SHARED CONTROL OF NATURAL RESOURCES (SCOR)

INTEGRATED WATER MANAGEMENT IN A WATERSHED CONTEXT

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SCOR seeks to increase the users' share of control of natural resources in selected watersheds through partnerships between the state and users that contribute to greater production while conserving the natural resources base. SCOR will promote integrated planning for the use of land and water resources in two pilot watersheds with spread effects to other areas. The SCOR project is a collaborative effort of the Government of Sri Lanka, the United States Agency for International Development (USAID) and the IIMI.

INTEGRATED WATER MANAGEMENT IN A WATERSHED CONTEXT[1]

Nihal Fernando[2]

1. INTRODUCTION

1.1 Integrated water management

Shared Control of Natural Resources (SCOR) means the Management of land and water resources within a watershed in resource productive, economically profitable and environmentally sustainable manner, with enhanced control of the resources by its users through effective and sustainable partnership arrangements between the users and the state. In this context, integrated water management within a watershed unit becomes a complex, yet an attainable task.

A few decades ago, the focus of water management was on 'on-farm water management', to improve water use efficiency and water productivity by adopting various agronomic and operational interventions at on-farm level. Application of water, land and water management within the farm, and removal of drainage water were the main areas of attention of this mode. But as our understanding about on-farm water management grew, the focus of attention too expanded to managing water within an entire irrigation system, covering not only on-farm water management, but also acquisition, storage, conveyance, distribution, application of water and removal of excess water. In this mode, main system operation and management, rotational delivery of water, pre-planned irrigation water distribution and delivery schedules, development and application of computer soft-ware models for main system operation were the key areas of attention. However, as our understanding on water management further grew, the overall framework of water management too expanded to encompass not only on-farm water management and main system management, but also to integrate water management with other complementary agronomic inputs such as seeds, farm power, fertilizers and agro-chemicals, institutional arrangements for credit and marketing management and farmers organizations. However, the scope of irrigation management mode too was limited to physical and socio-economic boundaries of a single irrigation project and not beyond it.

At present, our focus is on 'integrated water management'. Thus, the term 'integrated water management' becomes a special notion. The 'integrated water management' not only

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encompasses on-farm water management, main system water management and irrigation management, but also extends its scope of water management beyond geographical and socio-economic boundaries of a single irrigation project to cover all of the above water management ingredients within a larger geographical and socio-economic context. i.e., a single watershed.

Our broad research agenda on integrated water management derives from the 'watershed' approach of water management. Thus, the term 'management' implies not only the acquisition, storage, conveyance, distribution and application of water, and reuse and removal of drainage water for irrigated crop production, but also conservation of water in both rainfed and irrigated agriculture within a watershed. **In essence, integrated water management means both conservation (protection) and utilization (production) of water not only in irrigated command areas but also in rainfed highlands ensuring a package of different notions of 'integration' as briefly discussed below.**

2. INTEGRATION OF LAND AND WATER

2.1 Huruluwewa watershed

Figure 1 indicates the Huruluwewa Watershed. It is a narrow elongated watershed bounded by Ritigala Hill range to the East. Conventionally, it is the upper part of 'Yan Oya' Watershed. The land area enclosed within the two boundaries of Figure 1 does not follow strictly the watershed definition originally defined for SCOR purposes[3]. But yet, this land unit is designated as 'Huruluwewa Watershed' for special reasons.

The term 'integration' is broadly used to mean a package of notions. In the dry zone of Sri Lanka, where water is the most limited resource in quantity, and land the limiting resource in quality, 'integration' means, in the first instance, conservation (protection) and utilization (production) of water in a manner conducive to improving, if not sustaining, the quality and productivity of the land resource with the conservation and utilization of limited available water, while generating high and sustainable incomes (profits) to the users. Thus, in a very broad sense, integrated water management means a mutually complementary management mode for land and water resources in a watershed unit.

Reforestation of denuded lands, stabilization of chena and homesteads through measures such as alley cropping, contour bunding, green manuring, SALT technique and mulching are some key interventions required to conserve and integrate land and water resources within a watershed. A separate research program on the conservation aspects of integrated water

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[3] The term 'watershed' was originally defined as a closed land area unit comprising of four major components namely catchment, reservoir, command and drainage area. The 'Huruluwewa watershed' is an open land unit as shown in the Figure which includes Huruluwewa Feeder canal too.

management too is conducted in the watershed. This paper, therefore, does not provide more details about the impact of those interventions on integrated water management. Nevertheless, it focuses on the utilization and production aspects of integrated water management.

3. INTEGRATION OF UPSTREAM AND DOWNSTREAM

The term 'integration' also means establishing appropriate hydrological, organizational and socio-economic linkages between the upstream and downstream areas of a watershed to strike a proper balance between sustainability, productivity, profitability and equity of land and water resources use. This definition of integrated water management is applicable to a single irrigation tank, a cascade of tanks, a river basin or any other hydrologically inter-related geographic unit. There exists a greater need and a potential to implement integrated water management in Huruluwewa watershed under the notion of upstream and downstream integration.

4. INTEGRATION OF DIFFERENT SOURCES OF WATER

Water resource exists as three different kinds in four different sources in the Huruluwewa watershed. The **different kinds of water** are rainfall, surface water and ground water. These three kinds exists in four **different sources** in the watershed as: yala and maha seasonal rainfall; surface water in Yan oya and in other streams, drainage channels, and specially, Huruluwewa Feeder Canal commencing from the Bowatenna Reservoir of Mahaweli Complex; Huruluwewa Reservoir, which is one of the major tanks in the North Central Province of the dry zone and the only major tank in the watershed; about 200 minor tanks; and ground water extracted from large diameter, open dug-wells or agro-wells.

The integrated water management in Huruluwewa watershed, therefore, focuses on the integration of those different sources through operational manipulation for improving equity, productivity and efficiency of the land and water resources use in the entire watershed. The above tasks cannot be achieved overnight. It is a long-term process which should be backed and supported by a long-term action research programme focusing on the following key sub-tasks.

i. Assessment of the quantity, spatial and temporal availability and variability of the three kinds, i.e., rainfall, surface water and ground water.

ii. Identification and quantification of hydrological linkages that exist between the rainfall, surface water and ground water and hydrological balance between the sources, i.e., Feeder Canal, Huruluwewa tank, Minor tanks and agro-wells.

    Some examples for hydrological linkages between the three resource kinds are: the establishment of watershed rainfall-run-off relationships and models; drainage return flows in tank cascades ground water recharge relations by rainfall and irrigation canals; aquifer hydro-geological properties etc.

Some examples for hydrological balance between the sources are: water allocation and use in Feeder canal - 3 minor tanks - Huruluwewa tank; between Huruluwewa and minor tanks; between irrigation canals and agro-wells etc.

iii. Development and pilot testing of appropriate techniques for conjunctive use of rainfall, surface water and ground water, based on the knowledge and understanding generated through i and ii above, for manipulating the operation of Feeder Canal, Huruluwewa tank, minor tanks and agro-wells.

Some examples are: combined operation of the feeder canal, 3 tanks and Huruluwewa tank system; seasonal operation of Huruluwewa tank and minor tanks in the command; conjunctive operation of Huruluwewa irrigation system and agro-wells; guidelines for agro-well development, and water pumping; cropping patterns; seasonal planning techniques and water balancing models; water scheduling; rules and guidelines for adjusting irrigation system operation to take into account the effective rainfall etc.

iv. Development and establishment of organizational arrangements and institutional environment to pilot test the techniques and implement those in actual practice.

Some examples are: user groups; user organizations, state-user working arrangements and committees; water allocation policies; operational guidelines etc.

The paper addresses the tasks i, ii and iii based on the limited research information so far collected during a period less than a year to highlight the integrated water management concept in Huruluwewa watershed.

5. RESOURCE ASSESSMENT

5.1 Rainfall

Rainfall is the main source of water in the watershed. But its variability in space and time makes integrated water management a necessary task.

Rainfall shows a diverse variability over space both at macro and micro-level, although its temporal variability is uniform over space. Figure 2, which illustrates the macro-variation of 75 % probability rainfall for maha season at 13 locations of the dry zone, and Figure 3, the micro-variation of monthly rainfall measured daily at four locations within the Huruluwewa watershed, illustrates this fact. At macro-level there is a difference of 240 mm rainfall between the highest and the lowest 75 % probability rainfall, which is approximately 25 % of the modal value (558 mm) for that agro-ecological region. At micro-level too there are significant daily variations.

In order to identify the hydrological linkages between the different spatial unit of the watershed and to develop techniques for conjunctive use of water, it is essential to understand and quantify the rainfall that can be anticipated at a given location and at any give time, with a reasonable degree of accuracy. While, accepting the fact that micro-level rainfall variability in the dry zone is well understood, there exists a greater need to expand our present understanding on the micro-level rainfall variability. It is the micro-level variability that has to be well understood for seasonal planning, irrigation scheduling, and adjusting scientifically, the irrigation water releases from a tank to make the best use of effective rainfall.

5.2 Ground water

It has been generally believed that the dry zone, with the exception of Jafna peninsula and Vanathavillu area, do not offer a great potential for deep ground water extraction for irrigation on large scale. However, ground water extraction from the shallow weathered rock overburden, that exists upto a depth about 10 m in the Huruluwewa watershed and elsewhere, is possible.

However, our understanding on the spatial and temporal variability of the ground water reservoir, the hydrological linkages between rainfall and groundwater, and safer limits for tapping ground water for agricultural production is limited. Scientifically verified criteria and standards are not available at all, for the utilization of the ground water in the best productive, profitable and environmentally sustainable manner. Also, techniques for manipulating the operation of irrigation canals for utilizing the ground water in the best possible manner are yet to be developed.

