Staff Working Paper No. 7.1

Water Supply and Demand

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IMPSA

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* Prepared as a paper to support IMPSA Policy Paper No. 7 . 'Sustainable and Productive Resource Management: Macru Policies for Land and Water Resources.'

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WATER SUPPLY AND DEMAND

1. INTRODUCTION

1.1. Background

This staff working paper (SWP) on "Surface and Groundwater Resources: Supply and Demand", together with another four SWPs, is intended to support the Policy Paper No.7 entitled "Sustainable and Productive Resource Management: Macro Policies for Land and Water Resources."

The IMPSA Policy Paper No.1, entitled "Irrigated Agriculture and Irrigation Management in Sri Lanka: A Vision for the Next Decade and beyond", clearly spells out the need for a national policy, an adequate data base, adequate legal provisions and an effective institutional framework for allocation, use, and conservation of the water resources of the country. It identifies the need for a water resources policy and planning body which will compile and manage a data base of the water resources of the country and advise the government on the allocation of water among competing uses and optimum uses of water in particular river basins,

Therefore, the assessment of the ground and surface water resources of the country and review of the interactions of those resources with the socio-economic development and the environment, are the preliminary activities required for the policy formulation, planning, development and conservation of water resources. The SWP is prepared to fulfil this broad objective.

1.2. Objectives

The objectives of this SWP are to:

1. Assess the present availability of the water resources and the supply, demand and use of water by various sectors of the economy.

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[1] **The author was assisted in the preparation of this paper by a Consultation Panel composed of Prof. C.D. Dissanayake (University of Peradeniya), Dr. Douglas Merrey (IIMI), Dr. Thillak Siyambalapitiya (CEB), and Messrs. L.T. Wijesuriya (ID), H.B. Jayasekera (CECB), P.M.R. Pathirajah (NWS&DB), G.T. Dharmasena (ID), Ananda Gunasekera (M/LI&MD), M.W.P. Wijesinghe (WRB), P. Samaraweera (WMS/MASL), Joe Alwis (M/CI), Roy Jayasinghe (M/IS&T), and Nihal Fernando (IMPSA).**

ii. Analyze the trends in present water use, management practices, demands, and the activities, affecting the water resources and the bio-physical and socio-economic environments.

iii. Analyze and assess potential and opportunities for meeting the balance and: resolving, conflicts between the future supply and demand. for water by the various sectors of the economy.

iv. Identify present data and information gaps, ,and major technical, organizational and institutional constraints for developing and managing a water resources data base, and recommend ,appropriate measures for alleviating such constraints.

1.3. Scope of Work

The objectives require examination and analysis of the following:

Objective 1

* What are the major surface and groundwater resources of the country? How are those. distributed in space, time and extent?

* What is the total availability of surface and groundwater? What fractions of the available sources are utilizable?. What are their quality status in relation to various socio-economic needs (irrigation, inland.fish-culture, domestic and municipal supplies; .industries)?

* What is the present levels of utilization of the water resources for various uses and by different users?

* What are the key water-deficit and water surplus river basins, areas and regions of the country in relation to the different needs? What is the existing potential for meeting those demands?

* What are the major water resources, development proposals .already in hand? What are their key implications on the future supply and demand for water?

* What are the major data gaps to assess the above? Which are, and should be, the agencies responsible for monitoring, collecting, analyzing, evaluating and compiling those data? What are the technical, organizational and institutional constraints of reconciling the current availability, supply, demand and use of water for the different uses and by the different users?

Objective 2

* What are the implications of present water use and management practices affecting the water resources itself! Are their information available on major modifications of natural patterns of existence, availability and movement of surface and groundwater? Are there any information on water quality degration due to agricultural and industrial uses?

* Are there specific evidences of alterations of natural ecosystems due to the water resources development, use and management? Are their any evidences of increased flood hazards,, droughts or any healthy hazards? What are the environmental implications of the water resources development projects in hand or in the pipe line?

* Which agencies are, and should be, responsible for monitoring the above? What are the present technological, organizational and institutional constraints for monitoring the above?

Objective 3

* What are the projected water demand patterns for different purposes (agriculture, power, drinking, industries, transportation, health and recreation) in the next 10-15 years? How do the demands in the major river basins or regions compare with each other?

* Will there by major conflicts in demand? Will there be major constraints in meeting demand? What are the strategies for meeting with scarcity of water for double cropping of paddy in some areas and some schemes? Can those areas or projects be identified? What should be the broad government policy in allocating water resources for different uses? What should be the principles of water allocation among different users, between different provinces and for different purposes?

Objective 4

* What are the gaps in data and information required for forward planning of water resources policies? What would be the desirable organizational and institutional arrangements to fulfil the above tasks in the long run?

1.4. Methodology

This paper has been developed within a limited time period which has not allowed an exhaustive study of all the existing-materials. Therefore, it relies heavily on limited literature review, consultative panel discussions and IMPSA team discussions.

The Special Consultation Panel set up to assist the author to developp this paper was composed of the following professionals:

Prof. C.D. Dissanayake, Department of Geology, University of Peradeniya;

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2. SURFACE AND GROUNDWATER RESOURCES

2.1. General

Water is a prime natural resource, a basic human need and a precious national asset. A resource becomes an asset when it is developed (harnessed) and made to satisfy society's needs. Considerable amount of investment have gone in developing both surface and groundwater resources of the nation. Within Sri Lanka, competition among sub-sectors is growing more acute, and government must provide water to their rapidly growing population for domestic use, for agriculture to feed them, and for industry to employ them keeping in mind that these water related activities should create less environmental degration. Hitherto the emphasis has been mainly on supplying water to agriculture, hydropower generation, drinking and industrial water supplies with very little attention paid to environmental protection. The water related planning and implementationprocess took into account only local needs but neglected basin and regional impacts; it emphasized short-term gain but neglected the long-term sustainability; and it focussed on structural components but paid less attention on non-structural measures.

Water supply projects provide both positive and negative impacts. Some of the most visible adverse impacts are:

- environmental degration and losses to flora and fauna;

- large scale resettlement of people from their original habitat;

- public health consequences with water acting as a carrier of disease, toxics and carcinogens;

- waterlogging and soil salinity degrading agricultural lands;

- lack of equity and social justice in water distribution;

clashes among policies and strategies among competing uses.

