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DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

MINISTRY OF LANDS, IRRIGATION AND MAHAWELI DEVELOPMENT

THE STUDY ON EXTENSION OF THE MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

MASTER PLAN

(PHASE - II)

EXECUTIVE SUMMARY

JULY 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Democratic Socialist Republic of Sri Lanka, the Japanese Government decided to conduct a study on Extension of the Feasibility Study on the Moragahakanda Agricultural Development Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Sri Lanka a study team headed by Mr. Shin-ichi Yano, Nippon Koei Co., Ltd., for Phase-I study of updating Feasibility Study conducted in 1978, and the report presenting the results of study was submitted in May, 1988.

In succession to Phase-I study, JICA sent the team to Sri Lanka from July to December, 1988.

The team held discussions with the officials concerned of the Government of Sri Lanka and conducted field surveys in the Amban Ganga basin and its adjacent areas. After the team returned to Japan, further studies were made and the present report was prepared.

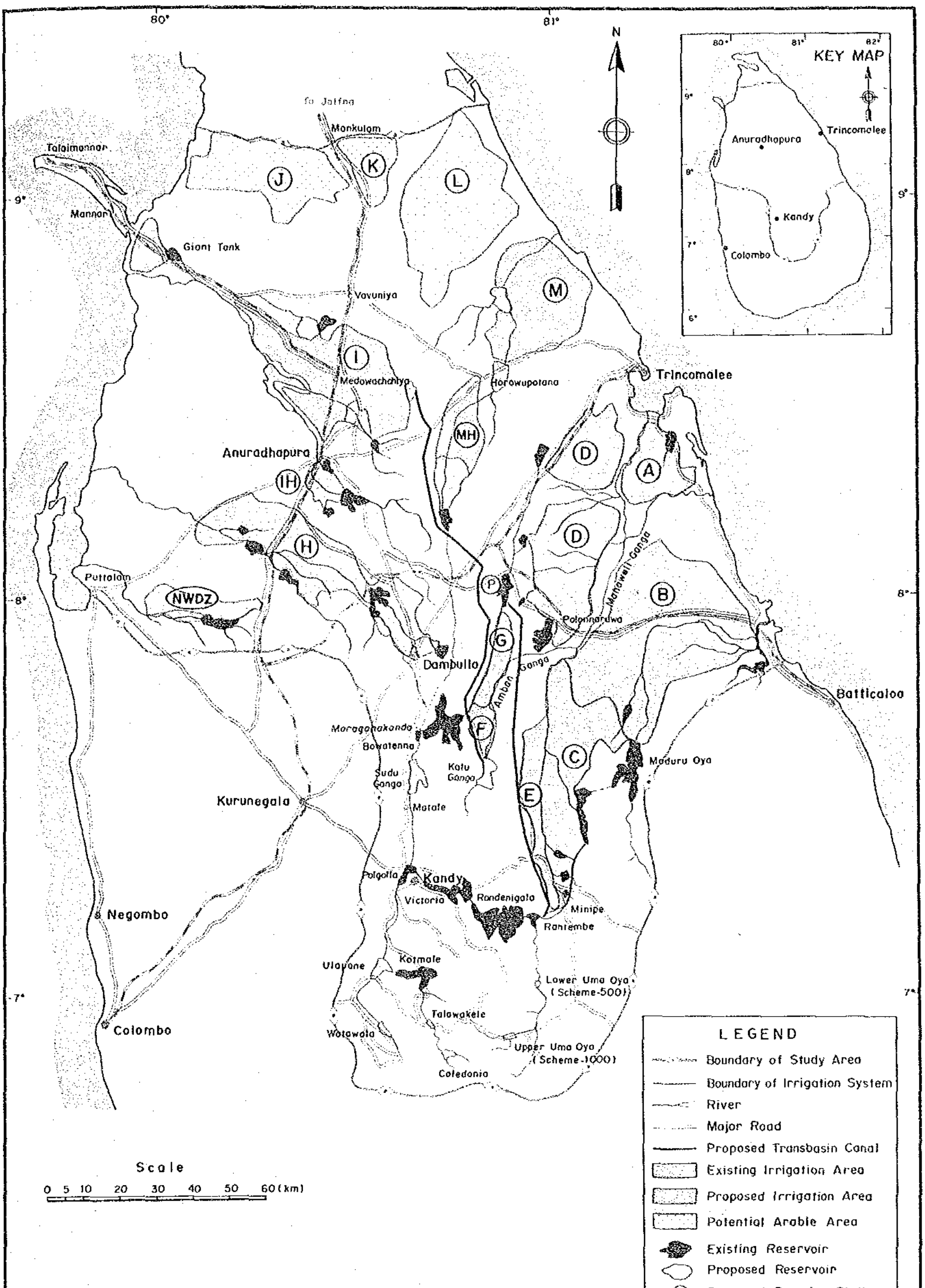
I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Democratic Socialist Republic of Sri Lanka for their close cooperation extended to the team.

July, 1989

Kensuke Yanagiya

Kensuke YANAGIYA
President
Japan International Cooperation Agency



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I. INTRODUCTION

01. This report is prepared in accordance with the Scope of Work agreed upon between MMD and JICA in October 1987, and presents the results of the Phase-II study on the Extension of the Moragahakanda Agricultural Development Project. The objectives of the Phase-II study are to formulate an overall agricultural development plan (Master Plan) in the Amban Ganga Basin for (1) the most effective use of available water in the Mahaweli river system for irrigation development in the Amban Ganga basin and its adjacent areas, and (2) priority irrigation projects and implementation of these projects.

02. The Government of Sri Lanka (GOSL) has promoted the Mahaweli Ganga Development Project, which aims to develop the potential arable land in the central and north-central parts of Sri Lanka by supplying water diverted from the Mahaweli Ganga and its tributaries which are blessed with abundant water resources. In 1968, a master plan for the Mahaweli Ganga Development prepared with the assistance of UNDP/FAO comprised irrigation development of about 365,000 ha and hydropower development of 500 MW in installed capacity. GOSL commenced the development of the Mahaweli Ganga Basin on the basis of this master plan in 1968. In 1976, GOSL completed the Polgolla diversion project consisting of a diversion dam at Polgolla, hydropower station at Ukuwela, and a dam and reservoir at Bowatenna to divert Mahaweli water to the Kalawewa basin. This diversion project realized development of fertile land in the north dry zone by irrigation with the abundant water of the Mahaweli Ganga, as well as hydroelectric power.

03. In 1977, GOSL revised master plan to accelerate the Mahaweli Development Programme for yielding the quickest return to the nation. The revised plan, called the Accelerated Mahaweli Development Programme (AMDP), involves (1) irrigation development of about 204,000 ha with 8 irrigation systems, from A to D, G, H, IH and MH, and (2) hydropower development schemes of about 470 MW in installed capacity through the construction of 5 dams: Kotmale, Victoria, Randenigala, Moragahakanda and Maduru Oya dams.

04. Since 1978 GOSL has commenced implementation of the hydropower generation and irrigation development projects in the Mahaweli Ganga basin as recommended in AMDP in 1977. As of 1987, GOSL had almost completed four multi-purpose dams on the Mahaweli Ganga and one multi-purpose dam on the Maduru Oya with a hydropower generating capacity of 611 MW and a total development area of about 135,000 ha irrigated with water from the Mahaweli Ganga, the Amban Ganga and local catchments. GOSL is going to complete the principal components of AMDP except System A and the Moragahakanda Agricultural Development Project.

05. Having substantially completed several hydropower and irrigation development projects particularly along the main stem of the Mahaweli Ganga during the period from 1978 to 1986, GOSL in 1986 wished to take up the Moragahakanda Agricultural Development Project and requested the Government of Japan (GOJ) to undertake (1) the updating of the feasibility study on the Moragahakanda Agricultural Development Project which was originally prepared in 1979 (Phase-I study), and (2) to formulate an overall agricultural development plan in the Amban Ganga basin, the North Central River Basin (NCRB), and the North West Dry Zone (NWDZ) (Master Plan, Phase-II study). In response to the above request, GOJ decided to conduct the present Study on Extension of the Moragahakanda Agricultural Development Project .

06. Based on the agreed Scope of Work, the Phase-I study was duly completed in May 1988, and this Report presents the results of the Phase-II study covering the overall development plan for exploiting most efficiently the water resources of the Mahaweli Ganga and its tributaries as well as local inflows to the proposed agricultural areas, particularly in NCRB and NWDZ.

2. BACKGROUND

07. The population of Sri Lanka was approximately 16.4 million in 1987, corresponding to 249 persons/km^2. The annual growth rate of the population during the period from 1981 to 1987 was 1.63%. The population is expected to be over 20 million in 2001 and 24 million in 2020 (see Fig. 6). The number of unemployed persons in 1987 was estimated to be about 1.19 million, corresponding to an 18% unemployment rate.

08. The Gross Domestic Product (GDP) in 1987 was estimated at about Rs. 177.7 billion with an annual growth rate of 4.8%. Per capita GDP was estimated to be Rs. 10,863 (about US$350). Agriculture in Sri Lanka has played an important role in its economy, contributing to about 27% of GDP and employing about 45% of the active labour force. Earnings from agricultural exports accounted for about 42% of the total exports in 1987.

09. The climate of Sri Lanka is suitable for year-round cultivation and the soils are generally suitable for agriculture if irrigation water is properly made available. The main export crops are tea, rubber and coconuts of which production was approximately 213×10^3 tons, 122×10^3 tons and $2{,}291 \times 10^6$ nuts respectively in 1987. The main food crop is rice, of which production was about 2.59×10^6 tons of paddy in 1986 and 2.13×10^6 tons in 1987 respectively. The following table shows the average cultivated area and production during the period of 1983 to 1987:

Item		Maha	Yala	Total
Net cultivated Area	(10^3 ha)	500	274	774
Production (Paddy)	(10^3 tons)	1,595	860	2,455
Yield per ha	(ton/ha)	3.19	3.14	3.17

Source: Paddy Statistics 1983-87

10. Irrigation development in Sri Lanka has a long history. There are a great many ancient tanks scattered all over the northern part of the island. The total wet paddy area is about 500,000 ha (in net area) comprising 210,000 ha of major irrigation schemes, 115,000 ha of minor irrigation schemes and 175,000 ha of rainfed paddy areas. Due to lack of irrigation water in the dry season, rice production is still vulnerable to weather conditions. GOSL aims to maximize the irrigation area with reliable water supply and to increase cropping intensity and yield in the existing irrigation areas.

11. Self-sufficiency in foodstuffs, especially in rice, has been one of the main and most urgent targets of the Government. Rice production has increased significantly in recent years to the near self-sufficiency level but it is still vulnerable to weather conditions due to the lack of irrigation water in the Yala season. Indeed, in 1987 rice production was seriously affected by drought.

12. The current policies of the Government put emphasis on (1) attainment of the self-sufficiency of the important basic food crops, (2) expansion of export of agricultural products and diversification of export crops, and (3) improvement of income levels and employment in rural areas. In addition, the Government is emphasizing expansion of irrigated agriculture with proper water management and introduction of appropriate cropping systems, and extension of the cropped area into the dry zone through the development of water resources.

13. Hydropower development was expedited to eliminate the shortage of electric power in the 1960s. Based on the UNDP/FAO master plan, Ukuwela and Bowatenna hydropower stations were constructed in 1976 and 1981 respectively. In accordance with AMDP, hydropower in recent years has been developed as a component of multipurpose dam development, namely: the Kotmale, Victoria, Randenigala, Maduru Oya multipurpose dams, all constructed in the early 1980s. The Samanalawewa and Rantembe hydropower stations are under construction.

14. The entire public power supply in Sri Lanka is managed and operated by the Ceylon Electricity Board (CEB). The total installed capacity of CEB was 1,116 MW in 1987 comprising 916 MW of hydropower plants and 200 MW of thermal powerplants. Hydropower plants can generate 3,680 GWh under normal hydrological conditions, but under very dry conditions, hydro energy falls to a firm level of 2,540 GWh. Annual energy generated in 1987 by CEB was 2,707 GWh of which hydropower accounted for approximately 80%.

3. THE STUDY AREA

15. The study area for agricultural development covers approximately 27,000 km^2 or about 41% of Sri Lanka. The study area is situated in the northwest, the north central and the north east regions of Sri Lanka, which include existing irrigation areas in Systems H, IH and MH, and potential irrigation areas in Systems F, I and M located in NCRB, and NWDZ. 51,400 ha of Systems H, IH and MH are irrigated by the existing Dambulu Oya Huruluwewa and Kalawewa tanks receiving water mainly from the Mahaweli Ganga. NCRB consists of Systems F, H, IH, MH, M and I, commanding approximately 191,600 ha of gross agricultural land and NWDZ covers 12,100 ha. Present land use is summarized below:

(Unit: ha in Gross)

Land Use Category	NCRB (F,H,IH,MH,I,M)	NWDZ (NW-1)	Total
1. Agricultural Land	191,600 (49.3%)	12,100 (34.0%)	203,700 (48.0%)
2. Urban Area and Homestead	26,800 (6.9%)	500 (1.4%)	27,300 (6.4%)
3. Forest	101,500 (26.1%)	22,600 (63.5%)	124,100 (29.2%)
4. Barren Land and Shrub	59,500 (15.3%)	400 (1.1%)	59,900 (14.1%)
5. Others	9,400 (2.4%)	0 (0.0%)	9,400 (2.3%)
Total	388,800 (100%)	35,600 (100%)	424,400 (100%)

16. The geology of the study area is composed of very old, highly crystalline metamorphic rocks, the so-called Highland series (Pre-Cambrian) and Vijayan series (Cambrian). The proposed damsite areas are located mainly on the Highland series and agricultural lands are on both series. Quaternary deposits overlay the above base rocks. One of these deposits is river bed deposits, along the Mahaweli Ganga, its tributaries and other rivers. The others are reddish brown or light brown coloured sand, silt and loam, which prevail over most of the Study area. The river bed deposits are generally loose unconsolidated sediments, composed of sandy silt and clay, sometimes containing gravels.

