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Diagnostic Analysis of Kaudulla Scheme, Sri Lanka: 1986 Yala Discipline Reports

Water Management Synthesis Project
WMS Report 60

DIAGNOSTIC ANALYSIS OF KAUDULLA SCHEME, SRI LANKA: 1986 YALA DISCIPLINE REPORTS

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Larry J. Nelson
Coordinator of the
Diagnostic Analysis Project

I. INTRODUCTION

In Sri Lanka, the development of new irrigation systems, and the improvement and rehabilitation of old systems, are prime targets of agricultural planning. Large irrigation systems associated with resettlement projects have been constructed to extend and increase the agricultural productivity of Sri Lanka's Dry Zone. However, the operation of many of the schemes has been less than optimal, and the anticipated results have not always been realized. Consequently, new institutional policies and programs emphasize alternative strategies for improving the productivity and performance of irrigation systems.

One such plan by the Government of Sri Lanka involved creating the Irrigation Management Division (IMD) within the Ministry of Lands and Land Development (MLLD). In addition to other responsibilities, the IMD is expected to establish a system for monitoring and evaluating the performance of irrigation systems. These monitoring and evaluation methods will be based on diagnostic analysis procedures developed by the Water Management Synthesis Project at Colorado State University (Water Management Synthesis Project, 1983).

Diagnostic analysis techniques were introduced to Sri Lanka through three in-country, professional development workshops conducted in 1982, 1983, and 1984. Fundamental to diagnostic analysis is the philosophy that irrigation problems are not confined to one single discipline such as engineering or agronomy, but rather, that they involve a wide range of issues that include social and economic aspects as well. As part of the training workshops, interdisciplinary teams of participants investigated an existing irrigation system, identified constraints, and discussed various approaches to solving irrigation-related problems.

Reports from these workshops were written on the Rajangana Irrigation Scheme in 1982 (Alwis et al., 1983b) and System H of the Mahaweli in 1982 and 1983 (Alwis et al., 1983a; Jayewardene and Kilkelly, 1983). Although these reports were limited in scope due to the nature of the training workshop, they provided useful information and valuable insights into the operation of the irrigation systems studied. As a result, the MLLD recognized the benefits of this investigative approach and desired to employ these concepts as a practical, preliminary approach to identifying constraints in irrigation systems.

An opportunity to use diagnostic analysis as a tool for gathering baseline information arose with the creation of the Irrigation Systems Management Project (ISM). The ISM Project, funded by the United States Agency for International Development, proposes to rehabilitate and improve four irrigation systems in the Polonnaruwa District of Sri Lanka: Parakrama Samudra, Giritale, Minneriya, and Kaudulla.

This baseline data collection effort was called the Diagnostic Analysis Project. Diagnostic analysis was considered the most appropriate investigatory method to use; although physical improvements to the existing irrigation systems were important considerations, various socio-economic efforts were also included in the ISM Project design (Skogerboe et al., 1984).

In effect, the Diagnostic Analysis Project was designed to provide complete understanding of these irrigation systems in order to assist the ISM Project in determining pragmatic, cost-effective means for improving the operation of these systems. The collection of a reliable, extensive volume of data would provide valuable information concerning system operation. In addition, this information could later be compared to information gathered after the irrigation systems are rehabilitated and improved.

The overall objectives of the Diagnostic Analysis Project were:

1. To strengthen IMD's institutional capacity and the abilities of its associated personnel to use diagnostic analysis techniques to study existing irrigation schemes.

2. To assist in establishing a set of evaluation procedures and methodologies for continual monitoring of irrigation system operations.

3. To provide detailed background information on the selected irrigation systems for future use in rehabilitation and improvement projects.

The following report details the diagnostic analysis conducted during 1986 *yala* on Kaudulla Scheme. The report is divided by discipline into sections on main system engineering, on-farm engineering, agronomy, economics, sociology, and women in development. An interdisciplinary discussion of the results can be found in WMS Report 61, **Diagnostic Analysis of Four Irrigation Schemes in Polonnaruwa District, Sri Lanka: Interdisciplinary Report.**

II. KAUDULLA SCHEME

The Kaudulla Scheme was originally constructed by King Mahasen in the 3rd century A.D., with later improvements by King Parakrama Bahu in the 12th century A.D. During this time, extensive areas of land were irrigated and cultivated. After falling into disrepair, the scheme was abandoned with the collapse of the ancient civilization.