Sri Lanka is at the cross roads; it has opened up its economy for private investment with large scale restructuring of its public sector undertakings and involved in radical changes in policy transformation; rapid urban development and increasing tempo in industrialization are taking place; in the imgated agricultural sector participatory management and crop diversification have assumed greater importance. All these transformations are intimately related to water resources development. The govemment now is in an advantageous position to initiate mechanisms for integrated water resources planning according to due priority to all aspects of water demands.

In all these endeavors, the primary requisite is the development of a master plan for water outlining the availability of water supply, demand (present and future) requirements and ways and means of matching the supply to the demand. The staff working paper No 7.1 concentrates on the water resources availability and its future demand for different uses. It also provides certain guidelines for framing efficient water resources management policies.

2.2. Climate

Sri Lanka is situated in the large belt of monsoon climate in South Asia and experiences both South-West and North-East monsoon circulations. Apart from the general monsoon circulations, Sri Lanka's climate is govemed by local factors such as: the central highlands a barrier for both monsoons, and cause large differences in climate between the windward and the leeward regions especially with respect to rainfall; its position in the Indian ocean has a moderating effect on the climate. Thus the tropical climate conditions in Sri Lanka are characterized by the pattern and distribution of rainfall originating from the souther-west and north-east monsoons. The monsoon season also defines the **Sri Lanka** 'hydro-logicalyear' which runs from October until September.

2.3. Rainfall

Rainfall is the source of all available fresh water in Sri Lanka. When compared with most other countries, Sri Lanka is well endowed with an abundance of surface water resources. Rain occurs in four distinctive weather patterns made up as follows:

October-November	=	convectional, cyclonic-depressional
December-February	=	north-east monsoonal-depressional
March-April	=	convectional-inter-monsoonal
May-September	=	south-west monsoonal

The mean annual rainfall in the island which is around **2080** mm is almost three times higher than the world average of 750 mm. However, the variation of rainfall over space and time and its sub-optimal utilization makes it a crucial constraint in water resources development and use in many parts of the country, and in particular in the 'dry zone'.

While the hydrological year **is** relevant from October-September, the agricultural seasons are as follows:

Maha - October to February
Yala - April *to* September

The maha rainfall varies from 800 to 3000 mm. The yala rainfall varies from 150 to 3000 mm. The **1200** mm isohyet covers almost half the island during maha while during yala it covers about a quarter of the island. Also the maha rains are more dependable with lesser coefficient of variation.

The distribution of rainfall within a year shows a seasonality of varying degree throughout the country in accordance with the seasonality of the atmospheric phenomena.

The annual distribution of rainfall throughout the country is bi-model except in the eastern dry zone.

There exists a marked dry season from May to September in the dry zone and from January to March in the wet zone in view of the low monthly rainfall. Meteorological conditions, rainfall variability and reliability, and water balance characteristics all indicate that there is an inbuilt tendency for rainfall departures to occur. Such random events occur frequently enough for concern. The 'abnormal' conditions pose a basic dilemma in planning measures for the mitigation of this adverse impact. This is all the more *so* because in development planning average water availability conditions are taken as the normative; this assumption may be valid for the country as a whole or in the case of long-term planning but is patently inadequate for 'local operational purposes.

There is an urgent need to define and formulate norms and criteria for identifying and measuring droughts and to develop efficient methods for drought forecasting and warning.

A thorough assessment of the current policies and action programme in anticipation of, during and subsequent to drought situations should be undertaken with a view to laying down the guidelines for a long-term strategy and unified national policy for drought mitigation which are conspicuous by their absence now.

Floods are natural phenomena which are an off-shoot of incessant rainfall. Damages occur because rnan has exposed himself to the hazards of inundation. Human response to the phenomenon of flooding in the order of increasing costs of implementation are: human adjustment to minimize damage; socio-economic and engineering measures to abate floods: and engineering methods of flood control.

The problem of inundation and damages by floods in Sri Lanka are prominent in three major river basins, namely Kelani, Kalu, Nilwala, and the Mahaweli Ganga. Although the duration of the floods is relatively short, in most instances less than' four days, the inconveniences caused to the affected population and the concomitant government costs are significant. With the increasing population, there is likely to be a large scale encroachment of river banks and flood plains restricting the waterways and thereby increasing the flood stage.

Modem methods of flood forecasting, flood plain zoning, flood plain regulations and management of rivers 'are very essential to reduce future flood damages.

2.4. Streamflow

Sri Lanka has a predominantly monsoonal and tropical climate. The radial drainage pattern emanating from the high watersheds has demarcated 103 distinct natural river basins that cover over 90 percent of the island. River basins originating in the wetter parts of the hill country are perennial, while many of those in the dry zone are only seasonal. Only a few river basins, such as the Mahaweli Ganga that drains 16 percent of Sri Lanka, carry water from the wet to the dry zone.

Although there are 103 distinct river basins, many of them are so small, often less than 100 km^2 in the area and the beds of some of them very nearly at mean sea level, that regular streamflow measurement is hardly justifiable in terms of manpower development and financial resources. There are about 40 river basins out of a total of 103 where stream gauging 'could be meaningfully performed.

An assessment of water resources available in the island is given in Table No. 1. It is evident from this fable that Sri Lanka has a total annual surface runoff of around 42 million acrefeet of water. A considerable proportion of this amount is now utilized for irrigation and what escapes to the sea is less than **27** million acrefeet. Although water is used for hydropower generation, it is only non-consumptive use and therefore, does not affect the total quantum of water **use** for consumptive use, such as irrigation, drinking, industries, etc. With the development of Mahaweli project, a considerable portion of the dry zone runoff had already been utilized.