17. The soils in the study area are mainly composed of the following great soil groups and are shown in Fig. 1:

(Unit: ha in Gross)

Great Soil Groups	NCRB (Systems F,H,IH,MH,I,M)	NWDZ (NW-1)	Total
1. Alluvial Soils	45,800 (11.8%)	5,500 (15.4%)	51,300 (12.1%)
2. Old Alluvial	0 (0.0%)	500 (1.4%)	500 (0.1%)
3. Solonetz	3,900 (1.0%)	0 (0.0%)	3,900 (0.9%)
4. Low Humic Gley Soils (LHG)	83,900 (21.6%)	6,000 (16.9%)	89,900 (21.2%)
5. Reddish Brown Earth (RBE)	234,900 (60.3%)	21,500 (60.4%)	256,400 (60.4%)
6. Red Yellow Podzolic Soils	100 (0.03%)	0 (0.0%)	100 (0.02%)
7. Grumusols	200 (0.1%)	0 (0.0%)	200 (0.1%)
8. Lithosols (Rock outcrop)	16,200 (4.2%)	1,200 (3.4%)	17,400 (4.1%)
9. Marsh/Tank	3,800 (1.0%)	900 (2.5%)	4,700 (1.1%)
Total	388,800 (100%)	35,600 (100%)	424,400 (100%)

RBE soils generally extend over the undulating plains with gentle slopes of less than 4% and are well drained. Alluvial soils are well to moderately well drained soils, occurring on river levees and flood plains. Except for Solonetz and Lithosols, the soils in the study area are generally suitable for agriculture.

18. The climate in the study area is characterized by tropical monsoons with a dry (Yala) season from April to September and a rainy (Maha) season from October to March as shown in Fig. 2. The average annual rainfall ranges from about 1,300 mm to 2,100 mm of which about 70 to 77% falls during the rainy season. The monthly mean temperatures show rather little variation throughout the year, ranging from 25°C to 30°C as shown in Fig. 3. Annual mean pan evaporation ranges between 1,587 mm at Alutharama and 2,184 mm at Kantalai. The monthly mean relative humidity ranges between 60% and 90%. The daily mean sunshine hours vary from 6.3 to 7.8 hours.

19. The annual natural runoff of the Mahaweli Ganga at Manampitiya located at about 65 km upstream from its estuary is estimated to be 8,330 MCM for the 37 years from 1949 to 1986.

20. The population in the study area was estimated at approximately 4.1 million in 1981. The population in NCRB and NWDZ was estimated at 349×10^3 in 1981. The labour force in these areas was estimated at 120×10^3 in the same year, of which about 73×10^3 were engaged in the agricultural sector. The average population growth rate during ten years between the census years of 1971 and 1981 was 2.7% according to the District's base data, while the growth rate in Sri Lanka was 1.6% during the same period. This

high growth was caused by immigration from outside, since the natural rate of increase was about 2.0%.

21. Paddy is a main crop in NCRB and NWDZ. There are two cropping seasons for paddy production, Maha and Yala. In Maha, 97% of irrigated fields and 3% of rainfed fields were cultivated for paddy production, while in Yala only 26% of irrigated fields and less than 1% of rainfed fields were planted to paddy due to insufficient irrigation water. In irrigated fields, 3% in Maha and 26% in Yala were cultivated for upland crop production. Though 72% (45,900 ha) of rainfed fields were planted to upland crops in Maha, only 10% was utilized for crop production in Yala. The following table shows cropping areas as well as intensity:

Item	Net Area (ha)	Cultivated Area (ha)					Cropping Intensity
		Maha		Yala		Total	
		Paddy	Upland	Paddy	Upland		
Irrigated	69,600	67,500	2,100	18,300	18,000	105,900	1.52
Rainfed	63,500*	1,300	45,900	400	6,600	54,200	0.85
Total	133,100	68,800	48,000	18,700	24,600	160,100	1.20

* includes fallow area.

System H recorded the highest intensity of 1.65 among all Systems in the study area, while System M is the lowest with 0.71. The present cropping patterns in the various Systems are shown in Fig. 4. Chilli is the second most important irrigated crop in the study area. Chilli is cultivated as a rainfed crop in Maha and also as an irrigated crop during Yala.

22. More than 50% of the land is prepared by tractors in the less populated areas as in Systems H, IH, MH and I. In the other areas as in System F and NWDZ where fodder grasses are more available, more than 50% of the land is prepared by buffaloes. Manual ploughing is practiced in very limited areas. Except in System F, more than 65% of the paddy fields are directly sown. Direct sowing is practiced by broadcasting in most cases. In the transplanting method, random transplanting is predominant. In association with direct sowing, chemical weed control is widely practiced in the study area.

23. Paddy yields in Maha range between 2.8 ton/ha and 4.3 ton/ha under irrigation and from 1.5 ton/ha to 3.1 ton/ha under rainfed conditions, while in Yala they are between 2.0 ton/ha and 2.8 ton/ha under irrigation and from 1.8 ton/ha to 2.4 ton/ha under rainfed conditions as shown in Fig. 7. Dry chilli yields under irrigation are

between 0.5 ton/ha and 1.1 ton/ha in Maha and increase from 1.2 ton/ha to 1.5 ton/ha in Yala. Pulses like cowpea, green gram, black gram, soybean and groundnut are in most cases grown under rainfed conditions with yields from 0.5 ton/ha to 1.5 ton/ha. Sesame is mainly cultivated in the rainfed fields with yields from 0.4 ton/ha to 0.7 ton/ha. Onion is grown under irrigation and its average yields range between about 0.9 ton/ha and 8.4 ton/ha. However, since onion is a "high-risk" product, it is cultivated in quite limited irrigated fields in the study area. The average annual crops production in the study area is about 306×10^3 tons of paddy, 12.7×10^3 tons of chillis, 34.4×10^3 tons of pulses and 13.7×10^3 tons of maize respectively.

24. The CEB power supply system is predominantly dependent on hydropower, especially hydropower in the Mahaweli power complex as seen in the following table:

Item	Total Installed Capacity (MW)	Mean Annual Energy (GWh)		
		Firm	Secondary	Total
1. Hydropower				
- Mahaweli System	611 (55%)	1,234	876	2,110 (43%)
- Other System	305 (27%)	1,304	268	1,572 (32%)
2. Thermal Power	200 (18%)	1,265	-	1,265 (26%)
Total	1,116 (100%)	3,803	1,144	4,947 (100%)

The Mahaweli power complex totals 611 MW in installed capacity comprising Ukuwela (38 MW), Bowatenna (40 MW), Victoria (210 MW), Randenigala (122 MW) and Kotmale (201 MW). Moreover, the Rantembe hydropower scheme (50 MW) is under construction and will be completed in 1990.

4. PROSPECTIVE AGRICULTURAL AND WATER RESOURCES DEVELOPMENT

25. The available water resources in the study area consist mainly of the Mahaweli Ganga including its tributaries, and runoffs from the catchment areas of potential irrigable areas. Runoffs of the Mahaweli river basin and the potential irrigable areas are estimated at 8,330 MCM at Manampitiya and 1,580 MCM, respectively.

26. Food demand for national consumption in the year 2020 is estimated on the basis of both the projected population and the per capita consumption of food. Besides, exports of food crops are expected to grow at the same level as other major Asian countries. Thus, the total requirement of major food crops in the country is estimated as the sum of both domestic consumption and exports, and aggregated as follows: $4{,}220 \times 10^3$ tons of paddy, 89×10^3 tons of chilli, 131×10^3 tons of onion, 235×10^3 tons of pulses and nuts, 101×10^3 tons of maize, 25×10^3 tons of cashew (Kernels), and $2{,}294 \times 10^3$ tons of vegetables and fruits. In order to meet such requirement, the project area would play an important role of main food supplier in consideration of potentiality of both land and water resources.

27. Future cropping patterns under with-project condition are made for most-likely grown crops in the project area. The crops in irrigated fields are grouped into 6 categories, i.e., paddy, chilli, pulses, maize, onion and others. Cropping calenders for these crops follow existing typical cropping calendars. The future cropping calendar proposed for with-project condition is shown in Fig. 5.

28. Crop yields will increase year by year through improved farming practices. The following table shows the anticipated yields of proposed crops:

(Unit: ton/ha)

Crop			Present Condition	Without Project	With Project
1.	Paddy				
	Irrigated	Maha	2.8 - 3.6	3.5	5.5
		Maha (System H)	4.3	4.5	5.5
		Yala	2.0 - 2.8	3.0	5.0
	Rainfed	Maha	1.5 - 3.1	2.5	-
2.	Chilli		0.5 - 1.5	1.5	1.9
3.	Onion		0.9 - 8.4	10.0	15.0
4.	Pulses (Green gram)		0.5 - 1.5	1.0	1.5
5.	Maize		0.9 - 1.5	2.0	3.5

29. After implementation of the proposed agricultural development in the study area, a considerable increase of agricultural production can be expected. The following table shows the anticipated production of the crop for the two development cases:

(Unit: 10^3 tons)

Crop	NCRB		NCRB + NWDZ		Production Target in Study Area
	Present Condition	W/Project (161,600 ha)	Present Condition	W/Project (174,850 ha)	
Paddy	293	1,253	306	1,339	1,350
Chilli	13	37	13	38	36
Maize	14	24	14	31	32
Onion	-	50	-	54	52
Cashew (Kernels)	-	4.5	-	4.5	10

30. The irrigation water demand for existing, on-going, committed projects and potential irrigable area was calculated on monthly basis for 37 years from 1949 to 1986. Present overall irrigation efficiency was evaluated at 50% for Systems E and C, and 56% for other systems. The irrigation demand at the matured stage in the year 2020 was calculated by adopting an improved overall irrigation efficiency of 60%, since GOSL forces rehabilitation of existing projects to improve farming practices and to save water through proper water management. The irrigation demand calculated for each system and scheme is tabulated below:

System or Scheme	Total Irrigation Area (ha)	Average Annual Irrigation Water Demand	
		Present Efficiency (MCM)	Improved Efficiency (MCM)
A	20,300	581	542
B	42,000	1,328	1,239
C	24,500	635	533
D1	40,500	938	875
D2	10,100	223	208
E	6,100	165	138
F	1,900	58	54
G	5,400	147	137
H	42,400	923*	1,087
IH	4,700	122	114
MH	16,300	475	444
M	25,000	692	646
I	53,300	1,507	1,406
J	21,800	542	506
K	9,000	225	210
L	34,600	885	826
NWDZ	13,250	314	293
Total	371,150	9,760	9,258

* Cropping Intensity = 1.65

31. There are several transbasin diversion plans from the Mahaweli Ganga to NCRB, NWDZ and SEDZ which were studied by UNDP/FAO, subsequently in ISS and TDS. The increase of Polgolla diversion to the Amban Ganga will decrease hydropower generation at the existing hydropower stations on the Mahaweli main stream. However, this increased diversion will minimize losses of energy consumption at the pump station which will be necessary to irrigate the NCRB area. In order to establish an overall development plan, the following development plans of water conveyance are conceived for agricultural development in the NCRB and NWDZ .

1) NCRB Area

The following three alternatives as shown in Figs. 8 to 10 are considered:

	Conveyance System	Merit or Demerit
A:	New Alternative Plan (See Fig. 8)	
	Minipe - Minipe New LB canal - Minneriya tank - Pump station - NCP canal - NCRB area	Lowest pumping cost (40 m head) is required, but the canal has to pass through the National Park.
B:	Electrowatt (TDS) Solution Modified (See Fig. 9)	
	Minipe - Hettipola Oya (Pump Station) - Kalu Ganga dam - Elahera - NCP canal - NCRB area	Existing Minipe LB canal can be utilized but huge pumping cost (80 m head) is required. No disturbance to the National Park is expected.
C:	UNDP/FAO (ISS) Solution revised by NEDECO (See Fig. 10)	
	Minipe LB canal - Angamedilla - Kaudula - Kantalai Angamedilla - Pump station - NCP canal - NCRB area	Medium pumping cost (65 m head) is required, but the canal proposed still has to pass through the National Park.

2) NWDZ Area

In TDS, six alternative conveyance routes from the Mahaweli Ganga to NWDZ were studied. Among these six routes, it was concluded that irrigation water in NWDZ would be diverted through the existing Ukuwela power station and discharged into the Sudu Ganga, and then into the Bowatenna reservoir. From Bowatenna, water will be supplied through a second irrigation tunnel, being parallel to the existing irrigation tunnel. Diverted water is then impounded in the Kalawewa tank and supplied to NWDZ through the expanded Kalawewa LB canal.

32. CEB established the "Long Range Generation Expansion Plan - 1987" covering upto the year 2002. According to the Expansion Plan - 1987, the power demand will increase at an annual rates of 8.2% in 1988-90, 10% in 1991-1995, 9.5% in 1996-2002 and the peak demand and annual generation will exceed 2,000 MW and 10,000 GWh in 2002, respectively. The following table shows the projection of power generation and demand upto 2020.

Year	Peak Demand (MW)	Generation (GWh)	Growth Rate (%)	Load Factor (%)
1988	593	2,990	-	57.5
1990	682	3,500	8.2	58.5
1995	1,090	5,630	10.0	59.0
2000	1,710	8,860	9.6	59.0
2002	2,020	10,430	8.5	59.0
2005	2,580	13,320	8.5	59.0
2010	3,780	19,580	8.5	59.0
2015	5,440	28,110	7.5	59.0
2020	7,630	39,420	7.0	59.0

33. The forest area in the lower Mahaweli basin represents one of the richest and most diversified wildlife habitats in the dry zone of the country. Within the study area several National Parks and wildlife reserves have been demarcated as shown in Fig. 11. The Parks and reserves being created are the Maduru Oya National Park, Somawathiya National Park, Flood Plain National Park, Trikonamadu Nature Reserve, Minneriya-Giritale Nature Reserve, Hurulu Forests Reserve, Ritigala Strict Natural Reserve, etc. In formulating the development programme, careful consideration had to be given to environment assessments of impacts in order to minimize adverse effects. In this connection, GOSL commissioned a comprehensive environment impact assessment which was conducted for the entire river basin. An action plan for management of the Mahaweli environment is being pursued by the relevant Government Agencies. Progress has been notable in relation to wildlife and forest conservation.