In the late 1950s, the original reservoir was restored in two phases. Stage I began in 1958, while Stage II was not initiated until 1971, with completion of both phases by 1976. A more detailed description of the Kaudulla Tank and canal system is provided in the main system engineering section, with additional information concerning irrigation practices in the on-farm engineering section.

After the expansion and rehabilitation of the ancient tank was completed, approximately 4,000 allottees from the Wet Zone resettled there. On Stage I, allottees were given 3 ac of irrigated lowland for paddy cultivation and 2 ac of highlands for a homestead. On Stage II, 2-ac lots were given for irrigated cultivation and 1 ac for a homestead. Although this system was originally designed to serve approximately 10,500 ac, it is now estimated to serve 13,300 ac.

The Kaudulla Scheme is located in the North Central Province of Sri Lanka (Figure 1) and is characterized as gently undulating Dry Zone with elevations ranging from 45 to 456 ft above sea level. The average annual rainfall is 58 inches, which falls predominantly during maha (wet season; October to March).

The majority of cultivated area in the Polonnaruwa District is now under a number of major irrigation schemes. Prior to this arrangement, purana (old, traditional) villages cultivated paddy and other crops using local "cascade" tank systems for water storage and irrigation. There is no rainfed paddy cultivation in yala (dry season; April to September), but a limited extent of rainfed paddy cultivation may occur during maha. Paddy is the primary crop cultivated, but small areas of subsidiary crops such as chili, tobacco, maize, soybean, cowpea, groundnut, sesame, onions, and other vegetables are grown in yala where water for field irrigation is limited.

The Polonnaruwa District has been referred to as the "rice bowl" of Sri Lanka as it has some of the highest yields of paddy throughout the island. Average yala paddy yields from 1969 to 1985 were reported to range from 69 to 102 bu/ac in maha and from 46 to 86 bu/ac in yala (Polonnaruwa Kachcheri records). The use of short-season, high yielding varieties is fairly widespread. A more detailed presentation of agricultural practices in Kaudulla is contained in the agronomy section.

The highland allotments generally are not well utilized due to inadequate water. Even so, most families maintain perennial trees such

