PLANNING OF MODERN IRRIGATION SYSTEMS INTEGRATED WITH HUMAN SETTLEMENT FOR ENHANCED REUSE OF WATER

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ABSTRACT

There are five independent development areas situated in the dry zone of Sri Lanka each consisting of irrigation systems which are similar in principle, but substantially different as far as the design concept and the operations are concerned. These systems are to receive surface water in the corresponding basins plus diverted waters of the largest river in Sri Lanka, for socio-economic development.

The five systems presently in operation following settlement of farmer-families and non-farmer families, are H, C, B, G, and L. The irrigation and drainage network in each system demonstrates a planning concept, which is a combination of minor reservoirs, irrigation canals and drainages, towards optimization of irrigation system efficiency. The principle incorporated into the planning concept is therefore the "Cascade of minor reservoirs" constructed across the secondary and tertiary drainages to command the farm area below. This concept which was adopted several centuries ago, is still in existence in the dry zone.

In some of the major integrated rural development projects, the minor reservoirs have been incorporated into the irrigation and drainage system to provide a number of purposes, benefiting the human settlements and their environments. Another beneficial function of these reservoirs, when combined with the canals and drainages is its versatility in fitting into the irrigation and drainage network at any location.

The quality of irrigation water has still not been a serious problem in any of the areas described above. However, it has been recognized that there should be field research into the quality of water, from the planning stage to operation & maintenance.

The social benefits, both direct and indirect, are concerned collection and distribution of return flows, by means of Canal-Reservoir integration have produced a successful concept, in integrated rural development based on human settlement and irrigated agriculture.

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INTRODUCTION

The exercise of water resource development planning is a highly complex task. A new approach needs to be adopted in the initial planning, which ensures environmental aspects are integrated with social and economic considerations. The extension of irrigation and settlement systems can be justified in many areas, from the point of view of economic necessity and social betterment. The principal issues, upon which attention should be focussed on irrigation and human settlement in the tropics are, (a) Efficiency of water-use including conveyance from the source to farms (b) Socio-economic impacts, and (c) Integration of human settlement with the natural resources in the basin.

The ecological consequences of irrigation are part of a complex of practices, comprising management of available water resources, controlled distribution of water over cultivable land, and withdrawal of excessive water through drainage. These implications include the following changes:

(a) Creation of new ecological systems related to water bodies such as reservoirs, irrigation canals and drainages.

(b) Radical modification of ecological systems of the terrestrial habitat due to ploughing, cropping and addition of agro-chemicals.

(c) Modification of downstream flow regime within the river basin.

Irrigation is a significant change to the ecology of an area which creates new productive systems and land such as crop fields, forest areas, pasture and homegardens, and in water it produces fisheries and aquaculture. These changes in the physical and biological environment lead to radical changes in the ecology. In this transformation, human ecology occupies a significant place in the irrigation based settlement project.

GENERAL DESCRIPTION ABOUT SRI LANKA

Sri Lanka is an island lying off the southern tip of India. It is centrally located in the Indian Ocean with a land area of 65,000 Sq.km. Throughout its 2500 year history, kings of ancient Sri Lanka built large reservoirs and trunk canals to carry water for irrigation and agricultural systems to produce food to sustain the civilization. The early civilization centered around these reservoirs which were built to store rain water for agriculture. It was in the dry zone of Sri Lanka that the early settlements based on irrigated agriculture began. To cultivate a single annual crop of rice, the early people depended on the NE monsoon which brings in rain from October to February.

There are 103 river basins in the country. They flow radially from the highlands in the central part to the sea (Fig. 1).

Hydrology

The climate is controlled by its location within the tropics and the presence of Central Mountain mass within the country. Mean monthly temperatures in the lowlands, Range between 26^0 C and 29^0 C with little seasonal variations. In the central highlands, however the mean monthly temperature varies between 10^0 C to 21^0 C.

The island can be divided into the distinct wet and intermediate zones. The combined wet and intermediate zone covers about 30% of the land area. Annual mean rainfall in the wet and intermediate agro-climatic zones ranges from about 2200 mm to 3900 mm and is fairly distributed throughout the year (Fig. 2). Paddy and other food crops can be grown in these zones under rainfed conditions.

The annual rainfall in the dry zone, with average annual rainfall bellow 1800mm, is concentrated in the "Maha" season (September to March) and displays considerable year-to-year variability. Therefore irrigation is essential for cultivation in the "Yala" season (April to August) with some supplemental irrigation often necessary during the "Maha" season.

HYDRAULIC CIVILIZATION AND TRADITIONAL CULTURE

The traditional culture of Sri Lankans is agrarian and the most significant feature of the culture centres around the conservation and distribution of water. Since early times the people and their rulers began to store water and developed the distribution of the resource for agriculture and other purposes. This hydraulic civilization had its origins in the dry zone until about the end of the twelfth country. The dry zone receives water only during the North-East monsoons and the need for storing this water to be used during the long dry season that followed became the major concern of the people, whose responsibilities was to ensure availability of water for bountiful crops.

The traditional irrigation schemes are dependent on storage reservoirs designed to provide supplemental irrigation to the "Maha" crop, with any residual water used for limited dry season cropping. There are a total of about 180 such major irrigation schemes sustaining nearly 200,000 Ha. under agriculture, along with a vast number of minor irrigation schemes.

All these irrigation schemes in the dry zone, irrespective of the size, are supported by reservoirs, which have been formed by the construction of earthen bunds across ephemeral streams. A high utilization of the scarce water resource has been achieved by providing a number of storage reservoirs across the streams in cascade formation.

Systems of Irrigation

According to historians, two different systems of irrigation in the dry zone were built many centuries ago. Some function today for the same purposes, as they did many centuries ago. Those that have been damaged by time are of such quality that they can be repaired and made operational today.

One system was that water was impounded in reservoirs which gradually passed either directly onto the fields, or by man-made canals, which conveyed water to the fields.

With the other system, part of the water flowing down the rivers, was diverted along man-made canals, which diverted water into distant lands and reservoirs. Some of these diversions are transbasin diversions to bring water supplies from nearby basins with richer water resources.

Reservoirs (Tanks) in the Dry Zone

Literally, hundreds of small and large reservoirs occupy the vast expanse of dry scrub jungle, making it the "Kingdom of Reservoirs" (Tanks). The credit for building the reservoirs and canals that link them should go to the kings or rulers, who inspired the people to install such multipurpose facilities. (Fig. 3).

The earliest reservoirs were simple, consisting of an earthen dam across a small river. These village reservoirs served the needs of only a village or two. But with the discovery of the "valve-pit" (structural arrangement in the sluice), larger reservoirs were built.

Reservoir (Tank) and Village

The reservoir (Tank), even today, is the pivot on which life in the dry zone revolves. The villages that depend entirely on reservoirs for their economic sustenance are called Tank Villages. The structure of the Tank Village and its functioning illustrates not only the economical use of land and water but also the political and social mechanisms.

There have been four types of agricultural settlements in the country:

(a) Reservoir (Tank) villages
(b) Mountain villages of the central hills
(c) Rain-dependant villages in the East
(d) Chena villages

In the Reservoir villages, the amount of water supplied for irrigation can be controlled by sluices and spills. These villages consist of four main components:

(a) the reservoir or the Tank
(b) the paddy field under irrigation
(c) the jungle
(d) the cluster of houses

The reservoir, which is normally situated on a higher elevation, provides water for agricultural and domestic needs. It also provides fresh water fish and water plants for domestic consumption. The jungle provides the village with firewood, timber, meat and honey. The cattle are grazed and allowed to rest in the jungle.

AVAILABLE WATER RESOURCES

The hydrographic pattern is a function of the topography and in Sri Lanka with its central hilly area, a radial pattern of the rivers is clearly revealed. The rivers flowing to the West, South, and East are shorter that those flowing to the North.

There are 103 basins, draining areas varying from 10 sq. km to the maximum of 10500 sq. km. The largest and the longest river is the Mahaweli Ganga, which is 325 km. in length from source to outlet.

The average annual rainfall over the whole island is approximately 13.2 Million Ha.m. The average annual run-off into the sea from all rivers and streams has been estimated at 4.3 Million Ha.m, or approximately 30% of the precipitation. This volume of run-off is equivalent to an average depth of 660 mm over the total area of the Island.