TABLE NO.l. Surface Water Resource

	Wet Zone	Dry Zone	Island Total
Rainfall (Annual) mm	**2424.18**	**1449.83**	**1937.00**
Inches	**(95.44)**	**(57.80)**	**(76.26)**
Runoff (Annual) HM*	2.58×10^6	2.55×10^6	5.13×10^6
Acrefeet	20.93×10^6	20.66×10^6	41.59×10^6
Runoff rainfall ratio	**65.1%**	**35.8%**	**40.5%**
Escape HM	2.04×10^6	1.30×10^6	3.33×10^6
Acrefeet	16.50×10^6	10.56×10^6	27.00×10^6
Escape as a Runoff	**78.83%**	**51.11%**	**64.91%**

(*HM = Hectare Meters)

<u>Source:</u> Final Report of The Land Commission of **1985:** Sessional Paper **III** of **1990.**

The Hydrology Division of the Irrigation Department has arrived at a quantitative estimate **of** the surface water potential in Sri **Lanka** on the basis of available data on streamflow, rainfall and reservoir replenishment (Table **No. 2).** This gives only the potential available. In order to find out how much of this can be economically utilized (utilizable flow) additional studies need to be carried out. Table No.2 clearly indicates regional variations in surface water potential over the island. It *can* vary between **21** cm and **253** cm from the lowest to the highest. While Kalutara, Galle, Ratnapura, Kegalla and Colombo districts record over **243** cm most dry zone districts have values below **30** cm. A large proportion (over **60%)** of water that escapes to the sea is from the wet zone rivers like Kalu Ganga which has the highest discharge for any river except that for Mahaweli.

2.5. Hydrometric Networks

The hydrometric network collects information on rainfall, streamflow, evaporation, and reservoir storage. River basins of Sri Lanka, although small in size exhibit remarkable variability in terms of morphology, climate, geology, soils and landuse patterns. Therefore, their hydrologic characteristics are markedly different and calls for closer monitoring networks.

Measurement of rainfall in Sri Lanka dates back to the early 19th century when plantation agriculture kept records of daily rainfall measurements. Today the country has a family comprehensive rainfall data network, but 'its distribution is uneven and needs rehabilitation of some stations which are in operation for a long' time.

Hydrological information system of the country include over 500 daily read rainfall stations with records over 100 years in some of them. There are over 50 stream gauging stations with period of records for about 40 years. Available network is considered sufficient. for basic planning purposes and gathering information for project identification and formulation. However, for preparing comprehensive master plan, more refined data with greater reliability and additional advanced information systems will be necessary. This should *be* a priority consideration particularly in the area of weather forecasting, for future real-time operations and plans. Automatic recording and monitoring devices may be the best option at vulnerable places although conventional methods of data collection programme needs to be strengthened in terms of resources and training.

In Sri Lanka, the collection of hydrometeorological and hydrogeological data is being done by several government departments and statutory boards. Some of the most important ones are:

1. Department of Meteorology - rainfall

2. Department of Irrigation - rainfall, streamflow, evaporation and inflow to selected reservoirs

3. Department of 'Agriculture - evaporation and evapotraspiration

4. Water Resources Board - hydrogeologic data

5. Water Supply and Drainage Board - hydrogeologic data

6. Water Management Secretariat, MEA - rainfall, streamflow, and inflow into the reservoirs in the Mahaweli area

The meteorological data was published as year books upto **1974** and then it was discontinued. However, the Hydrology Division of the ID continues to publish its hydrological annually containing streamflow data.

Although hydrometeorological data are collected by a number of agencies,' there is no systematic procedure and organizational mechanism to develop'a systematic hydrometeorological data bank for processing, storage, retrieval and dissemination." It is very essential to develop such a data bank which will form an important part of management information system for water resources planning, interpretation, development and use. The existing database with agencies such as the CEB has to be updated-and made more readily available for user departments.

Modem water management practiced often aided by computer simulation and operational research require a mass of hydrological information which should have a comparable degree of reliability. Modem methods of operational hydrology provides this need by adopting optimally designed networks, modern methods of data observation, transmission, processing and storage. The operation of these instruments needs more skilled and trained personnel. Motivation and incentives for personnel are essential continuous process in a program of hydrologic data collection. Most observations are so routine that the work may soon become monotonous. Recruitment, training, providing requisite facilities, motivating and monitoring and reviewing their performance is a prerequisite in the data collection. Some of the equipment are very old needing replacement and rehabilitation. More than this, the personnel working in this division needs recognition and incentives for their work.

2.6. Geology

Geologically about 90 percent of the island consists of crystalline hard rocks, namely granites, gneisses and schists, charnockites and crystalline limestone of the Precambrian age. About 10 percent of the land mass consisting of sedimentary formations is confined to the North and North-western coastal belt. The sediments are predominantly tertiary limestone of miocene age. This highly karstic limestones form good aquifer system which have been studied in great detail. The remaining land mass is surface alluvium in the riverine and coastal areas.

Hard rock terrains of Sri Lanka consist of a great variety of metamorphic rocks and granites having virtually no primary porosity; but do have secondary porosity due to fracturing and weathering which allows free passage and storage of groundwater. In addition, the weathering processes also contribute a great deal to the storativity of hard rocks.

The use of groundwater from large diameter dug wells for irrigation has been the practice mainly in the Jaffna Peninsula while the use of dug wells for domestic water supply was prevalent in most parts of the country. The laterites found in the wet zone provides fairly reliable and required quantity of water for domestic use.. The first known systematic attempt to assess the availability of groundwater was undertaken in 1905. Recently, it has stepped up its activities.

Generally the need for the exploitation and utilization of groundwater arose. in areas where surface water sources were scarce and limited. In Sri Lanka, groundwater exploitation for agriculture was mainly restricted to the sedimentary miocene formations in the Jaffna Peninsula and more recently in the Vanathavillai area off Puttalam and hardly any attempt was made for the exploitation of groundwater estimated to be in the hard rock areas. In the mid-1960s, with the collaboration of Israel expertise, groundwater exploration was undertaken in the north-west section of miocene limestone. From 1978 the Water Resources Board has also commenced exploitation of groundwater. Recently, it has stepped up its activities.

A groundwater map of Sri Lanka was compiled in 1973. It was estimated that the total groundwater availability in the island to be of the order of 5.88 million acrefeet per annum which is about one eight of the country's surface water resources. In addition, about 0.5 million acrefeet of groundwater'is estimated to be available from artificial recharge from the existing major irrigation schemes.