A detailed field research programme is underway in Huruluwewa watershed to fill the above knowledge gaps. Daily water levels, irrigation practices, pumping regimes and agronomic practices of about 30 sample wells are monitored for this purpose. Figure 4 shows the frequency distribution of depths of agro-wells and the frequency distribution of minimum observed water levels in the agro-wells during the peak dry month of the year (August) over the past few years, observed from 754 wells in the entire watershed (100 % sample). The data used for this analysis were collected by farmers representatives of the Huruluwewa scheme and other selected local level farmers at very low cost through a participatory survey. The data collectors were given a half-a- day training on the data collection method and formats at SCOR field office prior to the survey.

The data shows that the maximum, average and minimum depth of an agro-well is 9, 5.4 and 2.4 m (30, 17.6 and 8 ft) respectively. The maximum, average and minimum well diameters are 5.5, 4, 3.0 m (18, 13, 10 ft) respectively. The average height of the water column remained in a typical agro-well during the driest day of the year was 1.46 m (4.8 ft), the maximum and minimum being 4.5 and 0 m (15 and 0 ft) respectively. These basic information will be very much useful in the assessment of the total available ground water, total utilizable ground water and the safe abstraction rates.

In the upland areas of tank catchments and highlands above the commands of irrigation canals of Huruluwewa tanks and most of the minor tanks of the watershed, ground water from agro-wells is used in conjunction with rainfall to produce vegetables and non-rice crops (NRCs). The most commonly grown crops are vegetables, chilli and big-onions. In the case of Chilli, farmers start cultivation in agro-well commands with the onset of maha rainfall season and make use of maha rainfall in the months of October, November and December during which the agro-wells too are replenished by the maha rainfall. Some farmers wait until December and begin a late crop ('meda crop') with the available soil moisture. Thus, the agro-well is used as a supplementary source of water to irrigate crops during January, February and March and perhaps in April for meda crops. A second season is cultivated in April and the agro-wells are used to irrigate NRCs from April to July and August in conjunction with the lesser rainfall in April and May.

In the lowland paddy areas of tank commands, only a few farmers use ground water during maha season to raise NRCs. But they use the agro-wells to raise NRCs during yala 1994 season . In Huruluwewa scheme, where water was issued from the tank for a yala cultivation, it was observed that farmers having agro-wells in their allotments cultivated paddy in the poorly drained portions using canal water and chilli in the well drained portions using both canal water and well water. Thus, the conjunctive use of rainfall, surface water and ground water is already practised by the farmers in Huruluwewa watershed although, it is not practised in a planned manner.

Figure 5 shows the typical ground water level fluctuation, recharge and discharge pattern, conjunctive use, and pumping regimes of three wells representing: an agro-well in the highland used only for domestic use during the period of observation (a); and an agro-well in the highland (b) and a well in the Huruluwewa command area (c) used for agricultural use. Well (a) shows the natural discharge pattern of the well with intermittent, but very insignificant well recharge by rainfall; Well (b) shows the recharge by rainfall as well as abrupt well discharge and well recovery due to pumping; and Well (c) illustrates typically the conjunctive use of canal water, ground water and rainfall as well as well discharge and recovery. These results shows the potential for systematic irrigation scheduling under agro-wells and systematic planning of pumping regimes taking into account the rainfall and canal water. These research will finally culminate at that task.

5.4 Feeder Canal

The Feeder Canal was commissioned in 1976 to convey supplementary water releases to Huruluwewa tank. It has been designed to convey 8.5 cubic meter per second (m^3 /s, 300 cusecs) from canal bifurcation 5 km downstream from its origination, at Lenadora. At the bifurcation point, which is called 'Kandalama Bifurcation', the feeder canal bifurcates to two feeder channels, each conveying 4.25 m^3 /s (150 cusecs) to Kandalama and Huruluwewa tanks.

The man-made part of the feeder channel ends at 'Sigirimulla', after traversing 40 km (25.4 miles) from Kanadalama bifurcation point to its point of confluence to Sigiriya Oya, a natural stream and which is also the uppermost reach of Yanoya. Beyond that the water route traverses through three minor village tanks: Pahala Talkote Wewa, Hiriwadunna Wewa and Habarana wewa in sequence, and then through Sigiriya Oya, which is also the middle reach of Yanoya, and finally through Yanoya to Huruluwewa tank. The total water conveyance route is about 96 km (60 miles) long from Lenadora to destination at Huruluwewa tank, as shown in the schematic diagram in Figure 6.

5.4 Huruluwewa tank

Huruluwewa tank has been a "water stressed" system since its commissioning in 1954. The tank, after restoration and enlargement did fill completely and spill only five times for the last fourty years. Incidentally, the tank had been spilling from December 1993 to end January 1994, after 10 years from its previous spilling in 1983, almost at the same time the SCOR interventions in the Watershed commenced.

Figure 7 shows the **cropping intensity** of Huruluwewa tank for the last 10 years from 1984 - 1994. It is seen that out of the 10 maha seasons, cultivation has taken place only in 7 maha sesaons [Cultivation Intensity (CCI) = 0.7], the average Cropping Intensity (CI) of the 7 maha seasons cultivated being 0.95. Out of those 7 'successful' maha seasons, 3 seasons were 'meda' seasons, meaning that the cultivation begun in January due to inadequate tank storage to begin the season typically in October or November. Out of the 10 yala seasons, no cultivation has taken place at all in 7 yala seasons [CCI = 0.3], and the average CI for 3 yala seasons cultivated being 0.24. Thus, the weighted CI [WCI = CI x CCI] for maha and yala are 0.66 and 0.072 respectively. These values imply that although Huruluwewa tank is supposed to have been augmented from the Mahaweli complex by the feeder canal, its 'water stress' has not reduced, nevertheless, has further worsened.

However, in yala 1994 season the full extent was cultivated as the tank spilled even in January 1994, during the tail end of maha 93/94 season. The daily discharges released from the tank were monitored during the season and total seasonal releases are as follows.

	Cropped extent Ha (ac)	Total issues MCM (Acft)	Tank duty m (ft)
Left Bank	1530 (3886)	19.08 (15460)	1.21 (3.98)
Right Bank	2460 (6248)	37.00 (29970)	1.50 (4.79)
Total	3990 (10152)	56.08 (45430)	1.40 (4.47)

The rainfall measured at four rain-gauge stations within Huruluwewa watershed indicates that on average total rainfalls of 44 mm (1.73") and 35 mm (1.37 ") have been received in April and May. This corresponds to a total seasonal effective rainfall[4] of 0.76 MCM (623 acft). Thus if we adjust the tank duty to take into account the effective rainfall the overall tank duty is 1.42 m (4.53). These values show a very efficient use of water during the season, when one considers the conveyance losses of the system too.

6. HYDROLOGICAL LINKAGES BETWEEN FEEDER CANAL AND HURULUWEWA SCHEME

6.1 Tapping of water allocated to Huruluwewa tank

It was earlier mentioned in this paper that the term 'Huruluwewa Watershed' is used for special reasons. The Feeder Canal was constructed in 1976 intercepting the catchment areas of several minor tanks in the area. The interception cut-off the natural water flow from the catchment and deprived the water rights of the people who were already settled in the area. After the canal was cut and commissioned, some of the previous users of water resorted to tapping of water from the feeder canal by illegitimate ways and means. In addition to these villagers, there were new comers too who opened up arable lands en-route of the feeder canal for cultivation after the canal was commissioned. A few of them are non-resident and operate larger holdings of land.

A participatory resource use survey and mapping covering present land use and tenure in the feeder canal area was conducted by SCOR. According to this survey, there are approximately about 1220 ha (3100 acres) under the Feeder Canal comprising of the lands irrigated by the Feeder Canal, rainfed chena and homesteads. The preliminary analysis of the survey data shows that out of the total extent of 1220 ha, about 785 ha (2000 acres) are irrigated lands under the Feeder Canal. These lands are cultivated along the entire stretch of the Feeder Canal using the water conveyed to Huruluwewa. Up to 1992, the illegitimate tapping had been done by syphoning of water using 50 mm (2 inch) alkathene pipes. In 1992, 36 parallel field canals, taking off from the Feeder canal from different locations along the canal were constructed by the Irrigation Department to discourage syphoning and regulate the tapping of water. At present, some of the field canals are only partially completed and some canal appear to have design and construction defects. Thus the parallel canals are not fully utilized and water use by syphoning continues even more extensively together with the water use by the parallel canals as well. The ultimate result of this state of affairs is a very low cropping intensity and cultivation intensity at Huruluwewa tank. although it is supposed to be augmented by the Feeder Canal. The wasteful use of water as well as excessive conveyance losses along the feeder canal are responsible for the situation.

[4] Effective rainfall (ER) for yala season is calculated from ER = 0.67 (R -1) where R is the rainfall in inches, and ER = 0 when R $<$ 1.0.

6.2 Conveyance losses

A conveyance loss study of the Huruluwewa feeder canal was conducted in 1989 as a part of the hydrological study consultancy under the Major Irrigation Rehabilitation Project (MIRP). The conveyance losses in different reaches of the Feeder canal from the Kandalama bifurcation (0 km) to Sigiriya Oya (25.4 km), were measured under this study. The results of the study is shown in Figure 8.

It is seen from the data used for the development of the cumulative conveyance loss curve given in Figure 8 that, when the discharge delivered to Huruluwewa feeder canal was 3.1 m^3 /s (110 cusecs), the discharge received at the tail end was only 1.66 m^3 /s (59 cusecs), after correcting for water tapped in between. This corresponds to an overall average conveyance (seepage) loss of 44 percent for the first 25.4 km of the Feeder Canal. This loss, expressed in terms of cubic meters per second per kilometre per cubic meters second of canal discharge (cms/km/cms), corresponds to 0.0175 cms/km/cms. It is also seen that the conveyance loss, expressed in terms of cubic meters per second per one square meter of wetted area of the canal bed and side slopes (cms/m^2 of wetted area), is 0.71×10^{-6}.