The monsoonal rains are dependent upon the prevailing winds during both the south-west and north-east monsoon seasons, and the annual average rainfall varies from below 1000mm. on the north-western and south-eastern fringes of the Island to over 5000mm. at certain places on the south-western windward hill slopes. One of the most significant features of the climatological characteristics of Sri Lanka, caused primarily by the orographic effect of the central mountains on the two monsoons, is that the Island can be divided into two distinct parts, The "wet zone" and the "dry zone"(Fig. 4). The wet zone, receives the major portion of its annual rainfall during the south-west monsoon.

However, it is more rational to define the dry zone as an area where the average annual rainfall is less than the average annual potential evapotranspiration. This implies that there can be little or no run-off if the rainfall is evenly distributed throughout the year. Since the potential evapotranspiration ranges from 1400 mm.

to 2000 mm per year in the low altitude areas of the Island, It is greater than the 1000 mm of rainfall.

The rivers flowing through the wet zone are perennial and their mean annual yield is about 65% of the yield of all the rivers.

The dry zone, which covers about 75% of the Island, exhibits wide variations in average annual precipitation and run-off and their spatial distribution merits discussion in greater detail. The available land resources suitable for agriculture are located in the dry zone, but shortages of water resources hamper their development.

About 750 mm. to 1900 mm. of rain falls on the dry zone in an average year, mostly during the short NE monsoon. During the rest of the year, there is practically no rainfall, so that productive plant growing is only possible with irrigation supported by regulation of the variable stream flows with storage reservoirs.

PLANNING OF IRRIGATION SYSTEMS

Sri Lanka has been somewhat fortunate that the combined effects of the mountain barrier and the monsoons have ensured ample quantities of water for all purposes including the irrigation of all available arable land in the country. Even though significant storage and regulation have been provided in the dry zone, the long-term mean water resources for irrigation have not been great enough to ensure a reasonable degree of success under individual projects. The implementation of the Mahaweli Ganga Development Scheme (MGDS) has further improved the existing conditions in most of the dry zone. It has provided an increase to the ground water resources.

Efficiency in irrigation requires that water be conveyed to the system and distributed with minimum losses in such a way as to secure maximum efficiency of water use as determined by the ratio of the amount of water used by plants to the amount of water withdrawn from the system.

Irrigation efficiency is also significantly affected by other factors such as the level of training of users, quality of management, type of flow being operated, method of water distribution and the size of the irrigation area. Therefore in designing an irrigation canal system, it is vital to strive for a distribution network, which is simple in function and requires a minimum of management.

Planing for multipurpose utilization of the water resources commenced about 50 years ago. The emphasis at that time was on basin-wide development and several promising rivers were taken up for detailed studies. The main purposes of multipurpose development have been irrigation, hydro-power generation and settlement of farmers and non-farming families.

In the case of paddy farms, cultivation has been traditionally using excessive irrigation water. With projects implemented several years ago, there has been a need for economical use of water, partly due to well-drained soils in the command area and partly due to unauthorized expansion of irrigable land area.

Planning irrigation systems is based on the findings of soil classification surveys. Greater control is being exercised over conveyance and distribution losses. Damage to crops due to water deficits are considerably reduced, while substantial increase in productivity are realized.

LEGISLATION

The most important legislative enactment governing the utilization and development of the water resources has been the Irrigation Ordinance of 1946 amended in 1968. This is an Ordinance to amend and consolidate the laws relating to water rates, irrigation districts, agriculture committees, construction, maintenance and protection of irrigation infrastructure and the conservation of water.

Another legislative enactment is the Paddy Lands Act of 1958, which has the objective to ensure the proper utilization and maximum productivity of all available land resources for the cultivation of paddy.

IRRIGATION SYSTEM INTEGRATED WITH MINOR RESERVOIRS

Reservoirs are important in the lives of settler-farmers and other resident in a development area, as water bodies mean more than water and the various sciences of water.

A reservoir cannot be separated from its drainage area. Its bund is designed using 50-year flood return intervals. The spillways adopted for these reservoirs were broad crested weirs. An earth or concrete spillway constructed in natural ground should convey the flood discharge over the spillway, to fall into the stream at a point downstream of the structure and the bund. Special consideration must be given to the design, if failure of any structural element could cause danger to life or serious property damage.

The capacity of the reservoir must be such that when used in combination with the other components of the irrigation system, it will provide the needed volumes of water at an adequate variable flow rate and in a timely manner.

Since the volume of water lost is dependent upon the surface area, evaporation losses should be minimized. Seepage losses are much more difficult to estimate to precision, based on the permeability of the foundation materials. Local experience with existing reservoirs built in similar soils in the area are the best guide for sealing the embankment. Seepage losses can seldom be completely eliminated.

USE OF MINOR RESERVOIRS

Under many circumstances, minor reservoirs are essential components in a complete irrigation system. Reservoirs are management facilities whereby a variable or steady flow can be regulated into a different variable steady flow that is more convenient or efficient in terms of water, labour, energy and crop production.

The most common uses of minor reservoirs in which the irrigation system is the key component, is to provide a number of functions as listed below.

(a) Storage of run-off from rainfall for irrigation during dry periods.

(b) Long term or temporary storage of water that may be available from surface or subsurface sources. 'Overnight' storage of the flow from a system delivering for use during the day. Re-regulating capacity needed to adjust flows of an undesirable size or to match the flow requirement of other elements of the irrigation system.

(c) Control needed to maintain a desired surface or sub-surface water elevation in an adjacent area.

(d) Flood mitigation.

(e) Domestic needs of settlers. Water needs for wild animals and domestic animals such as buffaloes.

(f) An aquatic environment for several water plants. Habitat for inland fish.

(g) High water table in the highlands and forest lands.

(h) Flexibility in the irrigation system. Re-use of drainage water.

RE-USE ASPECT IN DIFFERENT IRRIGATION SYSTEMS

The integrated development areas considered in the study are fully in operation except System-L of the Mahaweli Ganga Development Scheme (MGDS). To illustrate the principle of re-use of return flows in the MGDS, there are thirteen such Systems identified for development. They are scattered in the dry zone of Sri Lanka. System-H, System-C, System-B and System-G are the other independent development areas under evaluation. In each development area of the MGDS, there are three components, which form the integrated concept. They are given below.

- Terrestrial environment
- Aquatic environment
- Human environment

The five Systems of MGDS under consideration have been developed with the provision of irrigation and social infrastructure and settlement of both farmer and non-farmer families, in the last three decades. Of these areas being examined, analysed and compared, the concepts of planning in respect of irrigation, landuse and human settlement are similar in System-H, System-C and System-B (Fig. 5).

<u>System-H of MGDS</u>

The irrigable extent of System-H is about 30,000 Ha. The physical components of it shown in (Fig. 6) are listed below.

(a) Approximate boundaries of command area

(b) Large and medium size reservoirs incorporated into the irrigation system

(c) Main canals, Branch canals, Minor reservoirs, Distributory canals, Primary and Secondary drainages

(d) Town centres and Urban Centres

A salient feature in System-H is that the Large and Medium size reservoirs are in cascade, providing storage and regulation. All reservoirs receive drainage water in addition to augmentation by irrigation canals (Fig. 7).

However, the availability of reservoirs in close proximity to the settlement areas or villages is considered inadequate, as there are over 30,000 settler families resident in the highlands. The size of a village varies from 100 to 150 families or homesteads. Return flows are necessary to augment these minor reservoirs to cater to the needs of the settlers.

<u>System-G of MGDS</u>

The development area lies below an ancient trunk canal, which conveys water from the river Amban Ganga to a large reservoir. The trunk canal runs along a contour. Therefore all canals commanding the project area cut the ground contours laterally dropping towards the main drainage (river) with a substantial gradient. The irrigable area in System-G is about 5500 Ha. This system has been in operation for over four decades.

The command area, its boundaries, and the irrigation and drainage system are shown in (Fig. 8), a physical component that is not seen in System-G in reservoirs of any size. The irrigable area is therefore commanded by a system of canals only. Even the villages which are located in the areas above the canal are not facilitated with small reservoirs, thus compelling the settlers to depend on the canal or the ground well for their domestic needs.

