MAHAWELI GANGA IRRIGATION AND HYDRO-POWER SURVEY CEYLON

INTERIM REPORT
SUMMARY

URE ORGANIZATION OF THE UNITED NATIONS
TIONS DEVELOPMENT PROGRAMME
ROME 1967

THE GOVERNMENT PRESS, CEYLON

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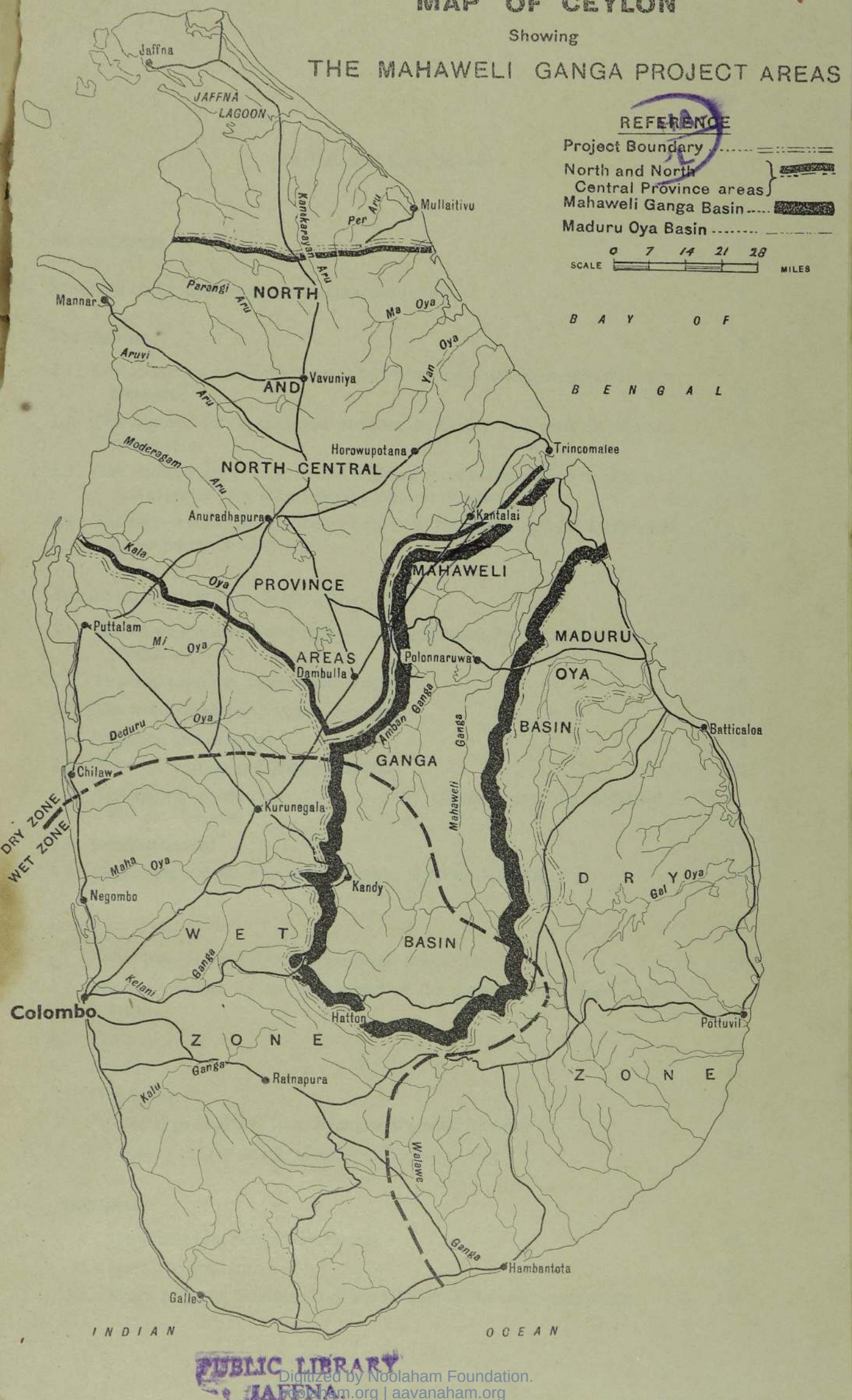
MAP OF CEYLON

Showing

THE MAHAWELI GANGA PROJECT AREAS



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INTRODUCTION

0.1 Background

0.1.1 In 1963, the Government of Ceylon requested assistance from the United Nations Development Programme to carry out investigations for the complete utilization of the Water Resources of the Mahaweli Ganga for irrigation in the Basin proper and in the North Central Part of the Island, as well as for power generation.

0.1.2 The UNDP/SF pre-investment survey of four years duration was started in March 1965 to provide basic information on the Land and Water Resources of the Mahaweli Ganga Basin and in the North Central provinces needed for planning irrigation development and the utilization of hydro power. It was sub-divided into two stages, each of 2 years duration.

Stage I Overall study of river basin potential and preparation of Master Plan.

Stage II Feasibility study of a first development phase.

0.1.3 An IBRD mission in May 1961 identified the Mahaweli Ganga as "a promising multipurpose scheme to meet Ceylon's economic needs". A U.S.O.M. report on a possible project for a part of the presently surveyed territory was presented in July 1961. A second IBRD mission in 1962 suggested a first stage of development and recommended a review of data used and the obtaining of further data.

0.2 Interim Report

This Interim Report on the work of Stage I describes an overall plan for utilization and development of the resources of the Mahaweli Ganga. Further studies will be undertaken in Stage II to prepare a Feasibility Report for the First Phase of development as outlined in the Master Plan.

1. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1.1 Outline of the Development Project

1.1.1 During the first stage of the survey, it was established that more water can be made available for irrigation through regulating the discharges in the river and its tributaries than could be used on available land in the Mahaweli Valley itself, and that considerable volumes could be transferred to the North Central Province. The proposed Master Plan is based on this fact.

The investigations carried out by the Project Team during the first stage of the UNDP/SF project have led to the conclusion that it is possible to provide some 6,000,000 acre feet of water for the irrigation of 900,000 acres, of which 422,000 acres lie in the Mahaweli and Maduru Oya Valleys, and 478,000 in the North Central Province. The total includes 273,000 acres already irrigated and 627,000 acres at present mostly uncultivated and state owned. In addition, the combined use of reservoirs and canal drops will permit the development of 460 MW of installed generating capacity and an average annual power output of 2,377 million kwh.

1.1.2 Four alternative projects have been studied, each embodying variants in respect of storage, diversion and main canal routes to achieve the general planning objective. The project selected contains cost advantages in respect of overall capital investment required and power generation potential achievable for the whole scheme.

1.1.3 The proposed cropping pattern is based on irrigation water being available for the full 12 months of critical years and for practically continuous cropping.

1.1.4 The cost of irrigation, drainage, flood protection and, land development and power stations is estimated at Rs. 4,580 million, including cost of land clearing and of the irrigation works required for water delivery down to blocks of 100 acres. The foreign exchange component of this expenditure has been estimated at 48 per cent. The total capital cost of the project, including power transmission lines, overhead expenditure etc. has been estimated to be in the order of Rs. 6,000 million.

1.1.5 It is estimated that at full development, the annual total value added by agricultural production, at World Market Prices, by the investment, will be Rs. 1,127[1] million. Similarly value added by power generation at the bus bars of power stations will be Rs. 84 million.

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[1] After deduction of current costs for operation and maintenance of irrigation works, extension and other free services.

1.1.6 In view of the vast dimensions of the scheme, special attention was given to step-wise development, not only because of the large financial requirements, but also because of the administrative and operational problems involved in such a project.

1.1.7 The selection of the first phase was based on the following criteria :—

(*a*) It should be capable of development as a separate unit, without financial commitment to the following phases.

(*b*) It should not prejudice the development of further phases of the Master Plan.

(*c*) The size and nature should be consistent with the capability of the Government for land development and should accordingly be in areas where problems of settlement, infrastructure and management can be minimised.

(*d*) It should meet the anticipated expansion in the demand for power.

(*e*) It should be economically viable.

1.2 The timing and phasing of the Project

1.2.1 The timing of construction has been planned on a tentative basis to cover the 21 years from 1970 to 1990. Provided finance is available, the engineering works could be completed in the scheduled period. However, the development and settlement on new lands will place a heavy load on Government finances and personnel, and the annual rate of development possible will depend critically on the ability of the Government to carry through an agricultural development program.

1.2.2 The project is planned in 3 phases of which Phase I Step I can be specified in terms of timing.

Phase I—It is recommended that the 1st phase should consist of construction in two steps :—

STEP I, 1970–76

The Polgolla Unit with one barrel of tunnel, Moragahakanda Unit, the Polgolla-Kala Oya Trans-basin canal and irrigation systems H, D_1, D_2 and G*. It is suggested that, in the first phase of development, the Moragahakanda Unit be used to irrigate lands on the left bank of the Mahaweli Ganga. Total irrigated area : 216,000 acres of which 115,000 are already cultivated ; installed capacity of power stations 58 MW ; total cost of works including land development : Rs. 652 million corresponding to US $ 137 million.

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* *See* attached map (Appendix I).

The first step recommended meets all the criteria mentioned in para 1.1.7.

(*a*) 1,000 cusecs can be diverted from the Mahaweli Ganga at Polgolla without prejudice to development within the basin in critical years. 2,000 cusecs could be diverted in a later phase after adequate storage will have been provided.

(*b*) The required rate of land development, bearing in mind the proportions of existing to new lands, should be within Government capacity.

(*c*) The power stations will provide an installed capacity of 30 MW of firm power.

(*d*) The social internal rate of return is 15 per cent.

1.2.3 STEP II (Date to be determined)

Victoria Falls, right bank canal irrigation systems C and (existing part of) E. Total irrigated area 87,000 acres : of which 14,000 are already cultivated ; installed capacity of power stations 80 MW ; total cost of works including land development : Rs. 420 million corresponding to US $ 88 million.

The date of implementation will be established during the second stage of the present UNDP project. A decision on timing has to be based on a continuing review of power requirements and of the capacity of the Government for agricultural development including the necessary infra-structure.

The social rate of return (18 per cent) as a multi purpose project is attractive, and it may therefore be expedient to schedule this project for implementation in the plan for electricity development of the country up to 1980.

Development of lands in system C will not entail great governmental expenditure since part of these lands have been taken over by private companies who have already cleared and cultivated a large part of the area.

1.2.4 SUBSEQUENT PHASES

(*a*) *Phase II* development would include the Randenigala Unit, the second barrel of the Polgolla tunnel, the reservoirs at Rotalawela and on the Maduru Oya, the left bank canal, and the North Central Province canal (up to the feeder of the irrigation system L), and irrigation systems A, B, E (new land), I, M, and part of L. In this phase the Moragahakanda reservoir waters will be diverted to feed the systems in the North Central part of the Island.

(*b*) *Phase III* corresponding to the last stage of the overall development of the Mahaweli Ganga, will consist of the construction of the remaining irrigation and power units and irrigation systems.

1.3 Economic Evaluation

1.3.1 The project appears feasible (possible) from a technical as well as an economic and social point of view, over a period of approximately 21 years, provided the necessary efforts of organisation are made to enforce the timely implementation of the different elements.

1.3.2 The project has been appraised from a national economic standpoint, as well as from the narrower financial point of view of the farmers :

(*a*) The social internal rate of return assuming World Market Prices for the whole scheme is 15 per cent, assuming the present price of the Ceylon rupee in foreign exchange. If " accounting " prices of the Ceylon rupee in foreign exchange higher than the present were used, the social internal rate of return would be higher by several points. An internal rate of return of this magnitude may be considered as characteristic of an economically commendable project.

(*b*) On the basis of " Guaranteed Prices " of farm products and the suggested cropping and settlement patterns, it is estimated that income per capita of the farming population will eventually reach Rs. 1,400 ($ 295). At this level of income, it should be possible for the farmers to make some contribution towards the expenditures on the project.

1.4 Significance and Impact of the Project

This project will have as its output : food products, agricultural products for industry and energy. It will bring into productive use large and yet untapped resources in the dry zone, resettle at least 500,000 persons in agriculture and provide employment to a large number of workers in the secondary and tertiary sectors, as a result of direct as well as indirect effects of the Project.