34. The Mahaweli river basin is divided into 21 sub-basins, in respect of existing and potential dam and intake sites, and the existing and potential irrigable areas are divided into 51 sub-basins. In the simulation model, a certain simplification for irrigation systems was introduced in representing irrigation systems as shown in Fig. 12 by exclusion of reservoirs and tanks with active storage of less than 5 MCM. For the water balance study, operation methods of the existing and proposed multipurpose dams employed variable draft operation to allow for downstream water demand with

retention of present water rights. The simulation runs were performed to evaluate rule curves to minimize diversion demands from the main system reservoirs and to make maximum use of local inflows, i.e. to minimize spillout from the various tanks, while at the same time, maintaining "allowable" irrigation reliability (as defined in next paragraph).

35. The water balance for two alternative cases, 875 MCM and 1,280 MCM diversion at Polgolla, was carried out by using the water balance simulation model and was based on allowable water deficit criteria for irrigation project, i.e. 80% probability in occurrence and 90% probability in quantity as adopted by ID. In this calculation, river maintenance flow was estimated at 15 m^3/sec at the estuary. The system flow diagrams under the present and future conditions are illustrated in Figs. 14 and 15. In case of 875 MCM diversion, the maximum possible irrigable area of about 304,000 ha including the existing schemes under AMDP could be irrigated with reliable water supply. In case of 1,280 MCM diversion, the irrigation deficit ratio shows a little higher figure than that in the case of 875 MCM, and annual energy output especially on the existing hydropower stations would decrease substantially on the Mahaweli river system.

36. According to the result of the water balance study, about 650 to 760 MCM depending on the Polgolla diversion is required to be pumped up to the NCRB area in Case A (new alternative plan). Under the 875 MCM diversion policy, increased diversion water from the Bowatenna reservoir to System H and the NWDZ area would result in substantial negative power generation at the Bowatenna power station as well as the Moragahakanda power station proposed, although about 1,400 to 1,500 MCM per annum could be diverted through the newly proposed Minipe LB canal to the Minneriya tank, depending on the transbasin diversion system chosen and the Polgolla diversion policy adopted.

37. Following two tables summarize the results of the water balance study:

Item	Unit	Present Polgolla Diversion 875 MCM — Alternative Plan: Case A145	Case B151	Case C145	Present Condition Case D
1. Combination of Irrigation Areas		AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP - -
2. Irrigation Area*	ha	323,750	323,750	323,750	200,300
3. Pump Station					
- Pumping volume	MCM	761	1,515	896	-
- Energy consumption	GWh	146	498	219	-
4. Energy Output					
- Existing hydropower	GWh	2,138	2,020	2,017	2,264
- Proposed hydropower	GWh	1,808	1,824	1,824	-
- Total	GWh	3,946	3,844	3,841	2,264

* Including 20,000 ha of non-irrigated cashew land.

Item	Unit	Present Diversion Policy 875MCM: A118	A145	Alternative Diversion Policy 1,280MCM: A209	A242
1. Combination of Irrigation Areas		AMDP NCRB -	AMDP NCRB NWDZ	AMDP NCRB -	AMDP NCRB NWDZ
2. Irrigation Area*	ha	310,500	323,750	310,500	323,750
3. Pump Station					
- Pumping volume	MCM	653	761	360	435
- Energy consumption	GWh	125	146	70	84
4. Energy Output					
- Existing hydropower	GWh	2,221	2,138	1,967	1,998
- Proposed hydropower	GWh	1,818	1,808	1,866	1,868
- Total	GWh	4,039	3,946	3,833	3,866

* Including 20,000 ha of non-irrigated cashew land.

5. DEVELOPMENT FACILITIES AND COST ESTIMATES

38. For the water resources development of the entire Mahaweli Ganga basin, eight (8) multipurpose dams and power schemes are conceived as shown in Fig. 13. The following table shows principal features and construction costs estimated:

Item	Unit	Wata-wala	Ula-pane	Cale-donia	Talawa-kele	Kotmale Extension	Upper Uma (S-1000)	Lower Uma (S-500)	Wewa tenna	Sudu
River		Maha-weli	Maha-weli	Kotmale	Kotmale	Kotmale	Uma Oya	Uma Oya	Badulu Oya	Sudu Ganga
Catchment area	(km^2)	69	220	235	363	562	421	622	267	305
Annual runoff	(MCM)	119	381	412	636	984	354	523	207	1,144
Dam type		Concrete	Rockfill	Concrete	Concrete	Rockfill	Rockfill	Concrete	Rockfill	Rockfill
Dam height	(m)	60	70	70	20	115	90	25	80	55
Net storage volume	(MCM)	17.7	150	30	2	383	60	1.5	90	100
Power station										
Rated head	(m)	179	109	144	468	233	434	251	114	47
Installed capacity	(MW)	18	44	44	204	39*	150	96	22	45
Energy output	(GWh)	49	91	135	674	59*	342	310	69	122
Construction cost	(US$10^6)	44	117	156	216	237	249	228	86	83

* shows only incremental value.

39. Construction costs of transbasin canals, irrigation tanks, main and branch canals, and on-farm development for the various cases described in this Report are estimated. The following table shows principal features and construction cost estimated:

Item	Unit	Polgolla Diversion					
		875 MCM				1,280 MCM	
		A118	A145	B151	C145	A209	A242
1. Combination of Irrigation Areas		AMDP NCRB -	AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB -	AMDP NCRB NWDZ
2. Irrigation Area*	10^3 ha	310.5	323.8	323.8	323.8	310.5	323.8
3. Development Facilities							
- NCP Canal							
. Kalu Ganga-Elahera (17 km)	m^3/s	15	15	80	15	15	15
. Elahera-Kiri Oya (42 km)	m^3/s	60	55	90	45/90	75	70
. Kiri Oya - Tammannewa (58 km)	m^3/s	----	----	90/60/40		----	----
- Minipe LB Canal							
. Minipe Pump Station	m^3/s	60	65	65	65	55	55
	km	113	113	75	75	113	113
. Angamedilla - Kantalai (40/20 m^3/s)	km	-	-	-	70	-	-
- Pump Station							
. Design capacity	m^3/s	30	35	65	45	15	20
. Rated head	m	52	52	88	66	52	52
. Required capacity	MW	23	27	84	44	12	15
- Agricultural Development							
. New irrigation area	10^3 ha	77.5	88.2	88.2	88.2	77.5	88.2
. Non-irrigated cashew land	10^3 ha	20.0	20.0	20.0	20.0	20.0	20.0
. Rehabilitation	10^3 ha	64.1	66.7	66.7	66.7	64.1	66.7
Total	10^3 ha	161.6	174.9	174.9	174.9	161.6	174.9
4. Construction Cost							
- NCRB	US$10^6	1,352	1,375	1,587	1,502	1,295	1,315
- NWDZ	US$10^6	-	121	121	121	-	121
Total	US$10^6	1,352	1,496	1,708	1,623	1,295	1,436

* Including 20,000 ha of non-irrigated cashew land.

6. BENEFITS

40. Agricultural benefits will accrue from incremental production by the balance of the "with" and "without" project conditions. The value of total production is estimated as a product of crop budget and production of each crop in the project area. Typical crop budgets are estimated on the basis of the recommended farming practices. Economic prices of farm inputs and products of international tradable goods were estimated by referring to the IBRD price forecast. Incremental agricultural benefits accruing annually from the project were estimated as follows:

(Unit: Rs. 10^6)

Crop	NCRB* (F,H,IH,MH,I &M)	NWDZ (NW-1)	Total
Paddy	3,672	284	3,956
Chilli	425	22	447
Pulses	31	32	63
Maize	39	13	52
Onion	236	23	259
Cashew	397	0	397
Others	62	20	82
Total	4,862	394	5,256
Total Equivalent to US$$10^6$	150	12	162

* Including the incremental benefits in Systems H, IH and MH.

41. Annual power and incremental benefits obtainable by the downstream power stations for the respective schemes were estimated as shown in the following table:

(Unit: US$$10^6$)

Scheme	Total Annual Benefit	Scheme	Total Annual Benefit
1. Watawala	5.52	6. Upper Uma Oya (Scheme - 1000)	31.95
2. Ulapane	13.83	7. Lower Uma Oya (Scheme - 500)	26.14
3. Caledonia	15.54	8. Wewatenna	5.24
4. Talawakele	52.75	9. Sudu Ganga	9.36
5. Kotmale Extension	20.91		

7. COMPARISON OF OVERALL AGRICULTURAL DEVELOPMENT PLANS

42. A comparison of three alternative transbasin conveyance systems and irrigable areas in NCRB and NWDZ under the present Polgolla diversion policy of 875 MCM was carried out based on the results of the water balance simulation and costs and benefits. The annual equivalent costs of construction for the various cases were calculated at a discount rate of 8% per annum. The following table shows in summary a comparison of the three cases A, B and C:

Item	Unit	Alternative Plan		
		Case A145	Case B151	Case C145
1. Combination of Irrigation Areas		AMDP NCRB NWDZ	AMDP NCRB NWDZ	AMDP NCRB NWDZ
2. Irrigation Area*1	ha	323,750	323,750	323,750
3. Annual Benefits	US$$10^6$	155.6	149.8	149.7
4. Annual Costs*2	US$$10^6$	135.6	176.2	151.1
5. Economic Comparison				
- B/C	-	1.15	0.85	0.99
- B-C	US$$10^6$	20.0	-26.4	-1.4

*1 Including 20,000 ha of non-irrigated cashew land.
*2 A discount rate of 8% was applied. No consideration was given to the implementation schedule and the built-up period of the scheme.

It is very clear from the above table that the economic viability in each case is greatly affected by the heavy energy consumption for pumping. Therefore the optimum solution for transbasin diversion must minimize energy consumption for pumping, and at the same time keep irrigated agriculture at a maximum. Accordingly Case A proposed in this study is recommended as the optimum plan in terms of B-C and B/C.

43. Two alternative development plans with Case A conveyance system were then studied under the present Polgolla diversion of 875 MCM and the possible alternative diversion of 1,280 MCM adopted for the Moragahakanda Project in 1979. This comparison may be summarized as follows:

Item	Unit	Present Diversion Policy 875 MCM		Alternative Diversion Policy 1,280 MCM	
		A118	A145	A209	A242
1. Combination of Irrigation Areas		AMDP NCRB -	AMDP NCRB NWDZ	AMDP NCRB -	AMDP NCRB NWDZ
2. Irrigation Area*1	ha	310,500	323,750	310,500	323,750
3. Annual Benefit	US$$10^6$	147.5	154.7	133.7	147.4
4. Annual Costs*2	US$$10^6$	122.1	135.6	113.3	126.3
5. Economic Comparison					
- B/C	-	1.21	1.14	1.18	1.17
- B-C	US$$10^6$	25.4	19.1	20.4	21.1

*1 Including 20,000 ha of non-irrigated cashew land.
*2 A discount rate of 8% was adopted. No consideration was given to the implementation schedule and the built-up period of the schemes.

It will be seen from the above that developing only NCRB, as in Case A118, is the most economical plan in terms of B-C and B/C among the four alternatives.

44. Economic analysis was made based on the estimated costs and benefits of each hydropower scheme, and the benefit-cost ratios, and ranking of each scheme were estimated as follows:

Scheme	B/C*	EIRR	Ranking
1. Watawala	1.25	9.8%	4
2. Ulapane	1.21	9.6%	5
3. Caledonia	1.55	11.9%	2
4. Talawakele	1.99	15.1%	1
5. Kotmale Extension	0.90	7.0%	8
6. Upper Uma Oya (Scheme-1000)	1.31	10.3%	3
7. Lower Uma Oya (Scheme-500)	1.17	9.2%	6
8. Wewatenna	0.62	4.4%	9
9. Sudu Ganga	1.14	8.6%	7

* Discount rate = 10%. No consideration was given to the implementation schedule and the built-up period of the schemes.

It will be seen from above that the Caledonia, Talawakele, Upper Uma Oya (Scheme-1000) are more economically promising than the other six schemes. The Wewatenna scheme has the lowest ranking of the above schemes, and will not be economical at the present value of hydropower benefit. The Wewatenna scheme is deleted from this study, but should be re-examined in future studies in connection with the agricultural development of the SEDZ area.

The Feasibility Study on Upper Kotmale Hydroelectric Power Development was carried out by JICA in 1987. The above comparison shows that the Upper Kotmale project including Caledonia and Talawakele schemes is the most attractive and economically viable project. Implementation of these schemes is imperative because in rapid increase in electric power demand as shown in Fig. 19.

45. As shown in the above table, the Kotmale Extension and the Sudu Ganga schemes received the lowest and 2nd lowest rankings in the proposed Master Plan. These schemes would provide certain agricultural benefits to the NCRB area, however these were not quantified in this study. In the final stages of development of the NCRB area, the Sudu Ganga scheme will play an important role in minimizing the differences between available heads for hydropower generation in the Mahaweli main stream and the Amban Ganga. Therefore, it is recommended that at the final stage of development in NCRB, all possibilities should be reassessed, taking into account the possibility in increasing the Polgolla diversion to the Amban Ganga, and implementation of the Minneriya pump station and the Sudu Ganga hydropower scheme. It will also be valuable to review in detail the future maximum utilization of valuable hydropower potential of the Kotmale Extension scheme.