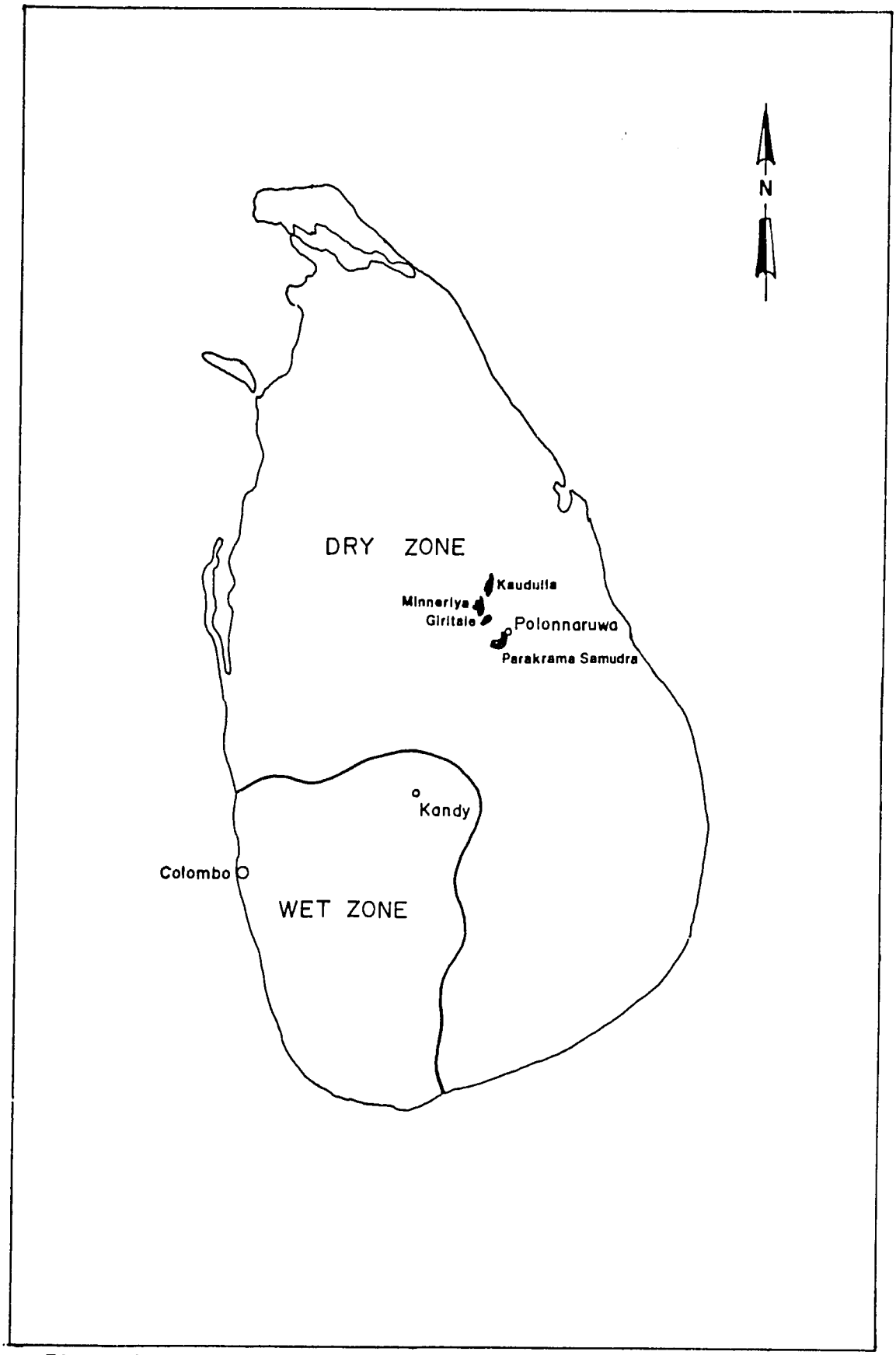

Figure 1. Map of Sri Lanka showing location of Kaudulla Tank.

as coconut, banana, or jackfruit. During maha, small gardens containing a diverse mixture of vegetables are planted, but yields remain low.

In the four decades since the major tanks were restored, inmigration created by the resettlement programs and natural increases have swelled population figures for the area considerably. The 1971 population total for the Polonnaruwa District was recorded at 163,700. In 1981 the total reported was 262,800. Figures from the Department of Census and Statistics, Central Bank of Ceylon, showed a total 1984 population figure for the Polonnaruwa District of over 284,000 people. This represents approximately 1.8 percent of the total national population with a density rateof 83 persons/km^2.

The most recent growth rate figure, reported for 1983-84, was 2.2 percent, well above the national average of 1.2 percent. This population growth factor, in combination with unemployment and underemployment, has led to a concentration of low income groups in the rural agricultural sector. The difficulty of absorbing a growing labor force when few alternatives to agriculture are available is considered a serious problem in the district.

Data from the 1981 census reported a district population composed of Sinhalese (90.9 percent), Tamil (2.2 percent), Indian Tamil (0.1 percent), Moor (6.5 percent), Burgher (less than 0.1 percent), Malay (0.1 percent), and other (0.2 percent). A more detailed description of the socio-economic background of Kaudulla can be found in the economics and sociology sections.

Figure 2 shows a map of the area studied in Kaudulla Scheme in 1986 yala.