1.5 Recommendations

1.5.1 A feasibility study for Phase I, (which shall be Stage II of the UNDP/SF survey) should be completed as early as possible with the present project team. A program of work for this purpose is given in Appendix II attached.

1.5.2 The implementation of the project as scheduled requires a larger capacity in land development activity and improvements to extension services and marketing facilities. It is recommended that the first step be taken *now* to expand the capacity of this activity, improve extension services and marketing facilities, in particular the supply of fertilizers.

1.5.3. Serious consideration should be given by the Government to establishing one or more pilot areas for development, in view of the major problems involved in bringing new land under cultivation at the rate required.

1.5.4 The institutional aspects, and more specifically the problems of organization and management of the scheme, should be the subject of further detailed studies.

2. THE SETTING

2.1 Ceylon and its economy (Present position, recent developments and future prospects).

2.1.1 PHYSICAL FEATURES OF CEYLON

Ceylon, an Island of 25,000 square miles (65,000 km²)[1] situated under the tropics (approximately between the latitudes of 6 and 10 degrees north) has at present (mid–1967) a population which may be estimated at 11·8 million inhabitants (density : 470 per square mile ; 180 per km²). From a geological point of view it is part of a ' shield ' area which embraces most of south India and has not undergone any major earth movements since early geological times : the rocks within this shield (granites, schists, gneisses, etc.) are mostly pre-Cambrian in age. The south-central part of the country consists of hills and mountains which culminate at 8,300 feet (2500m). The coastal plain, rather narrow on the west, east and south, broadens out to a vast tract in the north. Temperatures are very even throughout the year : mean temperatures are high on the coast (ranging from 80° to 82°F) ; in the hills they fall off at a steady rate of 1°F for each 300 feet in rise. Two monsoons : the south-east monsoon (the more important) from May to September and the north-west monsoon from December to February (corresponding respectively to the " Yala " and " Maha " seasons) are responsible for a major part of the annual precipitation. Due partly to the screening effect[2] of the mountains during the Yala season, rainfall is very unevenly distributed over the Island and is submitted to large seasonal variations. Annual average rainfall varies from below 40 inches (approx. 1m) in the driest zones to over 200 inches (more than 5m), at certain places on the south-west slopes of the hills.

The Island can be divided into a *dry zone* and a *wet zone* by a line following approximately the 75″ isohyet (1. 91m)[3]. The wet zone, corresponding roughly to the south-west quadrant of the Island, cover about 30 per cent of the land area of Ceylon but includes more than three quarters of its total population. (Density nearly 1,200 inhabitants per square mile ; 450 per sq. km.). Agricultural production in the dry zone is essentially based on irrigation (particularly during the Yala season). Further substantial agricultural developments in this zone would be practically impossible without irrigation.

The dry zone of Ceylon, which has a more hospitable climate than the wet zone was once (several centuries past) agriculturally developed and contained the main population centres of the Island (among which are the ancient capital cities of Anuradhapura and Polonnaruwa). Agriculture was then based on irrigation by hundreds of tanks principally fed by rivers ; some of these tanks, still in use, have been active for more than 2,000 years. Circumstances not very well understood (in which wars played a great part)

[1] Greatest length (N/S) : 270 miles (435 km.). Greatest breadth (E/W) 140 miles (225 km.).

[2] Foehn effect.

[3] More precisely the 20″ isohyet for the five south-west monsoon months (Yala season).

led progressively to the almost complete abandonment of this zone which reverted to jungle and became plagued by diseases such as typhoid fever and malaria.

These illnesses having been practically eradicated during the Second World War and population pressure upon land in the wet zone having since become extreme, attempts have been made for nearly a generation to redevelop the once prosperous Dry Zone. The waters which flow through this zone from the mountains to the sea and the good soils they could fertilize represent for Ceylon an important yet largely untapped resource. *The systematic development of these important natural resources will probably be, along with industrialization, the main economic development theme in the next 20 years.*

2.1.2 PRESENT ECONOMIC POSITION

Ceylon is poorly endowed with natural resources. However, it has a rather large hydro-power potential and the presence of highlands in the centre of the island permits a certain variety in agricultural production.

Economic activity is essentially based on agriculture which provided, in 1964, 44 per cent[1] of the Gross Domestic Product (GDP)[2] and which contributed a large part of the products transformed by the Ceylonese industry or traded by the Ceylonese merchants in the internal and external markets.

Government revenues representing almost one quarter of Gross National Product are mostly absorbed by current expenditure. Public capital formation (5 per cent of GNP) is almost entirely financed by loans and deficit spending. The levels of gross savings and gross investments (public and private) are low: respectively 11 per cent and 13 per cent[3] of GDP in 1964.

External trade plays an essential part in the economic life of the country : imports represent nearly 30 per cent of GDP ; exports being slightly lower, there is a small trade deficit. The balance of payments on current account which had been negative for several years was nearly in equilibrium in 1965, but this improvement may not be permanent.

GNP per capita estimated at rupees 660 in 1965 (corresponding to nearly US $ 140 at the present official rate of exchange) appears to be relatively high for south and south-east Asia.

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[1] 41 per cent in 1965 following crop failure.

[2] Manufacture plus construction 14 per cent ; miscellaneous services 42 per cent.

[3] 12.5 per cent in 1965.

The bulk of agricultural production is represented by the four following crops which cover nearly one quarter of the total land area of Ceylon (very close to the total cultivated area) :

Crops	*Acreage (in thousand acres)*	*Production (1964)*
Paddy	1,600[1]	50·4 million bushels[3]
Tea	600	482 million pounds
Rubber	670	111 thousand tons
Coconut	1,100	3,000 million nuts
	3,970[2]	

Paddy is grown for home consumption but it must be supplemented by large imports of rice (547,000 tons in 1964). Roughly 50 per cent of the coconut output is for the external market ; tea and rubber are grown essentially for external markets ; exports of these three commodities account for 95 per cent of the country's exports ; the proceeds of their sale abroad allows the import of food stuffs (rice, chillies, onions, milk products, etc.), other consumer goods and the equipment needed by the Ceylonese economy for subsistence and progress. The entire economy of the island therefore depends upon the production of these four commodities and the export of three of them.

2.1.3 RECENT DEVELOPMENTS

During the last 5–10 years, the Ceylonese economy has been prevented from making much headway by strong adverse currents (population growth and terms of trade). During the 5-year period 1959–1964 Gross National Savings as a percentage of GDP fell from 14 per cent to 11 per cent. Simultaneously total capital formation showed a tendency to decrease (in absolute as well as in relative terms) from a little over 1,000 million rupees in 1959 (17 per cent of GDP) to a little less than this amount in 1964 (13 per cent of GDP).

Nevertheless, during this period, production of the four main crops mentioned above rose substantially as indicated by the indices below :

	1950	*Average 1954–1956*	*1959*	*1964*
Paddy	67	86	100	139
Tea	75	91	100	117
Rubber	124	102	100	121
Coconut	83	106	100	129

Moreover, the compounded effects of population growth (+ 14 per cent in 5 years) and adverse terms of trade (– 16 per cent during the same period) counteracted this progress so that finally real per capita income did not appreciably increase.

[1] Acreage sown, out of which 645,000 acres are rainfed.

[2] Approximately 16,000 sq. km.

[3] Corresponding to 705,000 long-tons of rice.

The present situation resulting from this evolution is rendered more precarious by the progressive disappearance of foreign exchange reserves. [1]

2.1.4 FUTURE PROSPECTS

The population will no doubt continue to expand at a rate close to the present rate of 2.5 per cent per annum. At this rate it would reach 16.6 million inhabitants in 1981 and 21.3 million in 1991, thus nearly doubling between now and the end of the project implementation period. The project has been studied on an island-wide basis and future population changes in Ceylon are a very important factor in deciding its value, its market potential, and its place in the island's economy.

In view of the present serious difficulties, one should not expect a rapid increase in national income (total and per capita) during the next few years. However, after a progressive improvement on the present situation it may not be unreasonable to expect, over the life of the project (1971–1990), a steady growth at a rate of 5 per cent per annum (2.5 per cent per capita). This growth rate, close to present Government expectations, has been retained for long-term projections.

Future expansion will necessarily continue to be based largely on agricultural production as well as on the processing and marketing of agricultural products. On the basis of the above assumptions, it has been estimated that between now (1967) and the end of the period planned for the implementation of the project (1990), GNP will approximately treble and that agricultural production will have to be multiplied by about 2.5 while industrial production will be multiplied more than 5 times ; simultaneously per capita incomes will increase by two-thirds.

Population growth and simultaneous increases in per capita income will tend to raise the demand for food (especially rice and subsidiary foodstuffs) at rates close to 4 per cent per annum (doubling in about 15 years) which would place an unbearable burden on the balance of trade if home production of foodstuffs could not soon be rapidly expanded. In the coming 25 years the large increases needed in agricultural production will require an expansion in the order of 70 per cent of the cultivated area, *which will make it necessary to develop irrigation in the Dry Zone on a large scale.* General economic progress and the associated growth of industrial production at a rate close to 4 per cent during the next two decades will also bring about large increases in electric power consumption *which will require a rapid expansion of the capacity of hydro-power stations.* The expansion of the cultivated area in the Dry Zone and the growth of electric power production to promote industrialization will be necessary to relieve population pressure on land in the Wet Zone by providing employment opportunities in agriculture as well as in industry.

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[1] Net assets fell from 953 million rupees in 1957 to only 47 million in 1964.

2.2 The demand for agricultural products in Ceylon and the need for import substitution

It has been estimated that the Island's rice requirement will be about 2.4 million tons by 1990. The records show that production of rice in the Island was 687,000 tons in 1963, 705,000 in 1964 and 507,000 in 1965. The productivity of existing paddy fields can be increased by at least 50 per cent in the next 20 years with improved agricultural practices, i.e., the average yield per acre can be brought to 60 bushels from 40 as at present. This will raise production to about 1 million tons. The short fall, amounting to 1.4 million tons, must be met from the new land which will be developed and irrigated or from imports.

According to approximate calculations, the short fall for other major crops will be as follows : chillies 30,000 tons ; onions 35,000 tons ; cotton 140,000 tons ; groundnut 5,000 tons. Without expansion of production, the value of agricultural imports (including rice) may approach 4,000 million rupees ($ 840 million) per annum by 1990.

The project area covers about 60 per cent of the total irrigable undeveloped area of the Island. Consequently its development should be on such a scale as to narrow appreciably the gap between the consumption and local supply of agricultural products. Soils and economic conditions in the project area should make it possible to produce locally 60 per cent of the rice imports which would otherwise be necessary in 1990 and to meet completely the local requirements for certain other agricultural products.

2.3 The demand for electric power resulting from industrialization programs and expected long-term general economic progress

During the last 14 years (1951–65) electric power production and corresponding peak loads have grown rather rapidly at the overall rate of about 12.6 per cent[1, 2] which fell to 7.5 per cent for the last three years (1962–65). Such high rates are not uncommon in developing countries particularly in the early stages of economic growth. For the future, estimates have recently been made by Government for the period up to 1980. They forecast a very high rate of growth of 19.7 per cent up to 1970, then a levelling off down to 6 per cent for the period 1975–80, the overall average resulting rate of growth for the period 1965–1980 (15 years) being 11 per cent.[3]

The resulting forecasts for 1980 are : a power generation of a little over 2,000 million kwh and a peak load of 400 MW. For the period 1981–90, the mission has assumed a yearly rate of growth of 7 per cent (corresponding to a doubling in 10 years) which will raise power generation to approximately 4,000 million kwh and peak load to 800 MW in 1990.

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[1] 11.5% for peak load.

[2] Consolidated data for the DGEU and Jaffna and Gal Oya systems.

[3] 10.1% for peak load.