In contrast to the irrigation system in System-H, the distribution canals in system-G have been constructed along the contours with single banking, so that seepage and surface runoff could be collected. Some field canals also have been constructed to accomplish the concept of water reuse (Fig. 9).

Another significant feature in the design of the irrigation system is that small anicut structures are constructed across some secondary and tertiary drainages.

System-C of MGDS

The irrigable extent in System-C, which is shown in (Fig. 10), is about 3000 Ha. There are nearly 31000 settler families engaged in agriculture and services. The size of a village varies from 200 to 300 homesteads. The command area lies between Mahaweli river and a series of large and medium-size reservoirs which are storage facilities on the main canal. These reservoirs receive surface run-off from their own catchments, in addition to augmentation. Therefore, these reservoirs perform dual functions in receiving return flows and enhancing the flexibility of the canals with storage (Fig. 11).

System-B of MGDS

The irrigable lands in System-B are mostly of well-drained soils. The underlying layer below the top soil is nearly impervious. The irrigable area on the left bank of the main drainage, across the command reservoir, is about 30,000 Ha. The specification extent on the right bank is about 14000 Ha which has yet to be developed for agriculture and settlement of farmers. (Fig. 12) depicts the developed area of the basin below " Maduru Oya Reservoir", with a large number of minor reservoirs, which are settled. One important feature in the canal-reservoir irrigation system is that there are no reservoirs in cascade. The minor reservoirs are either fed by the canals or located to receive return flows (Fig. 13).

Pimburettewa is the only medium size reservoir constructed across a secondary drainage. All minor reservoirs are stipulated across the tertiary drainages. Of the six development areas which are subjected to evaluation, system-B is the only project having concrete lined Main and Branch canals.

Similar to System-C, the size of each village in System-B is in the range 200-300, and is in close proximity to a reservoir or two. The storage capacity of the entire developed area is concerned with the total volume of water available for agriculture.

<u>Walawe Basin (Right Bank of Walawe River)</u>

The project area or the study area (Fig. 14) lies in the dry zone of the southern part of Sri Lanka. The irrigable extent is about 12500 Ha. commanded by two large reservoirs. Udawalawe is the main reservoir situated across the river, while the Chandrikawewa reservoir is built across the main tributary, to receive water from the main reservoir via the main canal, which transverses along a contour.

The entire farm extent is irrigated by the canal network, which does not have a single minor reservoir within the command area. The only way return flows are collected is by Distributory canals and Field canals where they are in single banking.

On lands with well-drained soils, water has to be saved by growing subsidiary crops such as banana and vegetables.

<u>System-L of MGDS</u>

This is an area situated in the heart of the dry zone. Ma-Oya is the river basin, that is being provided with irrigation and physical infra-structure under the integrated development planning concept. The right bank of Ma-Oya had been provided with an irrigation system about 50 years ago, with the restoration of an ancient reservoir across a tributary of Ma-Oya. The boundaries of System-L, Padaviya reservoir, Ma-Oya and the minor reservoirs in operation on the left bank of Ma-Oya are shown in (Fig. 15). However, to date only about 2000 settler-families have been established on the left bank. The command area on the right bank is in operation independently and managed by the Department of Irrigation.

Although, System-L is among the thirteen development areas identified under the MGDS, this basin is yet to receive diverted waters of the Mahaweli River. At present the left bank is being developed under as integrated plan, with the construction or restoration of minor reservoirs. Villages are being established around the reservoirs. Each village consists of homesteads or farmer-families in the range 100-200 people.

The water use efficiently needs to be very high due to scarcity of water and limited storage capacity, therefore a cascade of irrigation system is to be established, wherever possible (Fig. 16). Thus, the return flows should be arrested, and stored or diverted by means of pick-up anicuts which then provides water supplies for both agriculture and settler needs.

CONCLUSION

Irrigation is a long established agricultural practice that enabled civilization to establish permanent settlements in the dry zone of Sri Lanka. The basic concept on which these hydraulic societies existed was their dependence on water reservoirs built across ephemeral streams to collect surface and ground water run-off during each year. The water reservoirs are multipurpose to accommodate the community living around it. This idea has been incorporated into the irrigation and settlement planning of the integrated rural development projects during the second half of this century.

Water reservoirs help to maintain the balance between surface run-off and water demand. Water is one of the basic elements of the environment and reservoirs have a fundamental impact, which cannot be overlooked when planning, designing and operating a reservoir system.

The minor reservoir concept can be described as the integration of the water reservoir system with the other important sub-systems to yield several beneficial results, which finally lead to community development.

Water is necessary for all forms of life. However, fresh water is a finite and vulnerable resource, which is essential to sustain life, development and the environment. It is therefore appropriate, in the light of the analysis and evaluation of this study, to reproduce below, a cardinal principle adopted by one of the greatest kings of Sri Lanka. "Not a single drop of water received from rain should be allowed to escape into sea without being utilized for human benefit"
(KING PARAKRAMABAHU THE GREAT, 1153-86 AD)