The greater part of Sri Lanka consists of hard rock formations of crystalline rocks that are weathered mostly in varying thickness depending on the climatic regions. The total extent of this formation is nearly 21,340 Sq.miles. These rocks themselves have very little inherent pore spaces in the rock textures except that become permeable'by differential weathering.

Hard rock formations generally offer scope for the construction of large sized dug wells, dug cum bore wells or bore wells. Deep tube wells and bore wells are more feasible in the synclinal troughs where sometimes sub-artesian or artesian conditions could be encountered.

Semi-consolidated formations include miocene limestone and the small patches of jurassics in the Talbowa and Andigama area near Puttalam. The miocene limestone,has considerable porosity and void space cavities 'and caverns which serve as reservoirs for groundwater.

'The'total area that falls into this category is about 1050 Sq.mls. The unconsolidated formations include the localized river alluvium, the old river courses, the coastal alluvium. The total area of this category is of the order of 2,500 Sq.mls.

The potential for tube well construction and their capacity vary from basin to basin' depending on their thickness and the amount of recharge both from rainfall and from the river itself. The south-western lateritic region is also a promising source for domestic supply. Salt water intrusion is a problem which has to be guarded against in the coastal alluvium. Good conditions are also encountered in the coastal alluvium. In the wet zone of Sri Lanka there are peat deposits in the lower reaches of the flood plains from Muthurajawela in the North to Dondra in the south along the south-western seaboard. These areas though they have a fairly high groundwater potential, their PH is less than 5 rendering them acidic and contain high amounts of organic matter which make their use restricted.

2.7. Groundwater

An accurate assessment of .the country's groundwater resources can be made only after a detailed picture of the hydrogeological formation and the water balance of the various river basins of the island are available. Due to the lack of accurate and reliable information at present, we have not yet reached a stage to undertake a basinwide accurate analysis of the groundwater except in very generalized terms. Considering'that the broad assessment of the groundwater resources of our country would help the planning process, an attempt has been made to arrive at the total groundwater recharge of Sri Lanka and of the individual river basins (A D N Fernando, 1985).

In order to compute the groundwater recharge in the different river basins in Sri Lanka, hydrogeological units in the different basins were delineated using the hydrogeological map of Ceylon, 1968. The mean annual rainfall map prepared under the Canada Ceylon Colombo Plan Project was used for computing recharge due to rainfall contribution.

For the computation of rainfall infiltration to the groundwater body the rock type and formations encountered in the country were broadly classified into seven categories. Different figures of percentage infiltration rates were assigned to each rock type formation according to the best judgement based on studies made elsewhere (Task Force CGWB, Government of India, 1972). In this study it was also assumed that 40% of this infiltration is lost in the form of evaporation and sub-surface flow. Therefore, the net groundwater recharge would be 60 percent of the gross infiltration due to rainfall which replenishes groundwater resources for extraction.

A groundwater map of Sri Lanka indicating the areas having different groundwater potentials has been prepared which would indicate to the engineers, planners and decision makers to determine priority areas on a national basis. Also for general purpose of planning it would be necessary to have some idea as to the depth of the water table; therefore a generalized map of the water table from numerous observations of wells taken all over the island has also been prepared.

Commencing from 1978, the Water Resources Board has constructed over 5000 tube wells in the hardrock terrian in different geostratigraphical and geolithological domains with adequate extraction potential for small-scale agriculture farms.

Ninety percent of the wells constructed in this country have been used for rural water supply using hand pumps with a small number for pumping water supply schemes. In addition to these, two extensive aquifers of the coastal sand deposits have been developed after intensive scientific investigation and evaluation of the water balance of the resource basins for supplying over 500,000 gallons of water per day to meet the requirements of the industrial zones at Katunayake and Koggala.

Also, most of the wells in the country have been inventorized by the Water Resources Board and the National Water Supply and Drainage Board, and a fair density of wells are available throughout the country on district basis for further potential evaluation purposes. This exercise is now beingattempted by the Water Resources Board in the hardrock regions on AGA unit basis.

Groundwater resources may be one of the crucial untapped resources available for alleviating the pervasive and intractable problem of rural poverty in the country especially in the hard rock areas of the dry zone of Sri Lanka. The greatest potential for groundwater development lies in the dry and intermediate zones which produce the bulk of rice and other subsidiary food crops wherein water has always been a limiting factor than land.

It is expected that even with the completion of the Mahaweli project and rehabilitation of many village tanks, there would 'Still be large tracts of arable land in the dry zone without an assured supply of water, not only for crops but also for animals and even for domestic consumption. Within the Mahaweli Project area, according to the UNDP Plan, some 600,000 acres will be without any imgation water. In the south-western parts of the country and in the' northern parts of the north central plains, there will be thousands of acres of fertile lands without any dependable water supply. The productivity of these lands could be increased through irrigation, thus contributing substantially to the national economy. In a recent publication, the Agrarian Research and Training Institute have observed that agricultural planners should not overlook the fact that nearly two and a half million acres of land suitable for agricultural development in the dry zone were not likely to come within any major irrigation projects in the near future. The crucial problem of water supply especially through ,groundwater extraction does not appear to have beeh'adequately appreciated and accounted for in the development of the dry zone for imgated agriculture. Nevertheless, the nature of these challenges should be properly analyzed and they should be executed if development planning, is to be more realistic under the dry zone conditions.

In formulating a national policy on groundwater development in hard rock areas, one is confronted with enormous deficiencies in hydrogeological data. While reconnaissance level geological maps of the country do exist, there is very limited data on surface geology, well yields, groundwater level variations and quality, and almost total absence of systematic pumping test data of any type and long-term records of groundwater level fluctuations.

Quite often, it is the failure to recognize the role of groundwater as a marginal resource in the dry and intermediate zones that led to the under-estimation of its potential uses. It is obvious that groundwater in the hard rock areas is not unlimited. Therefore, there is a real challenge for the agricultural planners to evolve ingenious farming systems that suit the use of limited groundwater resources. For example, there is a definite possibility of meeting certain types of agricultural water demand from groundwater in the hard rock terrains. In the case of supplemental irrigation, the concept of conjunctive use of surface water with groundwater and rainwater has never been extensively studied.

Extraction of groundwater needs power. Diesel pumps are costly; therefore the question of electrification of rural areas, financing of well construction, provision of supporting services and framing of legal frameworks for groundwater abstraction will have to be followed.