8. STAGEWISE DEVELOPMENT

46. Agricultural land development is recommended in NCRB as a result of economic comparison, water balance simulation, and social considerations. Development of NCRB is too large to be developed as one package. A stagewise implementation programme is necessary to minimize technical and socio-economic constraints. The proposed irrigation project in NCRB would therefore be divided into three packages as illustrated in Fig. 16 as a basis for a sequential implementation programme for overall water resources development as presented in Figs. 17, 18 and 19. A summary of the respective packages is given as follows:

Package No.	Development Category	Beneficiary Area	Systems or Schemes
Package-1	Joint Facilities	-	Kalu Ganga dam NCP Canal (Kalu Ganga-Huruluwewa)
	New Irrigation Area	23,900 ha	System F, Yan Oya (M) Huruluwewa Extension (MH)
	Cashew Land	10,000 ha	Huruluwewa Extension (MH)
	Rehabilitation	25,500 ha	Huruluwewa (MH) A part of System H
Package-2	Joint Facilities	-	NCP canal (Huruluwewa-Mahakandarama) Minipe LB Canal (Minipe -Minneriya Tank)
	New Irrigation Area	26,600 ha	Horowupotanna (M) Malwatu (I), Mahakandarama Extension (I)
	Rehabilitation	38,600 ha	System IH, A part of System H Mahakandarama (I), Malwatu Oya (I)
Package-3	Joint Facilities	-	NCP Canal (Mahakandarama-Tammannewa) Minneriya Pump Station
	New Irrigation Area	27,000 ha	Tammannewa (I)
	Cashew Land	10,000 ha	System I

47. The following is a summary of investment costs, economic costs, benefit and EIRR for the three packages:

Package	Area (ha)	Investment Cost (US$10^6)	Allocated Economic Cost (US$10^6)	Agricultural Benefit (US$10^6)	EIRR (%)
Package-1	59,400	543.2	411.1	50.9	9.3
Package-2	65,200	435.8	507.8	60.4	9.2
Package-3	37,000	373.0	364.5	39.2	8.0
Whole Project	161,600	1,352.0	1,283.4	150.5	8.9

48. In addition to the primary direct benefits, substantial secondary direct benefits will stem from the project outputs and be induced by project inputs, and favourable intangible socio-economic impacts are expected from implementation of the proposed project, such as foreign exchange savings, increased, employment opportunities, improvement in living standards, etc. Further implementation of the projects would increase inland fishery production and promote agro-based industries through introduction of diversified crops and various kind of fruits.

9. ACTION PLAN

49. Continued Agricultural Development for Rice Self-sufficiency

Although self-sufficiency in rice in Sri Lanka could be attained in the near future with proper water management and introduction of improved farming practices, constant development of agriculture, particularly for increased food production will continue to be essential, since the population of Sri Lanka is expected to increase as much as 1.5 times from 16.4 million in 1987 to about 24 million by the year 2020 as shown in Figs. 6 and 18.

50. Implementation of the Moragahakanda Agricultural Development Project

GOSL is going to complete the principal components of AMDP except System A and the Moragahakanda Development Project. In 1986, GOSL decided to take up the Moragahakanda project by maintaining continuously strong policy to complete AMDP and requested GOJ to update the Feasibility Study prepared in 1979. Updated Feasibility Study is ready for its implementation. The Moragahakanda dam plays an important role in supplying stable irrigation water to the existing and extension areas in System D. Moreover, since the Moragahakanda dam is of paramount importance for agricultural development in NCRB as recommended in this Master Plan, it is strongly recommended that the Moragahakanda project should be commenced at the earliest possible opportunity. Since the Moragahakanda dam is of paramount importance for development in NCRB, it is strongly recommended that the Moragahakanda project be also commenced at the earliest possible opportunity.

51. For Early Implementation of NCRB Development Package-I Mapping of Irrigation Areas and Preparations for Feasibility Study

Early implementation of Package-1, as proposed in the preceding Section, is necessary to ensure satisfactory achievement of the contemplated overall development target by the year 2020, and attainment of the socio-economic target. For Package-1, the necessary actions are to prepare Terms of Reference for a feasibility study. Moreover, budgetary arrangements for the following are essential:

- Topographic mapping of the 49,300 ha net irrigation area at a scale of 1/5,000 with a contour interval of 0.5 m (gross mapping area of about 150,000 ha) in Systems MH and M,

- Topographic mapping at a scale of 1/500 at irrigation tank sites,

- Topographic mapping at a scale of 1/5,000 with contour lines of 0.5 m along the diversion canal between the Kalu Ganga and Elahera, and along the NCP canal down to the Huruluwewa, and

- Core drilling at the Kalu Ganga dam site (500 m), and irrigation tank site (300 m x 2 site), and along the tunnel section of 7.2 km (30 m x 30 = 900 m)

Topographic maps in the irrigation areas and along the transbasin conveyance canal (NCP canal) mentioned above should be prepared in advance of the feasibility study.

52. Implementation of the Upper Kotmale Project (Talawakele and Caledonia Schemes)

In view of rapid expansion of power demand in Sri Lanka as shown in Fig. 19, power development by hydro and thermal power plants is urgently required. It is also strongly recommended that necessary and prompt action be taken for implementation of the Upper Kotmale project consisting of Talawakele and Caledonia schemes.

FIGURES

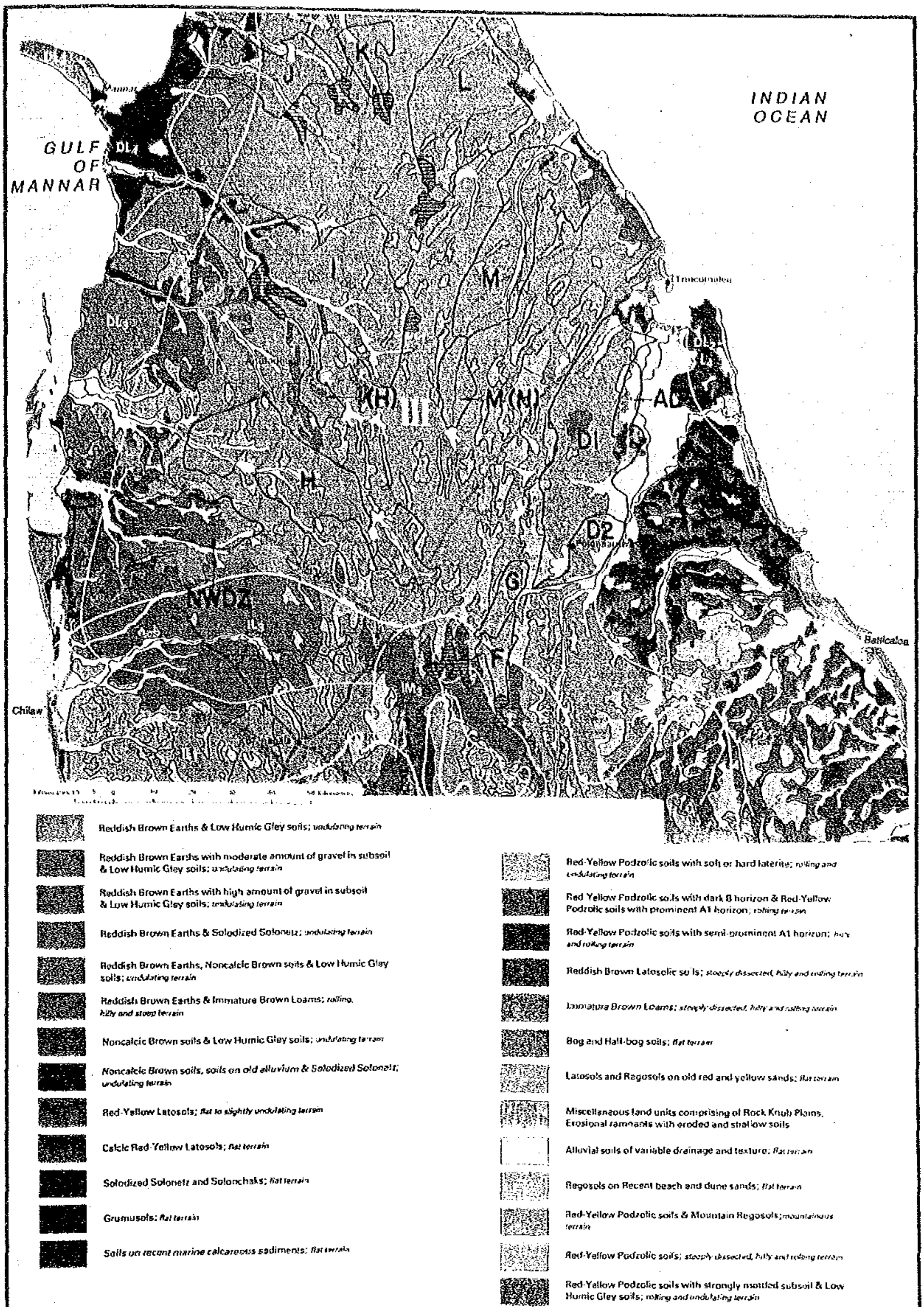

Fig. 1 National Soil Classification Map

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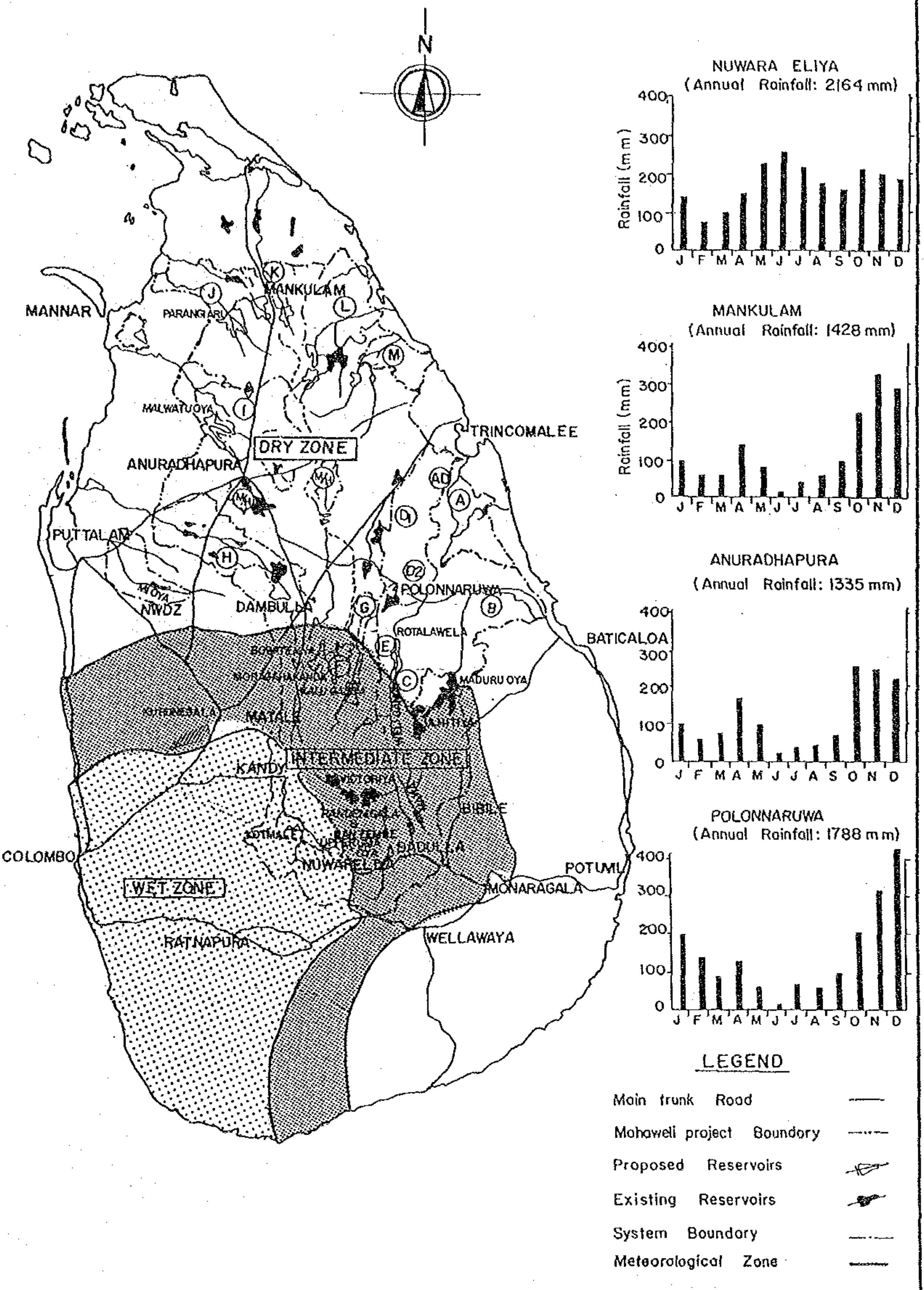

Fig. 2 Meteorological Zone in Sri Lanka and Average Monthly Rainfall in the Study Area