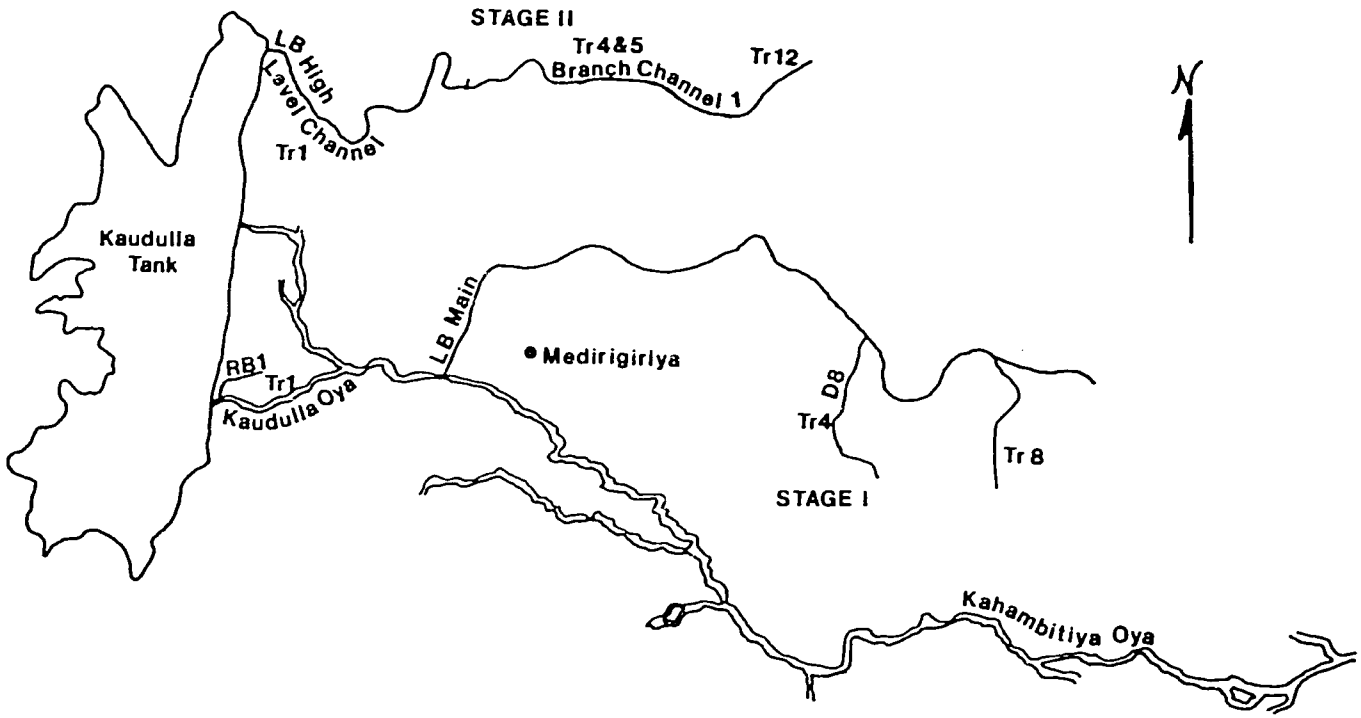

Figure 2. Kaudulla Tank, Polonnaruwa District, Sri Lanka.

III. DISCIPLINE REPORTS

A. MAIN SYSTEM ENGINEERING

1. INTRODUCTION

The objective of the main system engineering discipline was to study the delivery of water from the Kaudulla Tank to the on-farm system. Both the physical delivery of water and the management process used to achieve the delivery of water must be evaluated in order to establish the main system's performance.

With regard to the main system engineering, the performance of the main system should be evaluated according to its ability to meet the objectives of providing enough water control to ensure that farmers receive water at times and in the amounts needed. The performance of the main system can be evaluated based upon four parameters: adequacy, dependability, equity, and elevation.

Adequacy is the ratio of the amount of water supplied to the amount of water required. Ratios greater than 1 indicate oversupply, and ratios less than 1 indicate undersupply. Determining the water requirement may be difficult and may require gathering a large amount of data. For this report, adequacy was determined by comparing water supply to rice evapotranspiration in Kaudulla. (For some systems the amount of water required can be substituted with the amount the system was designed to supply. This adequacy ratio is appropriate for systems designed to provide supplemental or deficit irrigation.)

Dependability can be determined by evaluating the variability of adequacy over time. For this study, the coefficient of variation in the supply over time was used to describe system performance.

Equity, like dependability, can be determined by studying the variability of adequacy. However, with equity we are concerned with the variation of adequacy over the system (spatial variability). To characterize equity, the coefficient of variation in supply over the system was used.

Elevation as a performance parameter does not "fit" the other three parameters, but is nevertheless important. Elevation in this report refers to the system's ability to deliver water at a water surface elevation (head) that is adequate enough to command the fields or farms that are to be irrigated. Unfortunately, data to evaluate this parameter were not available when this report was written.

Quantifying main system performance through diagnostic analysis can provide system managers with data for making appropriate improvements. Describing the main system performance demonstrates the constraints on, and positive aspects of, the system. While the constraints within Kaudulla Scheme may be similar to other systems,

quantifying performance allows one to rank the problems in order of their severity. The priority problems and strengths of a system make that system unique.

Originally, the Kaudulla Tank received water only from its own catchment. Now Kaudulla depends on diversions from the Minneriya Tank for most of its water supplies. The flows from the Kaudulla catchments are now diverted to the Kantalai Tank under normal operating procedures.

The canals of the main system were usually unlined and initially designed with trapezoidal cross sections. At the time of the diagnostic analysis, the D-channels had wide cross sections with many drop structures along the channel length. Originally, the drop structures served as both drop and cross regulating structures. The cross regulation was done with flash-boards installed in slots in the concrete drop structure. The flash boards (stop logs) were not present so the structures no longer cross-regulate.