Based on the available information, the following broad conclusions can be drawn with regard to groundwater development and utilization.

1. There is an urgent need to delineate more precisely through groundwater drilling and geophysical surveys the areas of groundwater availability and evaluate the groundwater potential in those areas.

2. In the past, groundwater resources were explored and exploited only in places where surface water sources were either not available or insufficient. All the available potential of the country have not been identified in a systematic manner.

3. Emphasis of groundwater exploration from the geologically more favorable areas like miocene limestone areas would now have to shift to other parts of Sri Lanka which have greater demand for groundwater.

4. The cost of groundwater exploration and exploitation is very high. More exploration of groundwater potential on a large scale by government institutions is necessary before exploitation can become viable in the new area.

5. The abstraction of groundwater in a region should be regulated so as not to exceed the annual replenishment of the groundwater aquifer; otherwise the resulting ecological and environmental consequences will be difficult and in some instances, impossible to reverse.

6. The integration of groundwater use with surface water irrigation systems optimizing the full utilization of rainfall has yet to take place in Sri Lanka.

7. Systematic monitoring and evaluation of groundwater quantity, quality and water level fluctuations in many parts of the country is not yet very well understood.

3. IRRIGATION WATER MANAGEMENT

The land use pattern in this country had started changing drastically under colonial rule resulting in hill country forests denuded progressively for plantation agriculture. Development of imgated agriculture for settling farmers in the dry zone became the dominant state development policy in the latter period of British rule. Renovations of derelict ancient irrigation works and new land settlement around them became major concerns. This policy continued more vigorously after independence with construction of larger schemes such as the Gal Oya, Uda Walawe and Kirindi Oya culminating in the Accelerated Mahaweli Development Project. Nearly all major construction works undertaken have been completed.

With the completion of the Mahaweli project a few favorable sites such as lower Yan Oya, Mahwettu Oya, Hede Oya and a part of Dedru Oya remains for major irrigation development. Most of the Kalu Ganga waters could be used for future industrial requirements.

In the future, Sri Lanka's water resources development must increasingly focus on augmentation through conjunctive use of surface and groundwater, rehabilitation and improved water management. Government policies appear to be increasingly directed towards several measures to improve water use efficiency through institutional transformation; crop diversification and introduction of modem technology; rehabilitation of irrigation systems;

groundwater development as conjunctive use of surface and groundwater for agriculture, industrial and domestic purpose; and systematic watershed management.

The following are some of the changes observed during the recent past in the irrigated agricultural sector. A few suggestions are provided to improve water use performance.

1. Institutional strengthening of FOs, self- and joint-management of irrigation of systems by FOs and agency officials through INMAS, MANIS and ISM programmes. These institutional measures are likely to improve water management in irrigation systems if sufficient thrust is provided by government policies and commitment.

2. Minor aberrations observed in more recent years in the normal commencement and recedence of the maha rainy season in the dry zone have had some degree of impact on upland rainfed cultivation and commencement of irrigation in major irrigation schemes; there is a need to continuously monitor the variation Of rainfall over the dry and intermediate zones and to suggest cropping patterns and crop calendar to suit the onset of maha rainfall.

3. With a definite predictable shift towards the growing of non-rice field crops during the drier yala season in the major irrigation systems of the dry and intermediate zones, optimizing the use of early yala rains for land preparation, and maximizing the use of the limited irrigation supply acquires an increasing measure of importance.

4. The impact of drought is a very high risk factor and an essential characteristic of the dry zone during the drier yala season. There is significant potential for exploiting the underutilized groundwater resources of varying amount that' are located within 'the irrigation commands (shallow groundwater) and in the favorable flood plains of the rivers, especially those in the dry zone.

5. There may not be radical changes in the cropping patterns in the wet and intermediate zones id the near future; on the other hand, 'more significant changes and, trends in respect of crops, cropping calendars and patterns will essentially take place in the dry zone. These changes will take place as a response to having to stretch the limited water resources that are presently available within the river basin by recourse 'to improved water-saving practices in irrigated agriculture.

6: Current and future conflicts within an irrigation project will mostly centre around the use of existing supplies. between rice and non-rice' crops during the dry yala season, inequitable distribution of water between head and tail-end commands, and allocation of water between'the old and new settlers; Clear policies must be laid down for integrated operation and management of the system 'and proper monitoring aiid evaluation of the performance of the system must be carried out.

7. The topographical features of most of the river basins in the country is such that, unlike in the rest of Asia, the watershed boundary of the river is widest in the middle portion of the river basin and then it narrows down in its lower portion. As a result, the characteristic wide flood plains are absent. Opportunities for transbasin diversions are therefore present only within the upper or middle reaches of the rivers, as well as from the surplus wet zone to the deficient dry zone river basins.

Based on the present hydrological characteristics of the river basins, transbasin diversion from the rivers having surplus in the wet zone to the dry zone regions may not likely present any conflicts. On the otherhand, transbasin diversion between river basins located within the dry zone will present serious conflicts because the individual river basins themselves are already water deficient and has to be handled carefully based on surplus during the maha season.

Clearcut policies are to be framed for diversions from water surplus regions to water deficit regions to avoid any likely inter-regional conflicts.

4. DOMESTIC AND INDUSTRIAL USE WATER MANAGEMENT

The main sources of water for domestic and industrial supply are streams, rivers and lakes which form surface water sources, and springs and wells which form groundwater sources.

As in many tropical countries, the majority of the population in Sri Lanka lives in rural areas, constituting 78 percent of the total population; they have less access to proper water supplies or suitable methods of human waste disposal. Although the standards of water supply and sanitation facilities are much higher than its neighboring countries, water consumed by them is at times obtained from polluted sources such as rivers, streams and unprotected wells. Since 1979, a pilot project had been drawn up to drill into hard rocks and install hand pumps for getting protected water supplies for domestic purposes.

Domestic and industrial water supplies are required for many purposes: drinking and culinary uses; washing, bathing and laundering; watering gardens and lawns; varied industrial processes; fire protection; and removing offensive domestic and industrial wastes.