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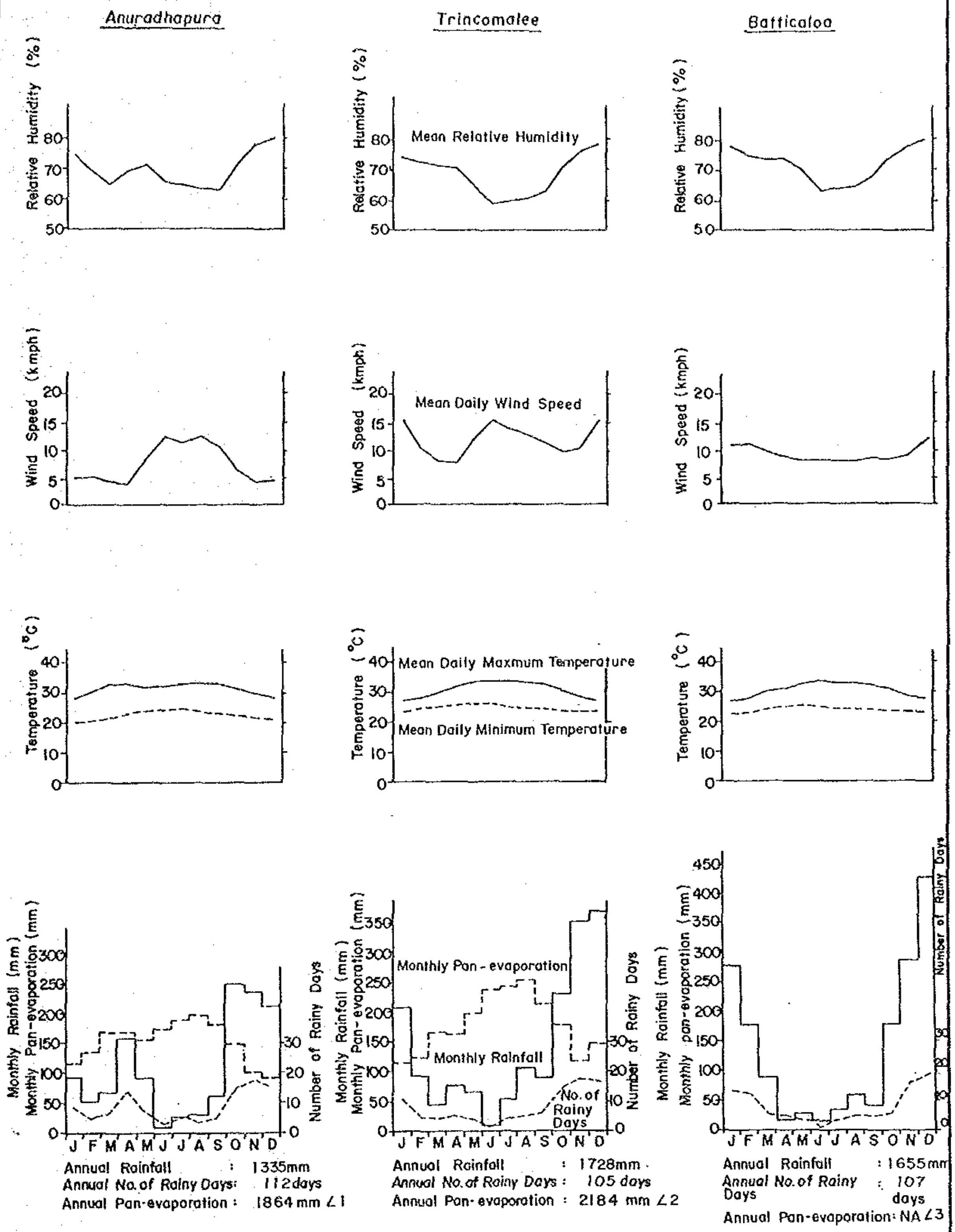

Remarks: ∠1 Data at Maha Illuppallama
∠2 Data at Kantalai
∠3 No data available

Fig. 3 Mean Annual Climatological Pattern in the Study Area

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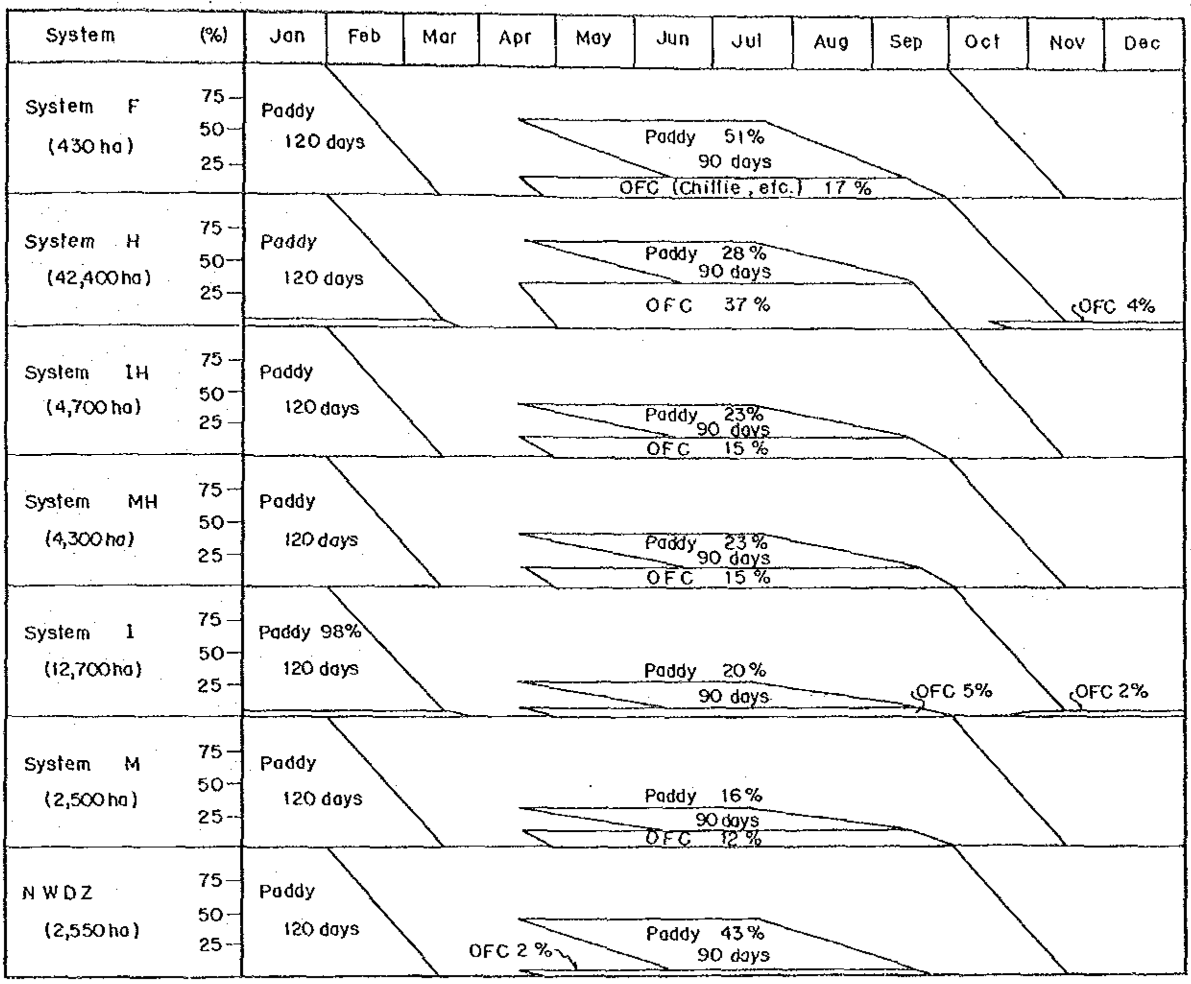
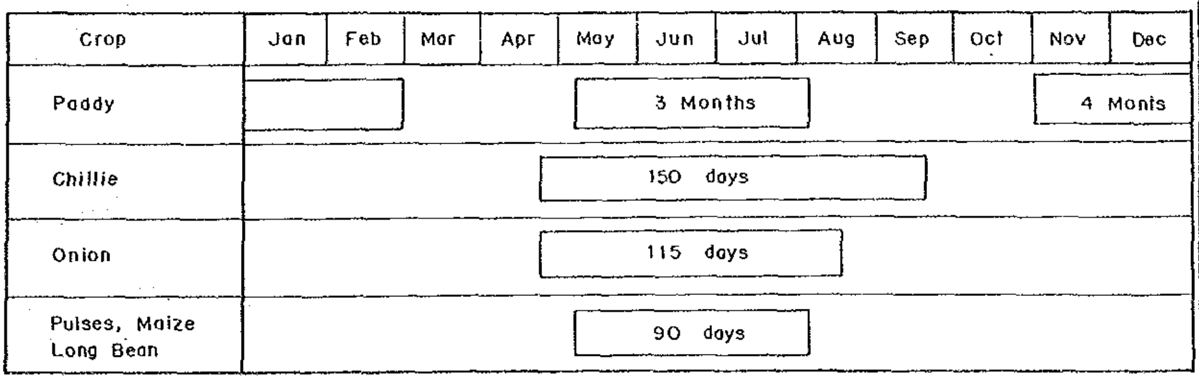


Fig. 4 Present Cropping Pattern in Irrigated Field



Remark : OFC = Other Field Crop

Fig. 5 Future Cropping Calendar for Irrigated Crops

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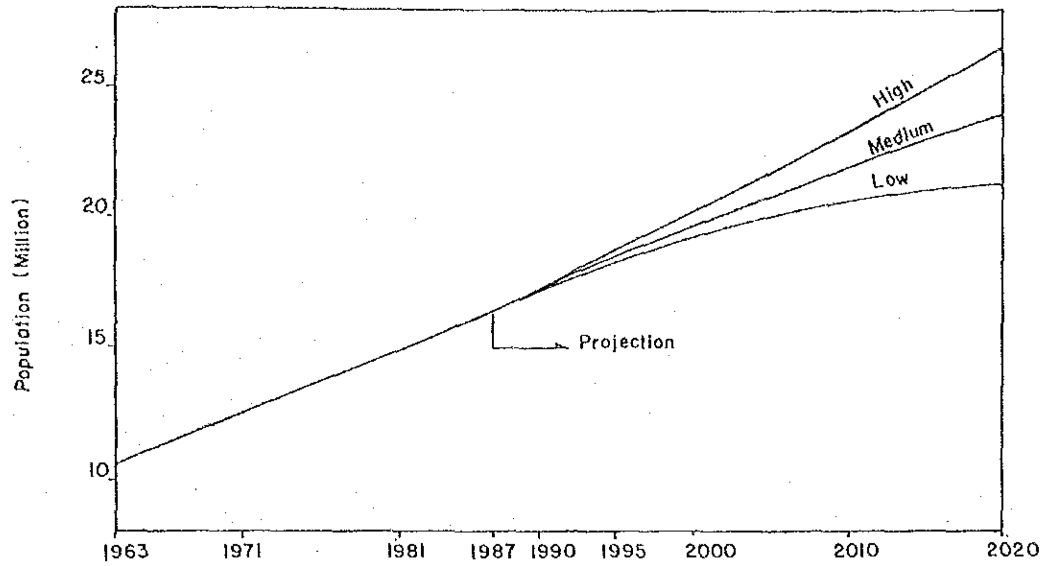