Irrigation use: The effects of syphoning of water on the planned diversions to Huruluwewa tank are indicated in Table 1 and Figure 9.

It is seen that, on average, only 45 percent of the total volume of water released have reached Huruluwewa tank in Maha and 22 percent in Yala season, based on the past 10 years official records. Although, these percentages represent the overall average of a successive 10 year period, illegitimate tapping of water has alarmingly increased over the period. The average percentage water receipts in yala and maha seasons have progressively reduced over this period and, therefore, the ten year average values do not represent the present status with regard to water use by feeder canal farmers.

At present, the percentage quantum of water received by Huruluwewa tank is very much low. For example, during Yala 1994, although 23.6 MCM (19120 acft) of water was released from Kanadalama bifurcation to Huruluwewa, only a very negligible percentage, was received by Huruluwewa. Even the three tanks below the feeder canal has not received much water during the season. If we allow for a total conveyance loss of 44 %, although, a fairly higher percentage of the seepage water reappears and is reused in the adjoining lands along the feeder canal, the feeder canal farmers have used the balance quantity of water, i.e., 13.2 MCM (10706 acft).

As the entire 2000 acres were irrigated in this yala, this corresponds to an irrigation duty of about 1.67 m (5.35 ft). The effective rainfall during the season corresponds to 0.73 " or 0.15 MCM (122 Acft). If we assume that 5 % of the conveyance losses reappeared in the lands downstream and were non-intentionally used to meet crop water requirements by the Feeder Canal farmers (a low estimate in the absence of conclusive data), the contribution corresponds is about 0.52 MCM (420 acft). Thus, the total estimated water duty of the Feeder Canal during yala 94 was 1.76 m (5.78 ft). As the main crop cultivated was B-onions, and not rice, this value indicates a very low water use efficiency due to wasteful use of water, in comparison to the higher seasonal water use efficiency at Huruluwewa. Although, the quantified data are not presented, it is of the general opinion that the land use efficiency and land productivity in the Feeder canal area are much higher than that of the Huruluwewa tank.

This conflicting situation of water allocation and water use and water productivity is the key concern of SCOR to consider 'Feeder Canal Area' as a part of the 'Huruluwewa Watershed'. The farmers of Feeder Canal area, both legitimate as well as illegitimate, who gain considerable benefit from the feeder canal water resources by way of stabilized irrigated agriculture due to a reliable water supply and high intensity of irrigation, nevertheless deprive of the share of water of Huruluwewa farmers. Similarly, the farmers under the three village tanks located in between the feeder canal and Huruluwewa tank too enjoys somewhat an assured supply of water particularly during maha season.

Thus, the integrated water management in Huruluwewa primarily focuses on these hydrological linkages between three groups of farming communities needing an upstream-downstream integration of the water users. SCOR believes that upstream-downstream integration of the three groups of water users is the long term solution for a rational water sharing policy among them and for a productive land and water use and management setting for the watershed.

In forging its efforts for an organizational integration between the upstream and downstream, it builds on the already existing water user groups in the three different locations and linkages among them. The Irrigation Management Division (IMD) of the Ministry of Lands, Irrigation and Mahaweli Development (MLI & MD) had already established water user organizations and a project committee at Huruluwewa tank. Recently, before the SCOR interventions commenced, it had established contact with the Feeder Canal farmers who were mindful of the consequences of their water use on Huruluwewa farmers. Ten user organizations had been promoted in the Feeder Canal area and they and the Huruluwewa Farmers Organizations had been made to work together to work out reasonable solutions to these problems. This has been a remarkable achievement by the IMD.

SCOR builds on the present upstream-downstream understanding to forge strong linkages among them to promote resource efficient, integrated land and water management of the watershed.

7. TECHNIQUES FOR CONJUNCTIVE USE OF THE THREE SOURCES

7.1 Seasonal planning models

Planning a cropping season is one of the key concerns in integrated water management. Seasonal planning, as its name implies, involves a number of ingredients namely: crop planning; water budgeting; planing of inputs (seeds, credit, extension and fertilizer); irrigation scheduling; O & M planning; market planning; M & E planning; and organizational arrangements for the implementation of the seasonal plan.

Seasonal planning was introduced to Huruluwewa tank scheme during yala 94 season. Although, it was not possible to cover all of the above ingredients of the seasonal planning during yala 94, it was possible to influence the decision of the farmers to agree for a more profitable cropping pattern in yala 94 season, i.e. soyabean on well drained soils and rice on the poorly drained soils.

As a pre-requirement for seasonal planning it was required to assess the percentage distribution of poorly drained and well drained soils of Huruluwewa tank command. This was done by superimposing an already existed soil map of the area on the scheme blocking out diagram, in collaboration with the Irrigation Engineer Huruluwewa. It was found that well drained and poorly drained soils are in the proportion of 70 % and 30 % respectively.

Taking the soils distribution, previous experience of the farmers in growing soya beans, and the relative profitability of alternative crops into consideration, a water balancing model was developed following the conceptual water balance model shown in Figure 10. The model was run for a number of different cropping patterns as shown in the sample result sheet in Table 2.

It is seen that only a few cropping patterns would lead to a reasonably acceptable, anticipated positive tank storage at the end of September 1994. The criteria for selecting a cropping pattern was done initially on the basis of the projected tank storages at the end of forthcoming months upto end of September 1994. When the projected storage becomes either negative or below or closer to a pre-detremined minimum tank storage that corresponded to minimum operational tank water level, it meant that the selected cropping pattern would be a failure and the crops would die due to water stress. Thus, corresponding cropping patterns were rejected. Out of the remaining cropping patterns, the most acceptable cropping pattern was chosen on the basis of farmers' preference, previous experience of farmers; low irrigation requirements, and more importantly; the anticipated profits to farmers. It was found that, as shown in Table 2, the most profitable cropping alternative was found to be 71 % soya bean with 29 % rice in the entire command, as shown against trial number 7. This was the cropping pattern agreed by the Huruluwewa farmers at the cultivation meeting for yala 1994.

8. CONCLUSIONS

a) Integrated water management in a watershed context is the logical evolution and expansion of on-farm water management concept over time through a time-tested process. The water management concept which began at on-farm level first, later expanded to system water management, and then to irrigation management, and finally culminated at integrated water management at watershed level.

b) Integrated water management in watershed context means a number of notions. With respect to Huruluwewa watershed, it means, integration of: land and water resources;

upstream and downstream; different kinds of water namely rainfall, surface water and groundwater spatially and temporally; different sources of water, namely Huruluwewa Feeder canal, Huruluwewa tank, Minor tanks and agro-wells by manipulating their operations; and more importantly the integration of people using water from different sources in different modes by developing and establishing appropriate organizational linkages and arrangements.

c) Integrated water management in a watershed context is a complex, but an attainable task. It has to be achieved through a gradual process involving:

  i. Assessment of the quantity, spatial and temporal availability and variability of the three kinds, i.e., rainfall, surface water and ground water.

  ii. Identification and quantification of hydrological linkages that exist between the rainfall, surface water and ground water and hydrological balance between the sources, i.e., Feeder Canal, Huruluwewa tank, Minor tanks and agro-wells.

  iii. Development and pilot testing of appropriate techniques for conjunctive use of rainfall, surface water and ground water, based on the knowledge and understanding generated through i and ii above, for manipulating the operation of Feeder Canal, Huruluwewa tank, minor tanks and agro-wells.

  iv. Development and establishment of organizational arrangements and institutional environment to pilot test the techniques and implement those in actual practice.

d) The integrated water management in Huruluwewa watershed is an action research programme implemented within the above conceptual framework. It focuses on the above four sub-tasks in its implementation. This paper presented some of the selected action research activities implemented in Huruluwewa watershed and presented some preliminary results based on the data collected during a period less than a year.

REFERENCES

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2 Irrigation Department, Tank Operation Records, 1984 -1992.

