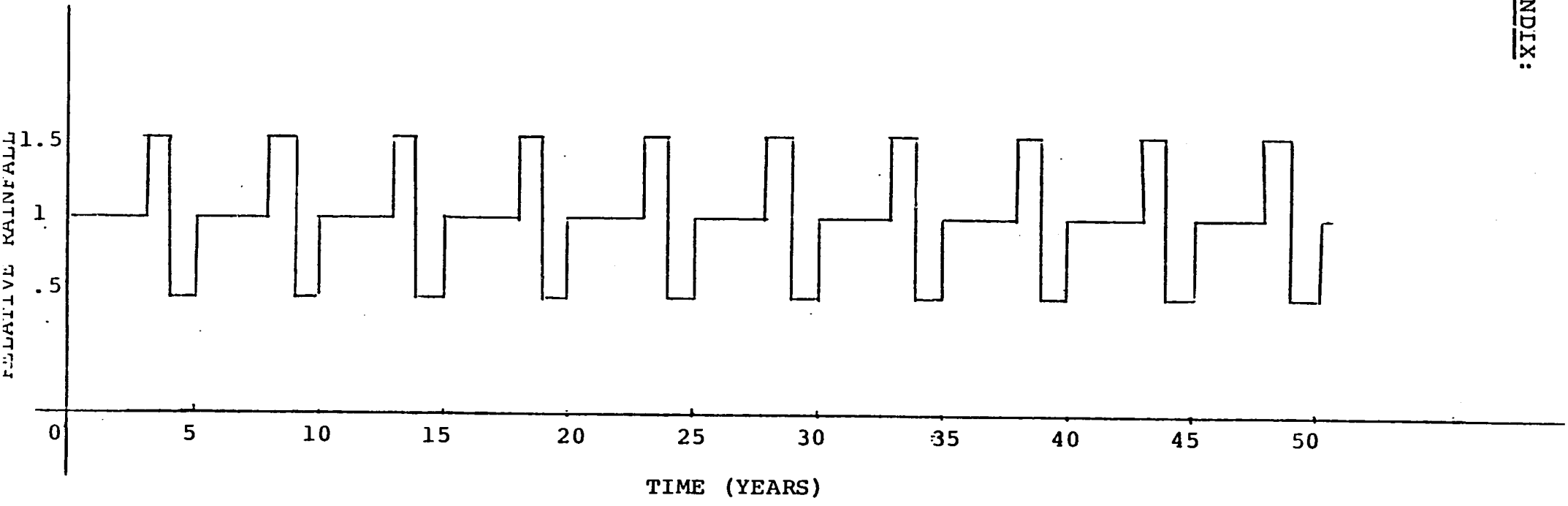
HERB=H,HPR=P,UHERB=U,PUH=%,TSTOCK=S



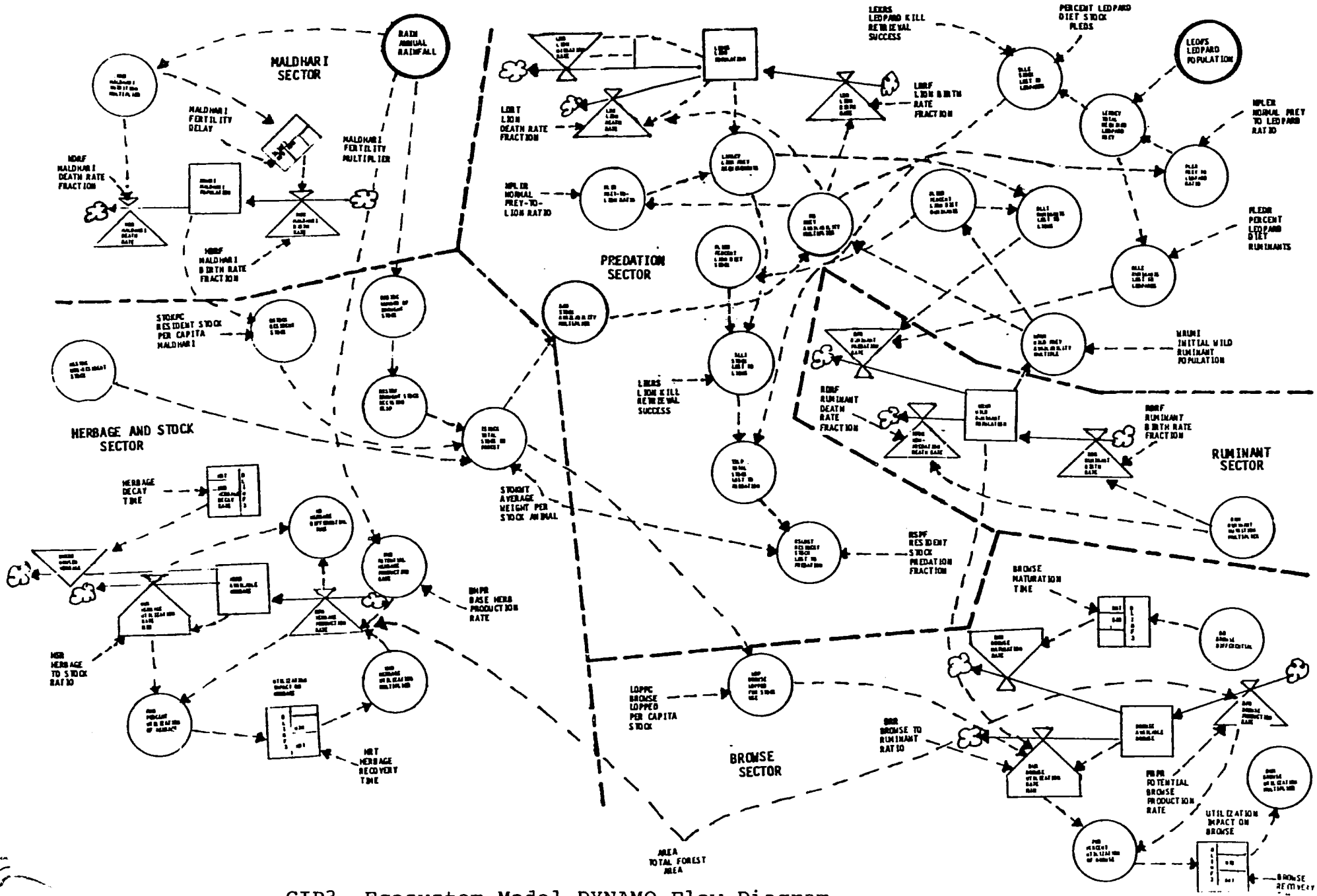
MHARI=M,MBR=B,MDR=D,RSLOST=S



APPENDIX:




```
NOTE
NOTE   RAINFALL FUNCTION
NOTE
A RAIN.K=1+STEP(.5,3)+STEP(-1,4)+STEP(.5,5)+STEP(.5,8)+STEP(-1,9)
X +STEP(.5,10)+STEP(.5,13)+STEP(-1,14)+STEP(.5,15)+STEP(.5,18)
X +STEP(-1,19)+STEP(.5,20)+STEP(.5,23)+STEP(-1,24)+STEP(.5,25)
X +STEP(.5,28)+STEP(-1,29)+STEP(.5,30)+STEP(.5,33)+STEP(-1,34)
X +STEP(.5,35)+STEP(.5,38)+STEP(-1,39)+STEP(.5,40)+STEP(.5,43)
X +STEP(-1,44)+STEP(.5,45)+STEP(.5,48)+STEP(-1,49)+STEP(.5,50)
```



GIR3—Ecosystem Model DYNAMO Flow Diagram

LITERATURE CITED

Berwick, Stephen H. 1974. The Community of Wild Ruminants in the Gir Forest Ecosystem, India. Ph.D. Dissertation. Yale University.

Berwick, Stephen H. 1976. The Gir Forest: an endangered ecosystem. Amer. Scientist. 64:28-40.

Joslin, Paul. 1973. The Asiatic Lion--a study of ecology and behavior. Ph.D. Thesis. Univ. of Edinburgh.

346

D. Hertzmark

A Spatial Model of Sage Grouse Habitat Quality[1]

Robert A. Nisbet, Stephen H. Berwick, and Kenneth L. Reed[2]

Computerized cartographic modeling of sage grouse habitat can predict probable lek sites. Habitat factors identified in data analysis of 41 lek sites were mapped, digitized, and processed to show areas of probable lek site location. Future invasion pathways of pinyon-juniper woodland were simulated to further screen unsuitable areas to prioritize management.

INTRODUCTION

Sage grouse inhabit upland meadows and valleys in much of the Great Basin of the western United States. Sagebrush (Artemisia spp.) is their preferred habitat, and sagebrush (along with forbs) is the primary food of adults. Sage grouse are linked to traditional and localized wintering areas and spring strutting grounds (leks) where mates are solicited. These areas are referred to as wintering - nesting complexes by Wallestad (1975). These complexes also include brood-use areas usually located within 2 miles of leks (Wallestad and Pyrah, 1974; Gill, 1975). Broods are greatly dependent on highly nutritious, succulent forbs to sustain them during their first months of life. As these forbs dry out during summer at the lower elevations, sage grouse and their broods move upward in elevation. During this time mountain meadows become very important to sage grouse survival (Oakleaf, 1971). Sage grouse are known to be negatively affected by sagebrush removal and will abandon strutting grounds, brood-use areas, and wintering grounds if adjacent habitat is disturbed (Braun et al.,1977). They apparently cannot adjust to land use patterns in which large tracts of sagebrush-grassland vegetation type have been eliminated or greatly disturbed (Patterson, 1952).

Recent population trends in Nevada/Utah indicate that sage grouse populations are either stable or increasing slightly (Molini and Barngrover, 1979). However, data for the distribution of upland game animals are generally less reliable than those for big game species for several reasons. Upland species are smaller than big game animals and, therefore, more difficult to observe. In addition, management of these species is usually less intensive than for big game, resulting in less time and effort expended in field surveys. The distribution of sage grouse in large areas of its range is unknown or uncertain.

HDR-System Sciences conducted a sage grouse lek characterization study during the summer of 1980. The objectives of this research were to describe lek sites in terms of their major environmental characteristics, to compare these leks with selected non-lek sites, and to ascertain through that comparison whether sage grouse select lek sites based upon one or a combination of environmental parameters located in obtainable data bases. The results could then be used to narrow the amount of unsurveyed sage grouse range requiring search to locate previously undiscovered leks and brood-use areas. Mapping high probability key sage grouse habitat would permit an optimal placement of any future development project features in anticipation of on-site verification. This approach is consistent with the Habitat Analysis Procedures developed by U.S. Fish & Wildlife Service (ESR 102, 1980).

METHODS AND RESULTS

Characterization of Strutting Grounds

Forty-one known strutting grounds were located during June 1980 in 18 valleys in Nevada and Utah with the help of Nevada Department of Wildlife field biologists. Since the survey was done after strutting ceased, leks were identified by the presence of dropping piles. Each lek site was characterized by vegetation type, percent shrub cover, visual obstruction, distance to escape cover, distance to nesting cover, distance to topographical change, distance to water, slope, and aspect (table 1). Vegetation type was classified according to standard BLM nomenclature. Visual obstruction readings (VOR) were recorded for each lek. This technique consisted of viewing a large wooden dowel from a distance of 4 m. The length of the dowel completely obstructed by live shrubs was recorded for views 1 m and 1 dm from the ground. The "bird's eye view" of the lek from dm may be related to the preference by sage grouse suitable lek sites. Shrub canopy cover listed in table 1 was determined by a line-intercept method. Ten sites adjacent to leks were chosen to represent non-leks, and characterized similarly to the lek sites (table 2).

Escape cover was defined as shrub vegetation at least 30 to 40 cm high. Substantial stands of big sagebrush (Artemisia tridentata) were assumed to constitute suitable nesting cover. Distance to nearest major vertical change in relief may be important as a buffer against raptors on rock outcrops and steep slopes.

Data Reduction to Determine Habitat Preference by Quadratic Assignment Analysis

Some lek characteristics were categorical (e.g., vegetation type); other variables were measured on a continuous scale (e.g., distance to water). Therefore a non-parametric quadratic assignment analysis (Hubert and Schultz, 1976) was selected to analyze data to indicate if sage grouse lek preference could be predicted by any characteristic(s). A similarity matrix is defined for each characteristic such that elemehts in the structure matrix (Q) are set to 1 for Q_{ij}, if both the ith and jth sites are leks or both are non-leks; otherwise $Q_{ij} = 0$. A proximity matrix (C) is defined for each characteristic, such that

[1]Paper presented at the Third International Conference on State-of-the-Art in Ecological Modelling, Colorado State University, May 24-28, 1982.

[2]Senior Ecologist, Chief Scientist, and Chief System Scientist, respectively, HDR-System Sciences, Santa Barbara, CA 93101.