Discharges from the main and branch channels into D-channels and field channels were controlled by gated pipe outlets. The gates had provisions for locking.

The nomenclature used for the channels and irrigated areas on Kaudulla Scheme follows. The main and branch canals are designated directly as main or branch canals. The distributary channels and field channels are designated with a channel number and a tract number. Tracts are smaller command areas of the larger division of Kaudulla Scheme into Stage I and Stage II. The two "stages" are supplied water from the tank through two separate sluices. Thus, there is a main channel for Stage I and a main channel for Stage II.

Both D-channels and field channels could receive issues from the main or branch canals. If the issue into the channel went directly to fields, then the channel was designated a field channel. If water issues were divided into other channels, then the channel was designated a D-channel.

For the diagnostic analysis, both stages were studied, and findings from both are presented separately in the results of the main system engineering report.

The scheme was designed with main and branch capacities of 40 ac/cfs of commandable area. The D-channels were designed for a capacity of 30-35 ac/cfs of commandable land. Since the system was designed, the irrigated area has increased. The designed irrigable area was 10,400 ac. According to Irrigation Department records, the most current acreage was estimated as 10,700 ac for both stages. There is some doubt about the current acreage figure since it is general knowledge that farmers have significantly increased their irrigated acreages, mainly by encroaching onto reserved areas.

The Kaudulla Scheme operated on a rotation schedule of 1 week. Both Stage I and Stage II received water for 4 days/week and were off

for 3 days. The rotation was implemented directly from the sluices. That is, when the rotation was "on," the entire stage received water supplies.

Paddy was the principal crop, and nearly the only crop, on Kaudulla Scheme. Growing one crop makes it easier for system managers to predict crop water requirements for the system and to make appropriate adjustments to supply rates of water.

2. METHODOLOGY

To thoroughly understand how the system operates and to identify both strengths and constraints, it was decided to collect data on water deliveries to points along the channels in Stage I and Stage II of the Kaudulla Scheme. Measurements were made along the main and branch channels and along some of the D-channels.

Stage I had 25 measurement points. Of these, 6 were not used in the analyses. The main reason for discarding a point (sampling location) was the inability to establish a head-discharge relationship.

In Stage II, 61 sampling locations were chosen. Thirty-six of the 61 sampling locations were used in the analyses. Originally, the main system engineering team planned to study in detail one long D-channel on Stage II. Unfortunately, because of inadequate man power, the time available for data collection was short. Also, a head-discharge relationship was difficult to develop for some of the field-channel issues on the selected tract (D1, tract 4). Therefore, only 3 of the 17 measurement points on this channel were selected for analyses.

The flow was measured by using a staff gauge installed in the channel. The staff gauge reading (in feet) was converted to flow rate after a head-discharge relationship was established. The relationship was calculated using a current meter to determine flow rate during several gauge readings (usually three). The current metering results and gauge readings were fit to a curve to establish the head (gauge reading) - discharge relationship. The major reason for discarding measurement points from the analyses was inability to develop a suitable head-discharge curve. Several conditions contributed to the inability to develop a curve, but the major one was that the channels were wide and small changes in the gauge reading indicated large changes in discharge. Small changes in head with large changes in discharge make the head-discharge curves steep and difficult to interpret.

a. Acreage

The acreage commanded by each measurement point is critical to the analysis of the data. The area of command for each point is used to convert flow rate (cubic feet per second, cusecs) to a supply rate (millimeters per day, mm/day). The supply rate allows for a comparison of the measurement points.

The acreage was difficult to accurately determine. Most of the acreage figures used in this analysis came from Irrigation Department records, although some of the area has been surveyed using aerial photographs. Indications were that the Irrigation Department records under-estimate the actual irrigated area in Kaudulla Scheme.

b. Distance

Distance along a channel from one of the main sluices to the measurement points were also obtained from the Irrigation Department records. These distances are probably accurate. The distance values were used to evaluate variations in supply rate with distance along the channels.

c. Location and Frequency of Readings at Measurement Points

Staff gauges were located along each of the two main canals at all diversion points on the main and branch canals. Staff gauges were also installed in the main and branch canals at a few locations. One D-channel (D1, tract 1) in Stage I and two D-channels (D2, tract 2 and D1, tract 4) in Stage II had staff gauges installed.