Fig. 6 Population Growth

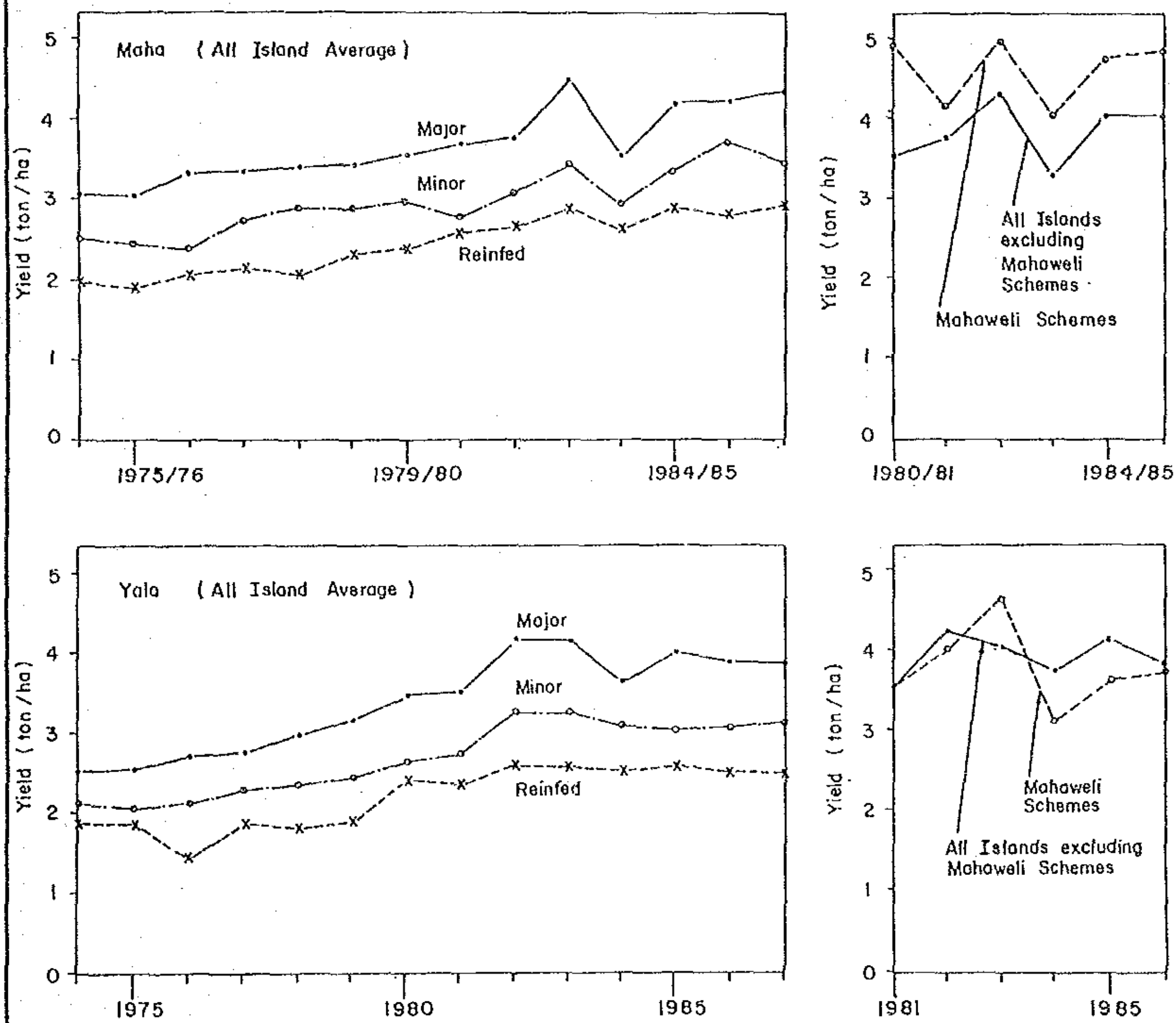

Fig. 7 Trend of Average Paddy Yield by Scheme in Sri Lanka:1974-1987

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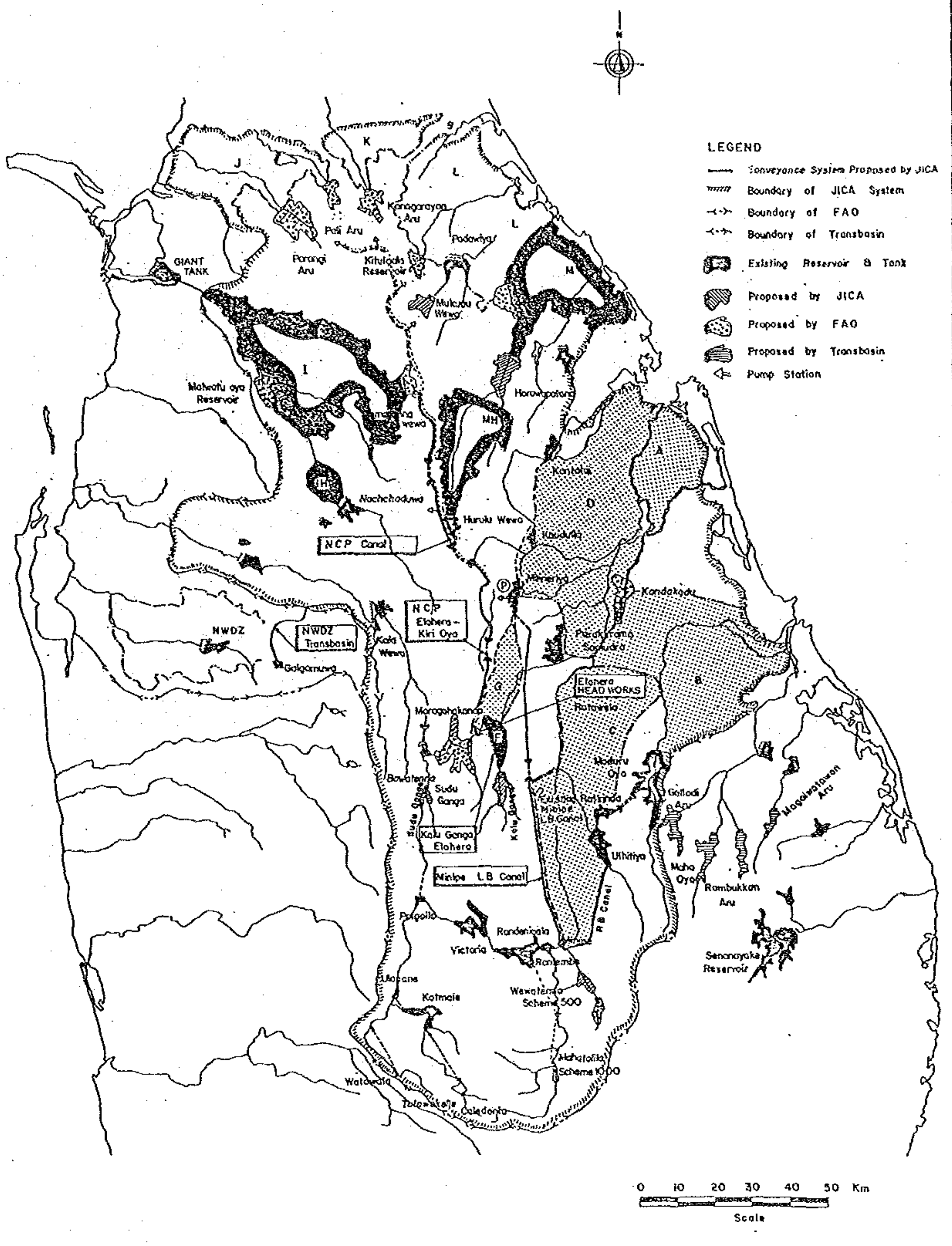

Fig. 8 Transbasin Conveyance System
(Case-A)

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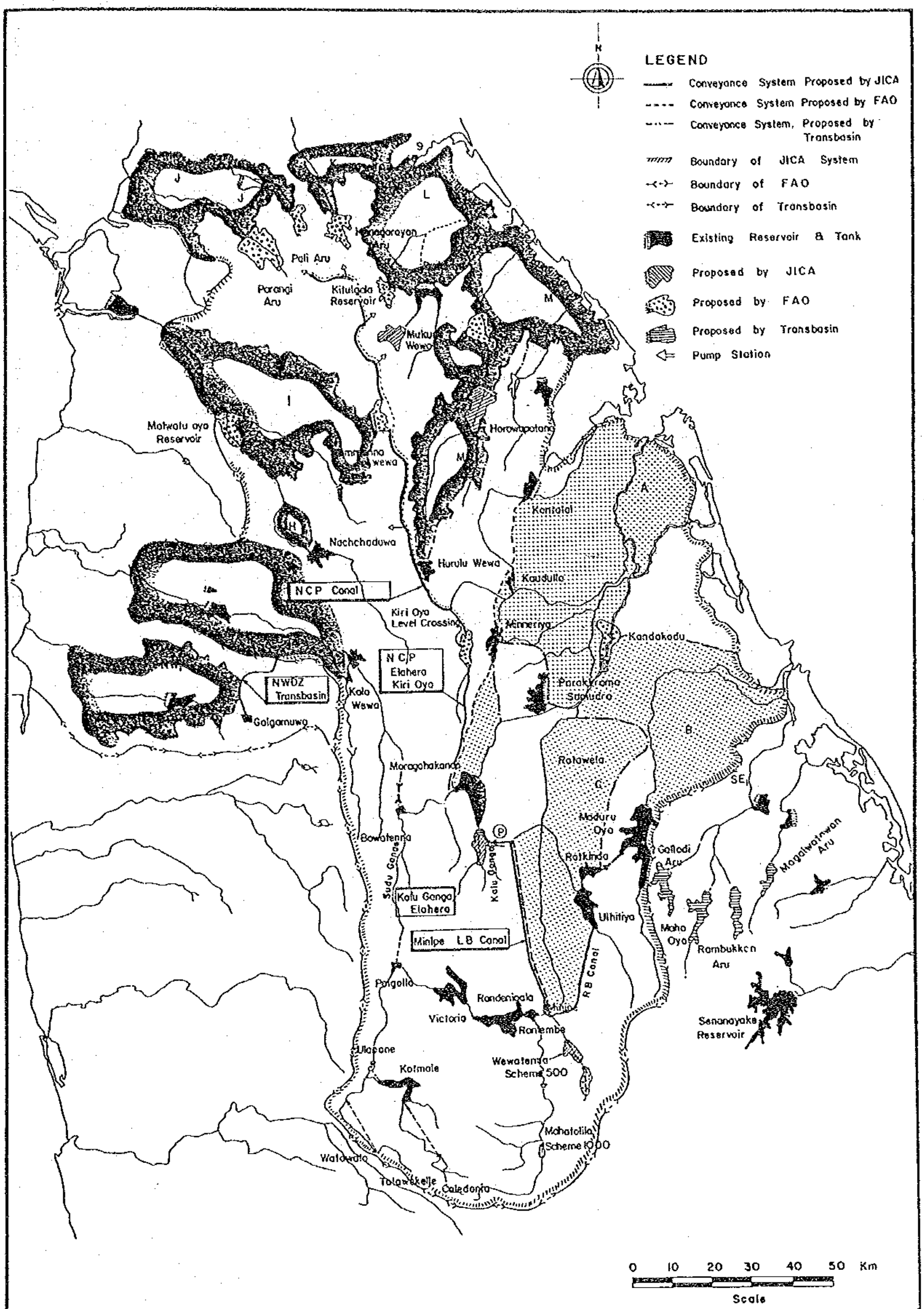

Fig. 9 Transbasin Conveyance System
(Case-B)

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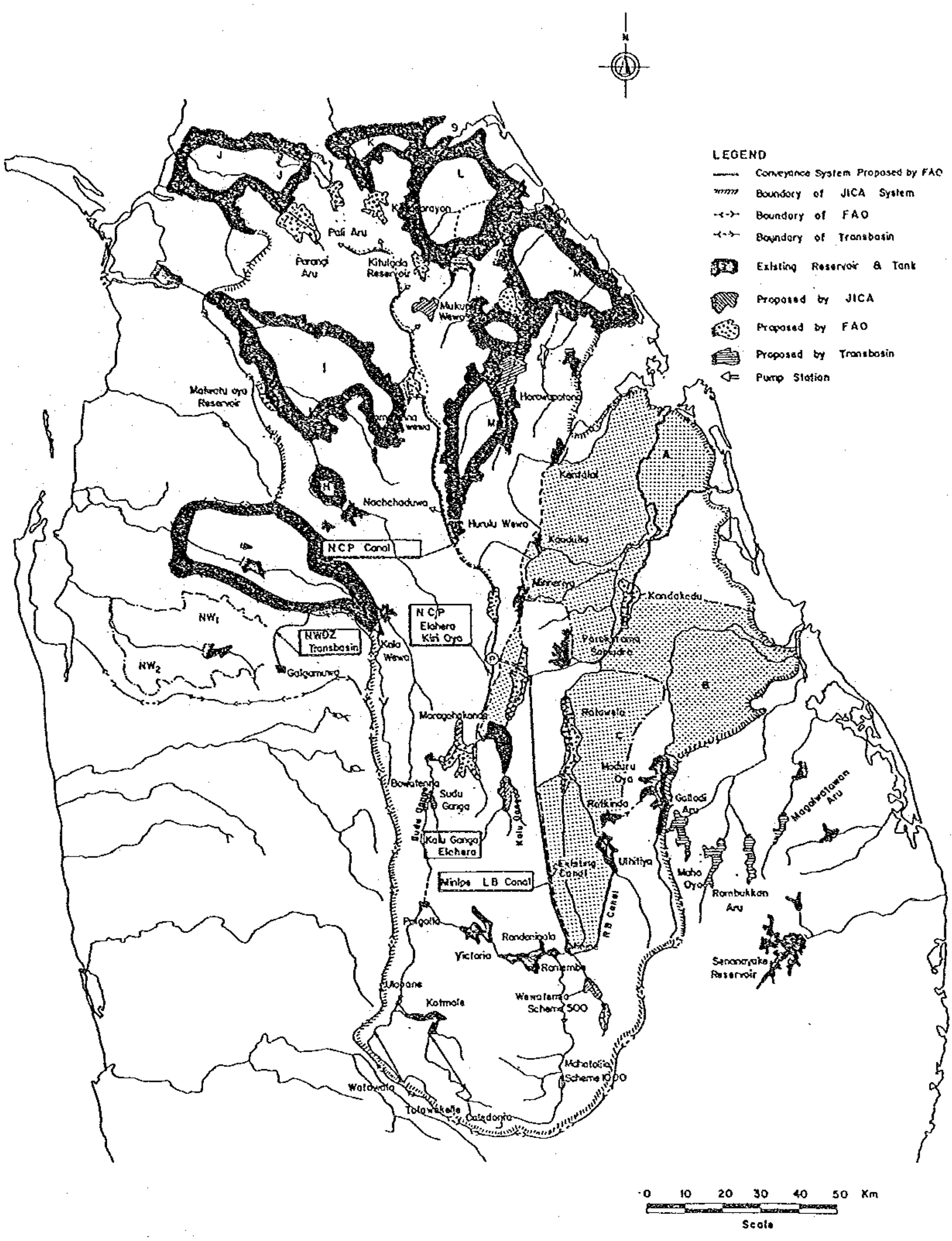

Fig. 10 Transbasin Conveyance System (Case-C)

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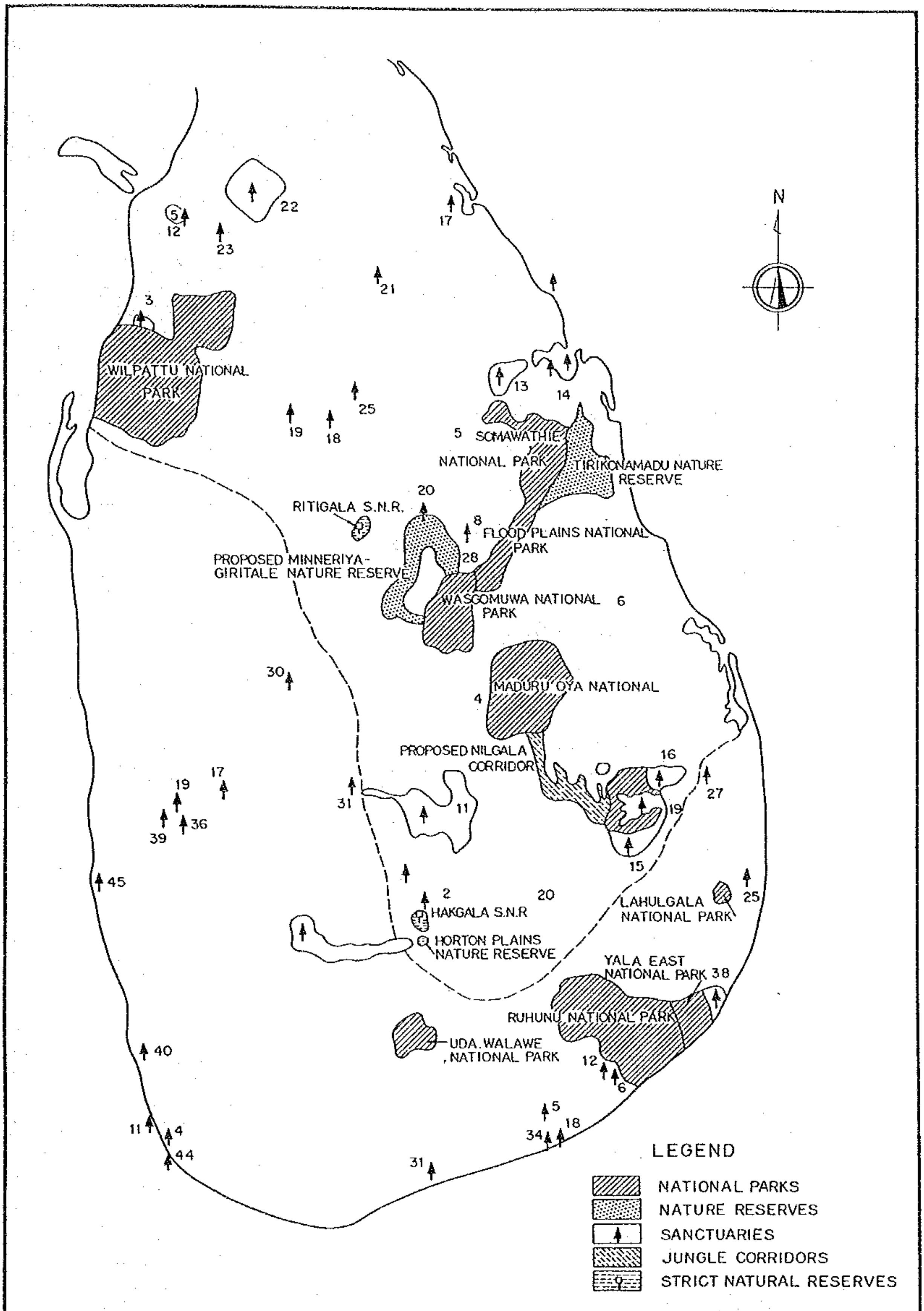