To provide for these varying uses, water must be adequate in quantity and satisfactory in quality, readily available to the user, relatively cheap and easily disposed after its use. Water demand for domestic and industrial use will keep on rising as long as population expands, standards of living rises and industrial expansion takes place. In view of increasing and diverse demands for water, there is a need to plan and regulate water use in a given geographical area.

There are about 200 piped water supply schemes in the country to-day serving about 45 percent of the urban population and 5 percent of the rural population. Many of the schemes are not providing the level of services expected of them both qualitatively and quantitatively due to poor maintenance. In formulating plans to provide safe water with easy access, the accent has been mainly to open Up new schemes and give water service facilities to new areas, paying little heed to rehabilitating and improving the existing schemes.

Experience indicates that it would be easier to provide industrial 'water as well as to treat effluents if industries are located in a clustered location such as an industrial estate. The economy of scale makes it much more 'easier to monitor and provide adequate treatment measures. Sufficient enactments for using and preserving industrial use water have been introduced recently. Therefore, provisions made in the industrial laws for strict regulation of siting industries and discharging their effluents should be enforced.

With rapid expansion of water'supply programmes for domestic: and industrial uses, it will be of immense benefit to establish water quality survey programmes to collect data that could be analyzed and evaluated. These data could be used in drawing up a future development programme. In the case of underground sources too, surveys are very necessary to ascertain chemical parameters such as fluorides, iron and chlorides present in the water. Necessary water quality monitoring and evaluation of both 'the surface and groundwater is also necessary.

The importance of chemical Contamination of water has been overshadowed by the more serious problem of water related infections. Chemical contamination of surface and groundwater results from application of pesticides, discharge of industrial effluent into waterways, and leaching out by rain. of treated agricultural land. Pesticides and some toxic metals, particularly lead, mercury and cadmium are known to accumulate in the food chain and present a long-term hazard to human and other forms of animal life. The increasing recognition of the important environmental factors in causing cancer has focussed attention on the presence of carcinogenic contaminants in water resources. For these reasons, the need for extensive protection of drinking water supplies from chemical contamination is gaining importance.

5. HYDROPOWER DEVELOPMENT

Ceylon Electricity Board (CEB) has developed 1015 MW of hydro capacity in 15 grid-connected hydro generating stations, with a total' annual 'average energy potential 'of 3527 GWh/year. The Samanalawewa project (120 MW) will soon be commissioned adding a further 357 GWh/year. In July 1988, CEB in association with GTZ, completed a Masterplan for the electricity supply in Sri Lanka. This study identified and costed the remaining hydroelectric sites and studied several generation expansion scenarios. The CEB updates their expansion plans every year, taking into account the varying demand pattern and foirecasts, **oil** prices and government policies. The following are some highlights, extracted from both the Masterplan (July 1988) and CEB's report on long term generation expansion (September 1991).

1. In 1990, the generation requirement was 3149 GWh, of which 99.8 percent was provided by hydro. In 1992, with no new additions of generating plants to the existing System, hydro electricity will provide 92 percent of the expected demand of 3537 GWh, under average hydrological conditions.

2. The CEB expects the generation required in the year **2000** to be nearly double the demand in 1990. If the trend continues, the demand in **2020** may be as high as 8 times the demand in 1990.

3. Over the next **20** years, the generating system will transform from a hydro-dominated system (presently over **90** percent hydro energy) to a predominantly thermal system. The most recent estimates indicate that **65** percent of electrical energy will come from thermal sources by 2010.

5. The Masterplan study screened **75** candidate hydro projects, of which **38** studied in further detail, to estimate costs and energy expected. Projects were ranked according to their long-term average specific generation costs in economic terms, at a discount rate **of** 10 percent per year, 50 percent plant factor and 50-year economic life.

Twenty-seven sites **(877** MW, **3682** GWh/year) capable of generating at less 15 USCts/kWh were found. Sixteen sites **(625** *MW*, **2636** GWhlyear) may generate at less than **7.5** USCts/kWh.

To be economically attractive under current price levels **of US$ 20** per barrel and coal price of **42** US$/MT, the specific cost should be below **6.2** USCts/kWh (diesel generation) and **5.4** USCts/kWh (coal generation). Ten hydro projects studied in the Masterplan **(341** MW, **1427** GWhlyear) will then be economical.

6. The Masterplan study also concluded that there are economic possibilities **also** to add **325** *MW* to existing plants.

7. Possibilities to develop small hydro electric potential to a further 100 MW.

8. The Maslerplan study has prepared a computerized water resources database, The data relates to a period from October **1949** to September 1985. CEB continues to maintain and update the database. The database consists **of**

a. monthly flow series of all the 169 hydrometric stations in the country;

b. daily flow series for **26** selected hydrometric stations;

c. flood peaks of **127** hydrometric stations;

d. sediment data of **12** sediment gauging stations;

e. monthly rainfalls at **148** selected meteorologic stations.

The development of hydropower should not be looked into a development activity in isolation. It has **to** be integrated to the overall planning **of** the water of the different regions and must, as far as possible, be designed and developed to act as multi-purpose and multi-user development projects.

6. MANAGEMENT OF WATER RESOURCES AND POLICIES

1. Present water resources planning and development is project oriented; (Except Mahaweli Development). Projects are the basic functional units (the smallest divisions) that *can* perform individually for developing water resources. Each water project is conceptualized, constructed and managed as a separate unit serving a definite locality. Present data collection and water resources planning methodology are strongly.oriented towards project planning. It has become necessary to identify current deficiencies in water resources development, opportunities foregone and problems made worse because project formulation and management are not coordinated at the river basin scale. Also conservation aspect of this natural resource and its impact on environment has not been used to develop planning tools and management structures to overcome them.

2. River basins historically been developed by satisficing and installing projects one at a time. The accumulated installation becomes less efficient as the basin as **a** whole becomes more fully developed. The inefficiencies are becoming larger (causing greater economic loss) and more public dissatisfaction. A new strategy is required in which all aspects of the problem, both at macro- and micro-level planning of water resources, are integrated and looked into in a holistic manner in order to achieve equitable and rational distribution of water 'resources among competing uses and users.

3. Integrated water resources planning is an essential need for rational water use. Fundamental activities for this planning process are water balance. studies; inventory and mapping of water resources (surface. and groundwater, their quality and 'quantity), planning for allocation of water resources, regulatory measures for water resources use and conservation and management of water resources development and use.