Table 1. Sage grouse lek characteristics

Location	Vegetation Type	Percent Shrub Cover	VOR[1] 1 m	VOR[1] 1 dm	Distance to Escape Cover (m)	Distance to Nest Cover (m)	Distance to Type Change (m)	Distance to Topo Change (m)	Distance to Water (m)	Percent Slope	Aspect	Hydrologic Subunit (Valley)
		Environmental Variables Measured										
Barley Creek	Agcr	--	--	--	1.5	792.5	792	--	1.5	5	NE	Monitor
Pott Ranch	Agcr	--	--	--	30	1,610	1,610	--	--	5	SE	Monitor
White River	Arna	31.25	0.36	6.50	--	396	3,871	--	3,220	0	--	White River
Danville Creek	Arna	9.58	0.25	5.77	--	305	305	--	305	0	--	Little Fishlake
Clover Creek	Arna Agcr	18.50	0.17	4.33	61	61	61	--	792	0	--	Little Fishlake
Jakes North	Artr Agcr	--	--	--	1.5	1.5	1.5	--	792	0	--	Jakes
Jakes Central	Arna Cela	32.25	0.14	2.80	46	46	46	--	--	0	--	Jakes
Willow Creek	Arna	20.00	0.38	2.25	640	640	640	--	640	2	SE	Little Smoky
Simpson Creek	Artr Agcr	11.50	0.33	2.30	1.5	1.5	792	--	--	2	W	Diamond
Pine Field #1	Arna	32.09	0.33	7.09	61	61	61	--	1,610	10	SE	Cardon
Horse Creek	Agcr	--	--	--	1.5	1.5	1.5	--	305	3	SE	Cardon
Lone Mountain	Arna	28.84	0.73	5.25	46	46	46	--	--	3	SE	Kaboh
Kaboh #1	Arna	27.83	0.73	5.67	--	396	396	--	--	10	SE	Kaboh
Kaboh #2	Arna	26.83	0.89	6.42	--	396	396	--	--	10	SE	Kaboh
Roberts Creek	Agcr	6.00	--	--	--	1,610	1,610	--	1.5	1	SW	Kaboh
Ferguson #1	Artr	16.50	0.30	6.88	1.5	1.5	2,377	--	2,377	2	S	Monitor
Ferguson #2	Artr Atco	9.84	0.19	4.81	1.5	1.5	30	--	3,170	0	--	Monitor
Ferguson #3	Artr	20.42	0.59	5.67	1.5	1.5	2,377	--	2,377	1	NW	Monitor
3-Bars	Arna	36.50	0.11	3.77	1.5	1.5	488	--	488	3	N	Monitor
Allison Creek	Atco	15.08	0.46	2.23	--	1,610	396	--	396	1	SE	Antelope
Cedar Creek	Artr	12.33	0.45	4.53	1.5	1.5	2,134	--	152	1	N	Antelope
S. Cottonwood #3	Guna	29.58	0.74	4.09	152	152	1,610	1,610	--	3	SE	N. Steptoe
S. Cottonwood #4	Guna	32.67	0.42	4.27	61	305	1,610	1,610	--	3	SE	N. Steptoe
Spruce Mountain	Guna	29.08	0.89	4.56	1.5	963	963	963	--	1	SW	N. Steptoe
Butte #2	Guna	25.08	0.35	3.00	61	61	1,610	1,610	--	2	SE	Butte
Butte #3	Guna	20.50	0.03	1.60	21	21	1,610	1,610	--	4	NW	Butte
Black Sage #3	Arna	21.08	0.33	4.28	15	15	1,610	1,610	--	1	NW	N. Ruby
Black Sage #4	Arna	32.42	0.42	2.99	8	8	805	805	--	6	S	N. Ruby
Black Sage #5	Arna	27.92	0.20	3.09	30	30	805	805	--	4	S	N. Ruby
High Beach #1	Arna	31.02	0.30	2.22	30	30	482	482	--	1	SE	N. Ruby
Loading Chute	Arna	33.13	0.38	2.50	46	46	46	--	--	2	SE	N. Ruby
Snow Fence	Arna	26.75	1.30	5.78	1.5	1.5	1,610	61	--	3	W	Clover
Indian Creek	Atco	7.83	--	--	1.5	2,414	2,414	2,414	--	3	E	Crescent
Horse Ranch	Atco	12.25	--	--	1.5	805	2,414	--	--	5	E	Carico Lake
Cook Creek	Atco	7.75	--	--	9	9	9	152	--	2	SE	Carico Lake
Pony Express	Artr	14.50	1.37	5.87	1.5	1.5	1,610	61	--	15	NE	Big Smoky
Cape Horn	Arna	22.83	0.32	4.01	3	3,218	4,828	1,207	--	3	S	Big Smoky
Escalante Desert	Artr	16.75	0.69	5.75	1.5	1.5	1,207	1,207	--	1	NW	Escalante Desert
Hamlin Wash #1	Artr	5.00	0.03	0.91	1.5	1.5	91	91	--	0	--	Hamlin
Hamlin Wash #2	Cela	45.92	1.17	5.35	27	27	27	91	--	1	SE	Hamlin
Hamlin Wash #3	--	0	--	--	46	91	91	91	--	5	SW	Hamlin

T3359/10-2-81

[1]VOR = Visual obstruction reading.

Vegetation type symbols:

Arta - Big sage *Artemisia tridentata*
Arna - Black sage *Artemisia nova*
Guna - Snakeweed *Gutierrezia sarothrae*
Atco - Shadscale *Atriplex confertifolia*
Cela - Winterfat *Ceratoides lanata*
Agcr - Crested wheatgrass *Agropyron cristatum*

Aspect = degrees azimuth

Table 2. Characteristics of sites adjacent to sage grouse leks.

Location	Vegetation Type	Percent Shrub Cover	VOR 1 m	VOR 1 dm	Distance to Escape Cover	Distance to Nest Cover	Distance to Type Change	Distance to Topo Change	Distance to H_2O	Percent Slope	Aspect	
Hamlin	Arta	24.58	2.31	7.36	0	0	60 m		·		220°	- SW
Cottonwood Bench	Guso-Arta	39.58	0.64	5.56	2.70 m	1300 m	860 m		4300 m	2-2	126°	- SE
Clover Creek	Arno	23.33	0.25	4.12								
N. Ruby A	Arno	31.09	0.58	3.67	17 m	17 m	650 m	650 m		2	180°	- S
N. Ruby B	Arno Guso	36.08	0.34	2.77	25 m	25 m	650 m			4	31°	- NE
Low Fence	Arno-Guso	26.75	0.64	3.66	0	0	1000 m		5000 m	2	60°	- NE
Danville Creek	Arno	19.25	0.01	3.22								
Pine Field	Arta	23.08	1.69	8.72								
Willow Creek	Arno	24.92	0.50	3.45								
Butte	Guso-Arta	10.84	0.06	2.28	17 m	17 m	500 m	2200 m	500 m	1-2	305°	- NW

T6117/1-4-82

$C_{ij} = D_i - D_j$, where D_i and D_j are distance measurements (e.g., distance to water) of leks in the ith row and the jth column.

Comparison of the similarity matrices involves calculation of the simple observed cross-product statistic (Γ_0).

$$\Gamma_0 = \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} Q_{ij} \qquad (1)$$

The statistical significance of the observed value (Γ_0) is determined by a Z-test described in Hubert and Schultz (1976). The Z-values presented in table 3 indicate that only distance to water is significantly related to lek presence. However, consistencies in other variables listed in table 1 suggest that these variables may also be important to sage grouse in selection of lek sites. For example, no leks occurred on areas covered by pinyon-juniper or on greater than 10 percent slope.

Table 3. Significance of data in Table 1 for defining sage grouse lek sites[1].

Variable	Z
Vegetation Type	- 0.637
Aspect	1.023
Percent shrub cover	0.68
Dist. escape cover	- 0.274
Dist. nest cover	0.52
Dist. topography change	- 0.389
Dist. water	- 2.99**

[1]Percent slope and visual obstruction reading data were not analyzed.

** 99 percent probability limits are ± 2.57.

(95 percent probability limits are ± 1.96).

Perhaps the occurrence of 17 leks in black sagebrush among 41 leks characterized may indicate a proportional habitat preference for black sagebrush. Another factor which might be important (and hard to characterize) is rainfall. General observations by HDR field personnel indicate that leks are seldom, if ever, found on areas with less than 25 cm/yr rainfall. It is hypothesized that drier sites would not support forbs long enough into the summer for sage grouse brood-use. Therefore, all areas with less than 25 cm/yr rainfall might be excluded from further analysis.

Cartographic Modeling

Data maps such as vegetation types and water sources were digitized and input to the computerized Map Analysis Package--MAP (Tomlin, 1980). This facility allows data maps to be manipulated as variables in a spatial configuration. Data maps are cell-based, in which data for each map are referenced to the centroid of each cell. Cells should be assigned biologically appropriate dimensions so cell size does not mask relationships such as lek size and movements. Arithmetic (multiply, differentiate, etc.) or combinative (cross-tabulate, clump, cover, etc.) operations are performed on respective cells of one to several maps (depending on the operation chosen). The set of MAP commands can constitute a high-level spatial analysis language. Spatial models can be programmed in MAP language syntax. The command language allows multiple overlay, screening, and mathematical and topological analysis of spatial information. Any two or three dimensional topological data can be stored in one or more maps in the program data base. All operations are performed on these maps, producing output maps, which are also stored and available for future operations. The values assigned to each cell in the maps after processing can be printed out on a scale of 1 to 100 using print and overprint capabilities of a line printer. Map categories can also be output as shaded polygons on a plotter, or as three-dimensional plots.

Conventional maps are represented as 2-dimensional arrays in memory and mass storage. This allows storage of Cartesian coordinates and a category or value representation for each map cell. New maps can be created by variously combining maps or map categories, and can be referred to as output maps.

Cartographic models are similar to algebraic evaluations in which mathematical algorithms are structured to solve complex problems. Nested parentheticals represent

449

intermediate solutions similar to the intermediate map analysis operations. Operational groups can be organized like a flowchart (fig. 1) to produce a cartographic model expressing a goal-oriented flow of spatial information. These goals may include habitat quality modeling (Tomlin et al., 1979), corridor analysis (Rasmussen et al., 1980) and impact risk assessment (Thompson, 1977, 1979), and fire gradient analysis (Kessel, 1979).

A Sage Grouse Lek Preference MAP Model

For this study, the input maps generated as a result of field data reduction were: vegetation type, elevation, rainfall, and available water. Vegetation, rainfall, and water sources were obtained from resource maps; elevation was obtained from a 1:250,000 scale USGS quad. The vegetation input map is shown in figure 2. Factors expressing lek preference in various vegetation types were calculated externally to the MAP program by equation 2.

$$PV_i = \frac{Lv/\Sigma L}{PA_v} \qquad (2)$$

where,

PV_i = the lek preference factor for vegetation

Lv^i = is the number of occurrences of leks in vegetation type v

ΣL = the total number of leks observed in all vegetation types

PA_v = the proportionate area of each vegetation type.

According to table 1, leks were associated with black sagebrush (Artemisia nova) at 17 of 41 sites (41 percent). Since black sagebrush constitutes only 7 percent of the total area in Pine Valley (fig. 2), the fact that 41 percent of the lek sites were located in black sagebrush suggests a preferential selection. The value of PV_i for black sagebrush was 6.2 compared to 1.7 for big sagebrush. The rainfall input map was transformed into a rainfall mask (RAINMASK) by excluding all areas with less than 25 cm rainfall per year. It was judged that these areas would not support annual forbs for brood use throughout the spring. This map was used for overlay as described below.

The vegetation map (fig. 2) consists of eleven vegetation categories, each with an assigned code value. These internal cell values were changed to PV_i values (lek preference factors) from equation 2 corresponding to each vegetation type. This intermediate map was overlaid by the RAINMASK map (see fig. 1) to produce a new map showing only those PV_i values for vegetation receiving more than 25 cm of rainfall per year. This map is illustrated in figure 3. Data in table 1 show that leks were not found in areas with greater than 10 percent slope. To consider this in the model, a slope map was generated by differentiating the elevation map. A slope mask was made to exclude all slopes greater than 10 percent and the PV_i map was overlaid by the slope mask. This step resulted in a map of PV_i values corresponding to areas with greater than 25 cm rainfall and less than 10 percent slope.

This slope exclusion was consistent with data shown in table 1, indicating that leks were not found in areas with greater than 10 percent slope. This intermediate map was then overlaid by a W..TERMASK map (fig. 4) excluding all areas greater than 2,000 m from a water source. The resulting map (fig. 5) represents levels of lek preference based on the habitat variables characterized by preferred vegetation type, rainfall, slope, and accessibility to water. Cells with PV_i ranging from 0 to 2.5 were accorded a low suitability for leks, moderate suitability ranged from PV_i values of 2.6 to 5.0, and high suitability was accorded to PV_i values above 5.0. Figure 5 also includes an area bounded by Utah's Division of Wildlife Resources estimated range of sage grouse.

Such a habitat quality model permits prioritizing of costly search effort. Areas of high suitability for leks can searched first. Areas of low lek suitability can be searched last, if circumstances permit.

Selection of Areas for Lek Management

A possible mitigation to reduce impact of disturbance in sage grouse range is to create lek sites in suitable undisturbed areas. Criteria governing selection of new lek sites might include those described above as well as projected habitat change. An important change affecting sage grouse is the encroachment of pinyon-juniper woodland into suitable sage grouse areas (West et al., 1979).

A prediction of pinyon-juniper woodland encroachment was attempted using a rainfall map of Pine Valley, a radiation load prediction model (Furnival, Reifsnyder, and Siccama, unpubl.), and the estimated elevation of the cold air lake, 1750 m (Ralph Holmgren, Desert Range Experiment Station, personal communication). Radiation loads predicted from latitude, slope, and aspect data were combined with rainfall for each cell in Pine Valley. The resultant rainfall-radiation values may provide indices to heat load and moisture status. While this relationship should be tested, Reed (1982) used a similar approach to model forest growth and succession. We were unable to make a thorough evaluation of this relation, but some comparison to existing vegetation was possible. Existing vegetation was compared with the rainfall-radiation (Rain-rad) load in each cell. The distribution of big sagebrush, black sagebrush, and pinyon-juniper woodland with respect to the rain-rad value is given in figure 6. On the basis of this analysis, potential pinyon-juniper habitat was assumed to include all areas with a rain-rad value in the range of 15 to 60 and above the cold air lake. Pinyon-juniper woodland and sagebrush types overlap in the 15 to 35 rain-rad range. Figure 7 is a map of present-day sagebrush that is in the 15-35 range and above the cold air lake. These sagebrush communities are vulnerable to pinyon-juniper woodland invasion, hence figure 7 is a map of potential pinyon-juniper woodland. This cold air lake results from a sharp thermocline of about 20° which often develops at night in Great Basin closed valleys.

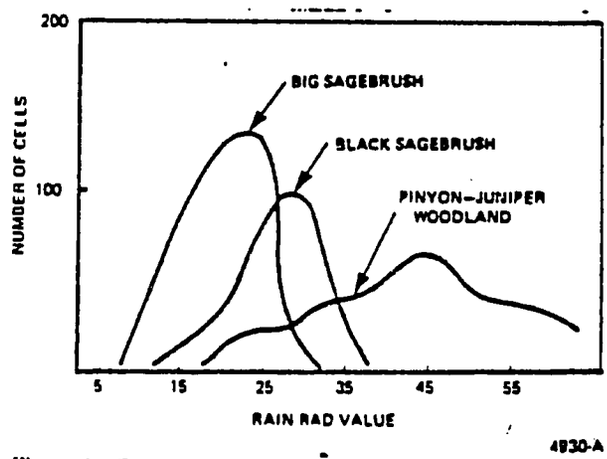


Figure 6.—Frequency of RAINRAD values in sagebrush and pinyon-juniper woodland.