This contemplated evolution is summarized below (rounded figures) :

Year	*Power Generation (10^6 kwh)*	*Yearly Growth rates Per cent.*	*Peak Load MW*	*Reserves[1] MW*	*Minimum installed capacity required MW*	*Effective installed capacity MW*
1951	81		21	8	29	40
1965	427	13	94	25	119	126/176[2]
1970	1,045	8	203	37	240	261[3]
1975	1,540	8	297	63	360	345[4]
1980	2,046	7	400	75	475	—
1990	4,090	7	800	140	940	—

Considering the Government's intention to further economic development at the rate of 5.5 per cent during the period 1966–1990, the target of about 4,000 million kwh in 1990 does not appear unreasonable. The attainment of this target would correspond to a growth of electric power production at a rate of approximately 9 per cent for the period 1965–1990. A rate of this magnitude would be perfectly consistent with a rate of overall development of the order of 5 to 6 per cent which would imply a rate of industrial development close to 10 per cent [5].

Shorter term forecasts may be less reliable. The recent fall in rates of electric power production down to yearly rates of 5–6 per cent may be attributed to import restrictions resulting from a slowdown in the rate of economic progress, linked to foreign exchange difficulties which are not likely to disappear suddenly.

Following on this slowdown, the high rates (close to 20 per cent) predicted for the period 1966–70 may seem rather unrealistic. The fact is however that a backlog of industrial development has been accumulating during the past few years and that many important industrial plants have recently come into production. Several are due to follow soon. However, as past forecasts of electric power consumption have often been rather optimistic, one may doubt that the present high rates of growth predicted for the period 1966–70 will be fully implemented.

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[1] Largest unit until 1980 ; 15% of total reliable capacity in 1990.

[2] Including newly commissioned Norton HPS.

[3] After commissioning of Polpitiya (75 MW) and Udawalawe (6MW) in 1969.

[4] After commissioning of New Laksapana (75 MW) in 1971 and Theberton (25 MW) in 1973 and retirement of two thermal plants for a total of 16 MW (in 1971).

[5] Due to the progressive substitution of electric power for other forms of energy, rates of growth of electric power production the world over tend to be notably higher than the rates of nat. inc. growth and even rates of growth of ind. production.

The following alternative rates of growth could be considered. They take account of the industrial backlog and are based on the hypotheses of low but rising rates of economic progress until 1970 followed by a period of sustained growth of National Income at the overall yearly rate of 5.0 per cent during the period 1971–90.

Year	*Power generation* 10^6 *kwh*	*% yearly rates of growth*
1965	427	
1966	470	+10%
1970	740	+12%
1975	1,130	
1980	1,730	+ 9%
1990	4,090	

These estimates may be considered as representing a conservative view of the future.

The above projections of the demand for electric power show that during the next two decades, there will be ample room in Ceylon for a scheme of the importance of the Mahaweli Ganga Project purporting to install 460 MW of generating capacity to produce finally approximately 2 milliards of kwh of energy every year.

2.4 **The Project Area** (Description and potential for agricultural production and hydro-power development).

Boundaries and area.—The surveyed territory covers the Mahaweli Ganga Basin, the adjacent basins of the rivers of the North Central part of the Island and the Maduru Oya in the east. The area is bounded by the watershed of the Mahaweli Ganga in the south, the Maduru Oya in the south-east and Kala Oya Basin in the south-west, the groundwater irrigation zone in the north and north-west and the sea coast on the north-east.

The gross area is 9,880 square miles, which is 55 per cent of the whole of the Dry Zone (i.e. 39 per cent of the whole Island). Approximately 300,000 acres are already developed and provided with irrigation from medium sized reservoirs or tanks. About 30,000 acres of the developed area is scattered in small plots separated by forest and far from major water sources. The supply available from these tanks does not permit full irrigation throughout the year and the average intensity of cultivation is equivalent to only 1.37 crops of paddy per year ; two crops are possible if there is enough water.

The undeveloped irrigable lands within the territory cover an area of 1,200,000 acres (net) of which 630,000 acres are available for cultivation ; 570,000 acres should be left for forest reverves. Thus the total irrigable area comprises

(in round figures) 630,000 acres (254,000 hectares) of undeveloped land and 270,000 acres (110,000 hectares) already under irrigation which needs improvement.

Meteorology.—Rainfall records are available over a satisfactorily long period and in some areas for over 80 years. The data are therefore adequate for planning purposes. Some other meteorological data have been recorded over a reasonable period, and though less complete, are sufficient for projecting conditions governing water control in the project area.

Hydrology.—Here again, data are available for reasonable assessments. Some of the records for gauging and current metering stations extend over 24 years but the data are in some respects dubious ; synthetic yield parameters have been used to assess the relationship between level and discharge relationships.

Sedimentation and Silt Transport.—Little observational data are available and the estimates of reservoir storage losses due to siltation and for the movement of silt in canals are therefore theoretical.

Geology.—The catchment of the Mahaweli Ganga consists generally of metamorphic rocks covered by loosely fragmented sedimentary formations. The construction of dams and control structures presents no serious problems.

Hydro-Geology.—In the upland part of the project area the groundwater resources are not abundant. In the alluvial plains of the lower Mahaweli Ganga Basin and to the north of the project area, groundwater of reasonable quality is obtainable at depths of between 3 and 6 meters. In the dry northern area groundwater development could be an important factor in augmenting the irrigation supply and re-using irrigation water lost by seepage.

Soils.—The construction of engineering works in the project area is not likely to give rise to any great difficulties, except that the nearness to the surface of the underlying rock is likely to increase the cost of the main canals. Land with soils suitable for irrigation is in excess of the water supplies that can be made available for irrigation. The prevailing soils are of good quality and suitable for the cultivation of all kinds of crops. In the river valleys and depressions the prevailing heavy soils with the low permeability are suitable for paddy cultivation.

Topography.—The hilly part of the Mahaweli Ganga Basin is suitable for siting storage reservoirs, but the construction of main irrigation canals will be expensive, particularly in respect of ancillary works required to control cross drainage. In the lower eastern part of the project area, where the terrain is flat, flood control embankments will be required. The terrain is most suited to irrigation in the northern part of the region but water conveyance costs and losses will be heaviest because of the long distances involved.

Contour maps and soil maps are available for the whole of the project area at a scale of 1 : 30,000 with contours at 6 meters (20 feet) intervals. Larger scale maps cover some small parts of the area. A considerable amount of field survey had to be done along the traces of main canals and at proposed dam sites. All major irrigation and hydro-power units, as well as trans-basin canals were assessed for work quantities and estimated costs on the basis of these additional and more detailed topographical data.

PRESENT LAND USE

The area already irrigated (272,700 acres) shows the following cropping pattern : Paddy—253,000 acres (93 per cent) ; sugarcane 7,700 acres (3 per cent); other crops (chilli, onion, vegetables, etc.) 12,000 acres (4 per cent). Most of the land is worked by small holders, holdings of not more than 5 acres comprising 85 per cent of the total *number*. Larger farms, in State or private ownership, of over 25 acres comprise 39 per cent of the total *land* under cultivation. The average size of private holdings does not exceed 4 acres and the population is mainly concentrated within the irrigable area. Undeveloped lands belong to the State.

Prevailing agricultural methods are not at a very high level although some machinery is in use. Rice is usually broadcast and only 2 per cent of the farmers transplant the rice seedlings. Weed control is mainly effected by allowing the water to stand on the fields ; a great amount of water thus is wasted, while because of lack of water in the dry zone only part of the land suitable for cultivation can be irrigated. The average intensity of cultivation is 1.37 instead of a possible 2 or even 3 crops per year.

The average yield, cost of cultivation and farm income for various crops is shown below :—

Crop	*Yield per acre*	*Value added at world market prices (Rs.)*
Paddy Maha	40 bushels	276
Paddy Yala	40 bushels	276
Bombay onion	80 cwt.	1,384
Shallot onion	90 cwt.	1,814
Chillies	8 cwt.	798
Groundnut	8 cwt.	315
Green gram	5 cwt.	126

The low yields are mainly due to shortage and wastage of irrigation water and the low level of agricultural practices. For irrigation systems which have a better water supply, for example Polonnaruwa, the averge yield reaches 57 bushels per acre in Maha. In Vavuniya and other districts where the shortage

of water is especially acute the yields are as low as 33-37 bushels per acre. A substantial increase in yields is observed on farms where the seedlings are transplanted, the average yield thus obtainable in the Maha season being close to 77 bushels per acre. As it has been demonstrated by the experiments of an FAO expert, optimal application of manure can raise the yields at the normal rate of irrigation, up to 70-80 bushels per acre for one season. However, the generalization of such results would require high improvements in present farming practices.

3. THE INVESTMENT PROJECT ("MASTER PLAN")

3.1 The water resources and their possible utilization for irrigation and power production

The main irrigation and power potential in the surveyed area is the Mahaweli Ganga, which has a long-term mean yield of 6,613,000 acre-feet per year at the lowest site of diversion Kandakadu. It has been established that by regulating the yield of the Mahaweli Ganga and its tributaries and the Maduru Oya, it will be possible to obtain a regulated flow, at 90 per cent frequency equal to 4,501,000 acre-feet per year. Apart from this the lateral inflow of unregulated yield can provide an additional 416,000 acre-feet per year with the same guaranteed frequency. The total assured water release is therefore 4,917,000 acre-feet, or 75 per cent of the long-term mean yield of the basin. The present regulated yield from the rivers in the north central part of the island, together with the smaller rivers in the Mahaweli Ganga Basin which have not been included in the above estimate, amounts to 745,000 acre-feet.

The total utilizable water resource of the surveyed area amounts to 5,956,000 acre-feet per year. This quantity of water would be sufficient to irrigate approximately 700,000 acres of paddy land or, alternatively, 1,300,000 acres under cotton, groundnut, chillies, or other high value crops.

To develop the natural yield of the Mahaweli Ganga and its tributaries, and to generate hydro-electric power, sixteen multi-purpose units (dams) have been desinged, with a total useful water release of 4,500,000 net acre-feet per year :

Unit	*Thousand of acre-feet*
Polgolla	420
Moragahakanda	1,318
Randenigala with Victoria	1,517
Upper and Lower Uma Oya	334
Taldena	108
Palewella	115
Hasalaka	45
Heen Ganga	153
Rotalawela	120
Kalu Ganga	172
Heppola Oya	22
Ulhitiya Oya	35
Maduru Oya	142
Kotmale	—

Eleven out of these units include power stations and another power station is projected on the trans-basin canal to Kala Oya. The parameters of the twelve power stations are summarized below :

Installed capacity	460 megawatts
Firm power	210 megawatts
Average annual energy output	2,380 million kilowatt hours

3.2 The Land Resources available for irrigation

3.2.1 Investigations into the agronomy and soils of the Project area show that the new irrigable land can be profitably assigned to different cropping patterns as below :

Croppig pattern	*Percentage of Irrigable area*
1. Paddy (Paddy-Paddy-Legume)	25
2. Mixed (Paddy-Cash crops)	12
3. Cash crops in rotation	55
4. Irrigated pastures	5
5. Sugarcane	3
	100

It is assumed that land which is already irrigated will continue to be cultivated under the existing cropping pattern, namely paddy. On the basis of " water balance " estimates, the available irrigation supply is sufficient for 900,000 acres according to the above cropping pattern in both Maha and Yala seasons. Of this 627,300 acres will be new and 272,700 acres land already developed.

3.2.2 The area proposed to be irrigated includes *all* irrigable land available in the Mahaweli Ganga and Maduru Oya basins. The water supply to these areas, being closets, is the least expensive and soil conditions are favourable. The other lands to be irrigated, in the adjacent north central part of the island, has been selected from areas commanded by existing tanks. This selection is supported by economic and sociological studies. The use of the tanks, to redistribute water supplied from trans-basin canals, allows a reduction in the cross section of the trans-basin canals and will reduce the cost per mile by about half. Settlement is also facilitated if the new land is close to populated areas.

On the above considerations, the lands proposed for irrigation have been distributed as follows :—

Basin	*Systems*	*Acreage*		
		Develop-ment	*Already irrigated*	*Total*
Mahaweli Ganga	A, C, D, E, F, G	209,500	102,400	311,900
Maduru Oya	B	103,100	6,800	109,900
Rivers in the north central part of the island	H, I, J, K, L, M	314,700	163,500	478,200
		627,300	272,700	900,000

3.3 The Water Distribution System proposed

The main structures are the irrigation and hydro-power units at *Randenigala*, providing 1,520,000 acre-feet of useful water and 100 megawatts of installed capacity, and at *Moragahakanda* 1,320,000 acre-feet of useful water and 40 megawatt of installed capacity. The former will serve as the main source of irrigation for the Mahaweli Ganga and Maduru Oya basins while the latter, augmented with water from the Mahaweli Ganga, will be the most important source for the irrigation systems in the north central part of the island.