4. While Sri Lanka receives ample rainfall, its spatial and temporal distributions and ,exploitablerun-off vary widely throughout the country. Similarly, groundwater storage potential and sustained utilizable groundwater resources vary with geographical location and distribution of rainfall in the country. Reliable estimate of these quantities and their long-term variation are essential for basic planning of water resources of the country. Areas where more information should be forthcoming include, but not limited to, weather forecasting (droughts, and floods), flood estimation (volumes and frequencies), utilizable water quantity and quality (both surface and groundwater), sedimentation of **tanks,** reservoirs and water bodies, return flows, groundwater parameter, wafer table fluctuations, etc.

5. The development of water resources involves the development of irrigation systems, hydropower generation, industrial use, community water supplies, **flood** control, etc. In the past, emphasis was more'on meeting irrigation-requirements and power generation

whose quantitative requirements have been very large compared with that of domestic and industrial water supply requirements. This approach has not proved satisfactory since it has tended to affect adversely the water quality, water related health hazards and environmental degradation. In general, the environmental impact of water resources development projects on health, environment and ecosystem has not received sufficient attention.

6. Conservation of water, waste water treatment, prevention of water pollution (surface and groundwater), recycling of waste water especially in industries and recharging of groundwater aquifers and conjunctive use management of surface and groundwater are all recent attempts at optimizing the utilization of available water resources at minimum cost. Sri Lanka is at the threshold of rapid and impending industrial urban development, and therefore, is now in an advantageous position to initiate mechanisms for integrated water resources planning and preparation of master plans according to due priority to all aspects of water demands.

7. For successful implementation of any programme, the need for training and development of manpower has been realized more than ever before. The man- power problems have to be carefully examined and personnel with adequate qualifications, experience and special aptitude in all categories of staff have to be recruited and trained.

8. Preparation and updating of river-basinwise development plans for utilizing water resources, grouping of basins for economy of operation and the need to identify water regions for comprehensive water planning need to be given top priority. For preparing a comprehensive masterplan, more refined data with greater reliability and additional advanced information systems are needed. Automatic recording and monitoring devices with adequate organizational structure staffed with qualified personnel with proper incentive structure are to be provided.

9. In the field of public water supply policy, emphasis could be for utilization of groundwater in preference to surface water wherever feasible owing to the fact that capital costs can be reduced as transportation and treatment costs will be less. For this, a comprehensive survey of groundwater potential is needed. Abstraction of groundwater, where there should be limitations, should be well guided by regulatory measures through a national policy.

10. Hydropower has been and will be an integral part in the national power grid. Future investment decisions for hydropower generation could influence water policy to a great extent. Water allocation policies for hudropower generation need not be on a regional basis since national power grid is an interlinked system with short transmission distances. Implementation of multi-purpose hydro-system should be integrated with the national water resources allocation policies and plans. Clear cut policies and guidelines are required over the question of maximization of benefits accruing out of water use allocation for different purposes. The nation's water resources must serve society's

needs efficiently and equitably while maintaining the quality of the resource and making optimal beneficial use of water as the basis for planning and investment decisions.

11. Industrial use of water' is on the increase. The quality of water required for certain industries are of high order. Although the quantity of water required for industries may not be that great, the effluents coming out of the industries must be treated effectively to prevent degration of surface and groundwater. Siting of industries is an important consideration in preserving the surface and groundwater..

12. Any water resources development project will cause adverse as well as beneficial impacts on both the natural and human environments. Therefore, various measures have to be taken both to minimize potential detrimental impacts and to enhance the beneficial aspects of the proposed development. Particular emphasis must be given for future environmental planning in order to promote effective management of the environmental resources. Some of the measures suggested for enhancing the environmental sustainability are:

i. **Coordinating Agency for Natural Resources**

Under the present system of administration, coordination between conservation oriented departments is either lacking or non-existent. This is largely because these departments are isolated units which are attached to separate ministries.

ii. **Watershed Management 'of'Upper Catchment**

Soil conservation measures through protection of natural forests, reforestation, plantation crop diversification and engineering works.

iii. **Forestry Management and Planning**

iv. **Wetlands Conservation and Aquatic Weed Control**

Data collection and monitoring on islandwater systems is still poorly developed and often not directed to the needs of policy makers or resource managers seeking sustainable development.

v. **Inland** Fisheries **Development**

vi. **Water and Soil Management in River Basins**

A surface-water quality monitoring network is long overdue and must be established. Long-term groundwater management is necessary. Systematic monitoring network must be established and coordinated by an agency. Economic incentive schemes to reduce pollution from industries will require careful monitoring of effluent quality.

Quality standards are also necessary. Discharge of highly toxic pollutants will need to be prohibited entirely from entering into soil and water bodies. **To** ensure that industries internalize the costs of their environmental impacts, fees might be established for industrial effluent, and penalties carefully set with a time-bound programme should be enforced Necessary executive powers, provided to an organization such as **CEA** should be supplemented with necessary resources (both manpower and financial) to effectively implement, monitor, evaluate and enforce these regulatory and control measures.

7. CONCLUDING REMARKS

1. Sri Lanka is an island nation with a land area of 65,525 Square kilometers. The population has grown from about 3.0 million in 1900 to just under **17** million at present (1989) and is expected to reach 25 million and stabilize at that level in the first quarter of the next century.

2. The average annual rainfall is about 2000 mm, which is more than double the world's average, but the distribution is uneven, both spatially, with there being three zones, the dry, intermediate and wet, and by time, with two monsoons and periodic droughts and floods.

3. Sri Lanka has a total annual surface runoff of around **42** million acrefeet of water. **A** considerable proportion of this amount is now utilized for irrigation and what escapes to the sea is less than **27** million acrefeet. With the development of Mahaweli project, a considerable portion of the dry zone runoff had already been utilized. At present, the last of the major reservoirs, Samanalawewa on the Walawe Ganga, is about to come on stream. It **is** estimated that about two-third of the water resources in the dry zone and about one-third in the wet zone have already been utilized.