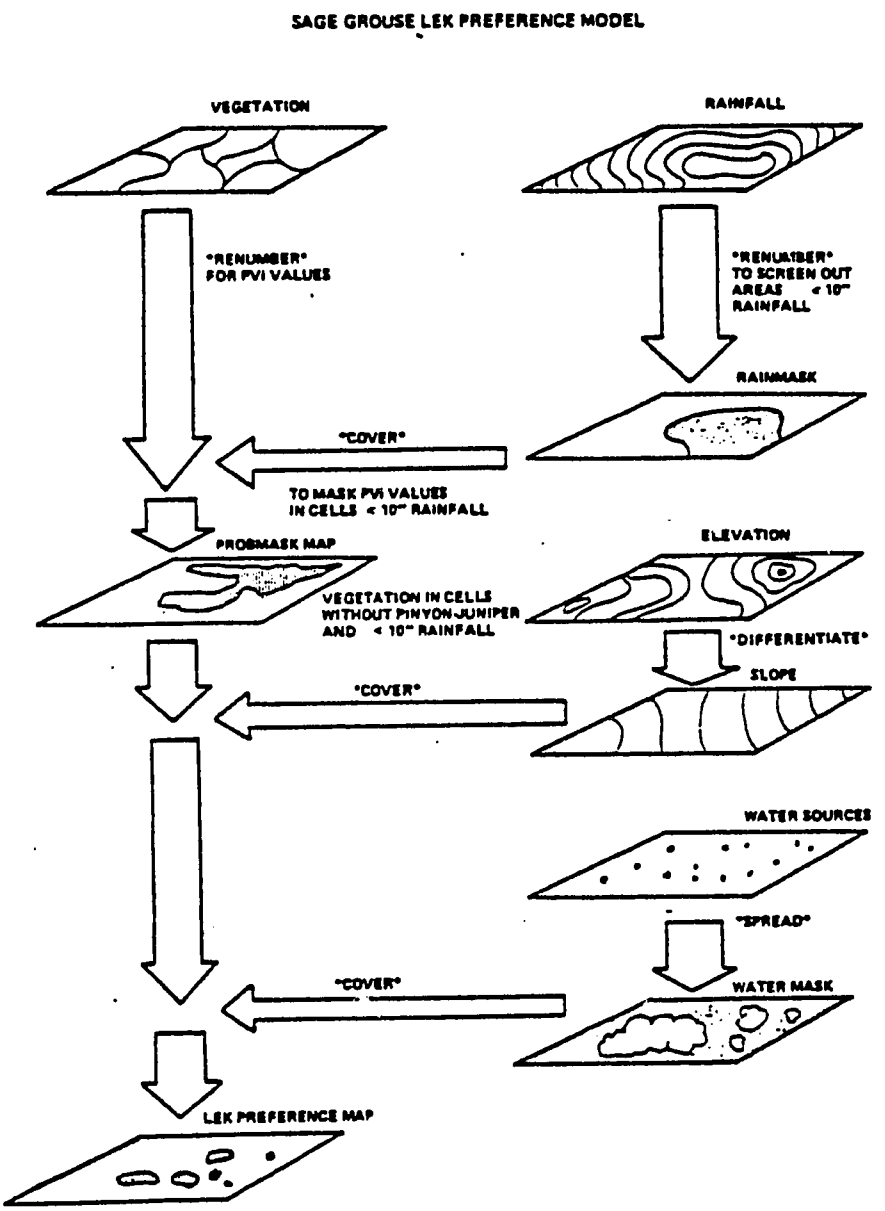


Figure 1.—Sage grouse lek preference model.

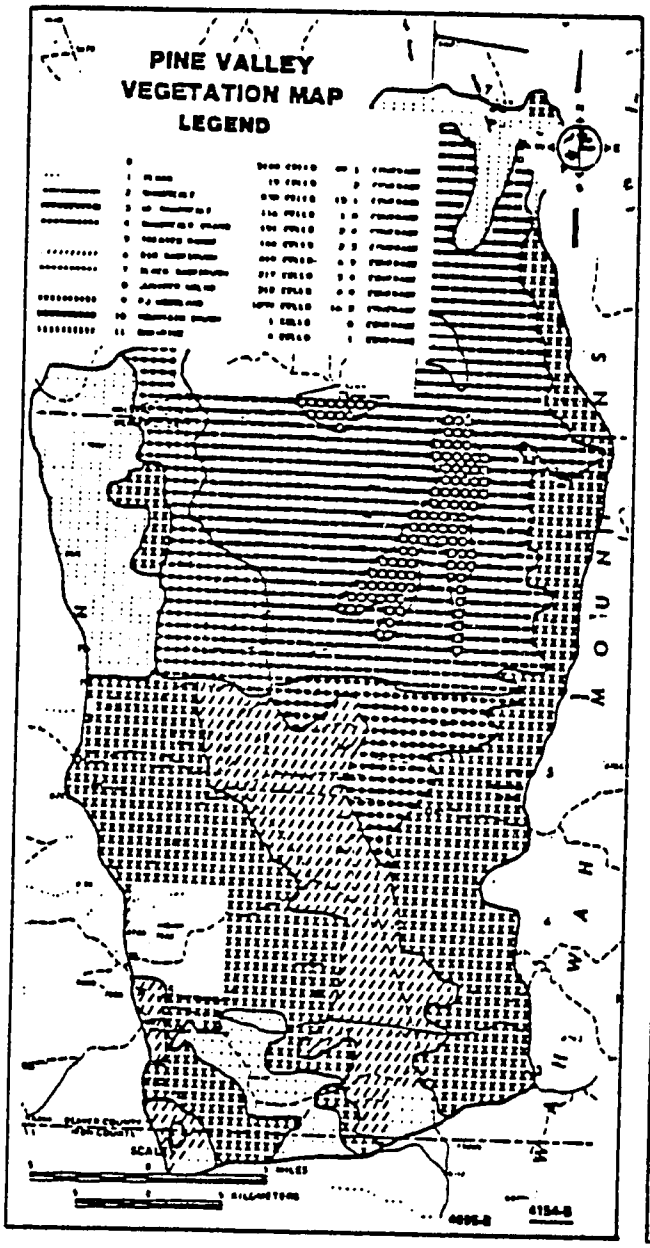


Figure 2.—Vegetation types of Pine Valley, Utah.

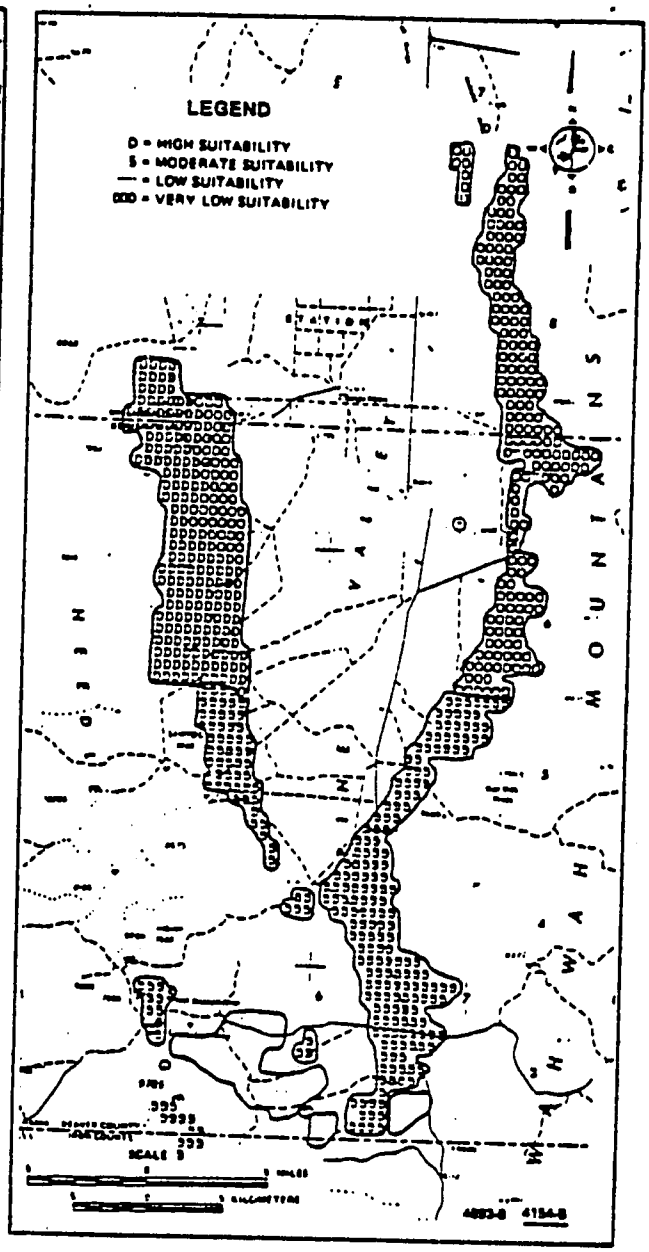


Figure 3.—PROBMASK map showing lek suitability before distance-to-water is considered.

458

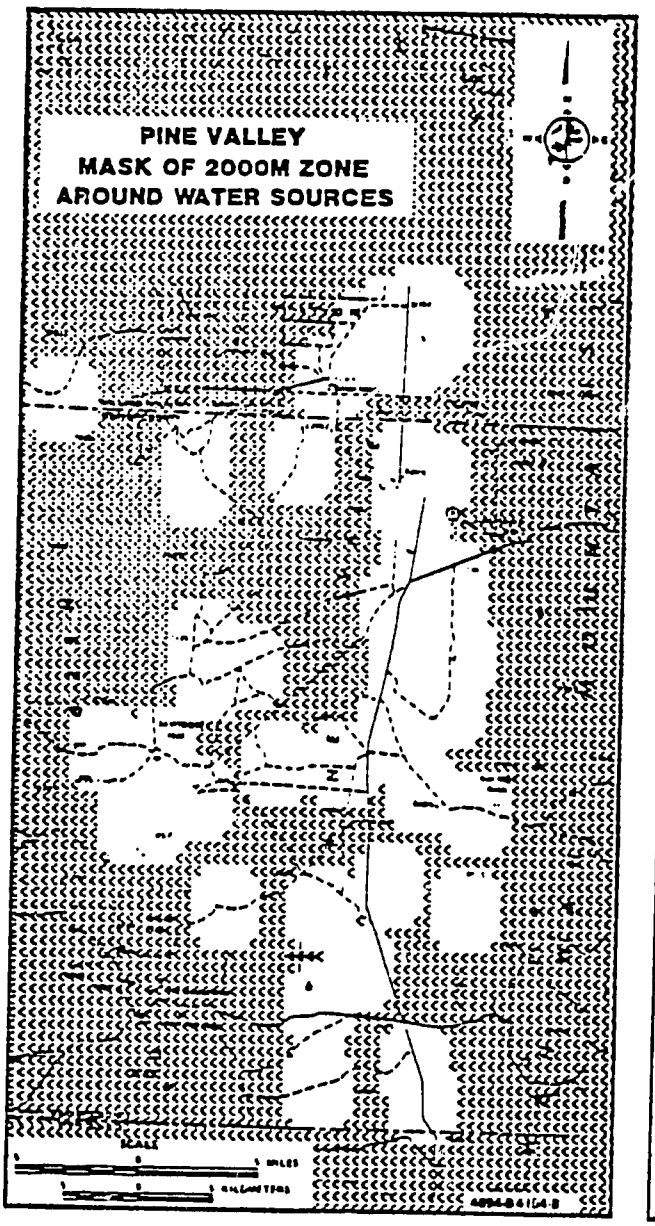


Figure 4.—WATERMASK map showing areas (blank) within 2,000 m of a water source.

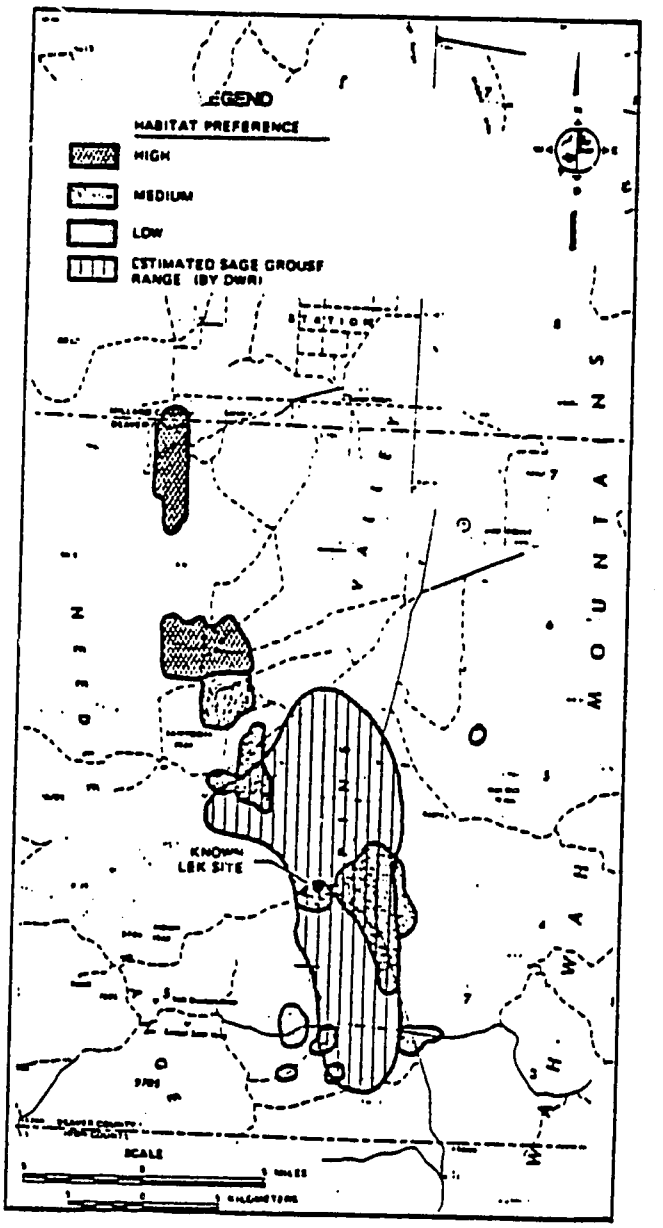


Figure 5.—Levels of lek preference, considering preferred vegetation, rainfall, slope, and accessibility to water.