The staff gauge readings were taken daily after installation. Readings started on 1 June 1986 (Julian day 152) on some channels and as late as 27 July 1986 (Julian day 208) on others. All data collection on flow rates ended 31 August 1986 (Julian day 243).

d. Recording and Analysis of Data

Data were collected by Irrigtaion Department personnel assigned part-time to the Diagnostic Analysis Project. The data were recorded in field books and then transferred to data sheets for entry in a microcomputer. Most of the data were analyzed on the computer. Calculations performed were simple mathematical and statistical manipulations. For instance, flow rate and acreage were converted to supply rate. The basic equation is:

$$qt = kd\,A$$

$$A/q = t/kd$$

where

q = flow rate
t = time
d = depth of water per unit area
A = area
k = constant for unit conversion

The quantity d/t is the supply rate presented in millimeters/day in this report. The term A/q is referred to as water duty and at times is presented as acres per cusec (i.e., 40 ac/cusec).

The statistical calculations used were the average, standard deviation, and coefficient of variation. Also a regression analysis was performed on some data. However, the coefficient of variation (CV) is the most important measure presented in this report.

To evaluate performance, a standard or reference criteria must be selected to show how much variation can be expected or accepted in an irrigation system. A rule of thumb used by engineers to evaluate, and sometimes design, systems is to allow $\pm$ 10 percent variation from a design value. In a discussion on maintenance of irrigation systems, FAO (1982) states that a 10-20 percent reduction in absolute efficiency with respect to the design is normally acceptable before maintenance is required.

For the purposes of this report, a value for the coefficient of variation of 0.15 or less was considered good. This states that the ratio between the standard deviation of the supply rate and the mean supply rate is 15 percent for the sample. Values greater than 0.15 were judged as indications of areas where improvements were needed.

CV is defined as equal to the standard deviation divided by the average, where both the average and the standard deviation refer to the sample. The coefficient of variation is dimensionless, and since it is a relative measure of variation, CV can be used to compare among systems. In our case, the average was the mean of the supply rate over a time period, or over an area, with standard deviation a measure of the sample's variation from the mean supply rate.

Regression analysis can indicate a relationship between independent and dependent variables. The relationship is determined by selecting a model and then testing the strength of the relationship or model. For this study, the following was selected as the model:

$$y = bx+c$$

The strength of the model is determined by the correlation coefficient, which is computed from the sample data. The correlation coefficient is usually designated as r^2.

To determine the water requirement for the system and for the command area of each measurement point, the following equation was calculated:

$$\text{Requirement} = \text{ET} + \text{losses} - \text{inflow}$$

where

losses = (on-farm losses) + (main system losses)

inflows = rainfall + other inflows to the system

To determine on-farm losses, the on-farm system must be evaluated. The on-farm section of this report presents the calculations for relative water supply and water use efficiency.

For the main system losses, information on conveyance losses in the system's channels was needed. Unfortunately, the main system engineering team did not directly measure conveyance losses. However, some data collected could be used to estimate conveyance losses on the system. Due to time limitations, these calculations were not performed.

When discussing main system losses, some idea of operational losses to be expected is needed. Operational losses include those due to channel filling, and losses due to closing the sluices and the subsequent loss of water in the channel. While these losses could have been estimated, it was decided to evaluate the supply rate data directly, without guessing on the other factors. Therefore, the discussion that follows in the results section of the main system engineering report presents an evaluation of supply rates on the system compared to evapotranspiration for rice.

e. Problems, Limitations and Strengths

To develop a good understanding of the Kaudulla system operation, more physical and management data should have been collected and analyzed. For example, the physical condition of the hydraulic structures within the system needed to be evaluated. Unfortunately, although the study called for structural evaluation, the task was not completed. Also needed was some insight into the management decision-making process; for example, determining what the rationale was for establishing the rotation schedule.

On the positive side, much data was collected, which should provide a good database for system managers to make appropriate improvements. In addition, personnel assigned to the project gained some valuable training and knowledge about the operation of their system. As an example, the staff gauges installed for the diagnostic analysis are now used in some areas to help operate the system. The next step is to use the gauges as a monitoring or management tool.

3. RESULTS AND DISCUSSION

The data analysis that follows is devoted to establising the performance of the Kaudulla Scheme by discussing adequacy, dependability and equity.

a. Adequacy

Rice is the major crop grown on the Kaudulla Scheme. Figure 3 and Appendix A present daily rates for rice evapotranspiration (ET) for Kaudulla Scheme.