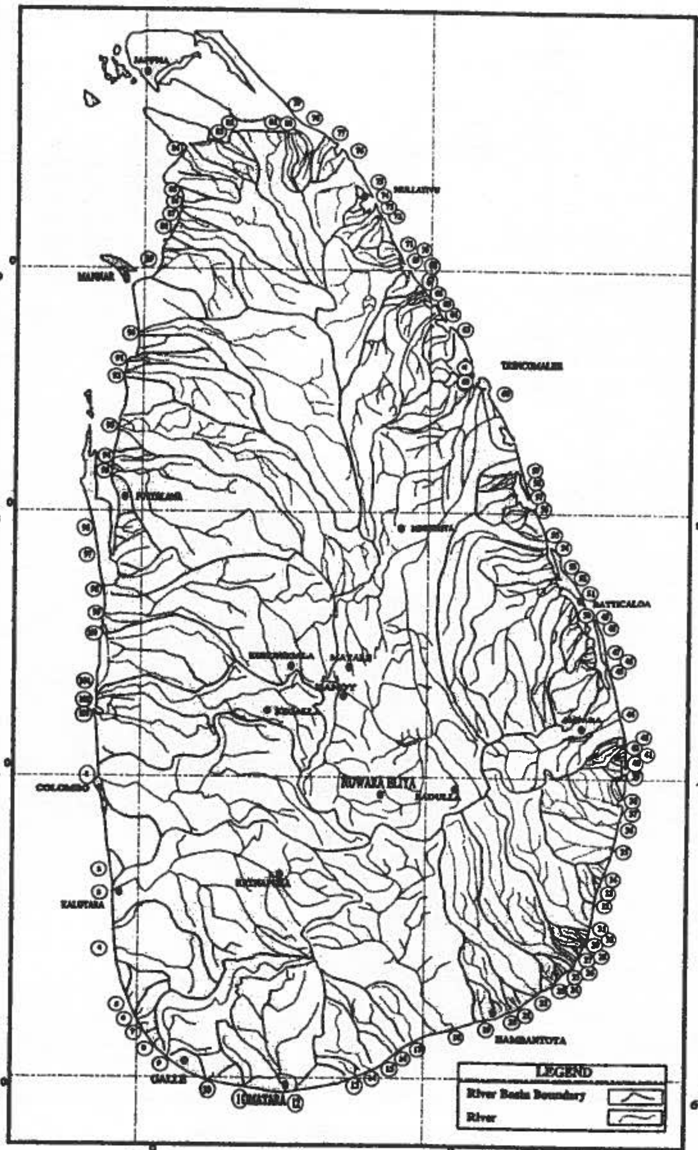

Fig. 1. River Basins of Sri Lanka

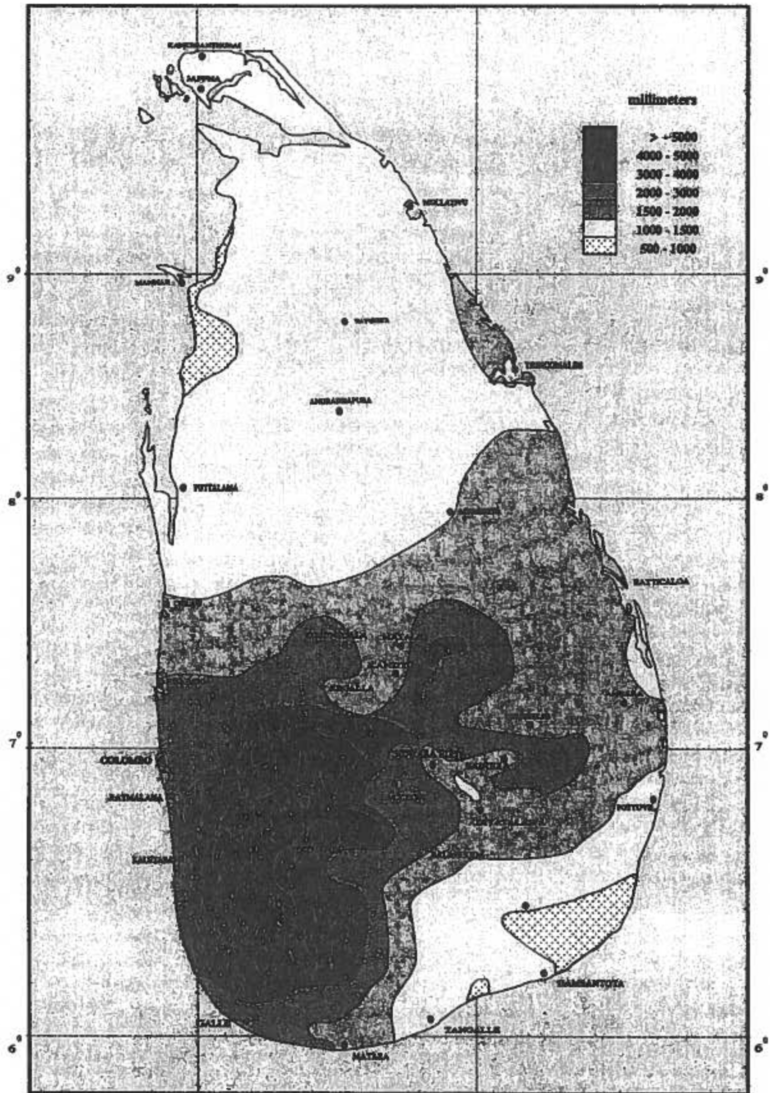

Fig. 2. Average Annual Rainfall (1961-1990)