The distribution of water from these sources is envisaged as follows :

(*a*) Irrigation systems in the central basin of the Mahaweli and the Maduru Oya basin (systems D_1, D_2, G, C, B, E in the diagram attached) will be supplied with water through the Mahaweli right bank (R. B.) and Mahaweli left bank (L. B.) canals, from the diversion structure at Minipe on the Mahaweli Ganga. These canals will be augmented en route from reservoirs on tributaries of the Mahaweli. System F and G will be supplied with water from the Kalu Ganga Reservoir.

(*b*) The lower basin (system A) will receive water from the diversion structure at Kandakadu.

(*c*) Irrigation system in the north central part of the island will be supplied by two routes :

(1) From the diversion structure at Polgolla on the Mahaweli Ganga, through a tunnel to the Sudu Ganga and the Polgolla-Kala Oya (P. K.) canal, to the Kala Oya basin (system H).

(2) From the diversion structure at Elahera on the Amban Ganga, through the N. C. P. canal to other irrigation systems (I, L, M, K, J, *vide* diagram).

The irrigation and power units at Polgolla, Randenigala and Moragahakanda as well as the trans-basin canals are inter-connected by a joint water supply system.

The useful release from the Moragahakanda unit will be augmented in this way by the unit at Polgolla through the Sudu Ganga which flows into the Amban Ganga, from 561,000 (from its own catchment) to 1,320,000 acre-feet per year. The Randenigala unit will also supplement the supply to the north central irrigation systems since Moragahakanda alone cannot meet the full requirement in critical years, when some 500,000 acre-feet will have to be pumped from the L. B. canal (at point where it crosses the Amban Aanga). The distribution of water resources is summarized in Table I.

The water discharge of 500,000 acre-feet to be pumped was estimated under the conditions of compensating regime of operation at Kotmale. The quantity of water to be pumped prior to this condition will comprise 634,000 acre-feet in a critical year.

TABLE 1

Distribution of Water Resources of the Mahaweli Ganga and its Tributaries

Water Diversion units and area under command	*Irrigated areas in 1,000 acres*	*Sources of water and ensured discharge (in 1,000 acre – feet)*							
		Randenigala	*Kotmale Polgolla*	*Right bank tributaries*	*Left bank tributaries*	*Moragaha-kanda*	*Rotalawela*	*Lateral inflow*	*Total*
Lower diversion structure Kandakadu Lower basin Mahaweli	87·2	80	—	—	—	—	120	266	466
Central Diversion structure tail race of Randenigala R. B. Mahaweli Basin and Maduru Oya Basin	186·8	180	—	614	—	—	—	40	834
Central diversion structure tail race of Randenigala L. B. Mahaweli Basin	147·8	552	—	—	350	—	—	110	1,012
Upper diversion structure Polgolla Kala Oya Basin	97·6	—	420	—	—	—	—	—	420
Diversion structure on Amban Ganga Elahera basins in the North central part of the Island	380·6	634	—	—	20	1,318	—	—	1,972
Total	900·0	1,446	420	614	370	1,318	120	416	4,704
Randenigala Extra Water									71
								GRAND TOTAL	4,775

3.4 Irrigation and Drainage

As already noted, the terrain is not an easy one for the conveyance of large quantities of water and the heavy rainfall experienced in the hill regions of the catchment will make it necessary to provide many control structures for fluctuations in flow and for cross drainage. Nevertheless, irrigation canals are already in existence in many parts of the region and have functioned satisfactorily although the cost of construction has been comparatively high.

The design is based on the irrigation requirements of the cropping patterns in relation to varying conditions of soil, terrain and hydrometeorology ; the annual cropped area is estimated at 2,000,000 acres (800,000 hectares). Rice (892,000 acres), groundnuts (288,000 acres), vegetables (230,000 acres), green gram (150,000 acres) and cotton (94,000 acres) are the chief crops. High value crops are chillies (85,000 acres) and onions (50,000 acres). Sugarcane, citrus, maize and pasture also feature in the cropping patterns.

Water consumption for the cropping patterns recommended (see para 3.2.1) has been determined on the basis of theoretical and experimental data as follows :

Cropping patterns	*Acre-feet per acre*
1	8·3
2	6·0
3	4·5
4	4·6
5	8·0

Irriagtion is assumed to be mainly by gravity along furrows or in basins. A small area not suitable fo surface irrigation will be irrigated by lift and sprinklers. A total of 13 irrigation systems have been designed tied to river basins (for details see Table 2).

The irrigation network estimates include the cost for all canals, controls and regulators required. On the flatter land, basin irrigation is planned, and on the steeper lands on the sides of the valleys, furrow irrigation.

Improvements to the existing irrigation engineering systems will increase water supplies by strengthening the canal network and providing water distribution structures where necessary with water measuring devices wherever possible. Small scale village irrigation systems will be absorbed into the new large irrigation blocks.

Drainage channels and controls are planned to provide cross drainage under irrigation canals, and field channels to natural drainage lines in the irrigated areas. Drainage facilities have to be provided in areas already irrigated as well as in the land to be developed. Some measure of flood mitigation will be obtained by storage in the reservoirs, but on the coastal plains of the Mahaweli Ganga embankments will have to be built to protect agricultural land from

inundation by flood water. The embankments have been designed and costed to provide protection against floods of 20 year frequency, with a flood plain half a mile wide, a cleared and maintained river channel and embankments at least 10-12 feet (3 meters) high.

Irrigation and drainage estimates have been prepared for major canals, down to 100 cusecs (3 cusecs) capacity, drainage channels and structures. These have been developed from detailed plans of some sample areas in the distribution network. These estimates will of course be revised when detailed designs are complete. They can however be accepted for the first stage of the study.

TABLE 2

Areas under the proposed Irrigation Systems, and Extent of Water Supply

System Index	Net area under irrigation (1,000 acres)			Crop rotation for new irrigable lands					Gross water requirements (thousands of acre-feet)	Water supply sources in (1,000 acre-feet)			Drainage water
	Total	Existing irrigation	New irrigation	1	2	3	4	5		Water from Mahaweli and its Tributaries	Local Yield (nett) (Add.)	Canal losses (deduct)	(Add)
A	87·2	14·0	73·2	3·0	28·9	11·0	30·3	—	503	466	—	—	37
B	109·9	6·8	103·1	27·6	20·0	55·5	—	—	655	420	185*	—	50
C	76·9	3·3	73·6	23·0	—	50·6	—	—	445	414	14	16	33
GD_1	91·4	56·0	35·4	10·3	4·3	9·6	—	11·2	706	620	75	49	60
D_2	27·3	18·2	9·1	—	—	—	—	9·1	223	215	10	—	18
E	20·4	10·4	10·0	3·0	—	7·0	—	—	143	130	—	—	13
F	8·7	0·5	8·2	2·5	—	5·7	—	—	50	47	—	—	3
H	97·6	40·7	56·9	14·6	4·7	37·6	—	—	656	420	195	15	56
I	140·0	52·2	87·8	28·3	—	59·5	—	—	1,007	825	156	60	36
J	56·3	7·1	49·2	15·5	—	33·7	—	—	339	280	43	10	26
K	52·0	32·6	19·4	5·2	—	14·2	—	—	332	265	58	18	27
L	96·4	19·9	76·5	20·0	3·4	53·1	—	—	590	502	51	9	46
M	35·9	11·0	24·9	4·2	10·8	9·9	—	—	236	100	120	4	20
Total	900·0	272·7	627·3	157·2	72·1	347·4	30·3	20·3	5,885	4,704	887	181	475

* Including 142,000 acre-feet of net regulated effect of the Maduru Oya Reservoir.

3.5 Power Generation and Flood Protection

3.5.1 POWER GENERATION

The proposed major dam sites have been examined geologically and no specially difficult conditions have appeared. The storage-cost figures for the dams vary considerably between $ 21 and $ 94 per 1,000 cubic meters, the smaller dams and those intended mainly for irrigation having the highest storage costs and the lower power output.

The power potential of the rivers has been considered in the design of structures and reservoirs, in order to provide multi-purpose benefits from the water resources. To determine the power potential, studies were carried out for the proposed structures along the Mahaweli Ganga and its tributaries, with approximate estimates of their main characteristics ; namely effective flow, installed capacity of power plants and annual energy output. These preliminary studies show that, in all, 58 irrigation and power units can be constructed, of which 29 will be purely for power generation and 18 purely for irrigation including the anicuts and new tanks. The total potential of the multi-purpose and power units amounts to 970 megawatts installed capacity, with an annual output of 5,000 million kilowatt hours.

The potentialities for power development considerably exceed the prospective demand for power in the whole country for the next twenty years. In view of this , designs for hydro-electric plants were only carried out for multi-purpose and power units, the parameters of which are given in Table 3.

As will be seen, the most important units are those of Randenigala, Kotmale, Victoria Falls, and Moragahakanda, with a total of energy output (in 1990) of 1577 million Kwh. per annum, or 66 per cent of the total. These main units as well as some other irrigation and power units have been designed in greater detail.

3.5.2. FLOOD PROTECTION

Flood protection of urban and rural areas subject to inundation under present natural conditions of the Mahaweli flow is provided by the absorption of flood peaks in the reservoirs at Kotmale and Randenigala and in other irrigation and power units on the tributaries of the Mahaweli. With the construction of Kotmale dam, the inundation of 5·2 square miles of urban areas would be prevented and damage would be considerably reduced even in a flood which occurs once in a 100 years. The absorption of flood peak in the Randenigala reservoir and on the tributaries of Mahaweli will reduce the cost of the embankments necessary to protect these lands.

TABLE 3

Power Characteristics of the Multi-purpose and Hydro-Power Units

Hydro Power Units	*Power capacity in MW*		*Average annual power output mln. Kwh.*	*Annual useful water issue (in thousands of acre-feet)*
	Firm	*installed*		
1. Polgolla	26·0	34	260	420*
2. Lenadora	8·0	11	78	—
3. Moragahakanda	19·0	40	205	1,318
4. Victoria Falls	30·0	80	390	—
5. Randenigala	42·0	100	472	1,517
6. Kotmale	48·0	102	510	—
7. Upper Uma Oya	10·5	25	123	204
8. Lower Uma Oya	12·8	29	144	130
9. Taldena	4·2	13	62	108
10. Pallewela	3·5	10	49	115
11. Hassalaka Oya	4·3	11	53	45
12. Heen Ganga	2·7	6	31	153
Total	211	461	2,377	4,010

* An additional 830,000 acre-feet is diverted to Moragahakanda Reservoir.

3.6 **Agricultural Production** (Land use and cropping patterns proposed : expected value added).

3.6.1 LAND USE PATTERNS

In the light of the needs of the country as already described, the land use patterns aim at reaching the two following main objectives :

(*a*) to minimize as far as possible the imports of food stuffs and to increase (or to establish now) exports of certain products ;

(*b*) to substantially increase farm income by inducing the production of high value crops and higher farm productivity.

At present paddy is the most important food crop in the island. The average yield per season, *given an adequate water supply* (Minipe irrigation system for example) approximates to 60 bushels per acre in certain areas. With fertilizers and better agricultural practices this can be increased to 70-80 bushels (data obtained from experimental stations and Dr. Constable's experiments of farmers' fields). The estimated yield of paddy in the project area should ultimately reach 70 bushels per acre, taking into account the assured supply of water and better agricultural practices. The expected yields of other crops have been similarly estimated.

The anticipated value added by crops has been calculated on the basis of world market prices and anticipated costs.