Stage I. A comparison of Figures 3 and 4 seems to indicate that the supply from the sluice could adequately meet evapotranspiration rates. As an example, Table 1 illustrates the evapotranspiration rate and supply rate for various days.

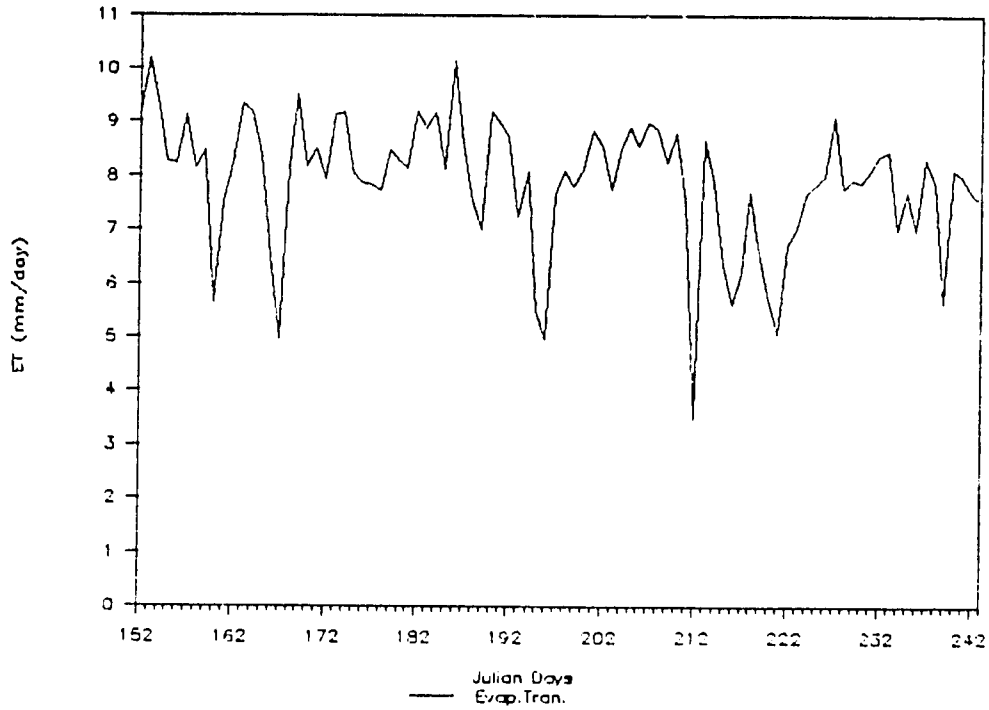

Figure 3. Rice evapotranspiration, Polonnaruwa, Sri Lanka, 1986 yala.