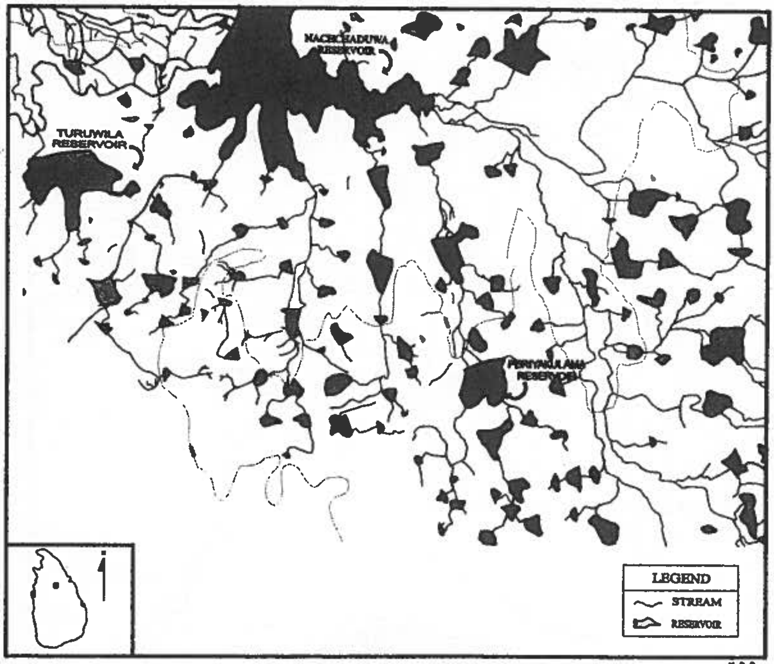

Fig. 3. Topographic Map Showing Minor Reservoirs In Cascade

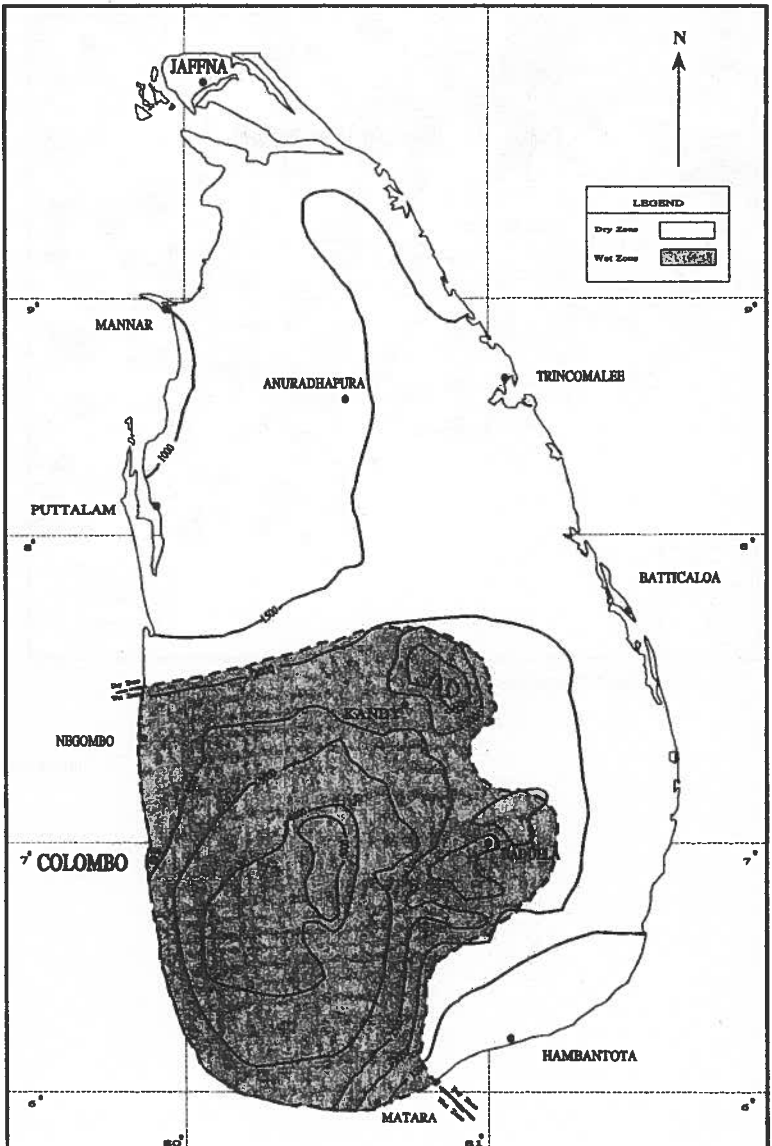

Fig. 4. Isohyets, Dry Zone and Wet Zone

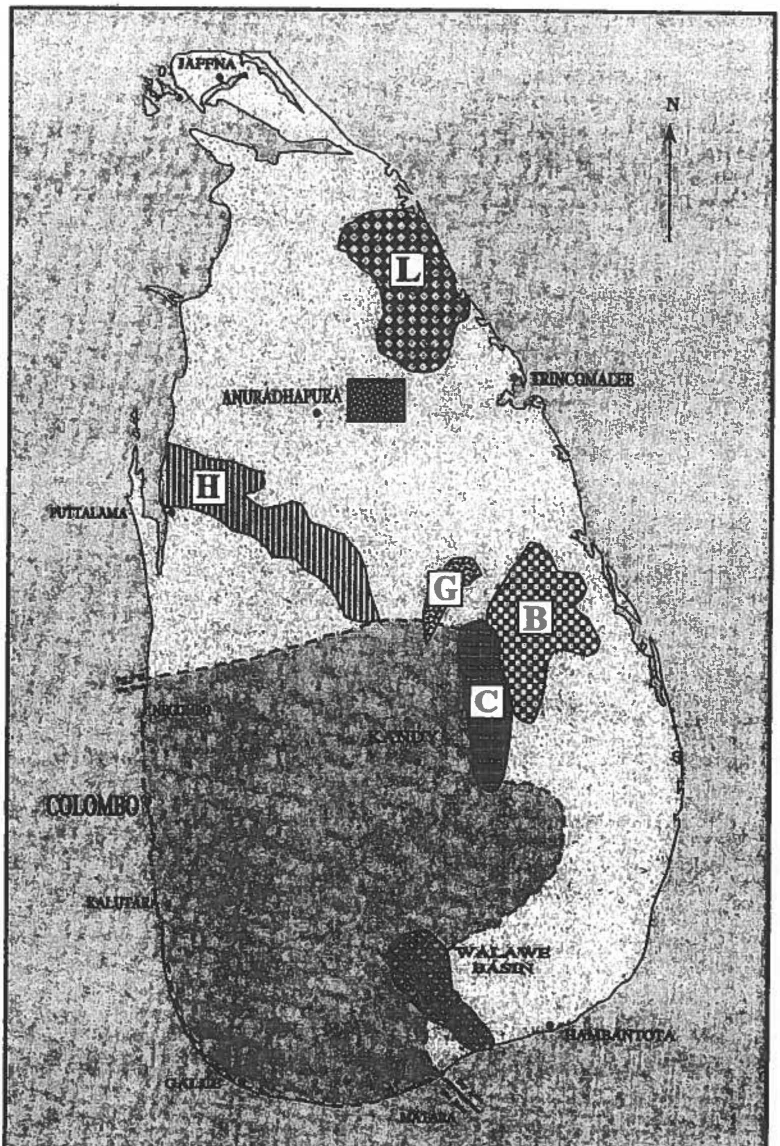

Fig. 5. Map of Sri Lanka Showing Development Areas

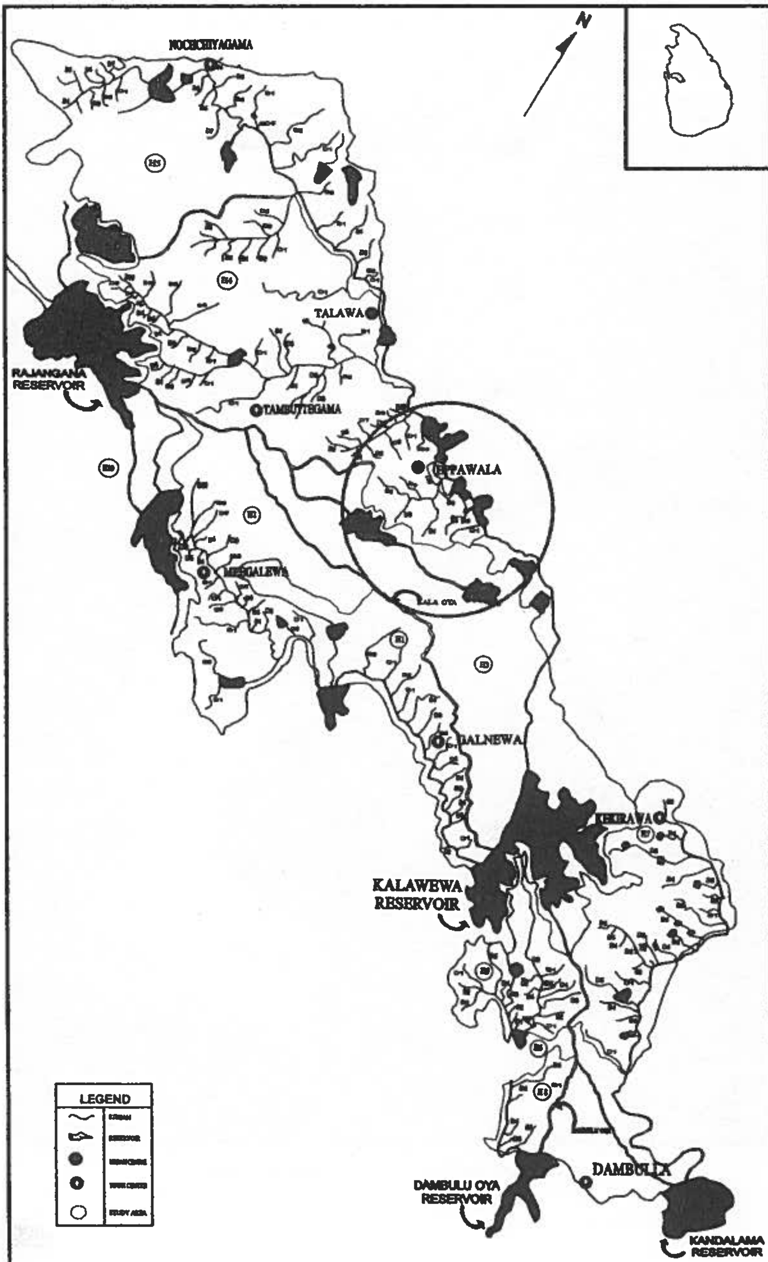

Fig. 6. Mahaweli Ganga Development Scheme (System - H)