Fig. 11 Wildlife Reserves in Sri Lanka

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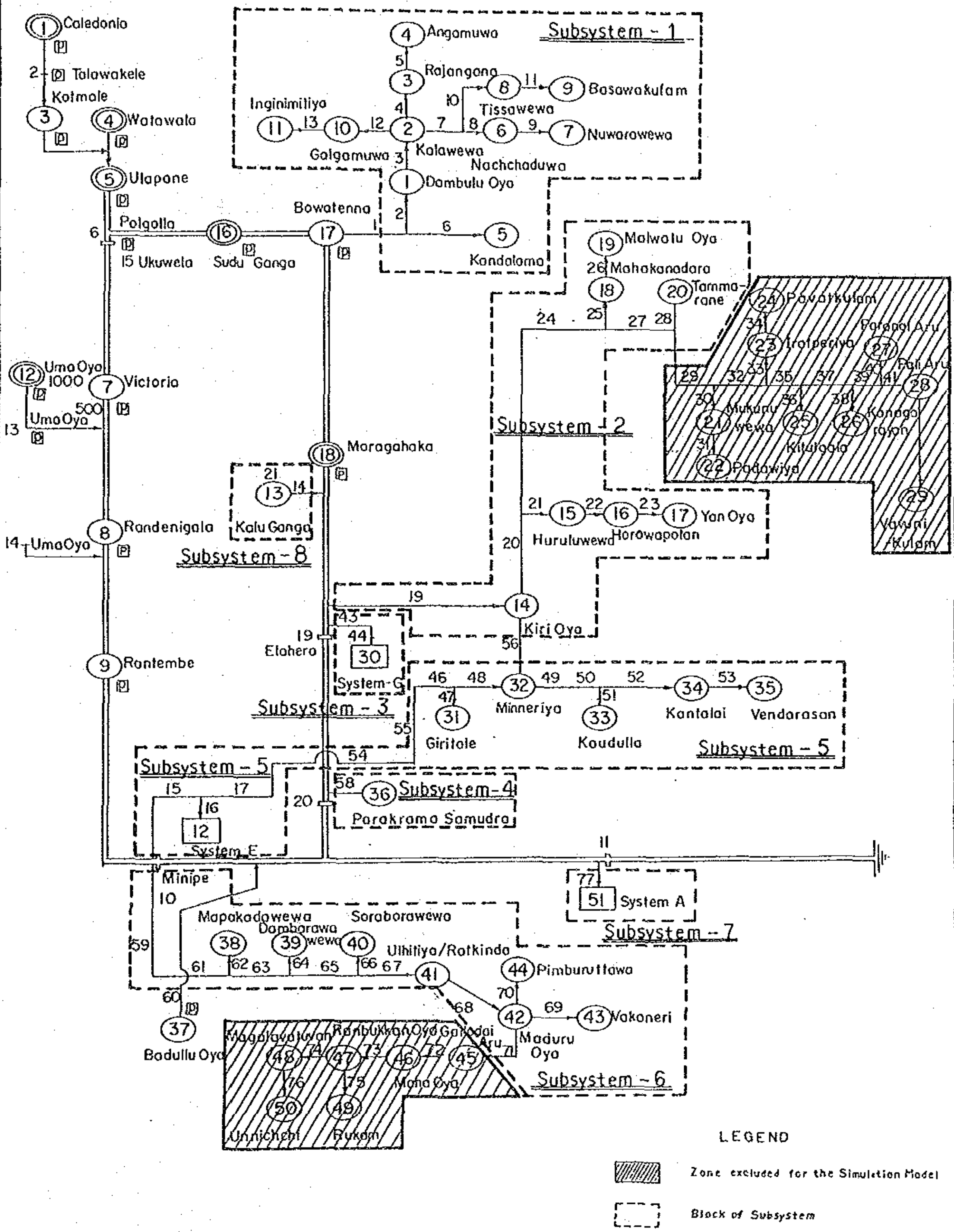

Fig. 12 Schematic Flow Diagram
(Future Plan: Case A)

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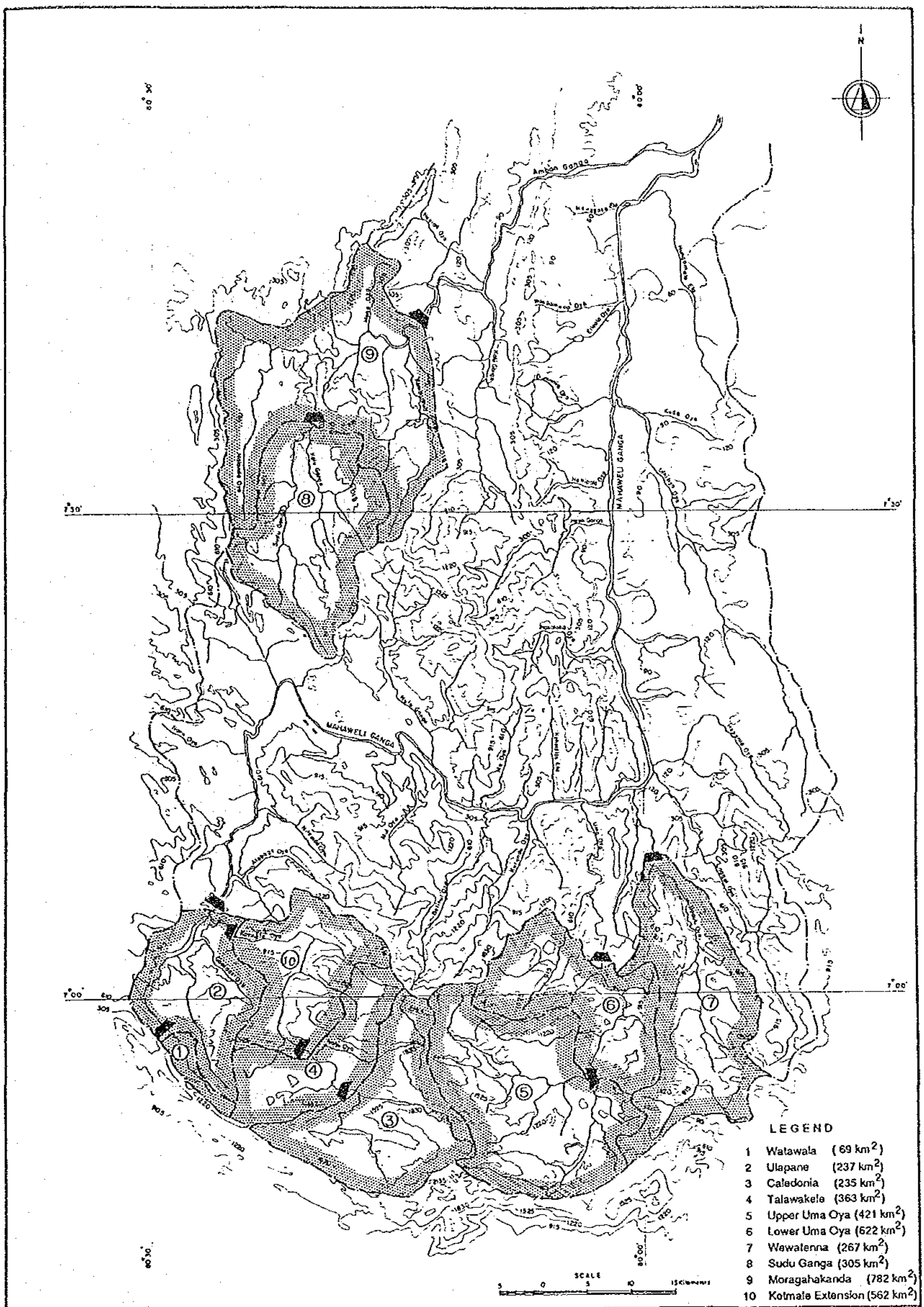

Fig. 13 Catchment Boundary for Candidate Hydropower Schemes

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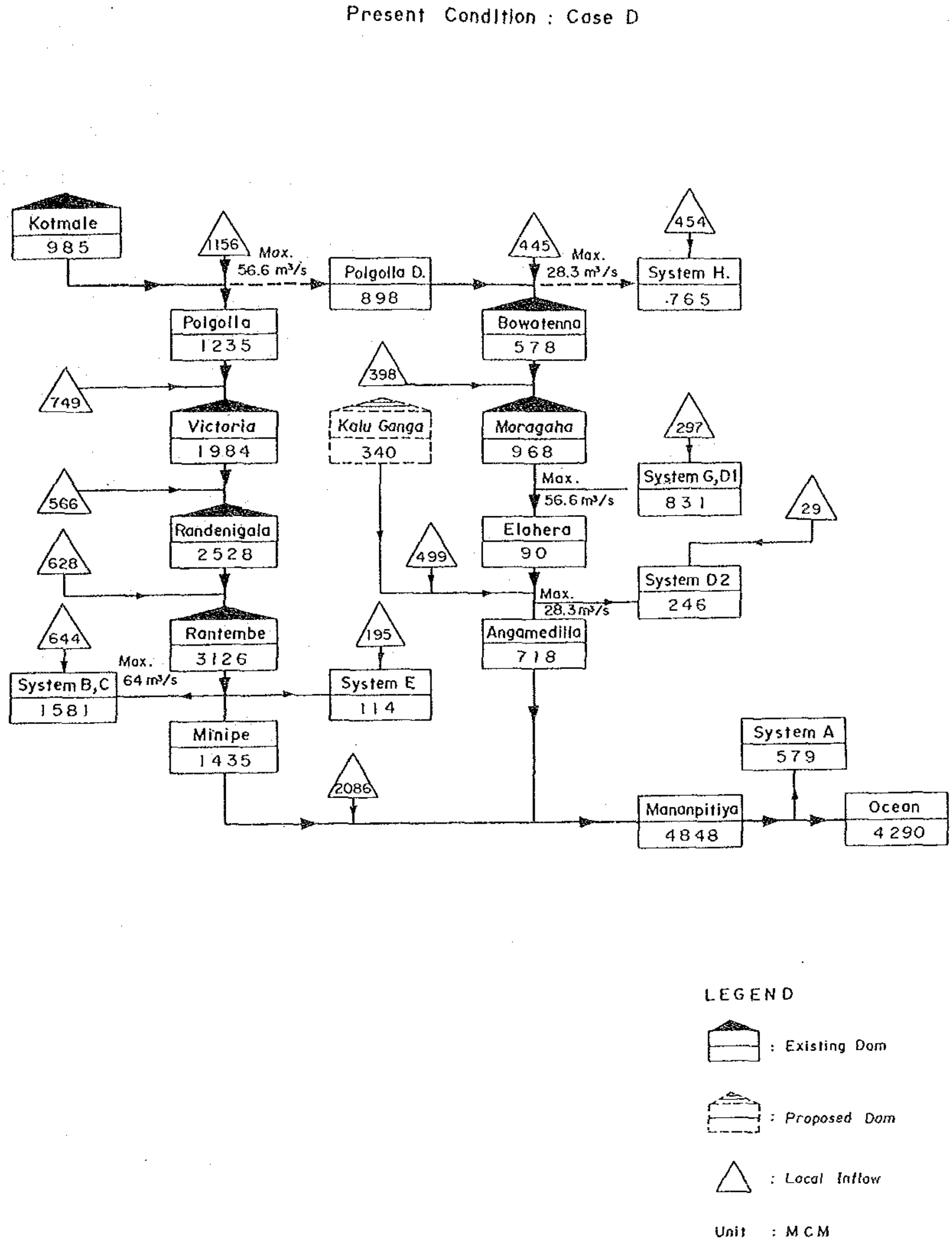

Fig. 14 System Flow Diagram
(Present Condition: Case D-109)