The expected yields and " value added " from main crops are given in the following table (paddy yields are in bushels, sugar cane yields in tons, other yields in hundredweights) :

	Paddy	*Cotton*	*Ground-nut*	*Chillies*	*Bombay onions*	*Vege-tables*	*Sugar-cane*	*Maize*
Average yield per acre per season	69[1]	15	16	10	100	69	35	30
Value added per acre (in Rs.)	390	649	645	963	1,622	1,257	1,009	389
Value added per acre feet of irrigation water (in Rs.)	102	270	322[2]	321	580	527	126	778[3]

Assuming a rate of growth of population of 2·5 per cent per annum and a constant per capita consumption of rice, the total demand for *paddy* in 1991 will be 3·5 million metric tons. Assuming approximately 50 per cent increase in the yield per acre and no increase in the area under cultivation or other changes, Ceylon will require to import 2·0 million metric tons of paddy which is the equivalent of 1·4 million metric tons of rice. In order to produce this quantity of paddy it would be necessary to cultivate 700,000 acres of paddy requiring 6 million acre feet of water. This would absorb the entire water supply from the project.

Land used in this manner in not advised as the value added per acre–foot by paddy cultivation is the lowest among the feasible crops. After due consideration of the government's desire for the production of paddy cultivation, it has been decided to propose that the following lands be cultivated with paddy :

(1) Areas presently cultivated with paddy,

(2) Areas where the soil and other physical factors do not permit the cultivation of crops, other than paddy.

These will amount to 446,000 acres under paddy of which 193,000 will be newly cultivated with paddy.

[1] This is an average for all project perimeters. Expected yields for each perimeter and season vary from 55 to 80 bushels in Maha and from 60 to 85 bushels in Yala according to quality of soils and other factors.

[2] For Yala season.

[3] Maha season.

The following land use pattern has been, therefore, recommended with the objective of maximizing value added per acre foot of water :

Proposed land use for the whole project**

(For more details, *see* Table 4)

	Paddy	*Maize*	*Cotton*	*Ground-nut*	*Others*
Area under cultivation (in thousands of acres)	890	80	90	290	660
Output (in thousands of long-tons)	1,260	140	70	230	1,880
Value of output at w.m.p.[1] (in millions of Rs.)	488	52	80	217	927

[1] World Market Prices.

** The proposed land use and corresponding agricultural product for *Phase I* is shown in the Table 5 separately for Steps I and II.

For all the three phases, total crop acres, total production of each farm product, value of production at World Market Prices and at guaranteed prices by Government

Crop	*('000) crop acres*	*('000 long tons) Total production*	*(In million Rs.) Total value of production at W.M.P.*	*(In million Rs.) Total value of production at G.P.*
Paddy	892.3	1,264.2	488.0	743.3
Sugarcane	30.6	810.0	28.3	28.3
Greengram	150.7	60.3	40.5	60.2
Blackgram	46.6	18.6	14.5	14.5
Shallot Onion	14.0	84.2	42.1	58.4
Bombay Onion	36.9	184.6	68.1	119.8
Chillies	84.7	56.8	122.7	286.3
Vegetables	229.8	757.8	303.1	303.1
Groundnut	287.8	230.2	216.6	227.0
Kenaf	5.8	2.8	2.1	2.1
Citrus	18.0	60.3	54.0	54.0
Cotton	94.1	70.6	80.4	80.4
Maize	79.2	138.6	52.0	52.7
Cowpea	6.8	2.7	1.8	1.8
Milk	30.3	69.1	49.6	49.6
Total	2,007.6	—	1,563.8	2,081.5

Crop		*Paddy*	*Sugar cane*	*Green gram*	*Black gram*	*Shallot Onion*	*Bombay Onion*	*Chillies*	*Vegetables*
WMP[1]	ton	386.12	35.00	670.80	780.00	500.00	369.40	2,160.0	400.00
GP[2]	ton	588.00	35.00	998.40	780.00	694.40	649.60	5,040.0	400.00

Crop		*Ground nut*	*Kenaf*	*Citrus*	*Cotton*	*Maize*	*Cowpea*	*Milk*
WMP[1]	ton	940.60	560.00	896.00	1,140.00	375.00	672.00	716.80
GP[2]	ton	985.60	588.00	896.00	1,140.00	380.00	672.00	716.80

[1] World Market Price.
[2] Guaranteed Price.

TABLE 5—PHASE I

Total crop acres, production, value of production at World Market Prices and at Guaranteed Prices by Government

(*In million Rupees*)

Crops	*STEP I*				*STEP II*			
	Crop acres ('000 acres)	*Production ('000 long tons)*	*Value at W.M.P.*[1]	*Value at G.P.*[2]	*Crop acres*	*Production ('000 long tons)*	*Value at W.M.P.*[1]	*Value at G.P.*[2]
Paddy	273·1	230·4	88·9	135·5	73·4	90·6	35·0	53·2
Sugarcane	30·6	810·1	28·4	28·4	nil	—	—	—
Green-gram	9·0	3·6	2·4	3·5	10·6	4·2	2·8	4·2
Black-gram	13·6	5·4	4·2	4·2	nil	—	—	—
Chillies	7·8	4·7	10·1	23·5	30·0	18·0	39·0	91·0
Groundnut	52·8	42·2	40·0	42·0	40·0	32·0	30·0	32·0
Kenaf	5·8	3·9	2·2	2·2	nil	—	—	—
Vegetables	17·2	56·4	22·6	22·6	20·6	67·9	27·2	27·2
Cotton	30·0	22·5	25·7	25·7	nil	—	—	—
Maize	3·6	6·3	2·4	2·4	10·0	17·5	6·6	6·7
Bombay Onions	nil				10·6	53·0	19·6	34·4
Total	443·5		226·9	290·0	195·2		160·2	248·7

[1] World Market Prices.
[2] Guaranteed Prices.

3.6.2 CROPPING PATTERN AND FARM INCOME

(1) The paddy crop pattern (paddy-paddy-legume) will be applied to an area of 410,000 acres located in the river valleys and in depressions with heavy soils and also on the irrigated area which is under paddy at present.

(2) The mixed crop pattern (paddy-high value crop-legume) will be applied to an area of 72,000 acres also located in the heavy soil area and on river terraces with normal facilities for drainage.

(3) High value crops will be grown on an area of 360,000 acres of light and well drained soils.

(4) An area of 30,300 acres in Mahaweli Ganga delta area will be devoted to irrigated pasture.

(5) Sugarcane will be grown on an area of 22,900 acres in the vicinity of the existing sugar factory.

Value added from the irrigated area, calculated on the basis of the above data, is shown in the table below :

Value added from irrigated area at world market prices

(In millions of Rupees)

	Present value added	*Additional value added*	*Total value added*
Presently irrigated land (273,000 acres)	107	143	250
New land (627,000 acres)	—	1,030	1,030
Total	107	1,173	1,280

3.7 Land Settlement

3.7.1. TYPES AND SIZES OF FARMS

The size and type of holdings must be decided with due regard to agricultural methods as well as sociological and economic and social factors.

The mechanization of agriculture is difficult under local conditions owing to the fact that most of the crops require a great deal of manual labour (vegetables, chillies and to some extent cotton, groundnut, etc.) ; lack of foreign exchange also restricts its application on a large scale. At least during the first 20 years of development a substantial part of agricultural work will therefore have to be performed by manual labour.

From a social point of view, it does not seem advisable in all instances to rely on large scale farms or plantations, as they would not provide permanent employment since the labour requirement is subject to marked seasonal variations. However, some crops such as maize and sugarcane may be cultivated with mechanized methods and organized as large scale farms or plantations. Cooperative farming seems both possible and advisable but can only be introduced gradually, due to local traditions. The proposed size of farms is designed to allow one family, with a minimum use of hired labour in the peak season, to cope with their farm work. This size is 5 acres per family. The possibility of developing large scale mechanized farming will be studied in Stage II of the survey.

3.7.2 COST OF SETTLEMENT

The above proposals would require the settlement of 125,000 farm families on newly developed land. The capital cost of building houses for the farmers and of providing social and communal services is estimated at Rs. 557 million. The expenses incurred by the Government could be recovered in part through payment for land which the Government would sell at a nominal price of Rs. 200 per acre. The total sum which would thus be recovered would amount to Rs. 125 million. In this study, the cost of resettlement has been allowed for in full.

3.8 Organizational and Managerial aspects (Implementation Agency)

A scheme involving large population movements and the settlement and training of many farmers over an area covering nearly 40 per cent of Ceylon is a major undertaking. For its successful implementation, an Agency, in charge at least of coordination at ministerial level would be advisable. It is recommended that these organizational and managerial aspects of the project be studied in Stage II of the study.

4. ECONOMIC EVALUATION

4.0 In evaluating the project, an attempt was made to answer the following questions :—

(i) Is the project " feasible " (in the sense of " possible "), taking into account technical, economic, financial, institutional and other social constraints ; what conditions, should be fulfilled to ensure its successful implementation ; what measures should be taken to satisfy these conditions and what would be the costs involved ?

(ii) Is the project, so formulated, economically advisable ?

The economic worthiness (advisability) of the project was considered from the national economic standpoint and from the narrower financial point of view of the farmers. The main criteria from the point of view of the national economy are (i) the contribution made by the project to national income, (ii) the net foreign exchange earnings (or savings) arising from the project. The important goals of providing employment and of meeting the food requirements of the country were also taken into consideration but the attainment of national self-sufficiency in food and full employment were considered less important than the maximization of national income growth and of foreign exchange earnings.

4.1 Feasibility and Conditions of Implementation

The feasibility (possibility) of the project has been considered from the following points of view ; technical, institutional (management, organization, extension services, settlement), and social, general economic and financial. This examination, which will have to be continued in greater detail during Stage II of the UNDP/SF study, has already led to the conclusion that the project, as described above, could be carried out in 20 years' time during the next two decades. However, it will *not* be easily feasible and certain essential conditions will have to be fulfilled if it is going to be successfully implemented.

The main conditions are :

1. A progressive increase in the rate of land development during the first few years of the project (Phase I),

2. Immediate action to build up by 1970 the capacity required to develop annually 20,000 acres of land (new). (Failure to do so will jeopardise the implementation of Phase I as planned).

3. Setting up of an Implementation Agency in charge at least of co-ordination at ministerial level to ensure timely execution of the project according to plan.

4. Provision of adequate extension services and setting up of pilot farms and experimental centres at an early stage.

5. Provision to the settlers of all production requisites (inputs) in due time. (Need therefore to plan carefully the delivery of these inputs, especially fertilizers).

In the project budget, expenses necessary to provide these requirements have been taken account of.

The following consideration should also be kept in mind :

Conflict between employment and productivity of the farms (plantations *vs.* small holdings).

The objective of *maximizing employment* may to some extent, conflict with that of *maximising output and economic return.* Indeed, until now, settlement schemes, aimed at providing even smaller plots of land to *larger number of peasant farmers*, have been disappointing from the point of view of farm productivity ; it is therefore felt, in many quarters, that in order to reap the full benefits of the heavy investments to be made in future irrigation schemes, one should adopt highly productive *capital intensive methods* of cultivation implying *large plantation-type farms.* The project master plan has been *provisionally* prepared and appraised on the assumption that the settlers would be small peasant farmers and, for this kind of settlement, farms of 5 acres in size have been recommended.

No recommendations have as yet been made concerning the type of settlement to be finally adopted (small proprietary farming, large farms or plantations). Studies, already begun, to make this essential decision should be actively pursued during Stage II of the UNDP study to determine the optimum types of settlement and of farming organization to be recommended, taking due account of (i) the abundance of farm labour, (ii) the scarcity of foreign exchange needed to purchase machinery, and (iii) the possibility of making available to small farms, *through cooperatives*, some at least, of the advantages of large-scale capital intensive farming (mechanization, managerial ability, technical guidance, etc.)

4.2 Method of assessment of the economic worthiness of the Project

4.2.1 DEFINITION OF THE PROJECT

For purposes of appraisal, *the project proper*, in the narrow sense has been defined as including the following activities :

(1) Supply of irrigation water to the 900,000 acres (364,000 ha.) of the project (Reservoirs, diversions, canals, irrigation system) ;

(2) Production of electric power to be sold *at the busbars* of the hydro power stations (excluding therefore transmission and distribution) ;

(3) Agricultural production of the farms situated within the project perimeters, farm products being sold *at farm gates* ;

(4) Housing of the farmers ;

(5) Extension and other agricultural services, " Implementation Agency ", experimental and model farms and other free services supplied by the Government for the benefit of the farmers ;

(6) Basic infrastructure (essentially roads) needed to support these activities.