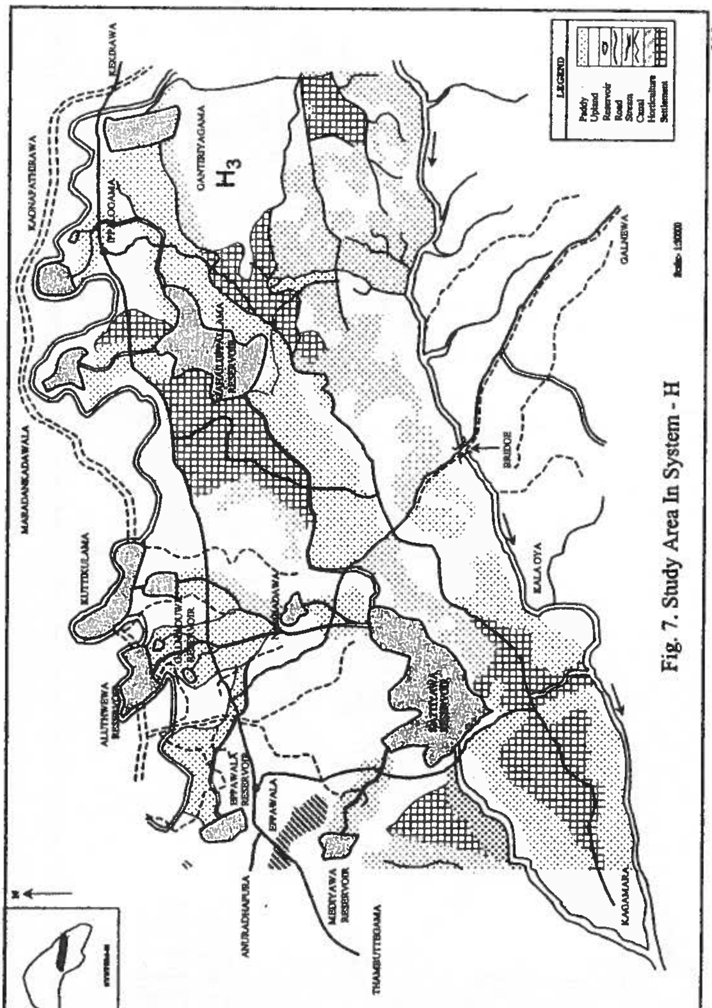

Fig. 7. Study Area In System - H

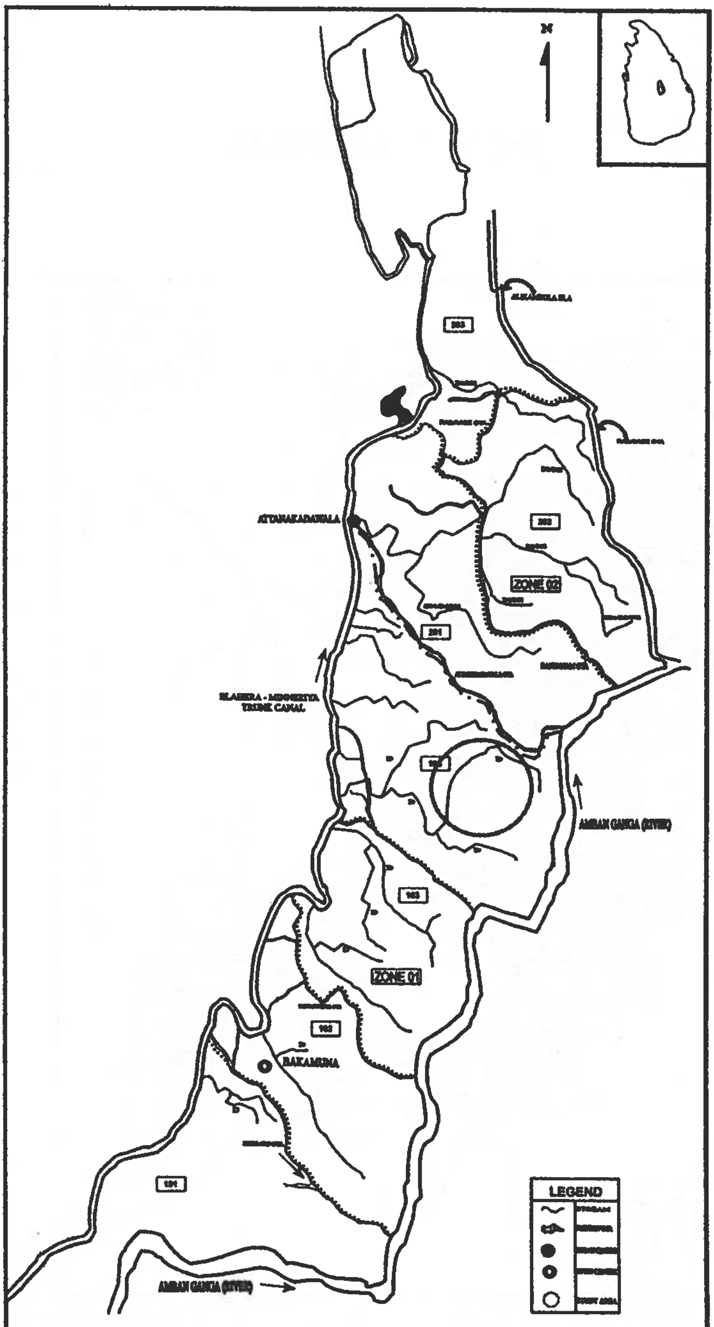

Fig. 8. Mahaweli Ganga Development Scheme (System - G)

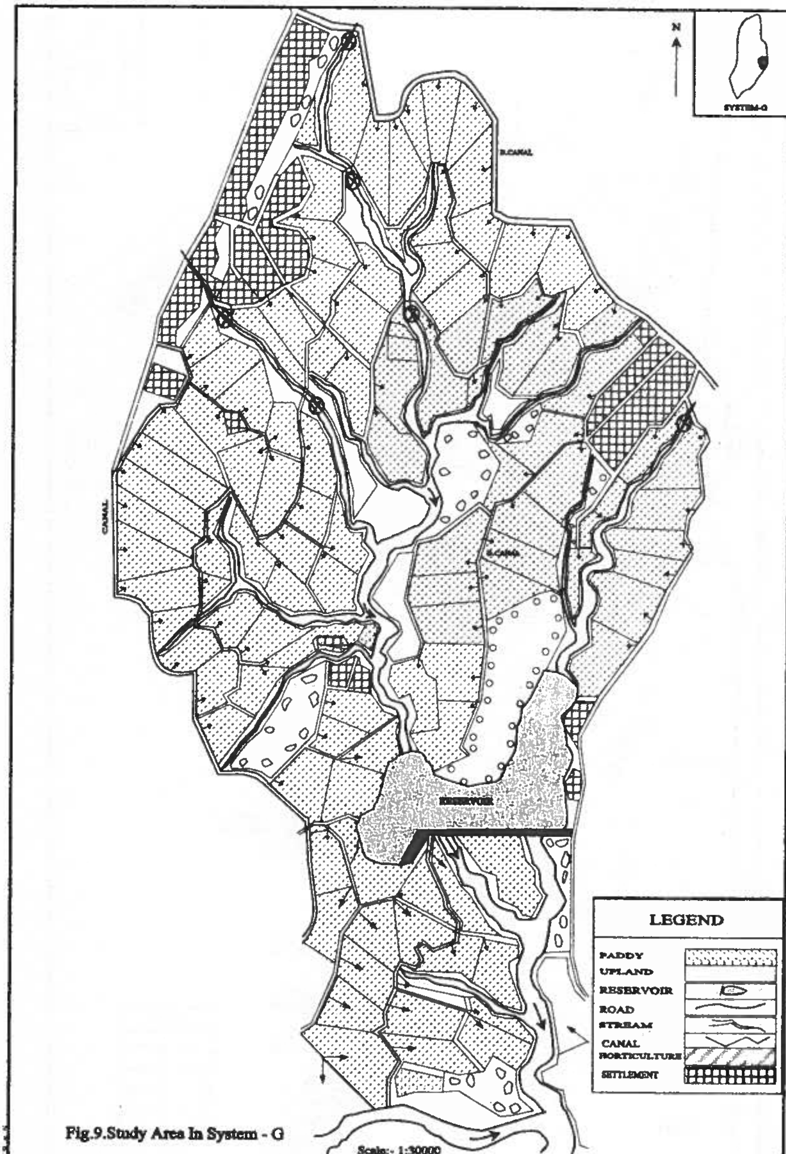

Fig.9.Study Area In System - G

Scale:- 1:30000

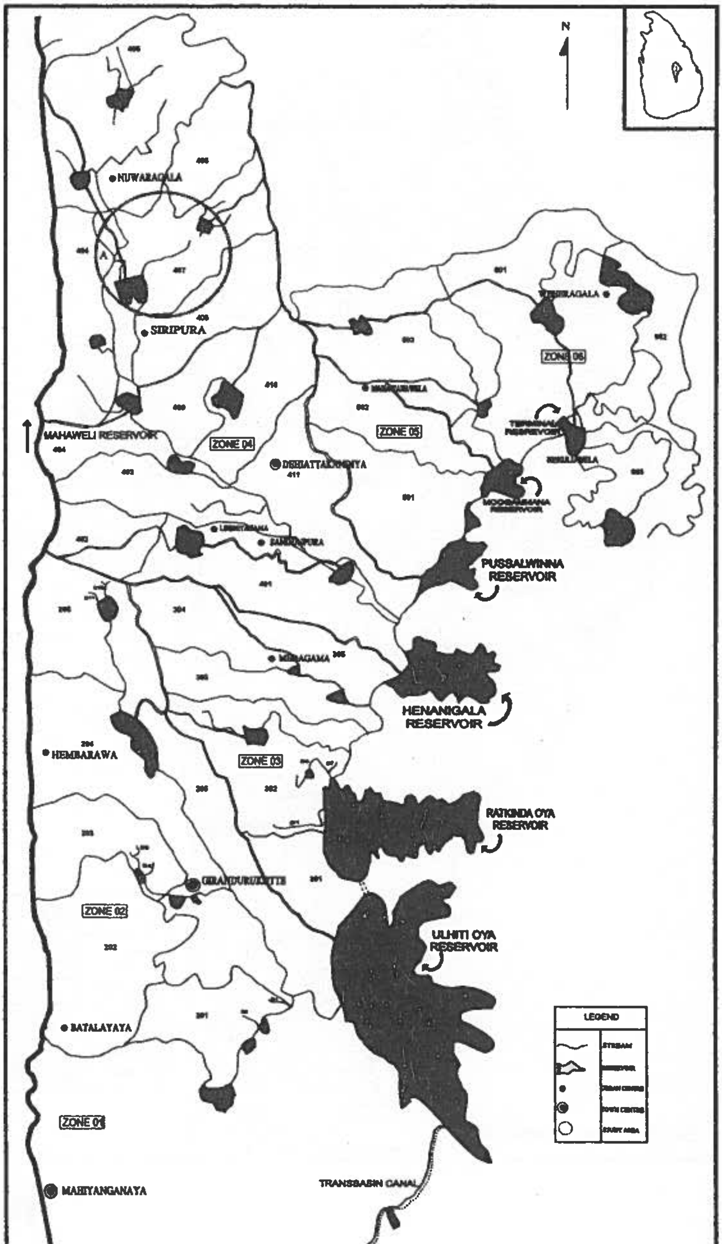

Fig.10. Mahaweli Ganga Development Scheme (System - C)