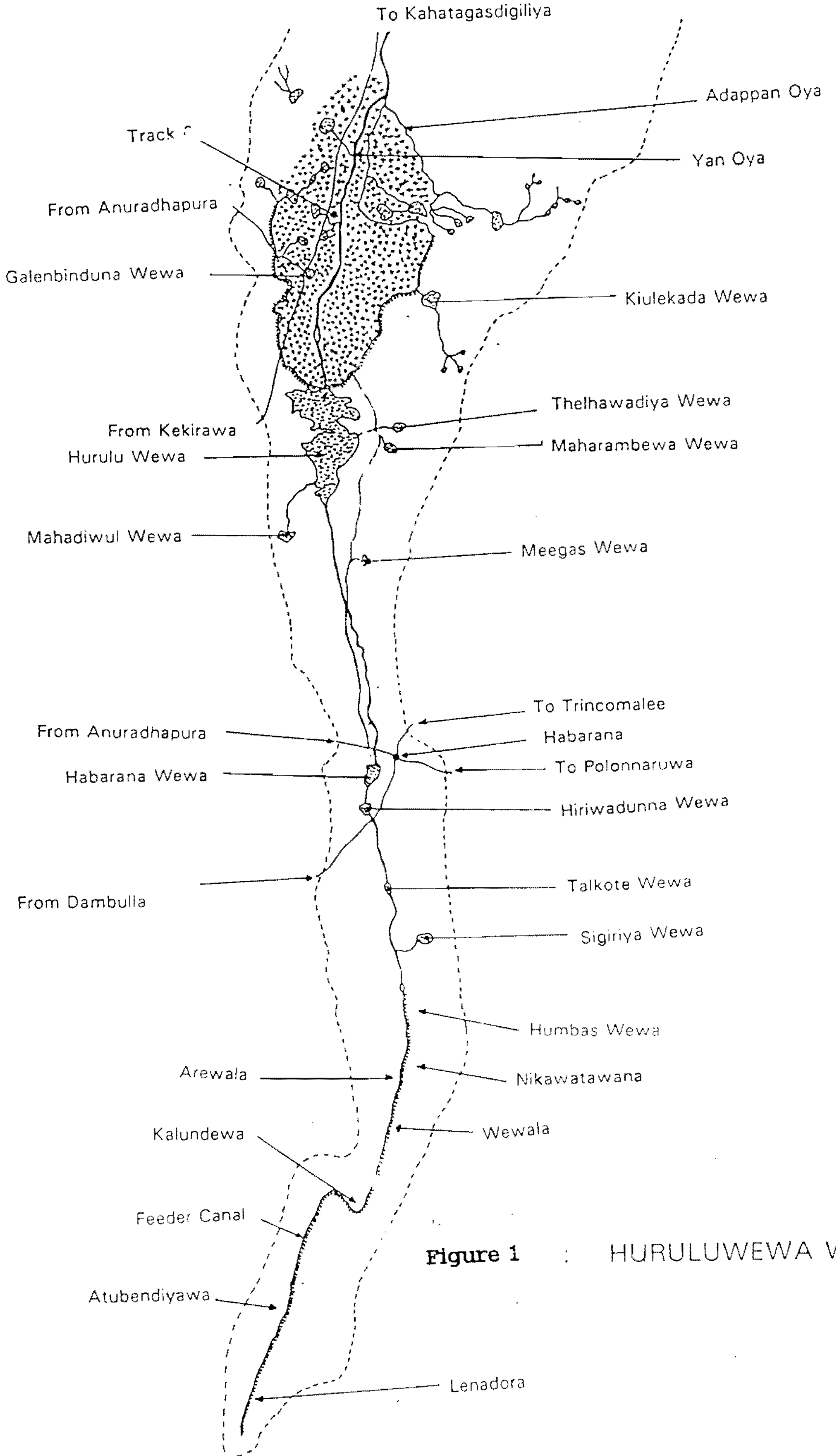


Figure 1 : HURULUWEWA WATERSHED

Macro Variation of Rainfall
Dry Zone

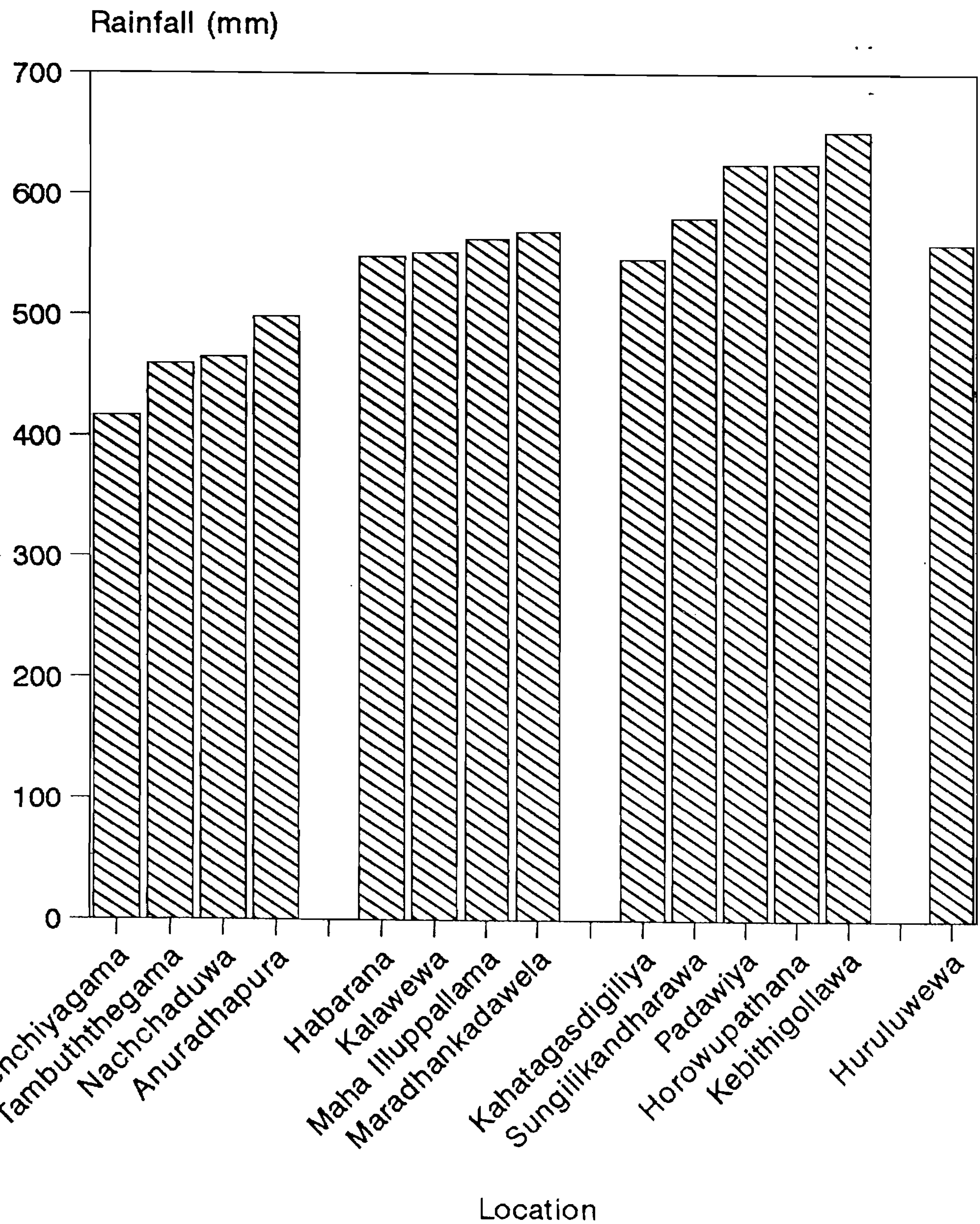


Figure :- 2

Micro level Variation of Rainfall
Huruluwewa Watershed . September 1994

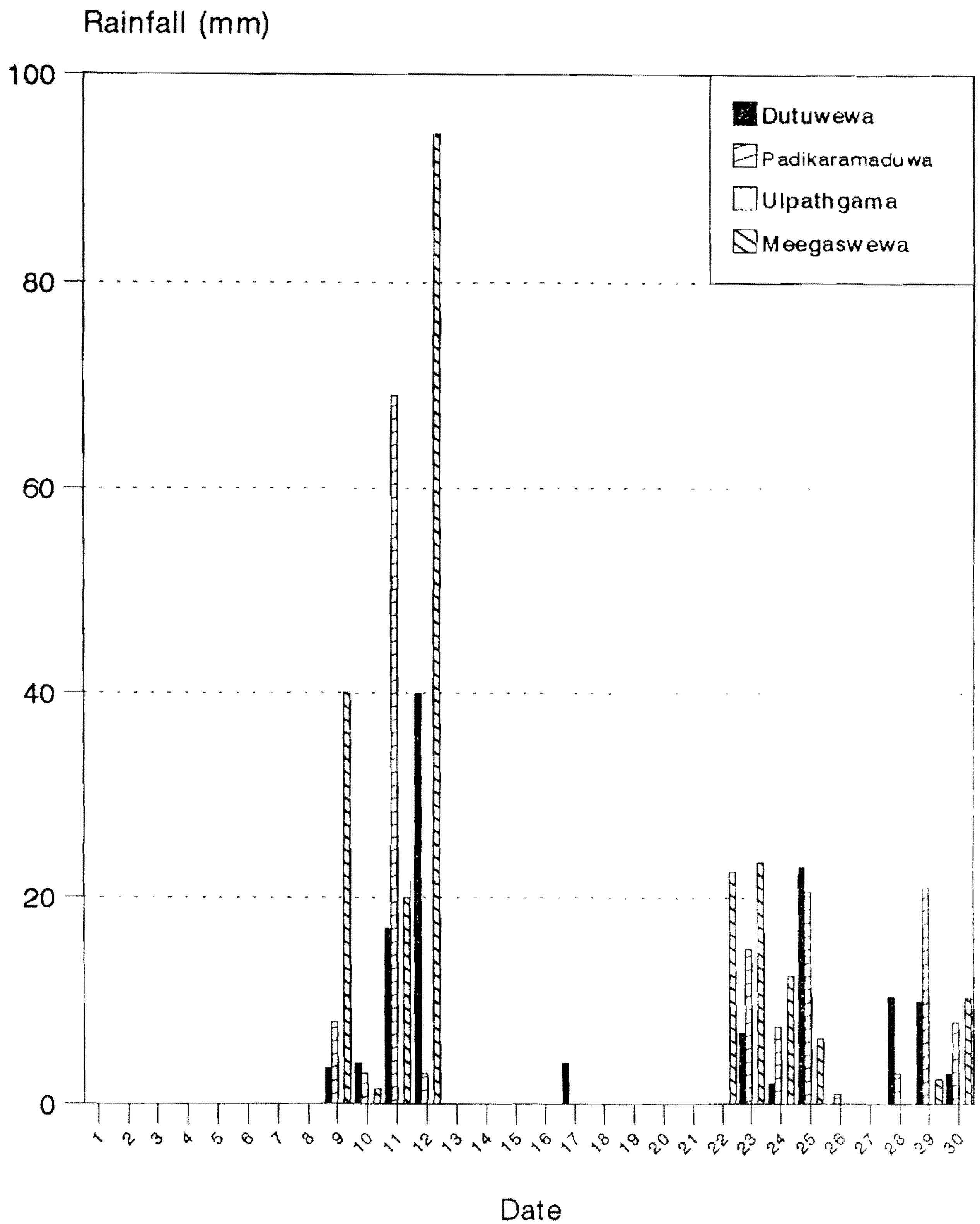
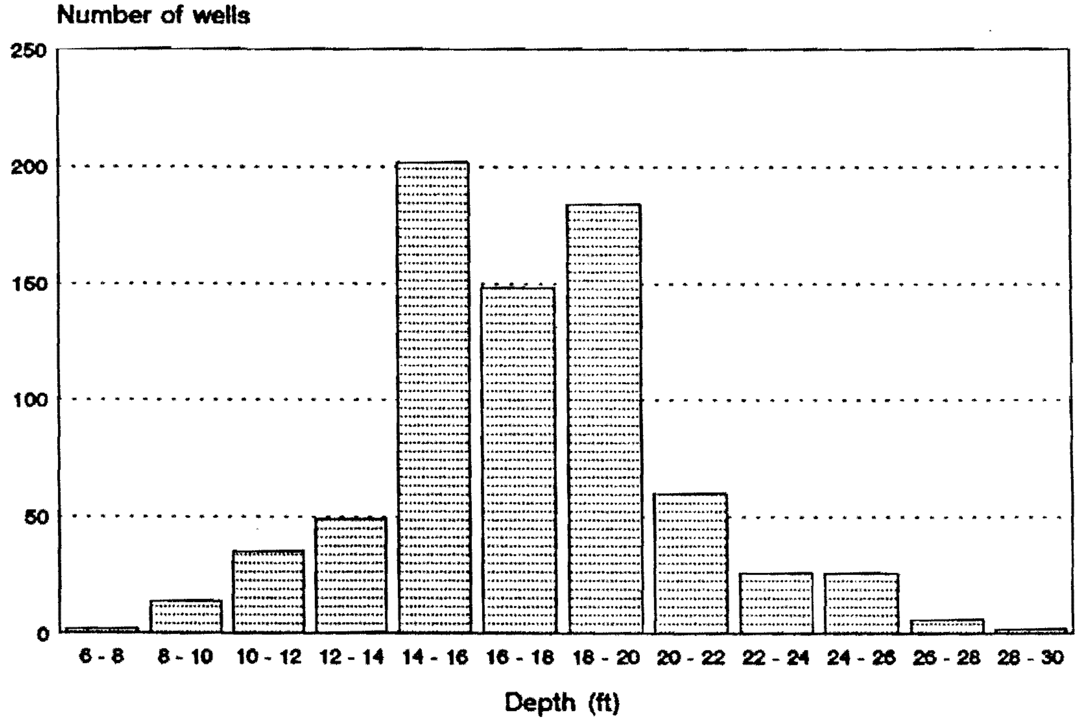