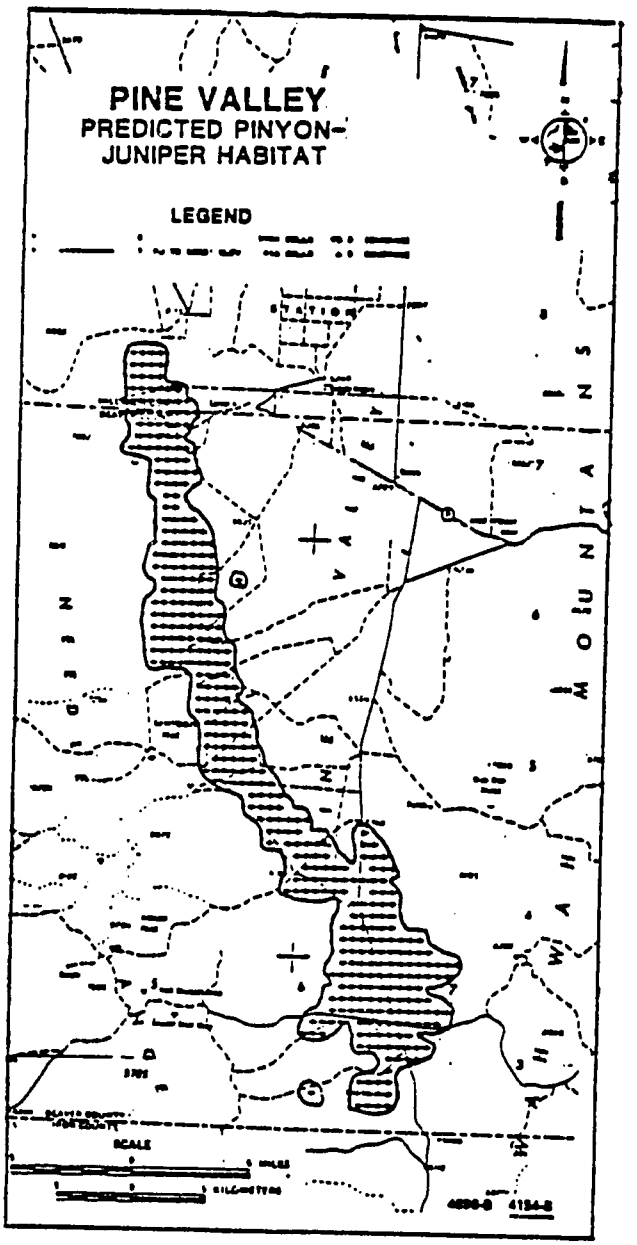


Figure 7.—Predicted pinyon-juniper woodland habitat in current sagebrush areas above 5,800 ft elevation.

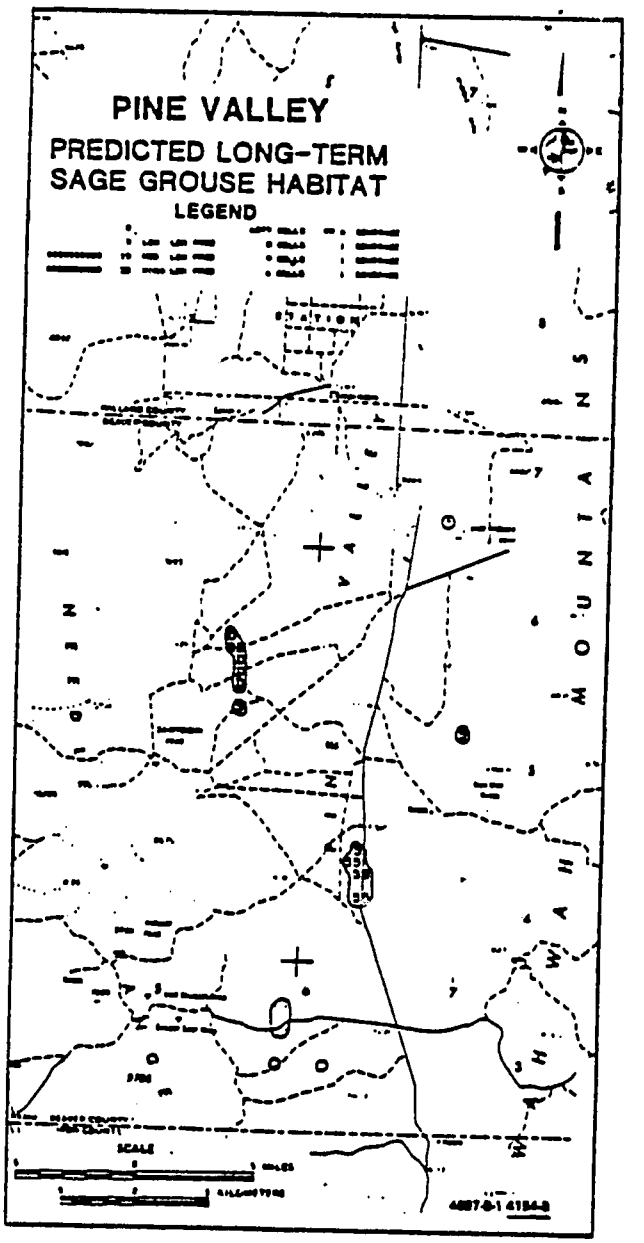


Figure 8.—Predicted long-term sage grouse habitat, excluding areas subject to invasion of pinyon-juniper woodland.

Temperatures below the inversion layer are sufficient to cause freeze damage to pinyon and juniper trees after the break of dormancy in the spring.

Cells containing predicted new pinyon-juniper woodland were excluded from subsequent analysis. Lek sites not excluded from the analysis (long-term lek sites) are displayed in fig. 8. The reduction in lek habitat can be seen by comparing figure 8 to figure 5. This difference is due to projected invasion of pinyon-juniper woodland in sagebrush communities. The obvious implications are that sage grouse management must include control of pinyon-juniper woodland invasion into sage grouse habitat, or to avoid creation of new lek sites in the invasion path.

DISCUSSION

Some variables used in the analysis were discrete and exclusionary, as in the case of elevation of the cold air lake, others were continuous and their effects are gradients of habitat suitability, viz. distance to water. In addition, future prediction is possible within the MAP context. Since this analysis is a habitat analysis, it would be amenable for use as a HEP model (ESR 102, 1980). Another application of spatial habitat analysis is identification of most probable locations for other efforts. Searches for rare species can be optimized by spatial modeling.

The distinctions of low, medium and high habitat preference in figure 6 are entirely based on vegetation preference factor values calculated by equation 1 for each cell. Better models can be constructed by incorporating other functional relationships. For example, Shurcliff (1980) found in Australian arid areas that dominance, diversity and total numbers in bird communities were primarily related to vegetation physiognomy and life form diversity. Wiens (1976) has shown that patchiness in Great Basin bird communities contributes to the distribution of species —again a demonstration of the importance of a spatial analysis. Subsequent spatial models could be improved by distinguishing various structural classes in each vegetation type. Such a vegetation structural map can be made for arid and semi-arid areas by combining vegetation type maps with classified Landsat images. Preliminary HDR Landsat classifications for portions of Utah and Nevada suggest that the major components of signature variance are vegetation height and percent cover, particularly on images with low sun angles. Subsequent classifications of sage grouse habitat should include measurements of average height and percent cover by surrounding vegetation.

The present model was developed principally as a methodological study. Identification of key habitat (high probability) areas can be useful in minimizing impacts due to development, project routing and siting. This model is currently being modified by the inclusion of more recent vegetation and precipitation data and additional field observation. Extension of similar analyses to other areas would require model validation with additional field studies. Such validation field studies are currently in the planning stage at HDR.

ACKNOWLEDGEMENTS

This analysis was performed on a remote terminal using a CDC CYBER computer (HDR-System Sciences, Omaha, Neb.). L. Neel and M. Costanzo were responsible for major portions of the field work and analysis, respectively.

LITERATURE CITED

Braun, C.E., T. Brigg, and R.O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. Wildl. Soc. Bull. 5:99-106.

Gill, R.B. 1975. Distribution and abundance of a population of sage grouse in North Park, Colorado. M.S. Thesis, Colorado State University, Ft. Collins. 187 p.

Hubert, L. and J. Schultz. 1976. Quadratic assignment as a general data analysis strategy. British J. Math and Stat. in Psych. 29:190-241.

Kessel, S.R. 1979. Gradient Modeling. New York: Springer-Verlag. 432 p.

Molini, W.A., and L. Barngrover. 1979. Upland game, migratory game birds, fur investigations, and hunting season recommendations. Nevada Department of Wildlife. Project W-48-10, study S&II, Jobs 7-13, 15, 17.

Oakleaf, R.J. 1971. The relationship of sage grouse to upland meadows in Nevada. Job Final Rep. Fed. Aid Proj. W-48-2. Nevada Department of Fish and Game, 64 p.

Patterson, R.L. 1952. The sage grouse in Wyoming. Denver: Sage Books, Inc., 341 p.

Rasmussen, W.O., R.N. Weisz, Peter Ffolliott, and D.R. Carder. 1980. Planning for forest roads - a computer assisted procedure for selection of alternative corridors. J. Environ. Manage. 11:93-104.

Reed, K.L. 1982. Simulation of forest stands in a hypothetical watershed using models and cartographic analysis. In. (J. means, ed.) Proc. Symp. For. Growth and Succession. Oregon State University, in press.

Reed, K.L. 1980. An ecological approach to modeling growth of forest trees. For. Sci. 26:33-50.

Shurcliff, K.S. 1980. Vegetation and bird community characteristics in an Australian arid mountain range. J. Arid Environ. 3:331-348.

Thompson, L.S. 1977. Identification of critical wildlife habitat using an "impact risk" mapping technique. Proceedings of a National Symposium on Classification, Inventory, and Analysis of Fish and Wildlife Habitat. U.S. Fish and Wildlife Service.

Thompson, L.S. 1979. Probability and the assessment of impact risk in utility corridor siting. Second Symposium on Environmental Concerns in Rights-of- way Management, Oct. 16-18, Ann Arbor, Michigan.

Tomlin, C.D., 1980. Cartographic modeling techniques in environmental planning. Doctoral dissertation, Yale School of Forestry and Environmental Studies.

Tomlin, C.D., S. Berwick, and D. Tomlin. 1979. The use of computer graphics in deer habitat evaluation. International conference on computer mapping hardware, software, and data bases. Harvard University. 18 p.

U.S. Fish & Wildlife Service. 1980. Habitat Evaluation Procedure. ESR 102.

Wallestad, R. 1975. Life history and habitat requirements of sage grouse in central Montana. Game Manage. Div., Montana. Dept. of Fish and Game. 66 p.

Wallestad, R., and D.B. Pyrah. 1974. Movements and nesting requirements of sage grouse hens in central Montana. J. Wildl. Manage. 38:630–633.

West, N.E., R.J. Tausch, and Ageli A. Nabi. 1979. Patterns and rates of pinyon-juniper invasion and degree of suppression of understory vegetation in the Great Basin. Range Improvement Notes, Sept. 1979. USDA, USFS, Ogden, Utah.

Wiens, J. A. 1976. Population responses to patchy environments. Ann. Rev. Ecol. Syst. 7: 81–120.

SPATIAL ANALYSIS FOR DETERMINING "REGION-OF-INFLUENCE" WHEN PREDICTING IMPACTS ON WILDLIFE AND OTHER RESOURCES

STEPHEN H. BERWICK, Director, Environmental Planning and Management, International Institute for Environment and Development, Washington, DC 20004
ROBERT A. NISBET, Senior Ecologist, HDR Systems, Santa Barbara, CA 93101
KENNETH L. REED, Senior Systems Ecologist, HDR Systems, Santa Barbara, CA 93101

Abstract: The natural areas and their constituent communities which are significantly impacted by a development project is commonly known a the "region-of-influence". The impacts can be directly upon the resources of concern (e.g. by scarification) or mediated by project-induced secondary impacts such as changes in the density, mobility, or social characteristics of an in-migrant construction worker population which in turn changes levels of poaching.

This paper presents a computer-assisted method which manipulates and overlays mapped resource variables, calculates and overlays travel times from population centers, and impediments to illegal exploitation of game populations such as habitat cover and high-use recreation sites.

The resultant map of areas with high probability of impacts due to the development of a coal-mine in central Utah illustrates that areas at risk and of concern are

- sometimes counter-intuitive. The juxtaposition of resources, disincentives, and access can require the integration of numerous factors which is difficult to informally discern for numerous sites.
- only a fraction of the area surrounding a site--in this case about 3% of the region described by a circle with a 100-mile radius from the site of the development.

The integration of topography, different grades of roads, key resource areas and current uses much more accurately and expeditiously describes a real region-of-influence than the commonly used circle which may well include diverse biomes and uses. The procedure employed in this analysis took about two days and used currently available software. With a focussing of attention on the small proportion of the total area normally considered within a region-of-influence, the savings in time and money to those who pay for such environmental assessments is considerable.

Environmental impact studies are of necessity generally constrained to a portion of the region within which a new project is to be located. The portion to be studied with respect to a given resource can be termed the "Region of Influence" or ROI. It is a geographically defined (mapable) area within which measurable effects of a project will occur upon resources that have been deemed significant by some previous type of magic. We all deal frequently with the concept of an ROI; for example, the notion of something happening in one's "neighborhood" is analogous. We receive maps of a city and its "surrounding areas" when renting a car. But the criteria for defining such an area are obscure and difficult to audit. Both the decision and the audit trail of rationale are particularly important in siting projects with environmental impacts. Experience with the process and follow-on problems that devolve from a less than rigorous determination of the ROI are particularly acute at this time.

The premise of this paper is that simplistic and often unrealistic methods have heretofore been used to determine a project's region-of-influence for a resource (such as wildlife), or family of resources with common characteristics or defining variables (such as Quality of Life and Recreation). Such current methods include the use of a circle of some arbitrary radius which encloses numerous resources, land uses and land tenure characteristics of spotty distribution. The region-of-influence is important to define because it influences many subsequent activities such as level of analysis, focusing data collection efforts, reducing variability of data and analyses, bounding the regions or strata within which extrapolations are valid, and enhancing the defensibility of the analysis. It is a seminal activity in impact evaluations because it is a first step which, if not carefully considered, results in wasted time and money downstream. Does a circle drawn around Denver imply a homogeneous region when it incorporates the disparate resources of the short--grass prairie and the alpine fell-fields? Even in the montane areas close to Denver resources may be seasonally inaccessible and require many hours of driving around closed mountain passes.