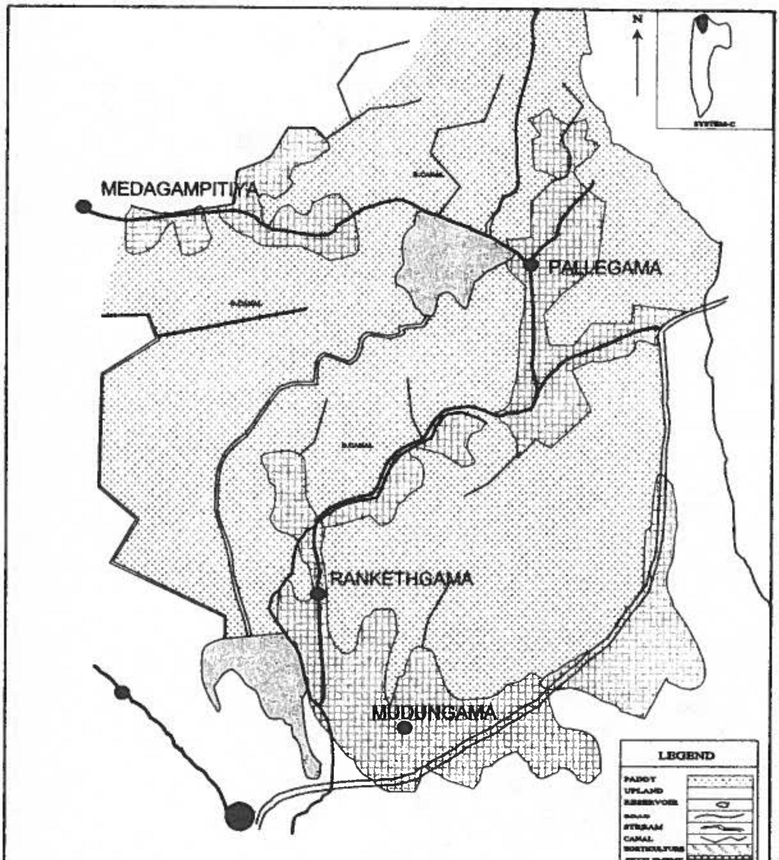

Fig.11. Study Area In System - C

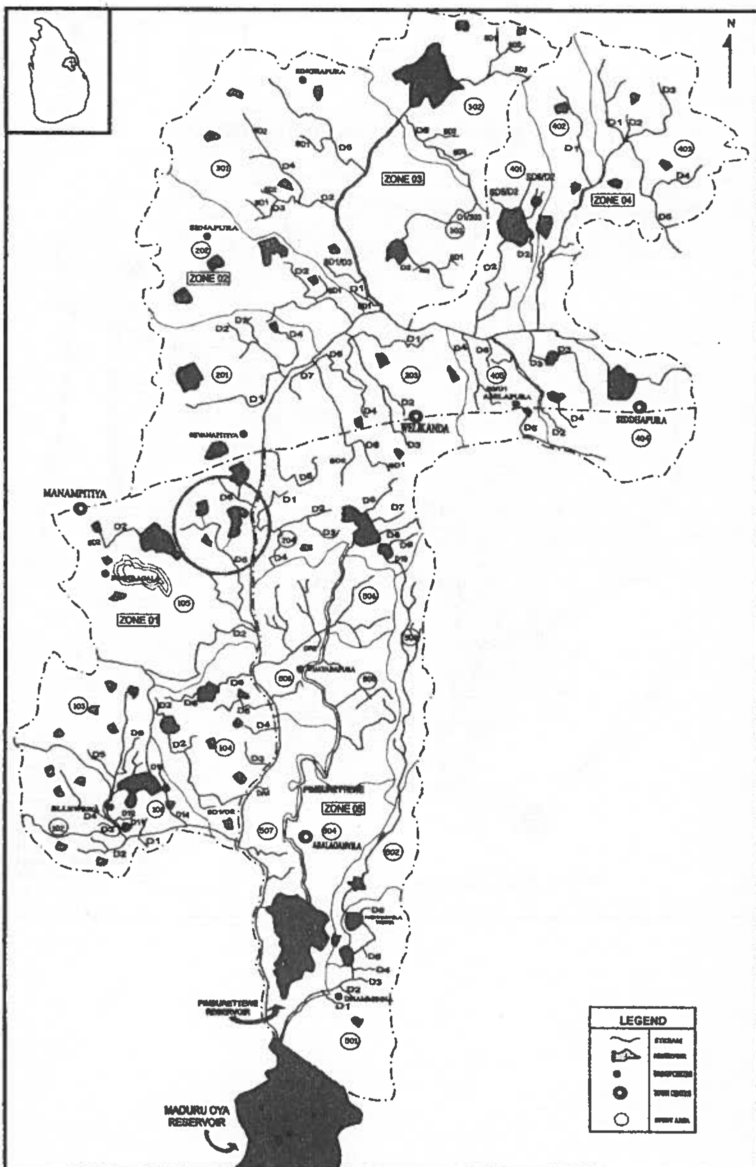

Fig. 12. Mahaweli Ganga Development Scheme (System - B)