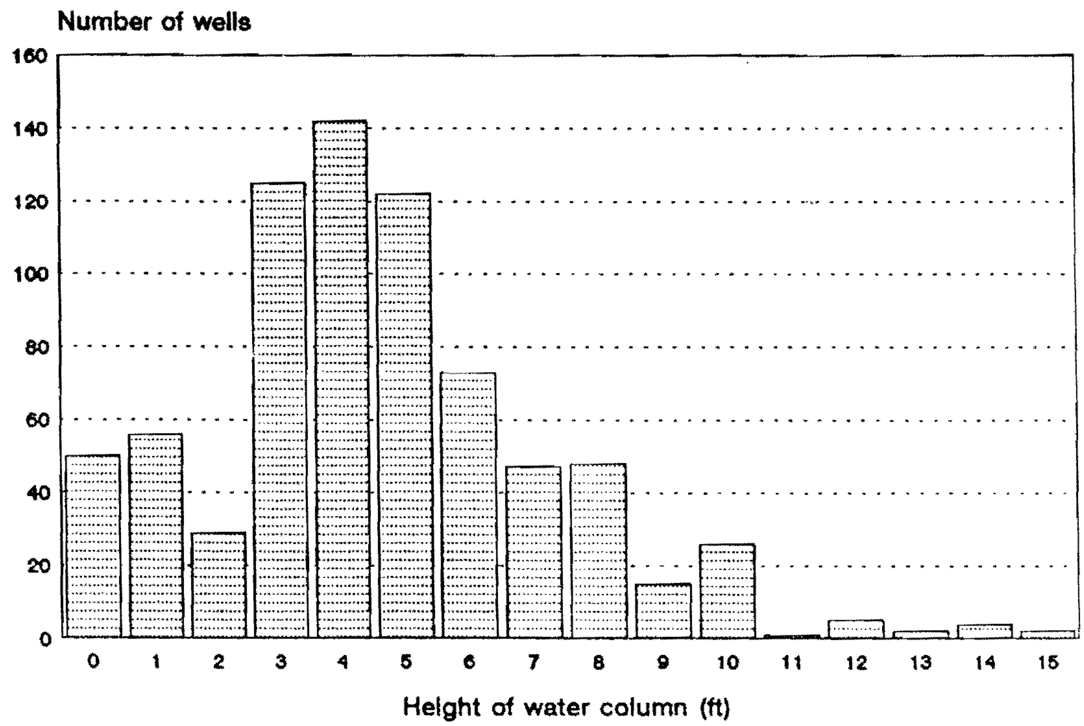
Figure 3

Depth Distribution of Agro-wells
Huruluwewa watershed



Data obtained from a participatory survey
Average Depth - 17.5 ft
Maximum - 15 ft, Minimum - 8 ft.

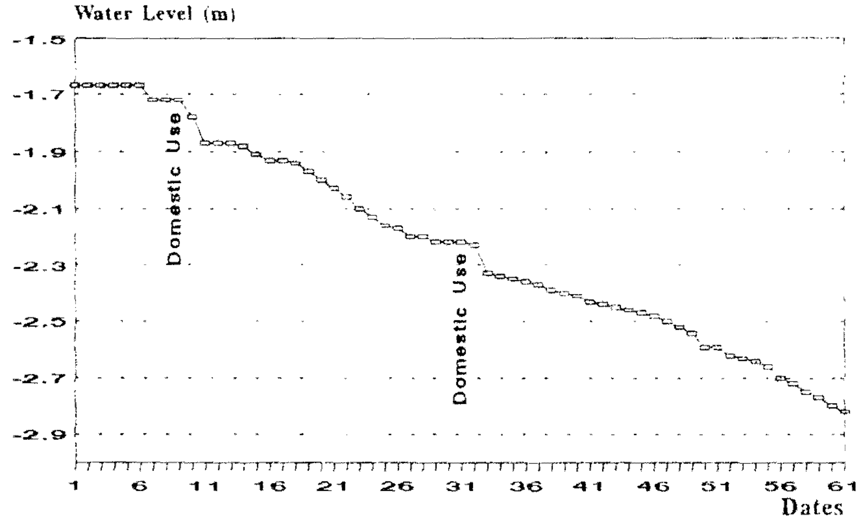
Minimum observed water levels
Agro-wells in Huruluwewa watershed



Data obtained from a participatory survey
Average - 4.9 ft, Maximum - 15 ft, Minimum - 0.
Figure 4

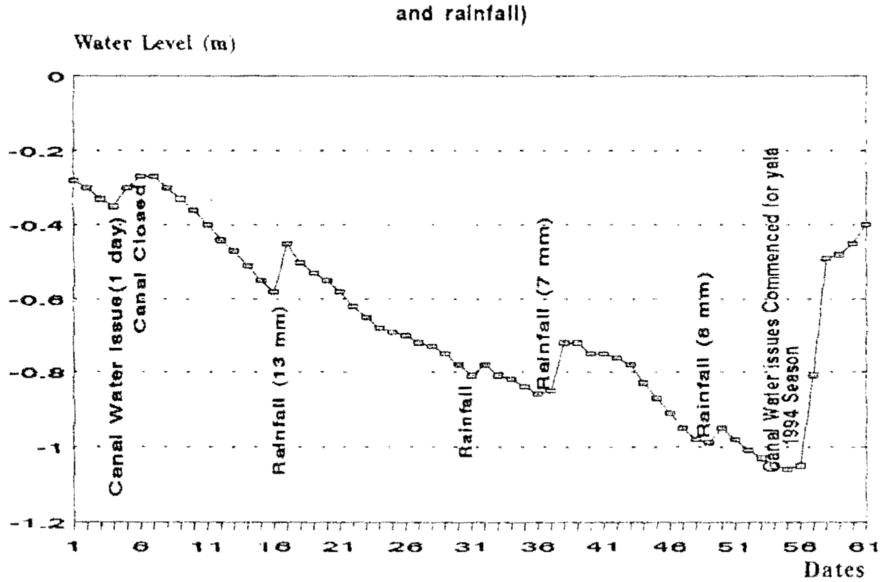
WATER LEVEL FLUCTUATION IN A TYPICAL DOMESTIC-WELL IN HURULUWEWA HIGHLAND AREA(March-April)

(Well No. 17B- Mainly Used for Domestic Purpose)



WATER LEVEL FLUCTUATION IN A TYPICAL AGRO-WELL IN HURULUWEWA COMMAND AREA(March-April)

(Well No. 02-Mainly Used for Irrigation; Recharged by canal and rainfall)



WATER LEVEL FLUCTUATION IN A TYPICAL AGRO-WELL IN HURULUWEWA HIGHLAND AREA(March-April)

(Well No. 16A-Mainly Used for Irrigation; Recharged by rainfall only)