4. There is a marked regional variation in surface water potential over the island. It varies between 21 cm and 253 cm (Note: potential is expressed in cm) from the lowest to the highest. While Kalutara, Galle, Ratnapura, Kegalla and Colombo districts record over **243** cm most dry zone districts have values below 30 cm.

5. Hydrological information system of the country include over 500 daily read rainfall stations with records over 100 years in some of them. There are over 50 stream gauging stations with period of records for about 40 years. Available network is considered sufficient for basic planning purposes and gathering information for project identification and formulation. However, for preparing comprehensive master plans, more refined data with greater reliability and additional advanced information systems will be necessary. Automatic recording and monitoring devices may be the best option at vulnerable places although conventional methods of data collection programme **needs** to be strengthened in terms of resources and training.

6. Geologically about 90 percent of the island consists of crystalline hardrocks; about 10 percent of the land mass consisting of sedimentary formation is confined to the North and North-Western coastal belt. The sedimentary formations form good aquifer systems which have been studied in great detail.

7. The total groundwater availability in the'island is estimated to be of the order of 5.88 million acrefeet per annum which is about one-eiglit of the country's surface water resources. In addition, about 0.5 million acrefeet of groundwater is estimated to be available'from artificial recharge from the existing major irrigation schemes.

8. The water Resources Board has constructed over 5000 tube wells in the hardrock teman in different geostratigraphical and geolithological domains with adequate extraction potential for small-scale agricultural forms since 1978. Ninety percent of'the wells constructed in this country have been used for rural Water supply using hand pumps with a small number for pumping water supply schemes. In addition to these, two extensive aquifers of the coastal sand deposits have been developed recently to supply 500,000 gallons of water per day to meet the requirements of the industrial zones at Katunayake and Kogalla.

9. Groundwater resources is one of the crucial untapped resources available for alleviating the pervasive and intractable problem of rural poverty in the country especially in the hardrock areas of the dry zone of Sri Lanka. The integration of groundwater use with surface water irrigation systems optimizing the full utilization of rainfall has yet to take place in this country. Systematic monitoring and evaluation of groundwater quantity, quality and water level fluctuations in many parts of the country is not yet attempted.

10. With the completion of the Mahaweli project a few favorable sites such as the lower Yan Oya, Mahwettu Oya, Hede Oya and a part of Deduru Oya remains for major irrigation development. Most of the Kalu Ganga waters could be used for future industrial requirements.

11. In the luture, Sri Lanka's water resources development must increasingly focus on augmentation through conjunctive use of surface and groundwater, rehabilitation of already built structures and improved water management. Government policies has to be directed towards several measures to improve water use efficiency through institutional transformation; crop diversification and introduction of modern technology; rehabilitation of irrigation systems; and systematic watershed management.

12. There are about 200 piped water supply schemes in the country to-day serving about 45 percent of the urban population and 5 percent of the rural population. Many of the schemes are not providing the level of services expected of them both qualitatively and quantitively due to poor maintenance. Water demand for domestic and industrial use increases with population expansion. With rapid expansion of water supply programmes for domestic and industrial uses, it will be of immense benefit to establish water quality

survey programmes to collect data that could be analyzed and evaluated. These data could be used in drawing up a future development programme.

13. Providing water to industries as well as to treat effluents from industries would be easier if industries are situated in a clustered location, such as an industrial estate. The economy of scale makes it much more easier to monitor and provide adequate treatment measures. Sufficient enactments for using and preserving industrial use water have been introduced recently. Therefore, provisions made in the industrial laws for strict regulation of siting industries and discharging their effluents should be enforced.

14. The development of hydropower should not be looked into as a development activity in isolation. It has to be integrated to the overall planning of the water of the different regions, and must, as far as possible, be designed and developed to act as multi-purpose and multi-user development projects.

15. Water resources development projects will, in general, cause adverse as well as beneficial impacts on both the natural and human environments. Particular emphasis must be given for future enviromental planning in order to minimize potential detrimental impacts and to enhance the beneficial aspects of the proposed development.

TABLE NO.2. Surface Water Potential

District,	N.E. Monsoon (Maha)		S.W. Monsoon (Yala)		Annual	
	cm.	ft.	cm.	ft.	cm.	ft.
Colombo	111.86	3.67	135.33	4.44	247.19	8.11
Gampaha	76.81	2.52	82.91	2.72	159.72	5.24
Kalutara	119.18	3.91	164.29	5.39	283.41	9.30
Kandy	55.78	1.83	66.75	2.19	122.53	4.02
Matale	42.37	1.39	6.71	0.22	49.07	1.61
Nuwara Eliya	85.04	2.79	144.78	4.75	229.82	7.54
Galle	119.18	3.91	134.42	4.41	253.59	8.32
Matara	98.45	3.23	73.36	2.42	172.21	5.65
Hambantota	34144	1.13	29.26	0.96	63.70	2.09
Jaffna	9.75	0.32	2.74	0.09	12.50	0.41
Kilinochchi	14.63	0.48	2.74	0.09	17.37	0.50
Mannar	22.25	0.73	2.66	0.12	25.91	0.85
Vavuniya	24.08	0.79	3.05	0.10	27.13	0.89
Mullaitivu	20.42	0.67	1.83	0.06	22.25	0.73
Batticaloa	19.20	0.63	1.83	0.06	21.03	0.69
Ampara	19.51	0.64	1.83	0.06	21.34	0.70
Trincomalee	19.81	0.65	1.52	0.05	21.34	0.70
Kurunegala	33.53	1.10	27.74	0.91	61.26	2.01
Puttalam	20.42	0.67	13.41	0.44	33.83’	1.11
Anuradhapura	25.30	0.83	3.96	0.13	29.26	0.96
Polonnaruwa	27.74	0.91	17.68	0.58	45.42	1.49
Badulla	50.90	1.67	35.66	1.17	86.56	2.84
Moneragala	34.14	1.12	35.66	1.17	86.56	2.81
Ratnapura	127.10	4.17	127.41	4.18	254.51	8.35
Kegalle	106.98	3.51	143.87	4.72	250.85	8.23

~~Note~~: Surface Water Potential is expressed in terms of water depth distributed over the land surface.

Source: Final Report of The Land Commission of 1985: **Sessional** Paper III of 1990.