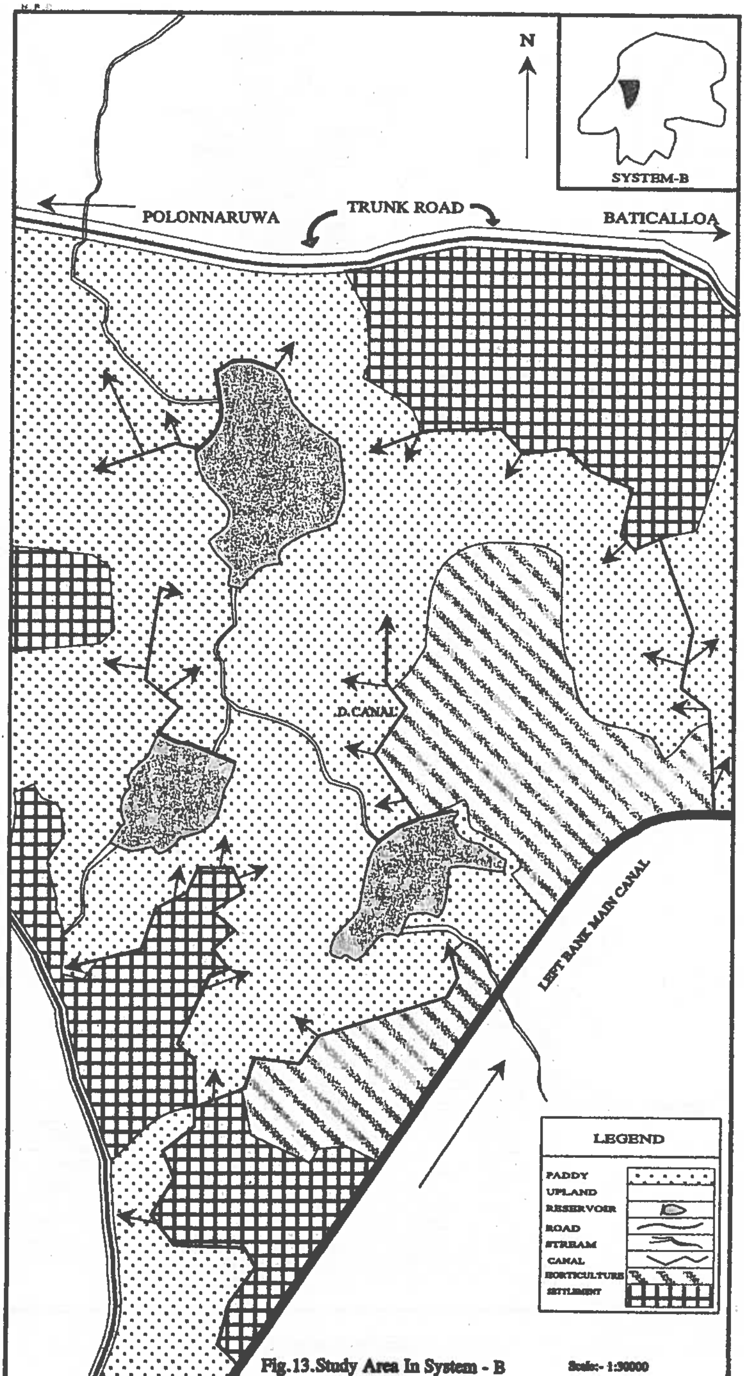

Fig.13.Study Area In System - B

Scale:- 1:30000

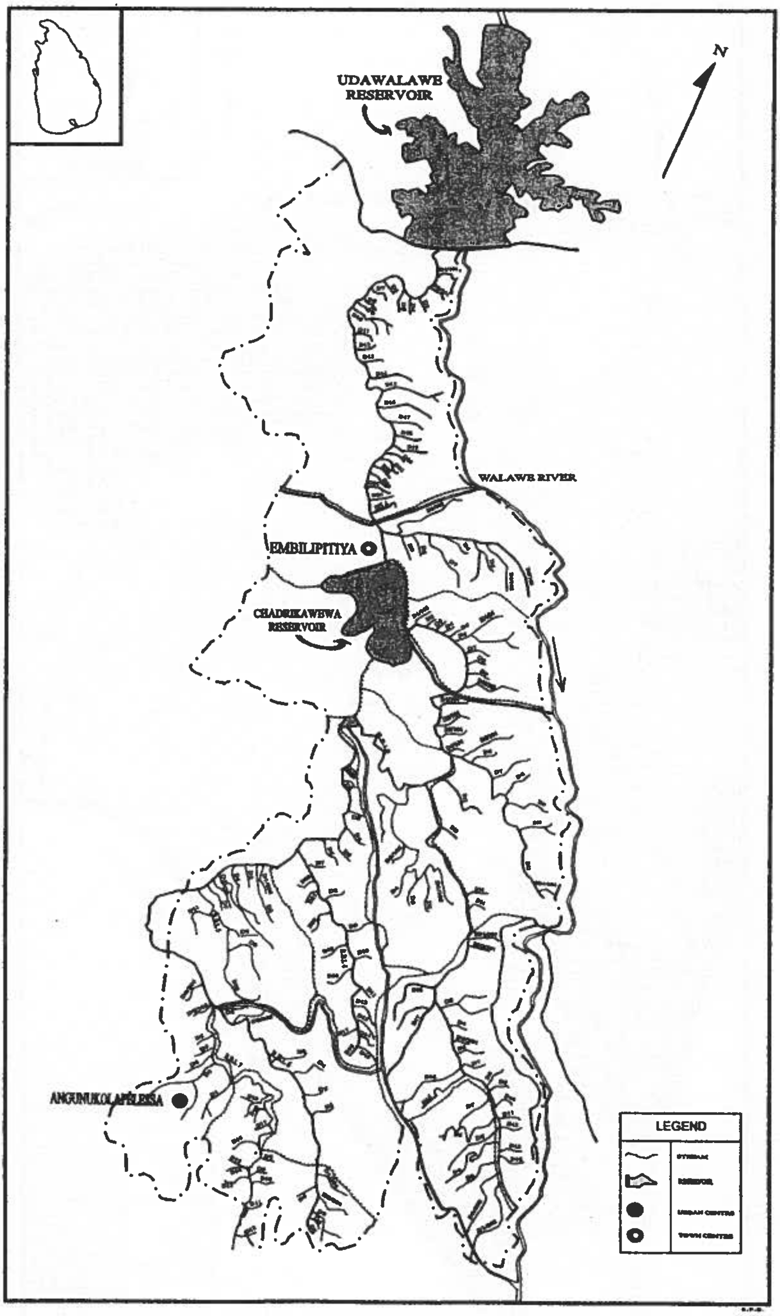

Fig. 14. Walawe Basin (Right Bank)

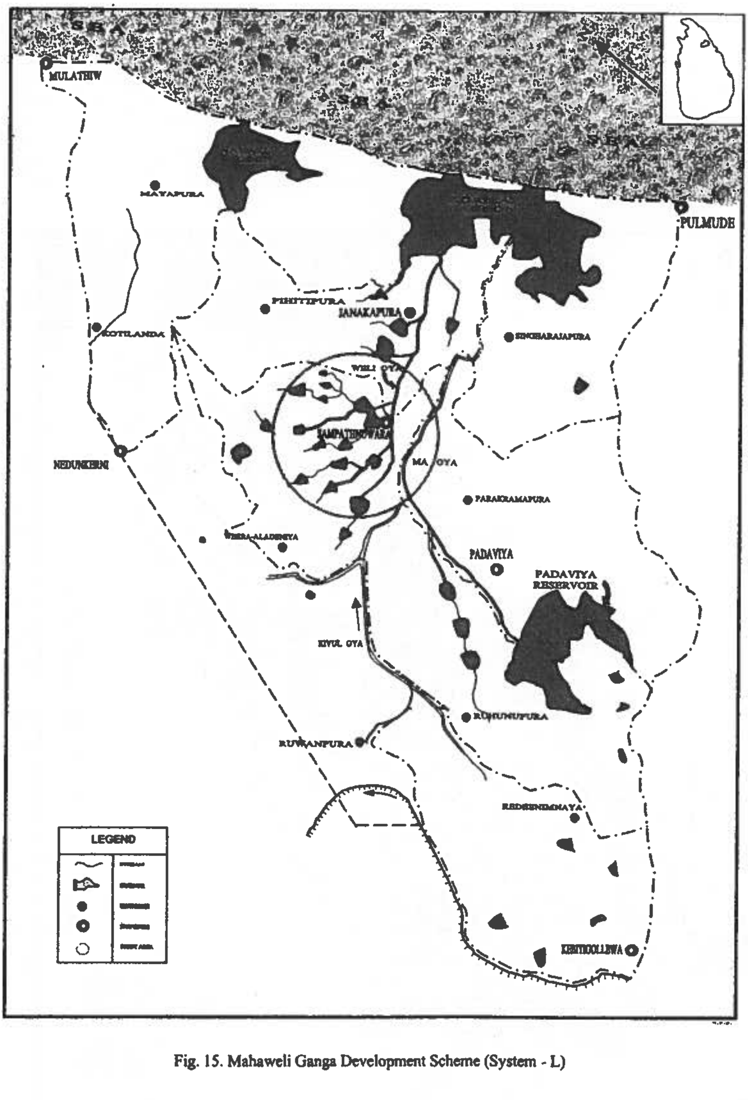

Fig. 15. Mahaweli Ganga Development Scheme (System - L)

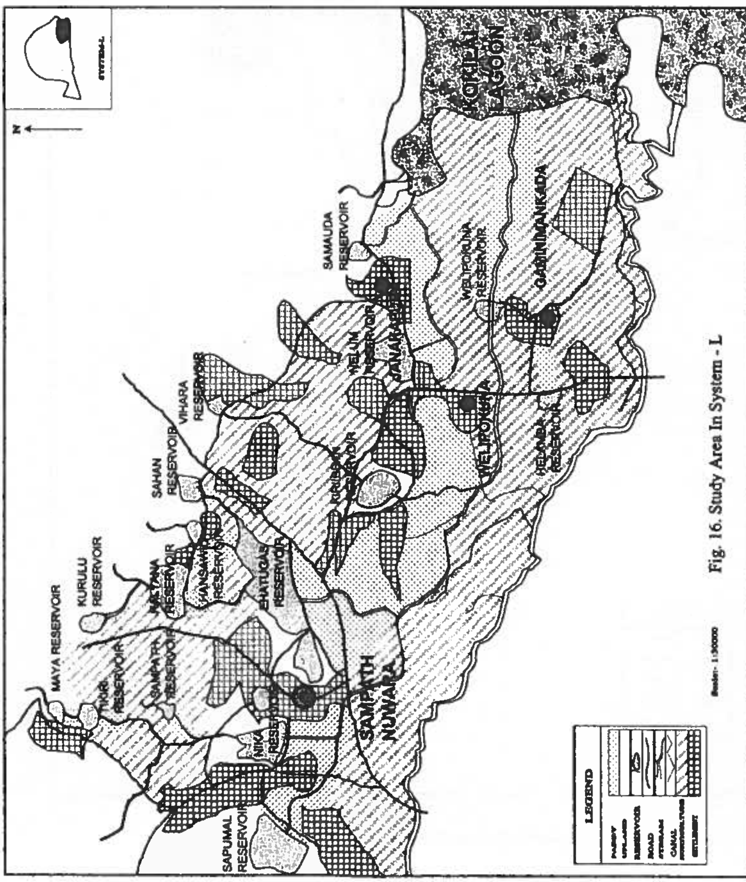

Fig. 16. Study Area In System - L