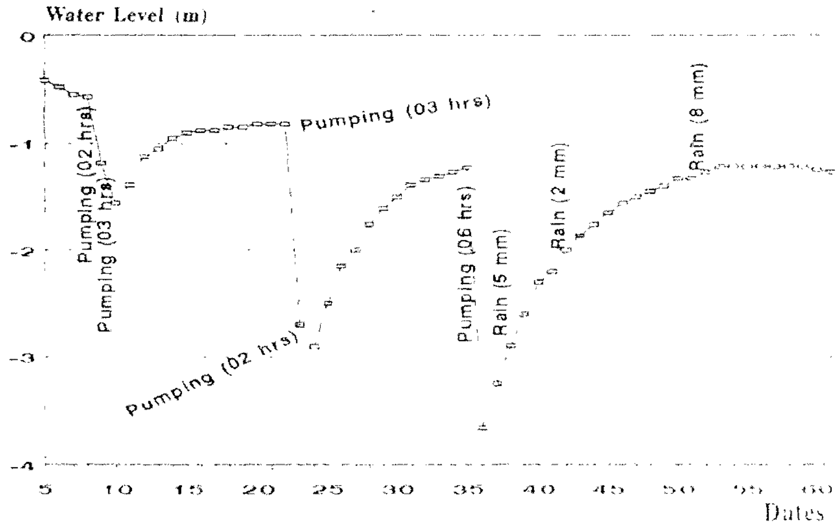
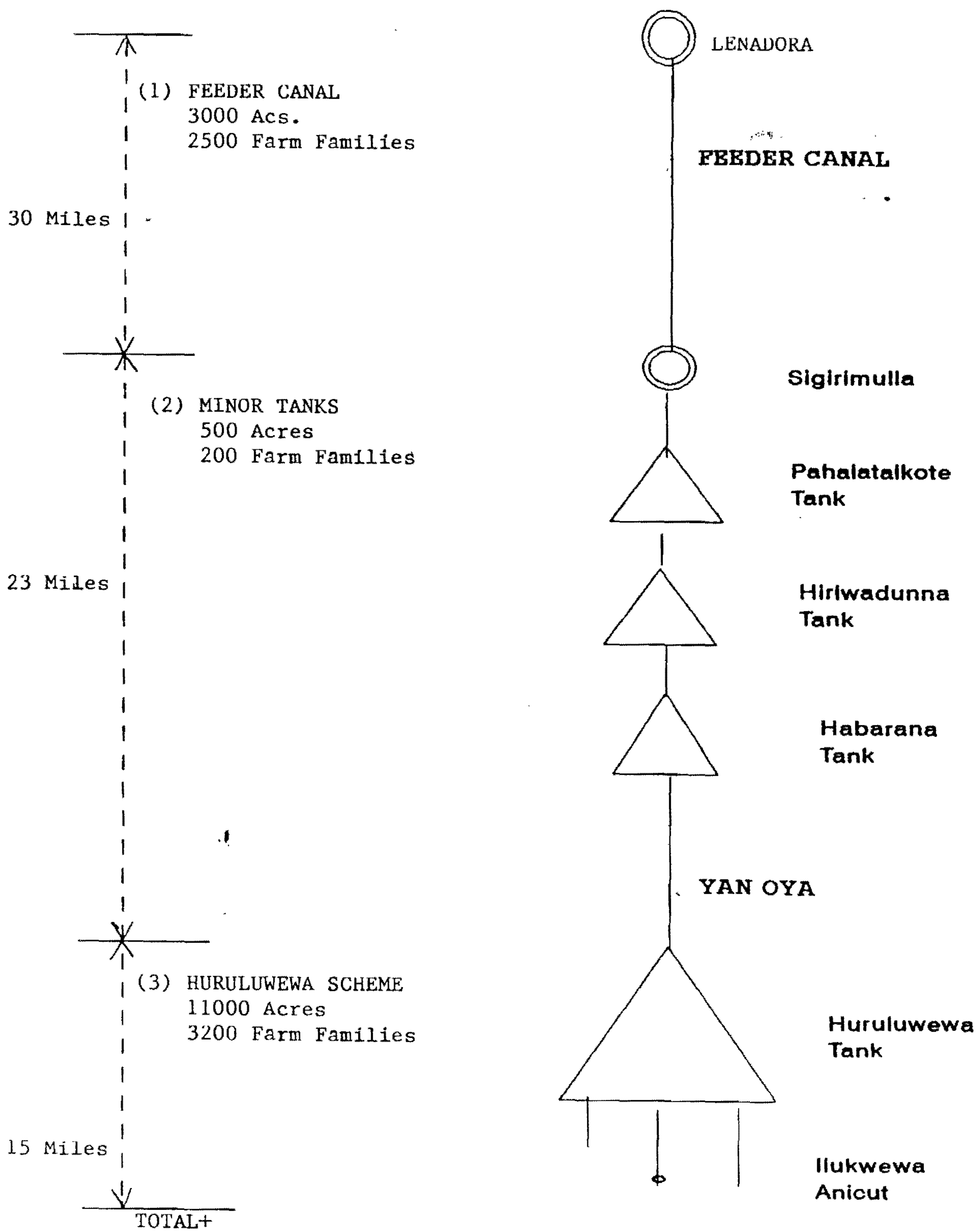


Figure 5:



TOTAL+
Extent 14,500 Acres,Farm Families 5,900
Farm

Figure 6. Schematic Diagram of Huruluwewa Watershed.

Cultivation Statistics of Huruluwewa Tank

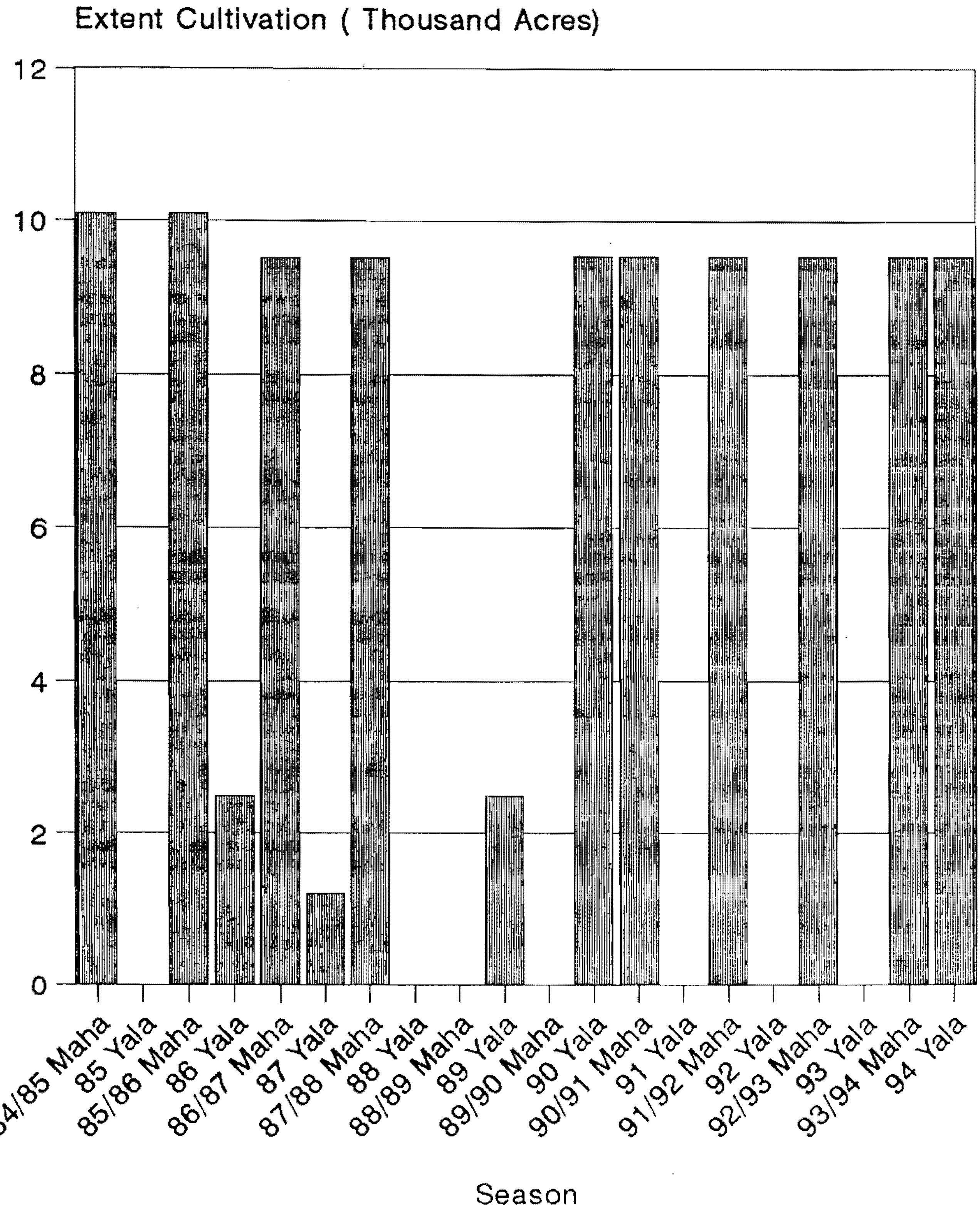
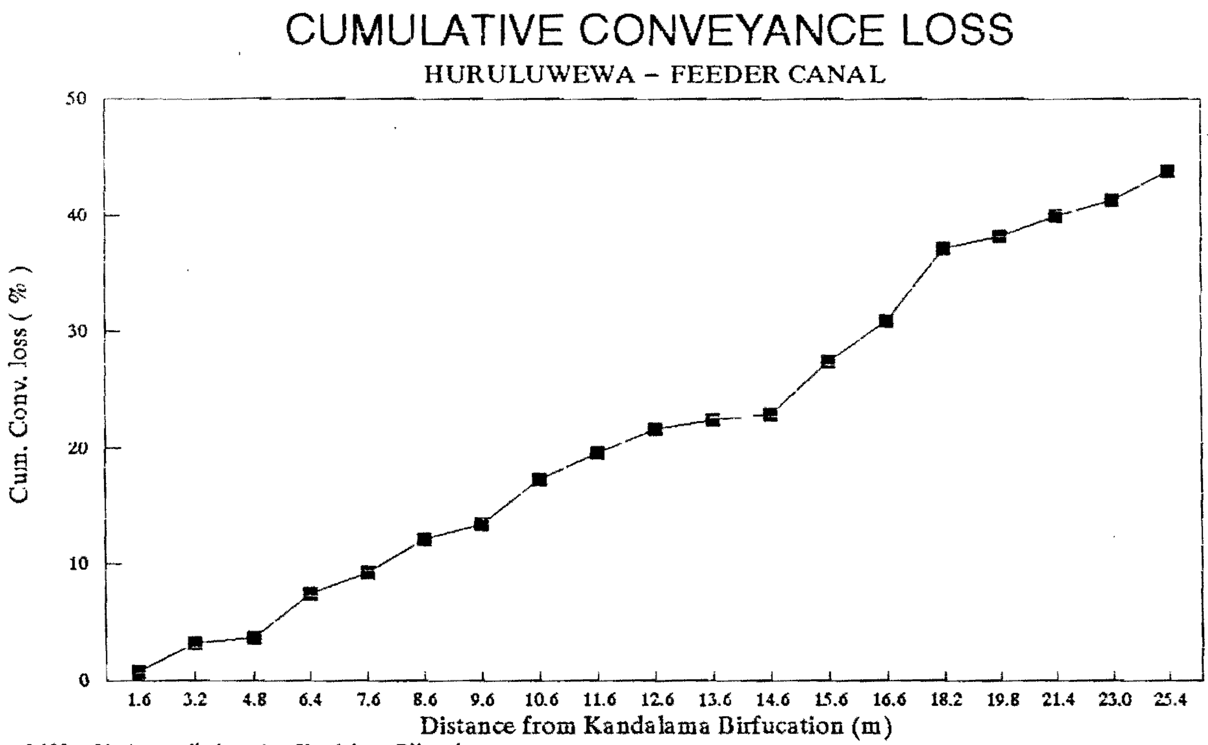