All activities situated outside the project thus defined have been considered as corresponding to indirect effects or aspects of the projects.

4.2.2 ASSESSMENT OF DIRECT, INDIRECT AND SECONDARY EFFECTS OF THE PROJECT

Only *direct effects* (benefits and costs) have been examined in detail, and used to appraise the project by the calculation of rates of return with as much precision as possible. *Indirect effects* have only been roughly estimated at this stage of the economic analysis, to show the investment and employment opportunities opened by the project in other sectors. *Secondary effects* (income effects) have been simply evoked to indicate the probable overall impact of the project on the economy of Ceylon.

4.2.3 CHOICE OF INDICATOR OF SOCIAL PROFITABILITY

To measure the overall social profitability of the project, from the national economic stand-point, the " internal rate of return " based on " accounting prices " has been adopted.

4.2.3.1 *Internal rate of return*

The " internal rate of return " may be defined as the rate of interest which, if it were applied to all receipts and expenditures of the project (on capital as well as on current accounts), would reduce net benefits to zero.

4.2.3.2 *Accounting Prices*[1]

" Accounting Prices " are prices different from prevailing market and official prices, which reflect more accurately the value of imputs and outputs to the economy. The following accounting prices have been used :

To eliminate distortions brought about by Government subsidies, agricultural products have, as far as possible, been valued at world market prices ; similarly import prices have been used for fertilizers. Moreover, an attempt has been made at valuing primary factors of production (land, labour, capital) at their "opportunity cost " which should be equal to the value of production foregone by their utilization.

[1] Also often called " Shadow Prices ".

Unskilled labour in Ceylon (considered as including that of the average peasant farmers), and irrigable land in the Dry Zone, being at present abundant factors, and likely to remain so for a long time, have for these reasons been considered as having an opportunity cost equal to zero ; on the contrary, skilled labour being scarce, despite educational and training efforts made by the Government, its opportunity cost has tentatively been taken as equal to twice the present prevailing salaries.

As the rate of return is itself a rate of interest, no such rate has to enter into its calculation. However, a rate of interest is still useful as a benchmark to which to compare the internal rate of return. To this end, it is proposed to adopt an accounting rate of interest of 10 per cent, reflecting the shortage of capital for productive investment in Ceylon. It is felt that no project yielding a return lower than 10 per cent should be taken into consideration. A readily acceptable project should yield a markedly higher rate.

Foreign exchange being very scarce, it is proposed to adopt, for the purpose of this analysis, an accounting rate of exchange equal to twice the present rate of 4·76 Rupees to one US $. However, because of lack of reliable data on the import component of certain elements of costs, and of great uncertainities concerning the equilibrium rate of exchange for the Ceylon Rupee, the accounting rate proposed will be used with caution (only to show in what direction and to what extent results obtained without it would be modified by its use).

4.2.4 THE FARMER'S POINT OF VIEW

For the assessment of the worthiness of the project from the farmer's point of view, traditional rules governing financial calculations have been followed.

4.3 Costs

It is convenient to distinguish between Capital (Investment) costs and recurrent costs for operation and maintenance.

(1) CAPITAL COSTS

(a) Cost of project works

The capital cost of the project works for irrigation, drainage, flood control and power production has been estimated at 4,584 million Rupees (US $ 964 million) on the basis of average prices for construction work prevailing on the the world market, taking into account the construction of the larger works (headworks, hydro-power stations and trans-basin canals) by foreign contractors.

This total is made up of the following components :

	Million Rupees		*US $ Million*	
	Irrigation	*Power*	*Irrigation*	*Power*
Reservoirs, Diversion Works and Power Plants	1,105	901	233	189
Trans-basin canals (and pumping station)	1,059	—	223	—
Irrigation systems	1,519	—	319	—
	3,683	901	775	189
	4,584		964	

The cost of irrigation systems includes land development work (clearing and levelling) and the cost of irrigation works required for water deliveries down to blocks of 100 acres (40 hectares).

(*b*) *Additional Capital Costs to be considered*

The full implementation of the project would require, in addition, the following capital expenditures which have only been roughly estimated :

	Million Rupees		*US $ Million*	
	Irrigation	*Power*	*Irrigation*	*Power*
Settlement expenditures	626	—	13[2]	—
Storage, marketing and transport facilities	200[1],[2]	—	42	—
Processing industries	200[1],[3]	—	42	—
General infrastructure such as roads	200[1],[4]	—	42	—
Power transmission lines	—	268	—	56
	1,226	268	258	56
	1,494		314	

[1] Order of magnitude.

[2] Including investment in cooperatives.

[3] Only those industries indispensable to avoid losing the value of the crops (such as sugar factories and ginning mills) have been taken into consideration.

[4] Construction cost of irrigation works include the cost of service roads along irrigation canals. Expenditure on roads considered here would include improvement of these services roads plus construction of new roads which may be needed to link the new irrigated perimeters to the main roads, railway lines and population centres of the dry zone.

Settlement expenditures comprise the following elements :

	Totals for the entire project		*Corresponding levels for newly developed land*	
	Millions rupees	*$ Million*	*Rs./Acre*	*$/ha.*
(i) Cost of farm buildings and farm working capital	418	88	600	312
(ii) Capital expenditure relating to agricultural extension and other free services and facilities provided by the Government[1]	139	29	200	104
Sub-total	557	117	800	416
(iii) Capital expenditures relating to revenue earning Governmet activities[2] (+miscellaneous)	69	15	100	52
Total	626	132	900	468

[1] Model farms, experimental stations, Project Implementation Agency, colonization officer's quarters, wells, village streets, community centres, etc.

[2] Essentially ; Electricity supply (rural electrification), postal services and telecommunications.

The above Settlement expenditures for the entire project include some resettlement expenditures in already cultivated areas, which have been assumed to be equal to only $\frac{1}{4}$ of the level of settlement costs for newly developed land (225 Rs./Acre for items (i) to (iii) above and 200 Rs. for items (i) and (ii) only).

(*c*) *Costs retained (or allocated) for direct benefit/cost calculations concerning the project proper*

Revenue earning Government activities related to land settlement (item (iii) above) which may be considered as having their own economic justification have been excluded from direct benefit/cost calculations made for the project proper. For the same reason, capital expenditures relating to storage, marketing, transportation facilities, and processing industries have been eliminated from these calculations. Similarly only approximately one half[1] of the general overhead (infrastructure) costs indicated above have been allocated to the project proper ; the rest have been allocated to other productive activities such as marketing and processing.

[1] Exactly 93 million Rupees ($ 19·6 million) corresponding to 1/6th of settlement expenditures (items (i) and (ii). This ratio has been adopted for cost allocations to different parts of the project.

(*d*) *Summary of total capital expenditures*

Total capital expenditures may be summarized as follows, distinguishing between the project proper and the economic activities resulting directly from the project :

	Million Rupees		*US $ Million*	
	Agriculture	*Power*	*Agriculture*	*Power*
A. Project proper				
Project works	3,683	901	775	189
Settlement	557	—	117	—
Overheads	93	—	20	—
Sub-total	4,333	901	912	189
	5,234		1,101	
B. Activities resulting directly from the project				
Power transmission	—	268	—	56
Marketing and processing of agricultural products (and revenue earning Government activities)	469	—	99	—
Overheads	107	—	22	—
Sub-total	576	268	121	56
C. Grand Total	4,909	1,169	1,033	245
	6,078		1,278	

(*e*) *Foreign exchange component of capital costs*

The import component of the capital cost of the project works has been estimated at 48·5 per cent of total costs, corresponding to the equivalent of 2,218 million Rupees at the present rate of exchange (US $ 465 million). This proportion is only slightly higher for power costs than for irrigation costs and does not appreciably vary from one phase of the project to another.

The direct labour components of capital costs (for both skilled and unskilled labour) are not known with precision, although it is felt that the skilled labour element is relatively important. For purposes of appraisal, it has been assumed that the opportunity cost of labour (skilled and unskilled) is equal to the total wage bill.

(*f*) *Phasing of capital expenditure*

Capital expenditures for the irrigation and power *works*, by phase are summarized below :

	Millions of Rupees			*US $ Million*		
Phases	*Irrigation*	*Power*	*Total*	*Irrigation*	*Power*	*Total*
I	863	209	1,072	181	44	225
II	1,938	190	2,128	407	40	447
III	882	502	1,384	187	105	292
Totals	3,683	901	4,584	775	189	964

Capital expenditure for Phase I (Steps I and II) can be summarized as follows :—

	(*Millions of Rupees*)				*Acreages (000 acres)*			*Power installed capacity (MW)*
	Works	*Settlement*	*Infrastructure*	*Total*	*Existing*	*New*	*Total*	
Step I	652	104	17	773	115	101	216	58
Step II	420	61	10	491	14	73	87	80
Total	1,072	165	27	1,264	129	174	303	138
US $	225	35	6	266				

(g) *Unit Capital Costs of works (by phases)*

Phases	*Developments*		*MW*[2]	*Cost of Irrigation per unit of area*		*Investment per kWh of annual output, of firm power*[1]		*Unit cost of installed capacity*	
	Irrigation '000 acres[1]	*Power 10^6 kwh*		*Rs./Acre*	*$/ha.*	*Ceylon Cents*	*US Cents*	*Rs./kW*	*$/kW*
I	239	634	128	3,600	1,870	33	6.9	1,510	334
II	370	423	127	5,200	2,700	45	9.5	1,500	300
III	154	795	196	5,700	2,960	63	13.2	2,560	540
Totals	763	1,852	461	4,800	2,500	49	10.3	1,950	410

[1] " New Acres Equivalent " : one improved acre being counted as equivalent to 1/2 new acre (from the point of view of added production).

[2] Installed capacity.

(2) CURRENT COSTS (OPERATION AND MAINTENANCE)

For the purpose of the rough economic evaluations required at this stage, current costs relating to *operation and maintenance of the project works* may, with sufficient accuracy, be estimated at 1 per cent of corresponding capital expenditures (46 million Rupees = nearly $ 10 million)[1]. This percentage excludes the cost relating to the pumping station (due to start operations in 1990) which are estimated at about 5 million Rupees per year (a little more than $ 1 million) including consumption of electric power.

Current costs relating to *housing* and *general infrastructure* allocated to the project proper, which are relatively small and difficult to estimate have been neglected.

Current costs relating to *extension and other services provided free by the Government* have been estimated at 10 Rupees per Acre per year ($ 5.2 per hectare) corresponding to 9 million Rupees for the whole scheme ($1·9 million).

[1] Production cost per kwh may be approximately estimated at 10% of these investment figures (6% interest + 3% for depreciation + 1% for operation and maintenance).

Current costs of a contemplated *Government Agency in charge of implementing the project* have been tentatively estimated at 2.6 million Rupees per year ($ 550,000). This would add up to 52 million Rupees ($ 11 million) for a 20 year project and would correspond approximately to 1 per cent of all capital expenditures directly allocated to the project proper. This category of costs has been allocated to different specific work on the basis of this percentage *and treated on the same basis as capital costs for accounting purposes.*

After completion of the project, in 1991, yearly current costs for operation and maintenance (excluding agricultural production costs) corresponding to the project proper will therefore be close to 63 million Rupees corresponding to $ 13 million (without the Implementation Agency : 60 million Rupees and $ 12.5 million).

4.4 Benefits

Project benefits are essentially derived from the sale of agricultural products and of electric power. Benefits derived from flood protection of land at present settled and of cities, as well as from the renting value of houses to be built for the settlers are small and difficult to estimate ; they have been neglected.

Benefits may be defined as the value of production minus the current costs involved in obtaining it.

From a national economic point of view, using the shadow prices indicated above (in the section on methodology), production benefits to be used to calculate an " internal rate of return " may be considered as close to the value added (V) concept of national accounts[1]. As regards farm benefits, the identity is complete (if one leaves out foreign exchange complications) for skilled labour for which one assumes an opportunity cost equal to twice its market value, practically does not enter into farm budgets. The identity may also be considered as complete for electric power production if one neglects the relatively small importance of skilled labour in operation and maintenance costs. Value added in the national accounting sense has therefore been adopted to measure agricultural and electric power benefits from a national economic standpoint.