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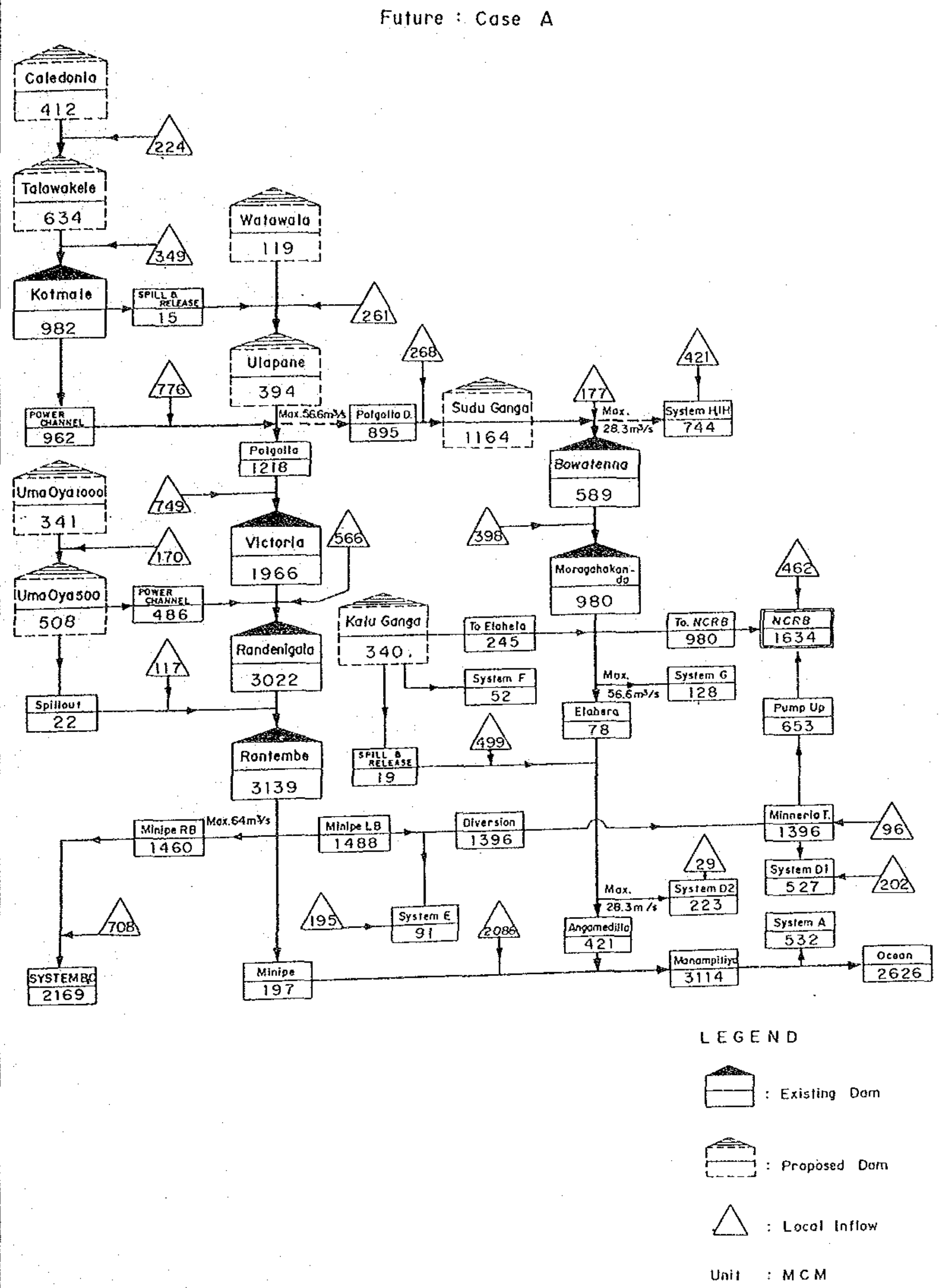

Fig. 15 System Flow Diagram
(Future Plan: Case A-118)

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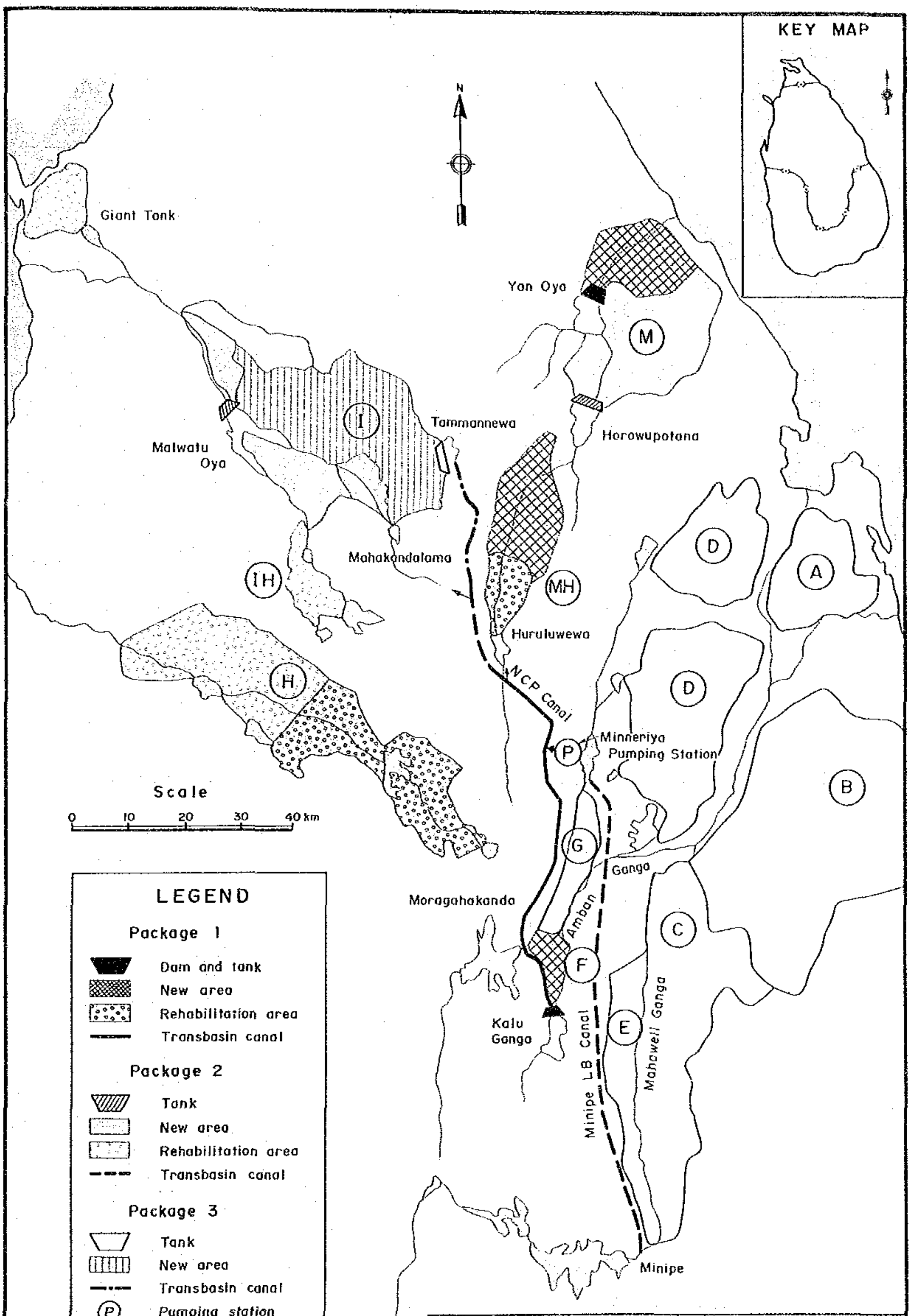

Fig. 16 Stagewise Development Plan

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	Benefitted Area (ha)	Year 1990 – 2000 – 2010 – 2020
I. Package-1 (NCRB)		
- Kalu Ganga dam		
- NCP canal (Kalu Ganga - Huruluwewa)		
- System F	1,900	
- Yan Oya (M)	10,000	
- Huruluwewa Extention	12,000	
- Rehabilitation		
. Huruluwewa (MH)	4,300	
. System H (1/2)	21,200	
. Cashew Land	10,000	
II. Package-2 (NCRB)		
- Minipe LB canal (Minipe-Minneriya)		
- NCP canal (Huruluwewa-Mahakandarama)		
- Holowupotanna	15,000	
- Mahakandarama Extension (I)	8,000	
- *Maluwatu Oya (I)*	13,500	
- Rehabilitation		
. System H	21,200	
. System IH	4,700	
. Mahakandarama (I)	2,800	
III. Package-3 (NCRB)		
- Minneriya Pump Station		
- NCP canal (Mahakandarama-Tammanewewa)		
- Tammanewewa	27,000	
- Cashew Land	10,000	

LEGEND: Preparation; Construction

Fig. 17 Implementation Schedule

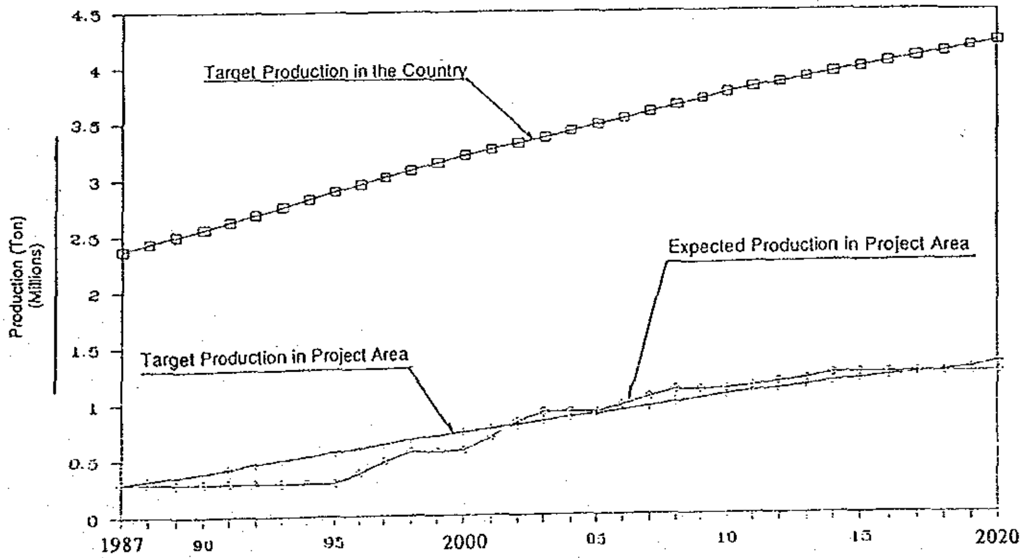

Fig. 18 Projected Paddy Production: 1987-2020

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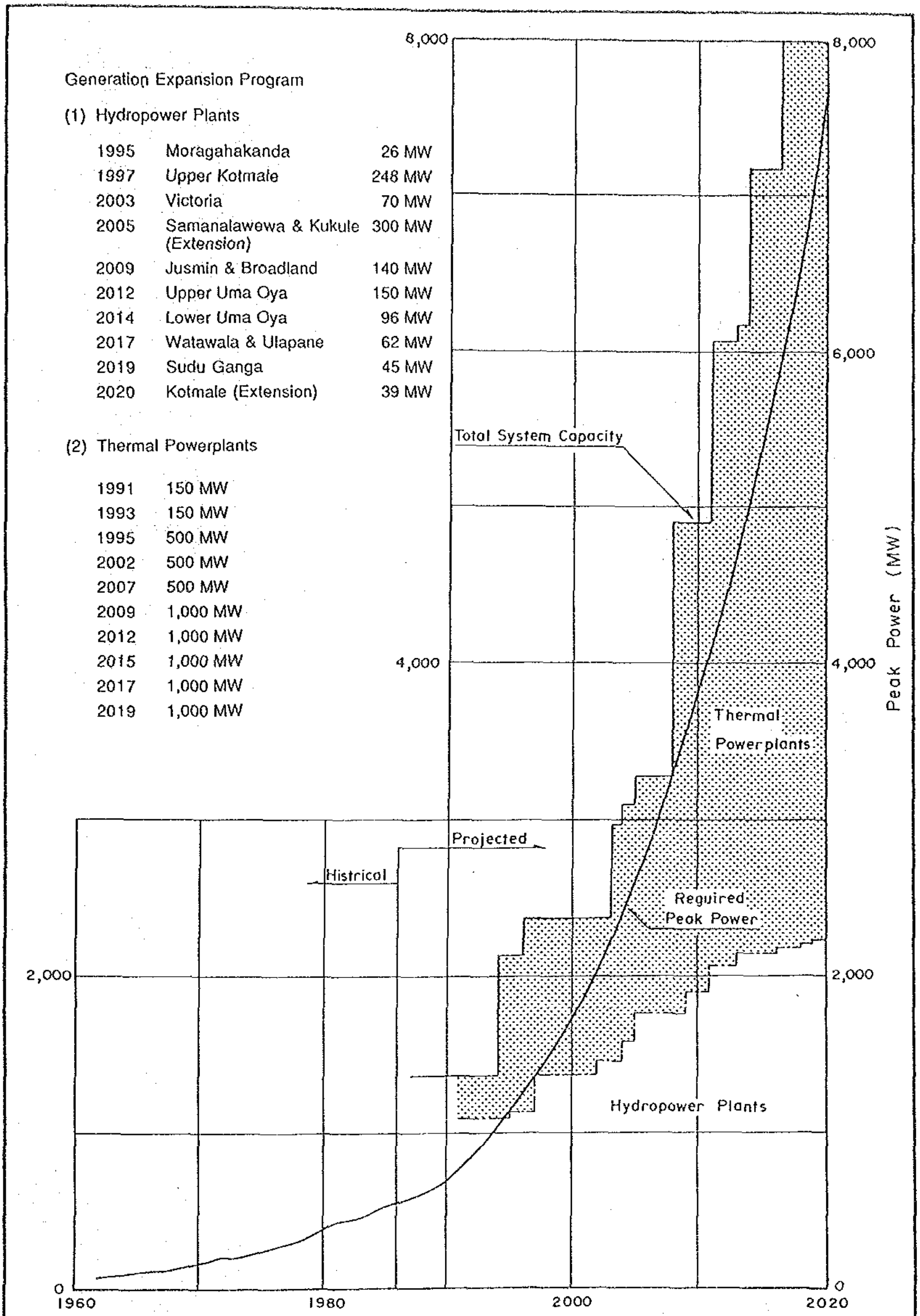

Fig. 19 Long-term System Generation Expansion Plan (Tentative)

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