Figure :- 7
Courtesy :- I.E. (Huruluwewa)

Figure 8:



3.105 m3/s (mean discharge) at Kandalama Bifucation

Distance (m)	1.6	3.2	4.8	6.4	7.6	8.6	9.6	10.6	11.6	12.6	13.6
Cumulative Conveyance loss (%)	0.8052	3.27	3.74	7.48	9.29	12.12	13.47	17.35	19.57	21.58	22.42

Distance (m)	14.6	15.6	16.6	18.2	19.8	21.4	23.0	25.4
Cumulative Conveyance loss (%)	22.90	27.37	30.94	37.10	38.13	39.89	41.28	43.72

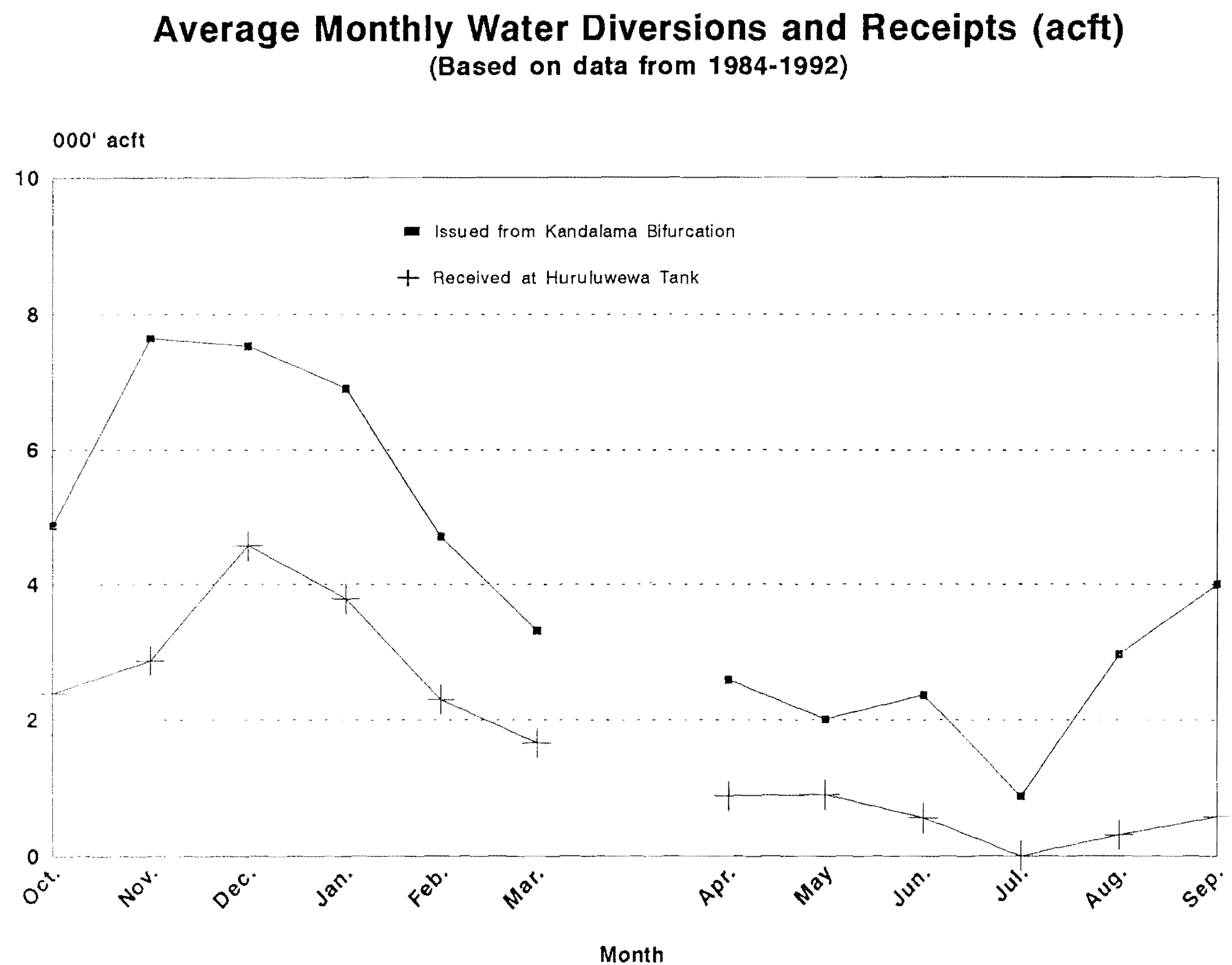
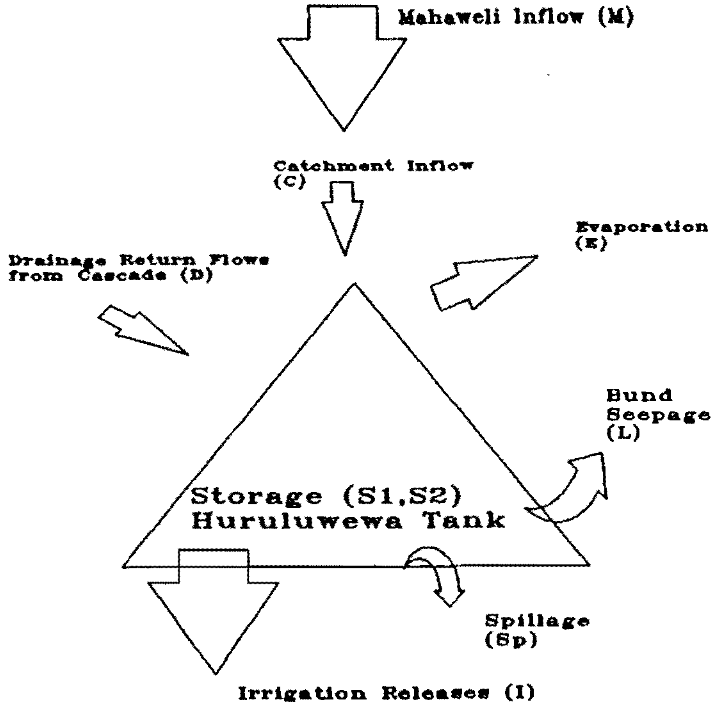

Average Monthly Water Diversions and Receipts (acft)
(Based on data from 1984-1992)
000' acft
10
8
6
4
2
0
Issued from Kandalama Bifurcation
Received at Huruluwewa Tank
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Month

Figure 9:



$$M + C + D + S1 = S2 + E + L + Sp + I$$

M - Measured C - Estimated
D - Estimated E - Measured / Estimated
L - Estimated I - Estimated
S1 - Measured S2 - Measured
Sp - Measured

Annual Water Balance (1993 - 1994)