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[1] V = Value of production minus value of goods and services purchased from " other enterprises " = remuneration of primary factors (national resources, labour and capital) plus taxes.

(1) AGRICULTURAL BENEFITS

Value added by Agricultural Production is given below for each phase of the Project.

Additional "Value Added" by Agricultural Production

(Millions of Rupees)

		With Minor Improvements in agricultural practices	*With Major Improvements in agricultural practices*
Phase I	Step I	133	187
	Step II	96	135
	Total	229	322
Phase II		377	509
Phase III		267	342
Whole Project		873	1,173

The figures correspond to two different levels of yields defined as follows :

(*a*) better yields attainable almost immediately after land development and settlement, because they only require the adoption of *minor improvements* in farming practices which could be easily introduced in a climate of change, with the assistance of the dense network of extention assistance recommended ;

(*b*) high yields requiring *major improvements* in farming practices which could be introduced only progressively in the course of a period of 5 to 10 years.

For the economic evaluation, it has been assumed that major improvements will not have been adopted before 1981.

To take account of any likely delays in land settlement and adoption of the improved agricultural practices recommended, it has been assumed that agricultural production will increase in the following manner after commissioning of a given irrigated perimeter.

Year	*Percentage of attainable agricultural output on the perimeters*
0 (Year of commissioning)	5%
1	33%
2	67%
3	90%
4 (and following years)	100%

Net agricultural benefits, after deduction of various related current costs of the project are given below for each phase. These current costs have been deducted fully on the simplifying assumption that they reflect the opportunity cost to the community of the services they provide[1].

Net Agricultural Benefits with major Improvements in Agricultural Practices

Phases	*Value added by Agricultural Production* 10^6 *Rs.*	*Operation and Maintenance of Irrigation works*	*Extension and other free services*	*Total (rounded)*	*Agricultural Benefits*	
					10^6 *Rs.*	10^6 $
I	322	8·6	3·0	12	310	65
II	509	19·5	4·3	24	485	102
III	342	8·7	1·7	10	332	70
Totals	1,173	36·8	9·0	46	1,127	237

Net Agricultural Benefits with *minor* improvements in agricultural practices are similarly given below for *Phase I* :—

Steps	*Value added by Agricultural Production* (10^6 *Rs.*)	*Current costs to be deducted* (10^6 *Rs.*)	*Net Agricultural benefits*	
			(10^6 *Rs.*)	(10^6 $)
I	133	8	125	26·5
II	96	4	92	19·5
Total	299	12	217	46·0

(2) ELECTRIC POWER BENEFITS

Benefits derived from the generation of hydro-electric energy have been estimated as follows : Only *firm* (*guaratneed*) *power* has been taken into consideration (non-guaranteed power being of little value as its use presupposes the presence of stand by thermal plants).

[1] A preliminary analysis of these costs considered as a whole has shown that this assumption is valid as skilled labour constitutes approximately 50% of the total wage bill and it has been assumed that the accounting price of skilled labour is twice its market value and that of unskilled labour is zero.

The value of one kwh of guaranteed energy to the economy has been estimated, on the basis of accounts of the D.G.E.U.[1] at 5 Ceylon cents. Operation and maintenance costs equal to approximately 1/10th of this price have been deducted. As they are small and contain only a small element of direct labour, the difference, equal to approximately 4.5 Ceylon cents may be considered as representing value added by the hydro power stations per kwh of energy produced.

The power benefits thus calculated are indicated below by Phase :

Phase	*Steps*	*Guaranteed energy* 10^6 kwh	*Sales value* 10^6 *Rs.*	*Operation and Maintenance* 10^6 *Rs.*	*Benefits* 10^6 *Rs.*	10^6 $
I	(i)	264	13·2	0·9	12·3	2·6
	(ii)	370	18·5	1·2	17·3	3·6
	Total	634	31·7	2·1	29·6	6·2
II		423	21·1	1·9	19·2	4·0
III		795	39·8	5·0	34·8	7·3
		1,852	92.6	9·0	83·6	17·5

Electric power benefits for the whole Project represent 7.4 per cent of agricultural benefits (with major improvements)

(3) TOTAL BENEFITS

Total benefits, as estimated above, with major improvements in Agricultural practices are summarized below by phase :

Phase	*Agriculture* 10^6 *Rs.*	*Electric Power* 10^6 *Rs.*	*Flood Protection* 10^6 *Rs.*[2]	*Housing* 10^6 *Rs.*[2]	*Total* 10^6 *Rs.*	10^6 $
I	310	30	—	—	340	72
II	485	19	—	—	504	106
III	332	35	—	—	367	77
Total	1,127	84			1,211	255

[1] Department of Government Electrical Undertakings.

[2] Pre Memoria.

Total benefits, with *minor* improvements in agricultural practices, are similarly given below for *Phase I* :—

Steps	*Agriculture*	*Electric Power*	*Total*	
	(*10^6 Rs.*)	(*10^6 Rs.*)	(*10^6 Rs.*)	(*10^6 $*)
I	125	12	137	29
II	92	17	109	23
Total	217	29	246	52

4.5 Profitability

Profitability has been considered both from an overall economic and from a financial point of view.

(1) SOCIAL PROFITABILITY

Social internal rates of return and some other indicators of social and financial profitability, based on costs and benefits already discussed above, are given in the attached Table 6, for the project as a whole, each of the three phases and the two steps of Phase I.

Table 6

Profitability Indicators for the Project, its Phases and the Steps of Phase I

Phases	Steps	Capital Costs (10^6 Rupees)				Annual Benefits (10^6 Rupees)				Capital Benefit Ratio	Social Internal rate of return %	Unit capital cost of		Production cost of power Ceylon cents per kwh[2]
		Works	Settlement and Infra-structure	Impl. Agency	Total		Agriculture	Power	Total			Irrigation works Rs./Acr.[1]	Installed power Rs./KW	
I	(i)	652	122	8	782	*a*	125	12	137	5·7	15	3,580	1,500	3·3
						b	179	12	191	4·1				
	(ii)	420	72	5	497	*a*	92	18	110	4·6	18	3,690	1,520	3·3
						b	131	18	149	3·3				
	Total	1,072	194	13	1,279	*a*	217	30	247	5·2	16	3,600	1,510	3·3
						b	310	30	340	3·8				
II		2,128	321	25	2,474		485	19	504	4·9	14	5,200	1,500	4·5
III		1,384	135	14	1,533		332	35	367	4·2	17	5,700	2,560	6·3
Whole Project		4,584	650	52	5,286		1,127	84	1,211	4·4	15.5	4,800	1,950	4·9
		5,234												

[1] Per new acre equivalent (of note [1] on page 36).

[2] Guaranteed energy only.

[a] Up to 1980 with only minor improvements in agricultural practices.

[b] As from 1981 with major improvements in agricultural practices.

A study of this table leads to the following conclusions :

(i) With a Social internal rate of return of 15.5 per cent and a Capital/ Benefit ratio slightly above 4 the scheme as a whole may be considered economically sound. However, Capital costs of Rs. 4,800 per acre for all irrigation works (from reservoirs to land levelling)[1] and of 49 Ceylon cents per kwh of guaranteed energy (which would correspond approximatley to a production cost of nearly 5 Ceylon cents per kwh)[2] may appear rather high.

It needs to be mentioned here that these results were obtained with the present exchange rate of the Ceylon Rupee. Had the accounting rate proposed earlier, of twice the present official rate, been used, all these costs, in terms of US $, would have been considerably reduced[3] and the rate of return itself would have been raised by several points. Although " shadow pricing "[4] in this field is subject to great uncertainties, such considerations should prevent excessive pessimism regarding the level of the unit costs recorded above. This remark applies also to the rates of return and unit costs discussed below.

(ii) On the basis of the rates of return calculated, there appears to be only minor differences in profitability between phases. However there is a definite tendency for unit costs to rise from Phase I to Phase 3. The higher unit costs in Phase 3 are more than offset by increases in benefits. One may reasonably expect that these costs could be reduced and the possibility should be examined later to find ways of reducing them.

(iii) Within the first phase one notices a significant difference in profitability between Steps 1 and 2—Step 2 (Victoria Falls), with an internal rate of return of 18 per cent and a capital benefit ratio of only 3.3 at full development appears particularly promising. Step 1 (Polgolla, Moragahakanda) with a rate of 15 per cent and a capital benefit ratio of 4.1 at full development would appear to be somewhat less profitable, within the scope of the project defined for purposes of appraisal[5]. However Step 1 has the advantages of making use of existing investments in infrastructure, general services, processing and marketing facilities, some of which appear to be at present under-utilized.

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[1] Corresponding to US $ 2,500 per hectare.

[2] Corresponding to a little more than one US cent.

[3] The reduction is a function of the share of local expenditures in costs.

[4] i.e., the determination of accounting prices.

[5] *See* paragraph 4.2.1. page 30.

(2) PRIVATE FINANCIAL PROFITABILITY (THE FARMER'S POINT OF VIEW)

On the basis of "guaranteed prices" for farm products, the average net farm income per acre in the project area will be raised by the project from the present low level of about 500 rupees to approximately :

1,400 rupees with minor improvements in agricultural practices, and

1,800 rupees with major improvements.

By the end of the project, the latter level at least, should be obtained over the entire project area.

Assuming farms of 5 acres for families of 6.5 persons, these levels of farm productivity would correspond respectively to per capita incomes of :

1,050 rupees ($ 220), and

1,400 rupees ($ 295).

These figures compare favourable not only with present average per capita income in Ceylon (Rs. 660 = $ 140) but also with tentative projections of this magnitude for the year 1990 (Rs. 1,050 = $ 220).

Such levels of income should make it possible for the farmers to contribute financially to the project in the form of payments for water rights, and for the progressive purchase of their land and of their house.

PHASE I
PHASE II
PHASE III

PROPOSED RESERVOIRS AND DIVERSION WEIRS IN THE PROJECT AREA

NO.	Name of Reservoir or Diversion Weir
1.	KANDAKADU
2.	ROTALAWELA
3.	MINIPE
4.	RANTEMBE
5.	RANDENIGALA
6.	VICTORIA
7.	HARAGAMA
8.	POLGOLLA
9.	HALOLUWA
10.	MAHAVILLA (Lower)
11.	KOLADENIYA
12.	CAROLINA
13.	WATAWALA
14.	TRAFALGAR
15.	ROZELLA
16.	ELEHERA
17.	MORAGAHAKANDA
18.	LOLUWELA
19.	DIGGALA
20	MAKELIYAWELA
21.	KIULA
22.	KALU GANGA
23.	LENADORA
24.	ULHITIYA OYA
25.	HEEN GANGA
26.	HASSALAKA OYA (Ratna Ela)
27.	HEPPOLA (Nagadeepa)
28.	PALLEWELA
29.	TALDENA
30.	KELAWELPOTA
31.	ANDENIYA
32.	ROOKATENNE
33.	LOWER UMA OYA
34.	DEMATAPELESSA
35.	UPPER UMA OYA
36.	ETTAMPITIYA
37.	PUHULPOLA
38.	WELIMADA
39.	BOMURAELLA
40.	MADULLU OYA
41.	NEEDANKANDA
42.	HULU GANGA (Naranpanawa)
43.	MAHA OYA (Tumpa)
44.	KOTMALE
45.	YOXFORD
46.	TALAWAKELLE
47.	TILLICOUTTRY
48.	PALMERSTON
49.	MADURU OYA (Mahaulpotha)
50.	KAPIRIGAMA RESERVOIR
51.	MALWATUOYA RESERVOIR
52.	PARANGI ARU RESERVOIR
53.	PALI ARU RESERVOIR
54.	KANAGARAN ARU RESERVOIR
55.	KITULGALA RESERVOIR
56.	MUKUNUWEWA RESERVOIR
57.	WAHALKADA RESERVOIR
58.	YAN OYA RESERVOIR