This paper illustrates a method by which important mapped variables that determine the vulnerability of a resource to project-related effects are overlaid and manipulated to generate a region-of-influence which may not be geometrically satisfying or contiguous but which logically defines the region where a resource is at risk. Such socio-economic resources as Quality of Life or Outdoor Recreation may, for

example, be defined by mappable variables like the major economic activity (mining, forestry, grazing, retail services, tourism), regions of varying disposable income, ratio of urban to rural population, recreational preferences and so on.

For wildlife resources we have disaggregated the topic into more homogeneous and analyzable strata such as upland game, waterfowl, carnivorous and herbivorous furbearers, and seral and climax ungulates among others. If detail is required, a featured species is examined from each group. The mapped variables for wildlife resources which can be employed in the computer-assisted analysis include:

- Travel time/distance up to two hours from the project after which travel decays rapidly (Sutherland, 1980)
- Location of key winter range or habitat suitability index maps
- Relative attractiveness of species under consideration for the region (Kellert, 1980)
- Vulnerability of the animals within different habitat types used
- Disposable time for human population units within two hours drive of the project site(s)
- Differential effectiveness of enforcement
- Land use activities which modify wildlife exploitation (energy developments, attractive recreation sites, etc.)
- Road network
- Increasing or "healthy" populations
- Decreasing or "unhealthy" populations

While some of these reflect detailed knowledge often not in-hand when ROI determination is required, some useful data are generally available in-house. The process of data collection will make an update of the ROI possible during the course of the assessment.

The maps are digitized and each map file is accessed to HDR's Cyber computer for manipulation and overlay by using a "Map Analysis Package" (MAP) software.

We believe that such a technique (cf. Figure 1) developed to address a recurring need which has been consistently neglected, demonstrates an ability to apply sophisticated technology and long experience to environmental analysis and problem solving.

STUDY AREA AND METHODS

The study site (Fig. 2) was selected because the necessary data were available in-house and the mine is typical of the genus of projects which will confront resource managers over much of the western United States until the turn of the century. The Sagepoint/Dugout Canyon underground coal mine seemed to constitute an instructive paradigm which could maximize the implications and utility of the analyses described in this paper. Streeter et al. (1979) note that roughly 77 percent of coal recoverable by surface stripping and over half of all coal resources in the United States are in the west. Larry Dalton, the state wildlife biologist in the area, noted that employment in the Price area has boomed--235 percent over the past decade. The mine considered in this paper is owned by the Sundeco Coal Co. (Sun Oil) and is touted as the largest underground coal mine west of the Mississippi. Construction will begin in 1983 and employ about 1,000 workers during its operation. The secondary impacts of construction and operations will add to the regional effects of over 40 coal and 200 uranium mines. The impacts will be added to the cumulative impacts of such regional energy-related development which, for example, has led to a 250 percent increase in game law violations (1972 to 1977) at a time the total population increased by 45% and numbers of enforcement personnel remained constant. Daneke et al. (1982) have demonstrated the potential for increased poaching in nearby mining construction regions of Colorado where 250 violations occurred for each 1,000 immigrants. Further, these reported violations represent less than 1/100 of actual illegal big game kills!

The roughly 5 x 10 km mine plan area is about 24 km eastnortheast of Price, Utah and occupies diverse habitats ranging from desert shrub of the Upper Sonoran zone to the montane Canadian life zone. The usual activity centers for such developments are represented at this site in addition to a rail line, about 25 km of improved road and a 9 km conveyor belt.

This analysis describes a region of influence within a two-hour drive of Price, Utah and focuses more on the indirect off-site impacts—particularly poaching.

The Map Analysis Package (MAP) described below was used to perform the analysis depicted in the flow diagram (Fig. 1). The logical flow involves obtaining resource maps from the state wildlife agency, and using available travel maps for locating recreation sites and roads. These maps are entered into the computer (the HDR CDC Cyber 170-730 system with 2.6 megabyte memory and 8 billion bytes of disc storage) by an electronic stylus at a digitizing board. The data can also be manually entered cell by cell by entering a defined integer value (e.g., a "3" which represents dirt roads with vehicular traffic averaging 30 mph) for each row and column in the matrix. The number of cells and the map distance represented by the cell dimensions are selected as appropriate for the scope and level of the project and resources. Cells can be 4 meters on a side for winter range analyses or 4 miles on a side for regional analyses. The present example employs fifty cells 4 miles on a side. The initial region upon which the more refined analyses were conducted was arbitrarily selected to be one hundred linear

The combination was done by creating maps by the "INTERSECT" command, combining the recreation map with specific categories of the wildlife composite map. All "low proability" maps were then added onto one map by the "COMPUTE" command. The same operations were used to create moderate and high proability maps.

RESULTS

A glance at the 1-hour travelshed (Fig. 3) illustrates the real world incongruities and patchiness between the predicted region-of-influence displayed in Figure 2, and one determined by a spatial analysis of several salient variables of the resource. It is

- not circular or square but ameboid, reflecting the differences or "friction" in travel on different routes
- note entire but fragmented--some areas very close to the mine site are not contained within the travelshed
- not symmetrical but dominated by greater case of travel in the more developed western front of the Wasatch.

The 2-hr travelshed reflects the same results. Neither travelshed resembles most ROIs in current use. The senior author has participated in studies which show that roughly 2/3 of the legal hunting in western Montana was done from roads (Taber, personal communication). We assume that an even greater proportion of illegal hunting is road-bound and thus the analysis does not address foot travel distance.

The area within the 2-hr travelshed represents about 28% of the original study area. The 1-hr travelshed is less than 5% of the base map. The reduction in data collection necessary would result in lower cost to the client and greater accuracy and defensibility of the evaluations--both presumably related to a more focused and surgical analysis. It is interesting to note that extensions (of the 1-hr travelshed) forming the 2-hr travelshed occur primarily in the north, south and west. The ROI is not extended further into the Roan Cliffs area due to lack of road access. A glance at the wildlife distribution (Fig. 4) indicates abundance of wildlife species in the Roan Cliffs area, distant from currently designated recreation areas (see also Fig. 6). These striking results augur well for the suggestion of certain mitigative measures, such as designation of refuges or controlled hunt areas.

When the fish, wildlife and recreation resources (Figs. 4-6) are superimposed upon the travelshed a further reduction in the ROI is accomplished. Figs. 7 and 8 graphically illustrate that when analysis addresses the most vulnerable resources within daily commuting distance the analysis effort will be greatly reduced. The most compressed ROI (less than one hour, greater than 2 resources, no popular recreation sites) represents only about 3 percent of the study area (Fig. 8).

CONCLUSION

Further, because of consistent inclusion of representative variables, the small ROI is relatively homogeneous lending (after the addition of vegetation data essential for homogeneous strata) to reasonable extrapolation of data and the broadest utility of analytical results. Such an ROI determination will aid in minimizing the need to artificially lump different and often incompatible resources when aggregating project effects and impacts prior to ranking alternative project configurations. By using such methods as suggested herein, the ROI determination has, in effect, become part of a sample stratification process prior to the beginning of the environmental assessments.

LITERATURE CITED

Berry, J. K., L. B. Nott, C. D. Tomlin, and A. Mansbach. 1980. Computer assisted map analyses of predicted timber felling breakage. IUFRO Sympos. on Forest Management Planning. VPI, Blackburg. 16 p.

Daneke, D., S. Berwick, and J. Berger. 1982. Boomtown growth and wildlife law violators. J. Wildl. Mgt. (submitted). 20 pp.

Kellert, S. R. 1980. American attitudes toward and knowledge of animals: an update. Int. J. Stud. Anim. Prob. 1(2):87-119.

McHarg, I. 1968. A comprehensive highway route-selection method. Highway Research Record No. 246. Highway Research Board, Washington, D.C.

McHarg. 1969. Design with nature. Doubleday Natural History Press. 197 pp.

Nisbet, R. A. 1981. Application of cartographic modeling techniques to valley-specific impact analysis. HDR Tech. Rept. 870. Santa Barbara, CA.

Streeter, R. G., R. T. Moore, J. J. Skinner, S. G. Martinez, T. L. Terrel, W. D. Klimstra, J. Tate, Jr. and M. J. Nolde. 1979. Energy mining impacts and wildlife management: Which way to turn. Trans. 44th No. Amer. Wildl. Nat. Res. Conf: 26-65.

Sutherland, R. J. 1980. A regional recreation demand and benefit model. EPA, Corvallis, 144 pp.

Tomlin, C. D., S. Berwick, and D. Tomlin. 1983. Cartographic analysis of deer habitat utilization In Conf. on computer mapping hardware, software, and data bases. Harvard Univ. 18 pp.

miles on each side of the proposed Sagepoint/Dugout Canyon Mine. Sutherland (1980) has shown that about 75% of all fishing and boating trips occur within 100 miles of the population centroids in three northwestern states. The 1:1,000,000 resource maps used were obtained from the Utah Department of Wildlife Resources and Utah State University.

The Map Analysis Package is software developed in PASCAL from the original IMGRID program developed at MIT and Yale (Tomlin et al. 1983). MAP receives cell-based data and various commands generate automatic overlay, cross-tabulation, manipulation, reclassification and transformation and other mathematical treatment of maps. Modeling algorithms can be developed from command structures as noted below. Most spatial data are amenable to MAP analysis. One example of its utility was in predicting the location of unmapped sage grouse leks by manipulating those habitat variables which a multivariate statistical analysis of data from 41 known lek sites had deemed most important in selection of the sites by the birds (Nisbet et al. 1981).

The CPU space required for the roughly 7,000 lines of code is about 50 K and for the matrices 2.5 K (50 x 50 cells) times the two or three maps used. The ability to pack arrays is a very useful feature of PASCAL. We are therefore able to forecast near-term use of MAP on current generation 16-bit micro computers.

MAP differs from early overlay-assisted analyses such as that developed by McHarg (1968) in these significant ways:

- Mathematical manipulation and transformation of data, often to abstract but useful indicators such as contours of habitat quality, is possible. For example, friction or impedence to travel based upon behavioral reactions to a disturbance can be mapped as can the geometry of slopes.

- Quantitative indications of cumulative impacts can be displayed in space. The reader is not required to gauge the summed colors of several overlays as in the more subjective analyses.

- Performing such tedious and time-consuming calculations as travel time by intersecting grades of roads with speed of travel ("friction") can be quickly accomplished by the "SPREAD" command.

- MAP can be used to model with cartographic information. Berry et al. (1980) used MAP to predict timber felling breakage employing maps of slopes, tree diameter, height, volume and wood defect weighted by appropriate regression coefficients.

To operate MAP, data can be entered by the cell ("POINT" command), the row ("STRIP" command), or by an entire map ("GRID" command). If digitizing facilities are available, output files can be formated to be read into MAP, using the "READ" command. To perform data manipulation and overlay, various travelshed maps were created by the SPREAD command. SPREAD operates on a "resistance map" of cells containing the travel time (in min/mile) across the cells representing roads with various speed limits. By spreading "thru" the resistance map, a travelshed map can be created containing all cells within a specified travel time from a starting point (Price, Utah, Fig. 2).

Composite resource maps were made to indicate wildlife resources (number of species), fishing resources (Class I, II and III streams and water bodies), and popular recreation areas (presence). It was assumed that the probability of poaching was directly related to the proximity of wildlife abundance and fishing opportunity, and inversely related to the proximity of popular recreation areas.

Various travelsheds were combined with various resources to predict low, moderate, and high probability of poaching impact. The following arbitrary criteria were used to assign to cells estimated levels of poaching-related impacts.

- Low probability of impact (most expanded ROI)
  - Popular recreation sites in cells plus,
    - 0 or 1 (key range) species within the 2-hour travelshed, or,
    - No recreation sites plus 0 species in the 2-hour travelshed.
- Moderate probability of impact
  - Popular recreation sites in cells plus,
    - 2 species in 2-hour travelshed, or,
    - 3 species within the 2-hour, but beyond the 1-hour travelshed, or
    - No recreation sites in cells plus 1 or 2 species within the 2-hour but beyond the 1-hour travelshed.
- High probability of impact (most compressed ROI)
  - Popular recreation sites in cells plus,
    - 3 spp. within the 1-hour travelshed, or
  - No recreation sites in cells plus,
    - 3 spp. within the 2-hour travelshed, or
    - 2 spp. within the 1-hour travelshed.

-460'

Nisbet, R. A., S. H. Berwick and K. L. Reed. 1982. A spatial model of sage grouse habitat quality. Proceeding of the Third International Conference on State-of-the-Art in Ecological Modeling. Colorado State University. 1982.