Huruluwewa Tank

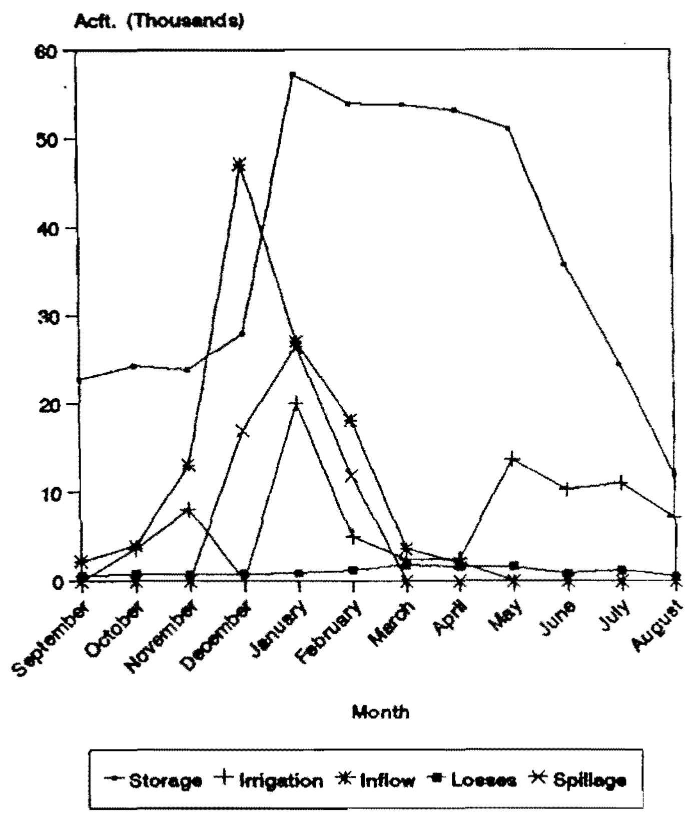


Figure :- 10 Water Balance Conceptual Model - Huruluwewa Tank

Table :– 1

Effect of Syphoning of Water in Huruluwewa Feeder Can
(Based on data from 1984 to 1992)

Month	Issued From Kandalama Bifercation (Acft)	Received By Hurluwewa Tank (Acft)
October	4869	2392
November	7650	2872
December	7533	4570
January	6912	3780
February	4707	2300
March	3312	1656
Maha Total	34983	17570
April	2592	879
May	2007	896
June	2367	559
July	873	0
August	2968	312
September	3888	577
Yala Total	14695	3223

TABLE: 2 (Contd...) **SEASONAL PLANNING: OPERATIONAL STUDY FOR HURULUWEWA TANK–YALA 1994**

% CULTIVATING LAND AREA OF CULTIVIABLE TOTAL LAND AREA	STORAGE END OF APRIL	STORAGE END OF MAY	STORAGE END OF JUN	STORAGE END OF JULY	STORAGE END OF AUG	STORAGE END OF SEP	profit (Rs) Including imputed cost
24 PADDY-HIGH53%+SOYA 18%	40223.46	23637.12	10874.18	-1611.53	-1541.23	-1474.29	12939678.72
25 PADDY-HIGH35.5%+SOYA 35.5%	42855.06	29141.01	16002.62	4186.50	4003.86	3829.96	12112551.72
26 PADDY-HIGH18%+SOYA 53%	45486.66	29380.57	16171.22	5956.05	5696.22	5448.81	11285424.72
27 PADDY-HIGH14%+SOYA 57%	46013.00	29954.94	16769.52	6560.49	6274.28	6001.76	11096367.12
28 PADDY-HIGH35.5%+SOYA 18%+GREEN 18%	42872.04	29211.66	16753.22	7237.94	6922.18	6621.52	11016978.48
29 PADDY-HIGH 14%+SOYA 28%+GREEN 28%	46040.17	30067.96	17970.43	11442.74	10943.54	10468.21	9130867.20
30 SOYA 71%	48118.26	32252.28	19162.57	8994.53	8602.14	8228.51	14696691.59
31 SOYA 35.5%+GREEN 35.5%	48152.21	32393.54	20663.67	15097.30	14438.67	13811.53	8129025.72
32 SOYA 53%+GREEN 18%	48135.25	32322.94	19913.16	12045.96	11520.45	11020.06	9265608.72
33 SOYA 57%+GREEN 14%	48131.85	32308.81	20142.87	11798.98	11284.24	10794.11	9525399.12
34 PADDY-HIGH 53%+CHILLIES 18%	40880.11	24495.78	12446.39	-1301.62	-4534.64	-4665.29	
35 PADDY-HIGH 35.5%+CHILLIES 35.5%	44168.37	30858.35	17890.09	3604.09	-3312.75	-4184.08	
36 PADDY-HIGH 18%+CHILLIES 53%	47456.62	31956.57	19002.39	5078.29	-5372.68	-6842.14	
37 PADDY-HIGH 14%+CHILLIES 57%	48114.29	32702.67	19789.43	5628.60	-5540.34	-7140.03	
38 PADDY-HIGH 35.5%+CHILLIES 18%+SOYA 18%	43511.72	29999.69	17574.88	4496.48	1010.51	639.01	14314650.48
39 PADDY-HIGH 18%+CHILLIES 35.5%+SOYA 18%	46799.97	31097.91	18058.68	5369.52	-1624.35	-2569.00	
40 PADDY-HIGH 18%+CHILLIES 18%+SOYA 35.5%	46143.31	30239.23	17743.43	6261.84	2698.86	2254.03	13487523.48
41 CHILLIES 53%+SOYA 18%	50000.00	34743.60	21913.22	8043.88	-2536.46	-4129.11	
42 CHILLIES 35.5%+SOYA 35.5%	49431.57	33969.62	21050.03	8412.12	1285.52	214.47	14632767.72
43 CHILLIES 18%+SOYA 53%	49780.52	35255.73	23512.46	13407.25	10954.96	10433.41	12563280.72
44 CHILLIES 18%+SOYA 53%+GREEN 18%	48791.89	33181.60	21485.37	12355.88	8527.04	7829.06	14039632.08
45 CHILLIES 35.5%+SOYA 18%+GREEN 18%	49448.56	34040.28	21800.62	11463.55	4203.83	3006.03	14972536.08
46 CHILLIES 71%	47720.37	32782.98	20175.70	5188.12	-8737.45	-13286.76	

TABLE: 2

SEASONAL PLANNING: OPERATION STUDY FOR HURULUWEWA TANK–YALA 1994

% CULTIVATING LAND AREA OF CULTIVIABLE TOTAL LAND AREA	STORAGE END OF APRIL	STORAGE END OF MAY	STORAGE END OF JUN	STORAGE END OF JULY	STORAGE END OF AUG	STORAGE END OF SEP	Profit (Rs.) including imputed cost
1 PADDY–LOW 29%+PADDY–HIGH53%+SOYA 18%	36614.87	20172.34	2691.46	–9438.11	–9026.37	–8634.31	
2 PADDY–LOW 29%+PADDY–HIGH35.5%+SOYA 35.5%	39246.47	25676.22	12707.49	1034.79	989.64	946.66	18458823.85
3 PADDY–LOW 29%+PADDY–HIGH18%+SOYA 53%	41878.08	25915.79	12876.08	2803.50	2681.19	2564.74	17631696.85
4 PADDY–LOW 29%+PADDY–HIGH14%+SOYA 57%	42404.41	26490.15	13474.39	3408.77	3260.06	3118.46	17442639.25
5 PADDY–LOW 29%+PADDY–HIGH35.5%+SOYA 18%+GREEN 18%	39263.46	25746.88	13458.08	4086.22	3907.96	3738.22	17363250.61
6 PADDY–LOW 29%+PADDY–HIGH 14%+SOYA 28%+GREEN 28%	42431.58	26603.17	14675.30	8291.02	7929.32	7584.91	15477139.33
7 PADDY–LOW 29%+SOYA 71%	44509.67	28787.50	15867.43	5842.81	5587.92	5345.21	21042963.72
8 PADDY–LOW 29%+SOYA 35.5%+GREEN 35.5%	44543.62	28928.75	17368.53	11945.58	11424.45	10928.23	14475297.85
9 PADDY–LOW 29%+SOYA 53%+GREEN 18%	44526.66	28858.15	16618.03	8894.24	8506.23	8136.76	15611880.85
10 PADDY–LOW 29%+SOYA 57%+GREEN 14%	44523.26	28844.03	16847.74	8647.26	8270.02	7910.81	15871671.25
11 PADDY–LOW 29%+PADDY–HIGH 53%+CHILLIES 18%	37271.52	21030.99	4263.67	–9128.19	–12019.78	–11825.31	
12 PADDY–LOW 29%+PADDY–HIGH 35.5%+CHILLIES 35.5%	40559.78	27393.56	14594.95	452.38	–6326.98	–7067.38	
13 PADDY–LOW 29%+PADDY–HIGH 18%+CHILLIES 53%	43848.04	28491.78	15707.25	1926.57	–8386.90	–9725.44	
14 PADDY–LOW 29%+PADDY–HIGH 14%+CHILLIES 57%	44505.70	29237.88	16494.30	2476.88	–8554.56	–10023.33	
15 PADDY–LOW 29%+PADDY–HIGH 35.5%+CHILLIES 18%+SOYA 18%	39903.13	26534.91	14279.75	1344.76	–2003.72	–2244.29	
16 PADDY–LOW 29%+PADDY–HIGH 18%+CHILLIES 35.5%+SOYA 18%	43191.39	27633.13	14763.55	2217.80	–4638.57	–5452.30	
17 PADDY–LOW 29%+PADDY–HIGH 18%+CHILLIES 18%+SOYA 35.5%	42534.73	26774.44	14448.29	3110.13	–315.36	–629.27	
18 PADDY–LOW 29%+CHILLIES 53%+SOYA 18%	46479.64	31363.52	18698.65	4969.23	–5476.98	–6941.91	
19 PADDY–LOW 29%+CHILLIES 35.5%+SOYA 35.5%	45822.98	30504.84	17754.90	5260.40	–1728.70	–2668.83	
20 PADDY–LOW 29%+CHILLIES 18%+SOYA 53%	46171.93	31790.94	20217.32	10255.53	7940.74	7550.11	18909552.85
21 PADDY–LOW 29%+CHILLIES 18%+SOYA 53%+GREEN 18%	45183.31	29716.81	18190.24	9204.16	5512.81	4945.76	20385904.21
22 PADDY–LOW 29%+CHILLIES 35.5%+SOYA 18%+GREEN 18%	45839.97	30575.49	18505.49	8311.84	1189.61	122.73	21318808.21
23 PADDY–LOW 29%+CHILLIES 71%	44111.78	29318.19	16880.56	2036.40	–11751.67	–16170.06	