LEGEND

PROJECT BOUNDARY
TRUNK ROADS
RIVERS & STREAMS
EXISTING RESERVOIRS
EXISTING CANALS
IRRIGATED LANDS
UNCULTIVABLE LANDS
EXISTING & PROPOSED WILD LIFE AND FOREST RESERVATIONS

PROPOSED

LIFT IRRIGATION RESERVATIONS
RESERVOIRS
SCHEME BOUNDARIES
CANALS
TUNNELS
PUMPING STATION
POWER STATION

SCALE 4 3 2 1 0 4 8 MILES

CEYLON GOVERNMENT & UNITED NATIONS DEV. PROGRAMME
FOOD & AGRICULTURE ORGANIZATION
MAHAWELI GANGA IRRIGATION & HYDRO POWER SURVEY
(STAGE I)

GENERAL LAYOUT PLAN

DESIGNED
DRAWN
TRACED
CHECKED

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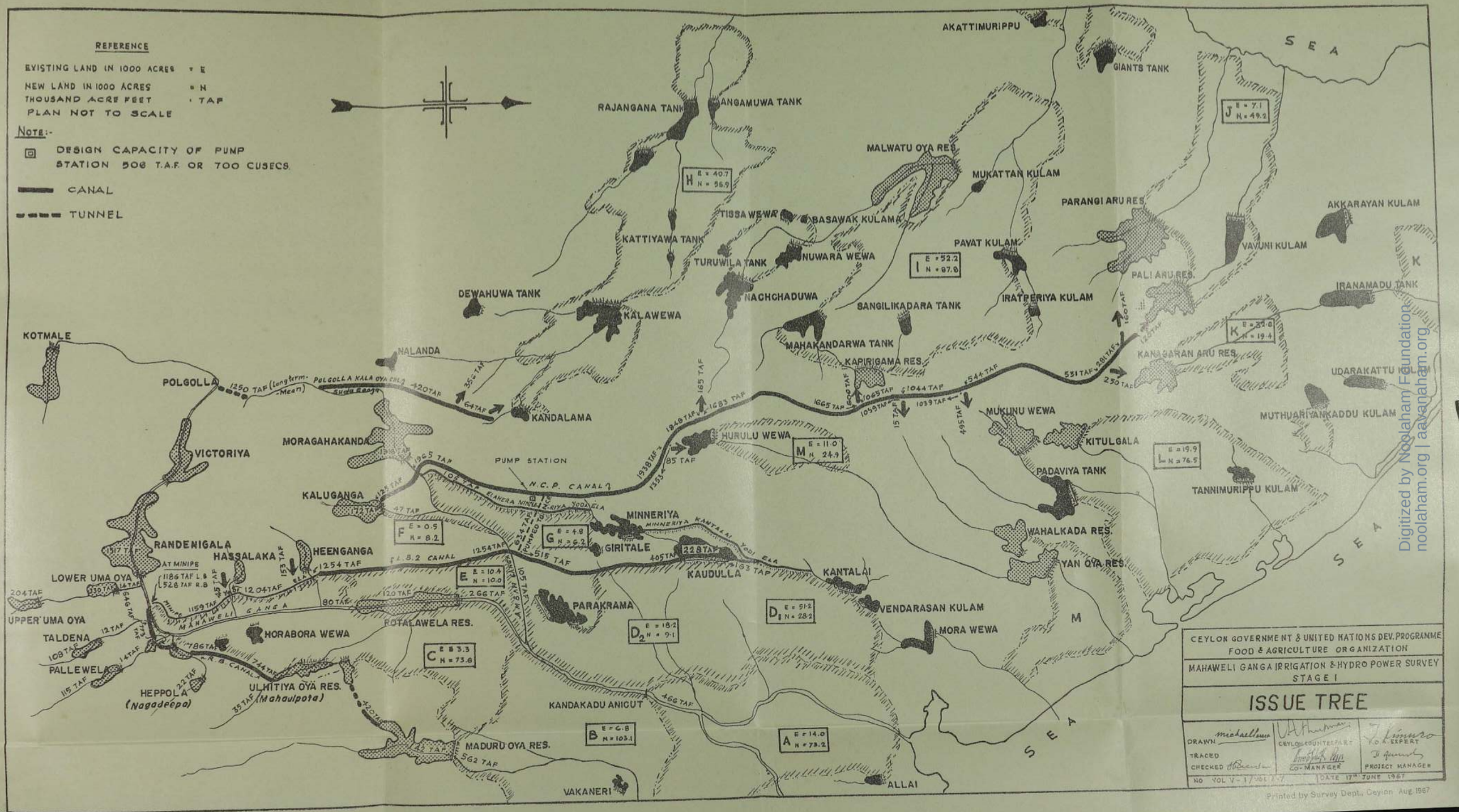

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APPENDIX III

UNITED NATIONS DEVELOPMENT PROGRAMS (SPECIAL FUND) IN CEYLON MAHAWELI GANGA IRRIGATION AND HYDRO POWER SURVEY STAGE II

Program of Research and Design work

The purpose of research and design work in Stage II of the Mahaweli Project is to prepare the Final Feasibility Report for the selected irrigation systems, and head structures and main canals.

The program will include the systems and structures in the first phase of development, namely :

(1) Diversion structure and hydro electric station at Polgolla ; diversion structure at Diggala, the P.K. (Polgolla-Kala Oya) trans-basin canal, and the irrigation system H. Kala Oya Basin).

(2) Irrigation and hydro power unit at Moragahakanda, irrigation systems D and G (i.e., P. S. S. Kantalai and Elahera systems).

(3) Irrigation and hydro power unit at Victoria Falls, diversion structure at Minipe (reconstruction), Right Bank canal, system C, (R.B.) and improvement of the existing system E. (Minipe).

Finalization of data obtained in the first stage of this project for the above mentioned systems and structures will consist in the following :

(*a*) For the irrigation and hydro power units, and diversion structures, it is proposed to finalize their dam axes, design parameters, viz. discharges and levels, to an accuracy within 10 feet for water elevations and 100 cubic feet per second for water discharges.

(*b*) For the trans-basin canals, it is proposed to finalize location of traces, obtain geologic information, and parameters of structures.

(*c*) For the irrigation systems, it is proposed to finalize the volume and scope of work on the selected sample plots for the irrigation network, and that of development and settlement of the territory.

1. The composition of research and design work, and priorities and its execution require the following :

1.1 TOPOGRAPHIC SURVEYS

(*a*) Survey to a scale 1 : 1,000 to 1 : 2,000 for structure sites, viz. Victoria hydro electric station, outlet portal of the Polgolla tunnel, weir and sluice at Diggala, and Lenadora hydro electric station.

(*b*) Survey to a scale 1 : 3,000 of the selected sample plots in the system H and C. (5,000 acres each).

(*c*) Preparation of plans to a scale 1 : 3,000 on the available surveys of the selected plots in the systems H. D. and C.

(*d*) Tracing of R.B. and P.K. canals with strip survey and levels every 100 to 150 feet apart and cross sections at structure sites at every 500 ft. Tracing of the R. B. extension main canal with surveys of a strip 1, 000 ft. wide.

(*e*) Laying of axes of main distributaries within the sample plots.

1.2 SOIL STUDIES

(*a*) Semi-detailed reconnaissance soils survey of the whole area under system H, viz : Kala Oya Basin.

(*b*) Detailed soils survey of standard plots on an area of 15,000 acres.

1.3 GEOLOGIC INVESTIGATIONS

(*a*) Exploratory drilling for the tunnel and structure sites of the Polgolla, Victoria and Moragahakanda and hydro electric station at structure sites and deep excavation points on the trans-basin canals, in accordance with the recommendation given by Geology Specialists.

(*b*) Geophysical prospection along the trans-basin canals 50 miles and main distributaries (about 25 miles) traced in the field, including auguring, trenching and geologic mapping as necessary.

1.4 HYDROLOGICAL STUDIES

(*a*) Finalization of run-off parameters for the site of irrigation and hydro power units at Polgolla and Koladeniya.

(*b*) Determination of daily values of effective precipitation for critical years and 20 years' series, in the Kala Oya Basin, right bank of Mahaweli Ganga, and Left bank of Mahaweli.

(*c*) Procession of records available on irrigation duties and finalization of their values for the systems H, C, and D.

(*d*) Hydrometric studies of sedimentation and rating curves Q=f (H) for the sites of Polgolla, Victoria, Moragahakanda and Minipe.

(*e*) Synthetic extrapolation of hydrology series to 50 years for the sites of Polgolla, Moragahakanda and Victoria.

(*f*) Continuation of field investigations in water ' balance ' at the pilot plot of Maha Illupallama and water losses in the unlined canals.

1.5 WATER MANAGEMENT ESTIMATES

(*a*) Finalization of water management and power operation estimates for the irrigation and hydro power units at Polgolla, Moragahakanda, Victoria Falls, Randenigala, taking into account the compensating regime of Kotmale and Koladeniya hydro electric stations.

(*b*) Finalization of water management estimates at different values of normal water surface elevation, and minimum operating elevations, as well as water discharges for the irrigation and hydro power units at Polgolla, Moragahakanda, Victoria falls and Randenigala.

(*c*) Study of operation regime of reservoirs and hydro electric stations on the 50 years' series and monthly distribution. Same with 5 and 10 days' distribution for the diversion structure at Minipe.

(*d*) Operation of study of water supply systems, viz, Polgolla, Sudu Ganga tanks in the Kala Oya Basin, and Moragahakanda—Elahera Yoda Ela tanks in the left bank systems, on the 20 years' series.

(*e*) Flood estimates to provide ' cutting ' of peak discharges in the reservoirs of the first phases, and Randenigala.

1.6 DESIGNS OF DAMS AND HYDRO ELECTRIC STATIONS

(*a*) Finalization of structures of dams and hydro electrical equipment, quantities and costs of works involved in the irrigation and hydro power units of Victoria, Polgolla, Moragahakanda, Diggala, on the basis of parameters selected (please see 1.4).

(*b*) Finalization of parameters of irrigation and hydro power unit at Randenigala in accordance with the adopted parameters of Polgolla, Victoria and Moragahakanda units.

(*c*) Finalization of parameters of irrigation and hydro power units at Kotmale and Koladeniya in relation to compensating regime of their operation.

(*d*) Preparation of monthly graphs of operation of the hydro electric stations entering the first phase of development and working out of operation regime of these stations in the National power system.

1.7 PROJECTING OF DEVELOPMENT AND SETTLEMENT OF THE NEW IRRIGATED LANDS IN THE FIRST PHASE OF DEVELOPMENT

(*a*) Finalization of agro-economical estimates to determine cropping patterns on the basis of semi-detailed soils map for the system H, and appropriate correctives for the systems D and C.

(*b*) Finalization of estimates to develop the systems H, C, D, G, including jungle clearing and levelling.

(*c*) Working out of facilities required for settlement of new lands.

(*d*) Preparation of detailed plans of land use and settlement for the standard plots.

1.8 DESIGNS OF IRRIGATION SYSTEMS

(*a*) Composition of graphs of irrigation regime, viz. hydro moduluses, for the standard plots.

(*b*) Detailed designs of irrigation, drainage, and roads network on the standard plots.

(*c*) Finalization of costs of construction and operation of the irrigation systems H, C, D, G, on the basis of unit costs per 100 acres of lands, obtained from the detailed estimates for the standard plots.

1.9 DESIGNS OF TRANS-BASIN CANALS

(*a*) Finalization of traces, and design parameters of the R.B. and P.K. Canals on the basis of additional information.

(*b*) Finalization of parameters of structures on canals.

(*c*) Finalization of quantities of works and cost of construction and operation of the R. B. and P. K. canals.

1.10 PREPARATION OF THE FINAL REPORT FOR STAGE II

The Report will contain the results of work done at Stage II, and certain items finalized pertaining to the irrigation and hydro power units in the first phase of development : namely, Randenigala, Kotmale, Koladeniya.

11. Organization of work

The work should be carried out with the available personnel of foreign and local specialists without interruption, i.e., with the present staff now working on the Project. The period for executing this work will be about six months after all the topographic information is made available. It is expected that all this can be completed in one year from 1 April 1967—instead of 2 years provided in the Plan of Operation.

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