461

FIGURE 1: LOGICAL PROCESS IN THE MAP EVALUATION OF REGION-OF-INFLUENCE AND PROJECT IMPACTS

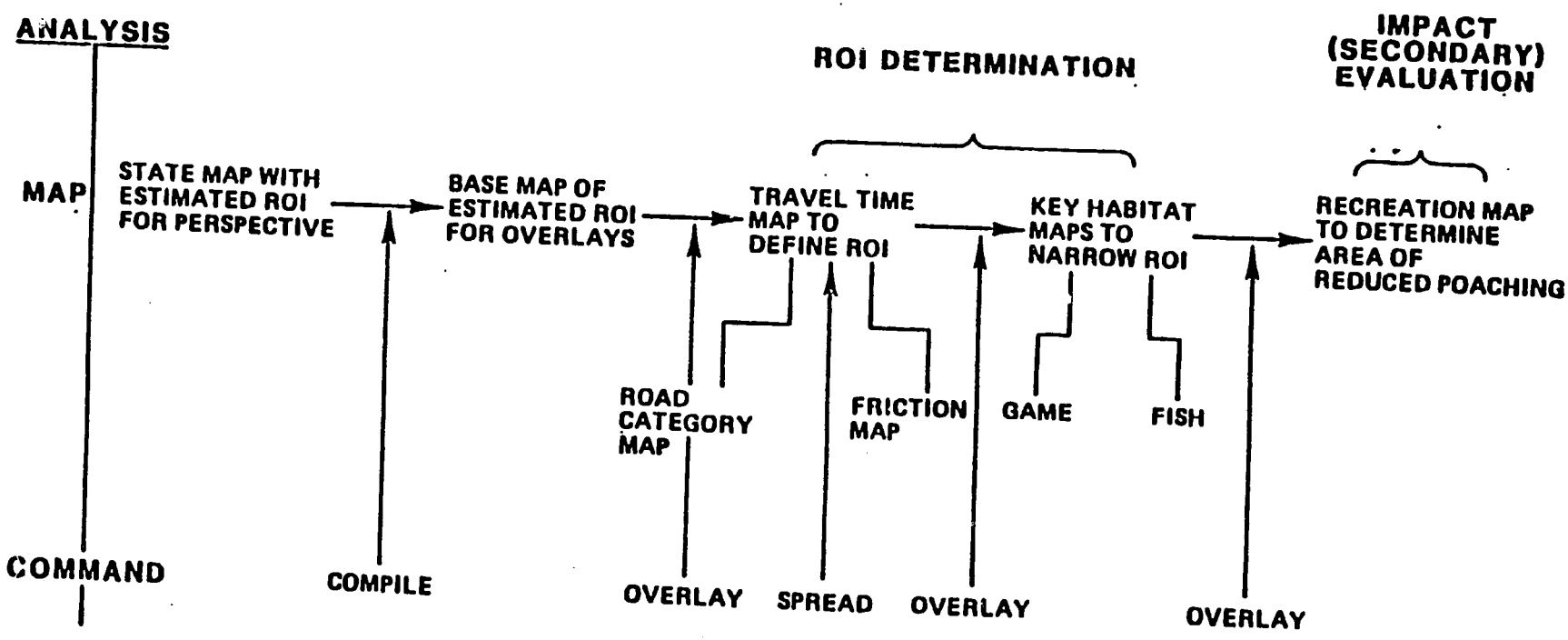
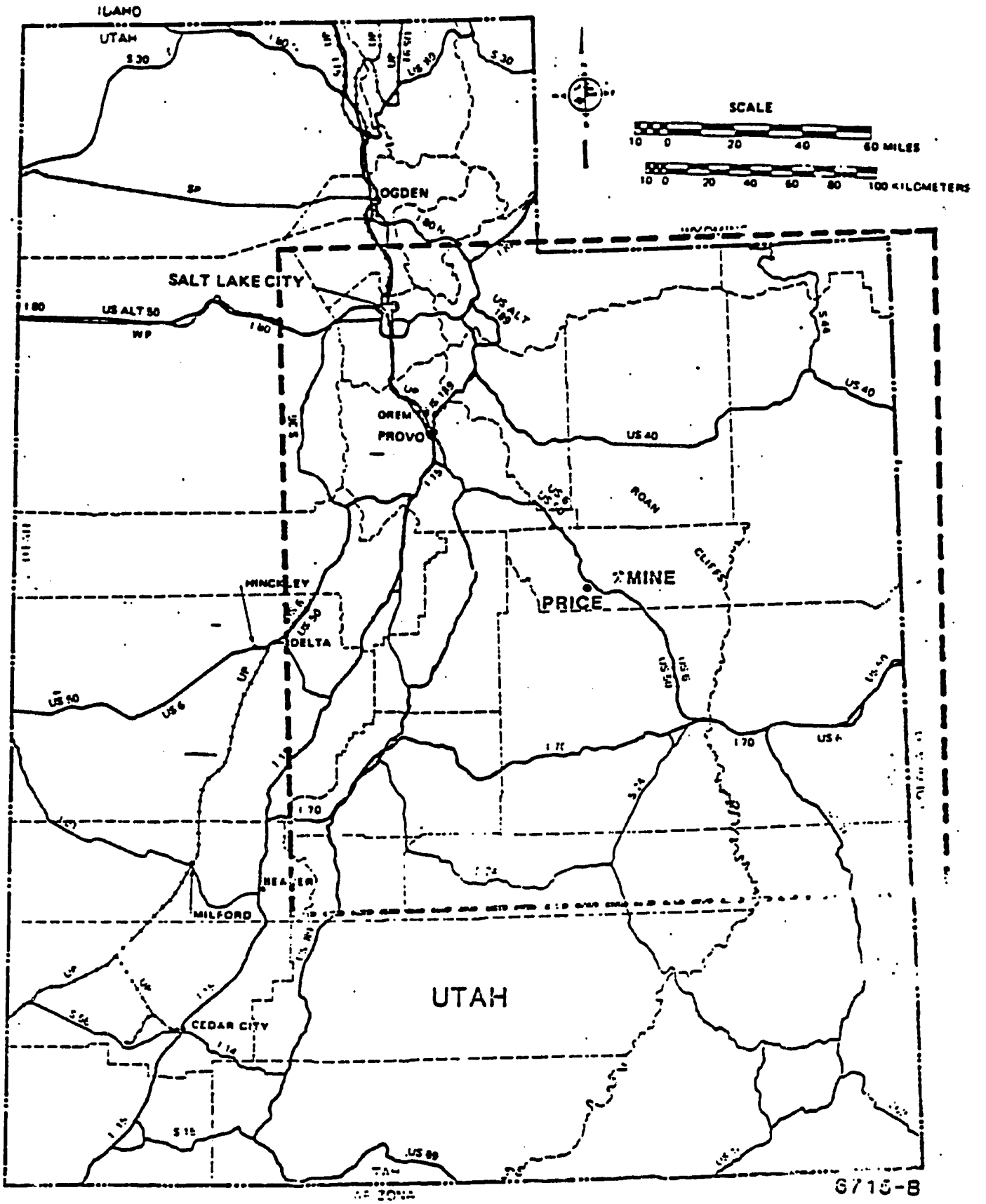


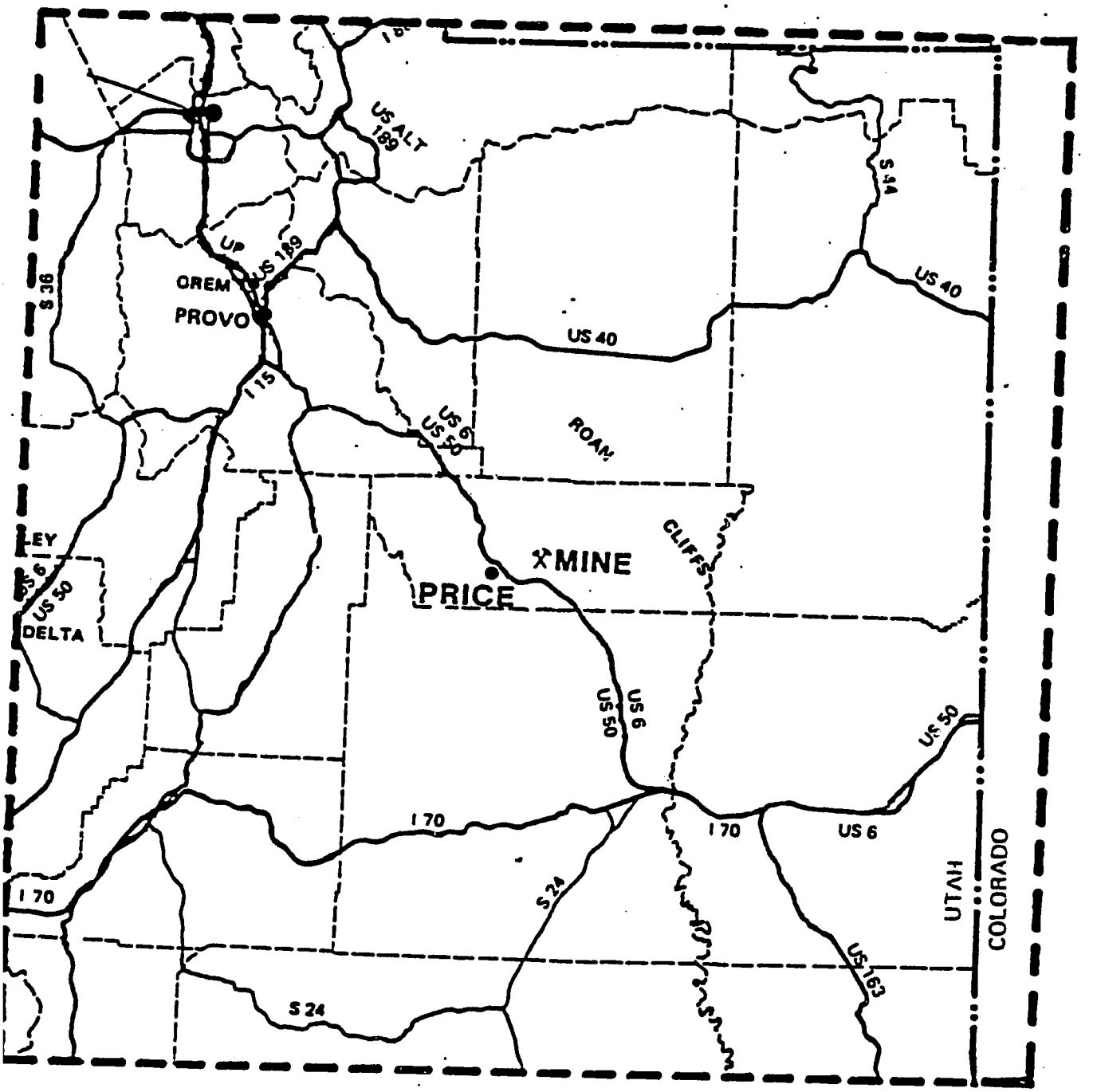
Figure 2. Predicted region of influence on wildlife resources for the Sagepoint/Dugout Canyon Mine.



PREDICTED BLIGHT ON INFLUENCE
ON WILDLIFE RESOURCES FOR THE
SAGEPONY/DUGOUT CANYON MINE

464

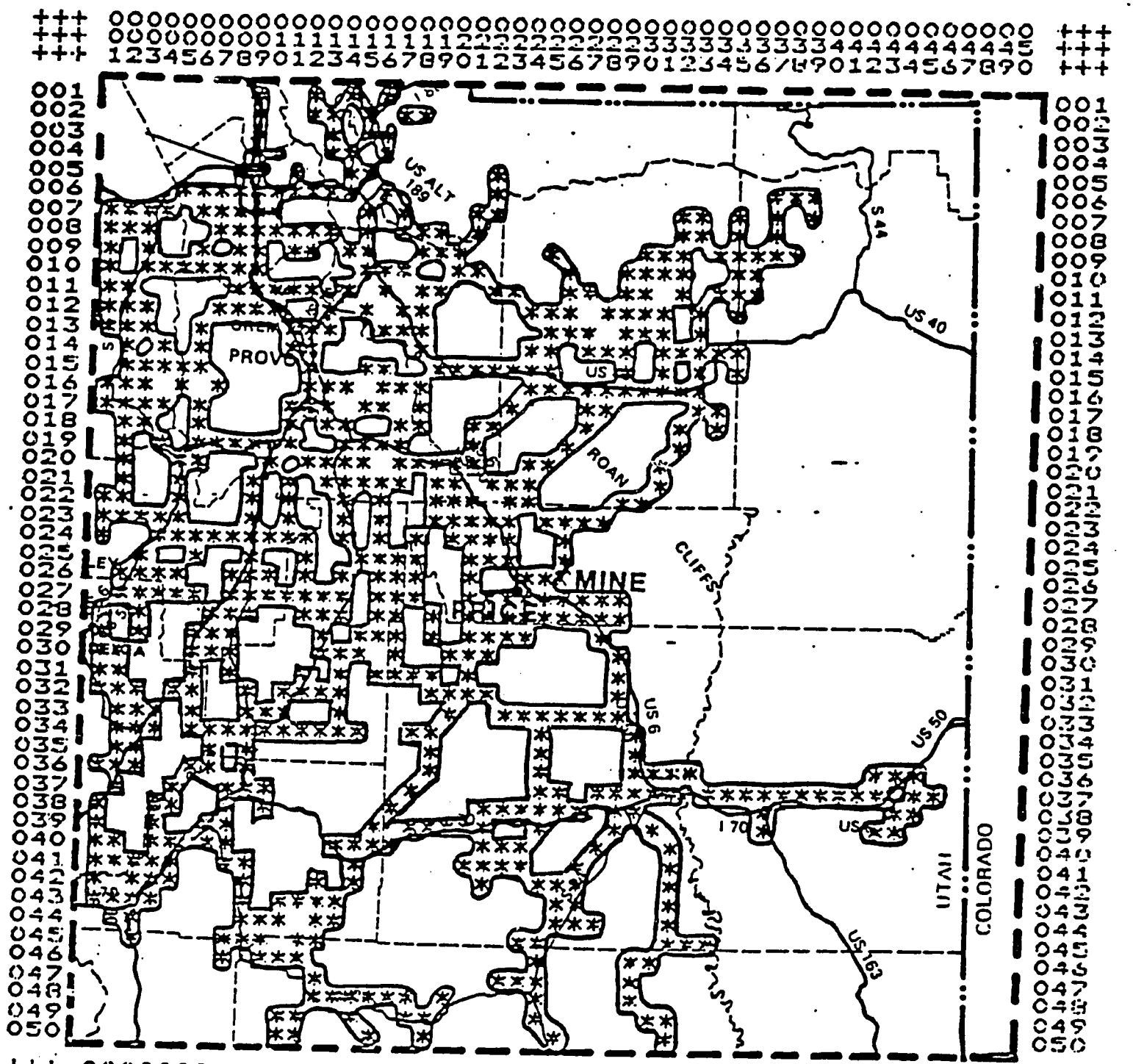
Figure 3. Central Utah study area for ROI determination.


US ALT 189
S 44
US 40
US 40
UP
US 189
OREM
PROVO
S 38
I 15
US 6
US 50
ROAN
CLIFFS
MINE
PRICE
LEY
US 6
US 50
DELTA
US 6
US 50
US 50
I 70
I 70
US 6
I 70
S 24
S 24
US 163
UTAH
COLORADO

6716-B

466

Figure 4. Two-hour travelshed from Price, Utah.



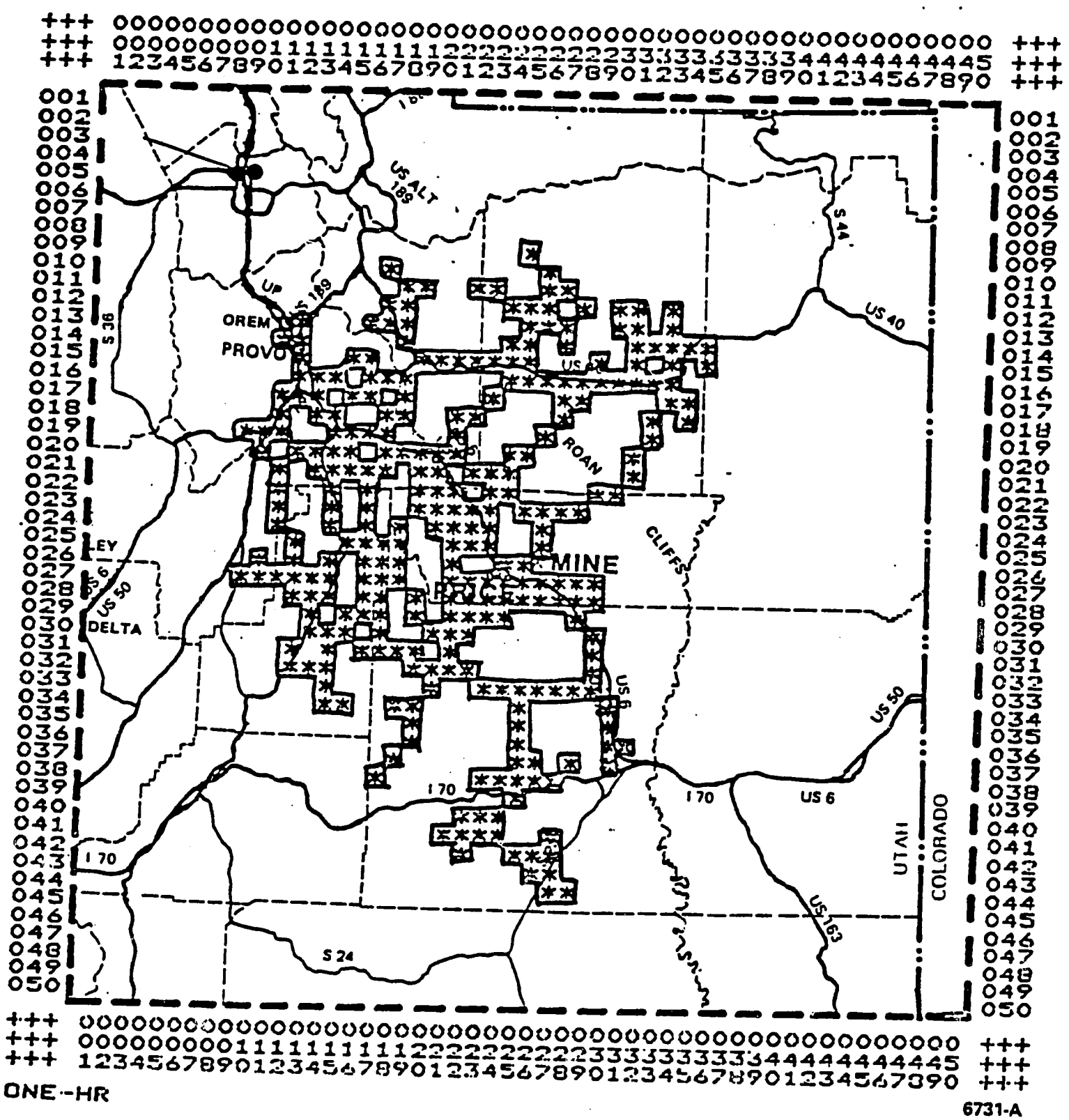
TWO-HR

6732-A

SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
**********	0		1793	71.72
	7		707	28.28
	TOTAL NO. OF CELLS =		2500	

468

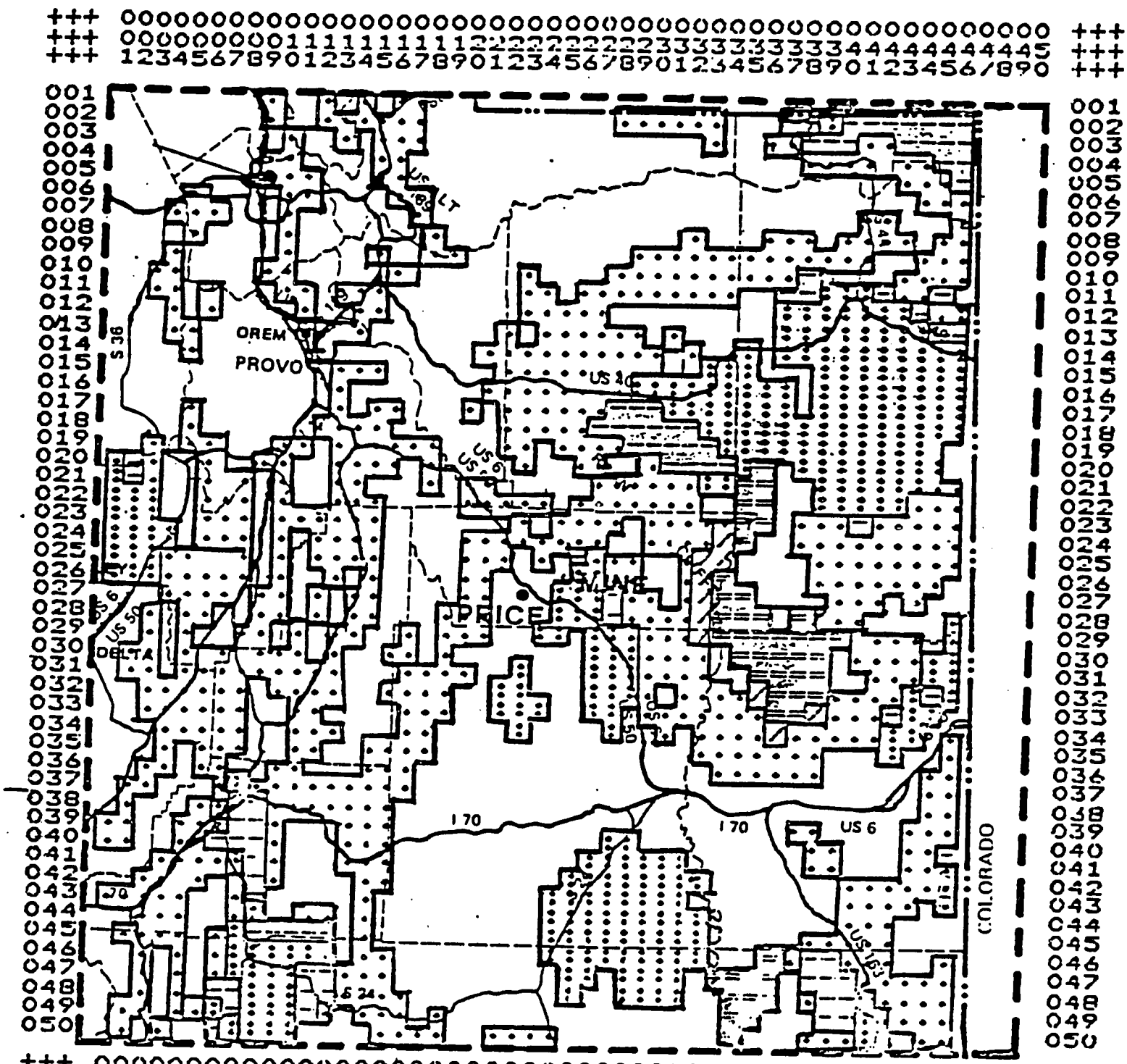
Figure 5. One-hour travelshed from Price, Utah.



SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
**********	0		2209	88.36
	7		291	11.64
	TOTAL NO. OF CELLS =		2500	

470

Figure 6. Key range of deer (number 1-dots), antelope (2 - double dots), deer and antelope (3 - dashes), bighorn (4 - double dashes), bighorn and deer (5 - slash) with study area.

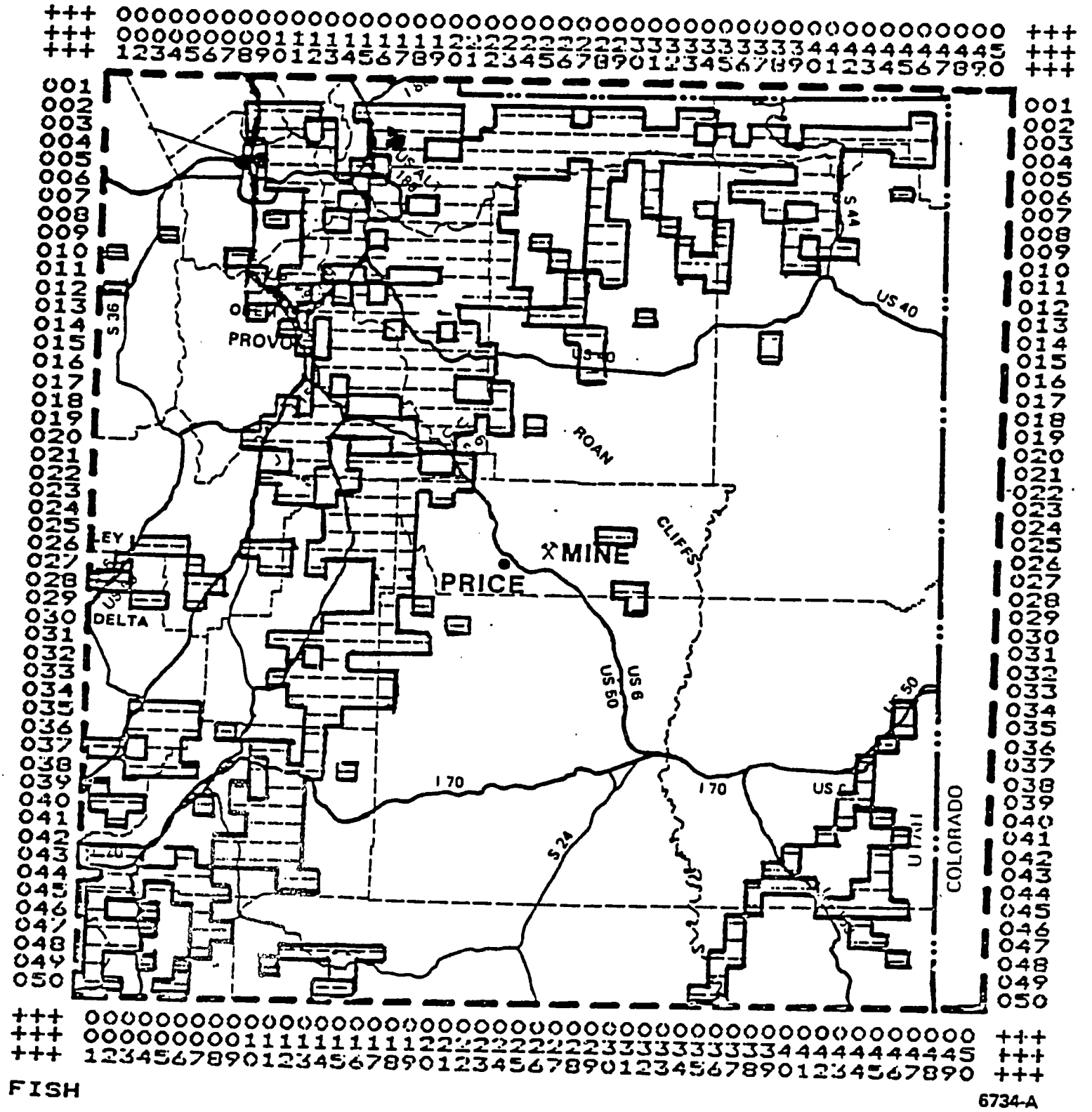


WILDLIF

6733-A

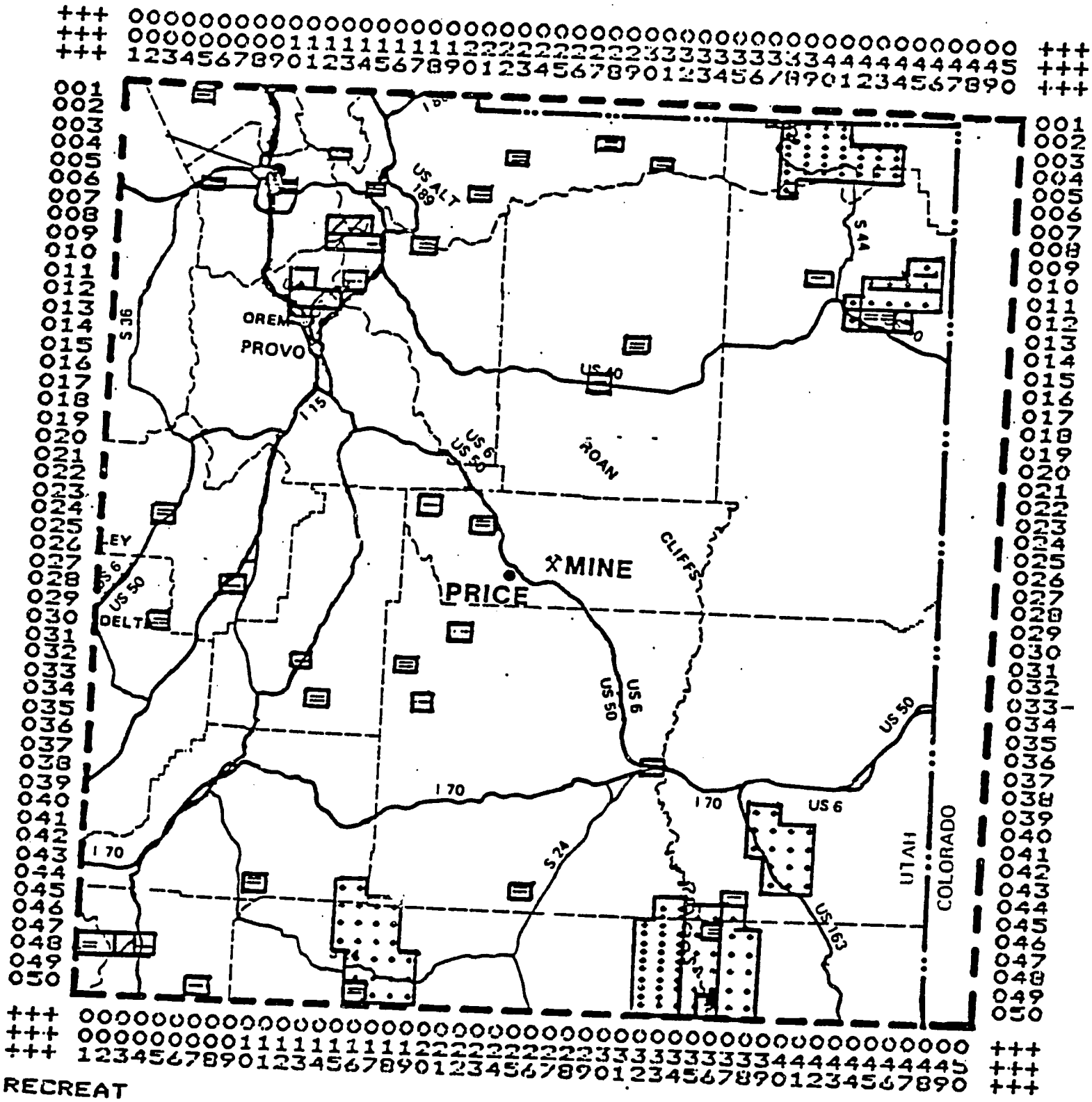
SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
	0		1338	53.52
	1		750	30.00
	2		269	10.76
	3		86	3.44
	4		46	1.84
	5		11	0.44
	TOTAL NO. OF CELLS =		2500	

Figure 7. Class I, II, and III aquatic resources in study area.



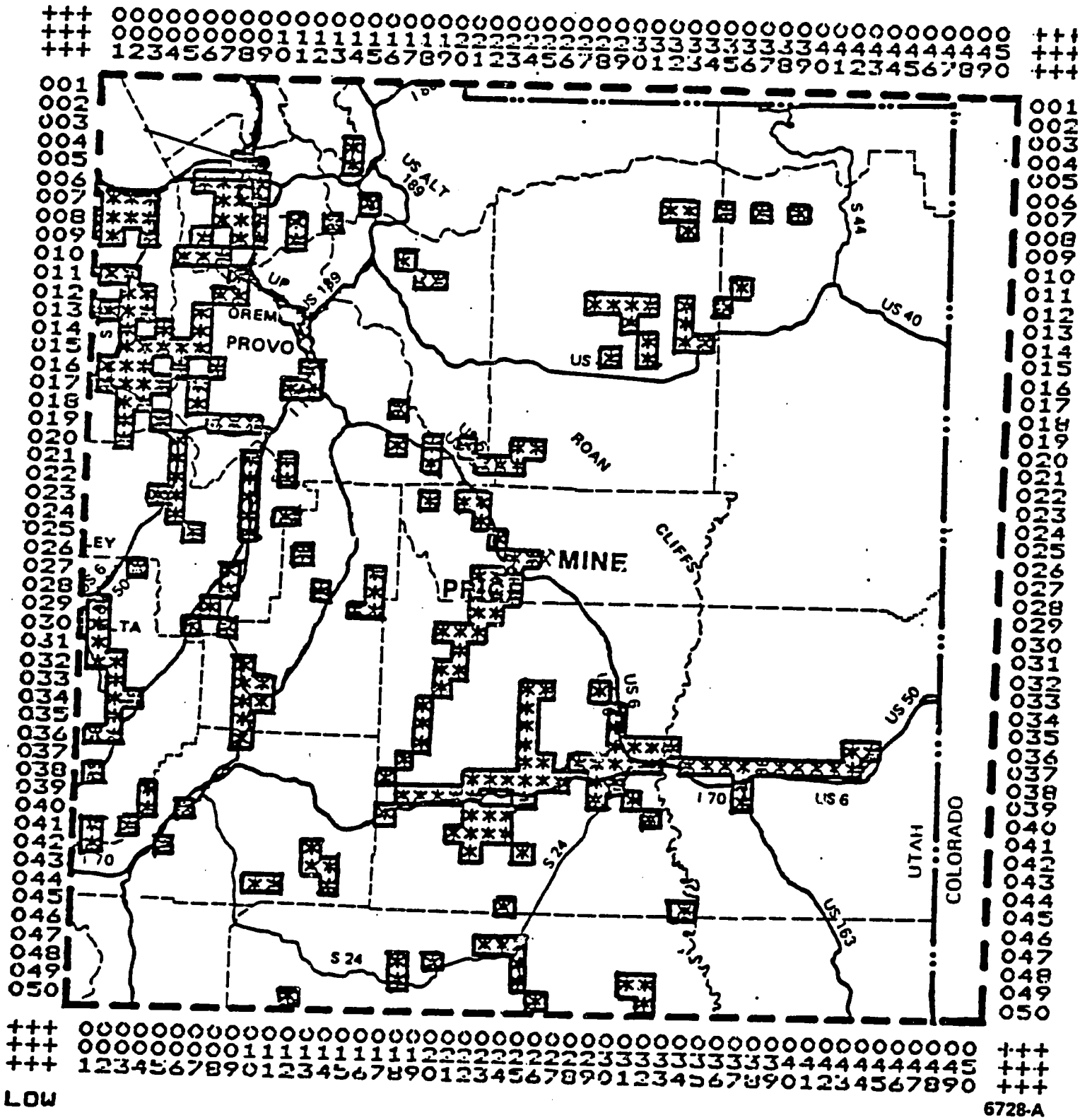
SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
----------	0		1965	78.60
	3		535	21.40
	TOTAL NO. OF CELLS =		2500	

Figure 8. Recreation sites of study area. National parks and monuments (1 - dots), National Recreation Area (2 - double dots), State Recreation Area (3 - dash), Campgrounds (4 - double dashes), and Ski Area (5 - slash)



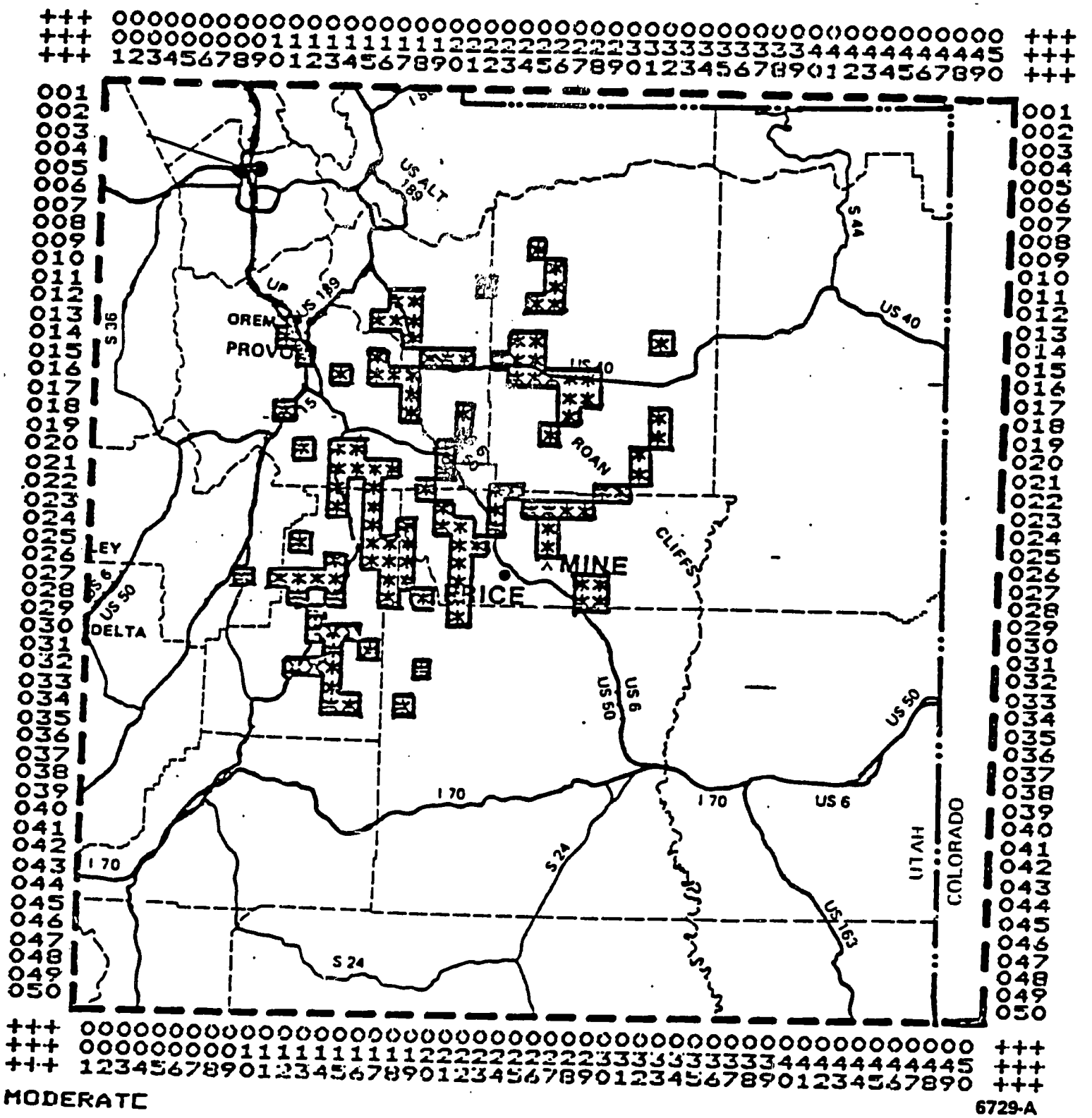
SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
⠿⠿⠿⠿⠿⠿⠿⠿⠿⠿	0		2346	93.84
═══════	1		77	3.08
═══════	2		34	1.36
//////////	3		17	0.68
	4		21	0.84
	5		5	0.20
	TOTAL NO. OF CELLS =		2500	

Figure 9. Low impacts/most extensive ROI.



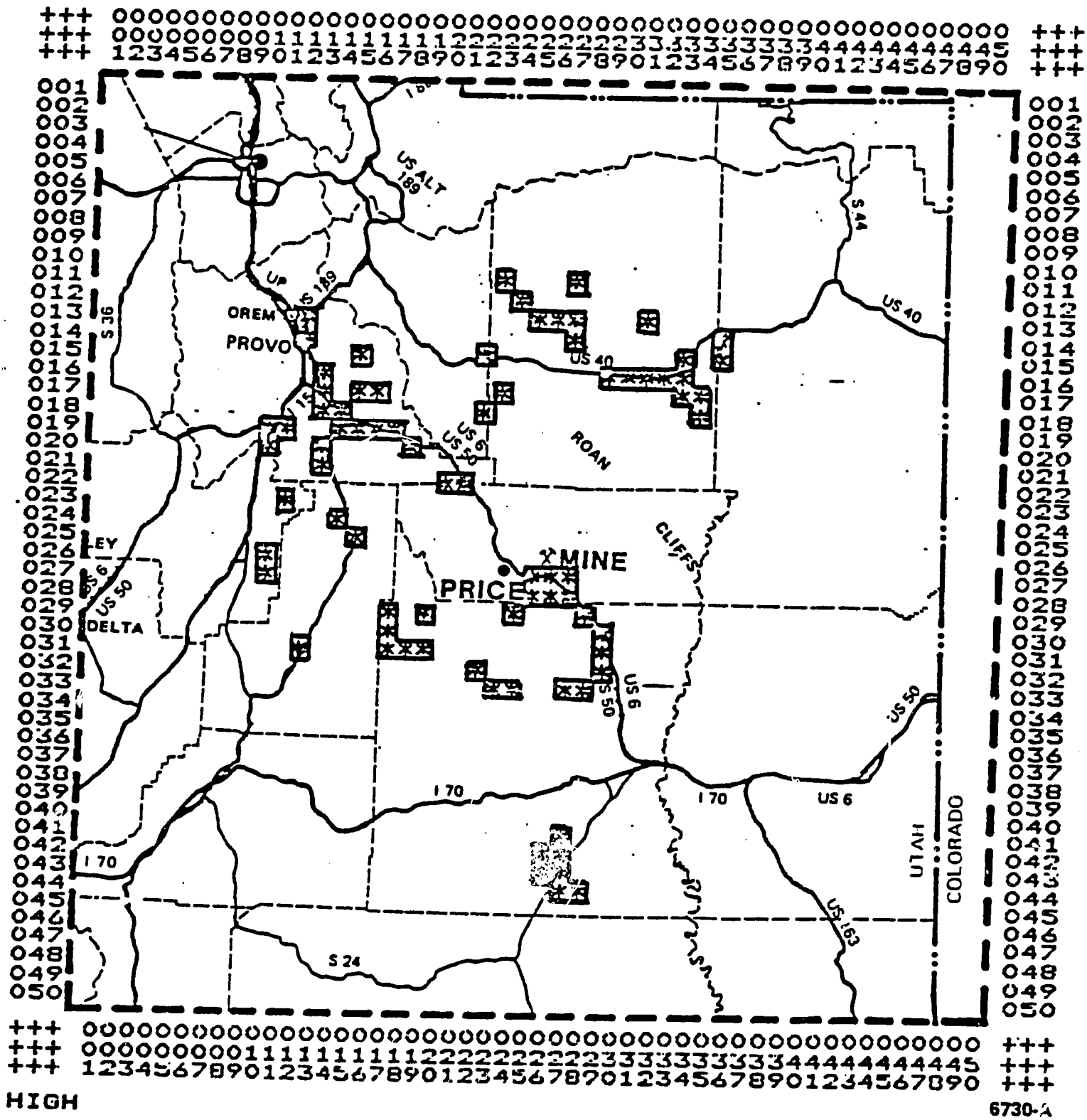
SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
**********	0		2233	89.32
	7		267	10.68
EDI ENCOUNTERED.	TOTAL NO. OF CELLS =		2500	

Figure 10. Moderate impacts.



SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
**********	0		2380	95.20
	7		120	4.80
	TOTAL NO. OF CELLS =		2500	

Figure 11. High impacts/most condensed ROI.



SYMBOL	VALUE	LABEL	NO. OF CELLS	PCT OF
**********	0		2422	96.88
	7		78	3.12
	TOTAL NO. OF CELLS =		2500	

482