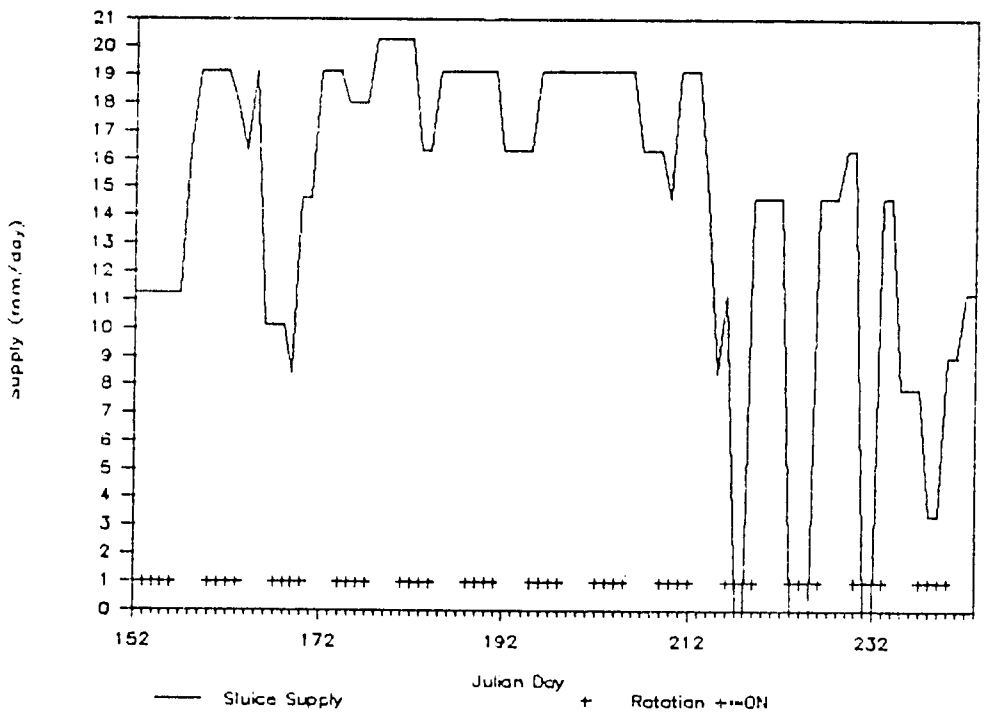

Figure 4. Kaudulla Stage I sluice supply, 1986 yala.

Table 1. Example evapotranspiration and supply rates for Stage I, Kaudulla (Polonnaruwa District), 1986 *yala*.

Julian Day	Rice ET (mm/day)	Weekly Average Supply (mm/day)	Adequacy (supply/ET) (mm/day)
165	8.4	18.6	2.2
186	10.1	18.8	1.86
207	9.0	18.7	2.08
228	7.8	8.4	1.08

In the four cases shown in Table 1, adequacy is greater than 1, which indicates more than adequate supply. However, if losses in the system are added to ET, or a 50 percent system efficiency is assumed, then the supply is close to being inadequate and probably is inadequate at times. (An overall system efficiency of 50 percent may be considered good for many surface irrigation systems.)

The weekly average supply varied from a high of 48.4 mm/day to a low of 0.0 mm/day. Figure 5 and Table 1 (Appendix B) show the supply rate versus distance from the sluice for Stage I. Each bar in the figure represents the average daily supply to a channel. The average

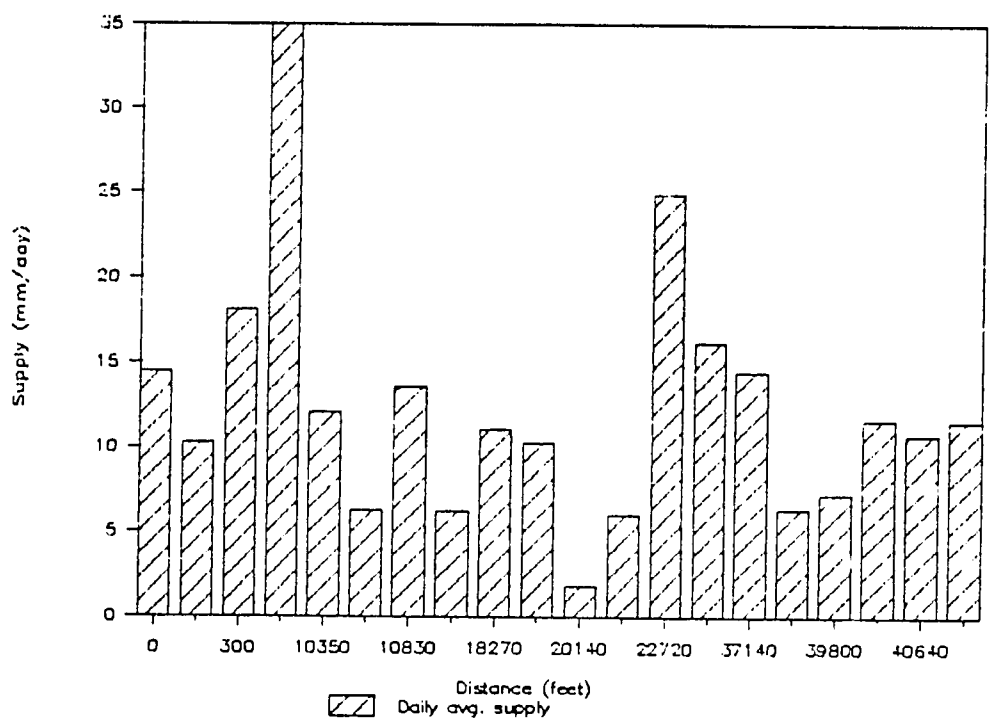

Figure 5. Kaudulla Stage I -- average supply rate versus distance, 1986 *yala*.

daily evapotranspiration rate for the period of study was approximately 9 mm/day when percolation and seepage losses at the field level were included. If the overall efficiency of the irrigation system is assumed to be 50 percent (typical of an adequate surface delivery irrigation system), the water supply requirement becomes approximately 13.5 mm/day. When this requirement was used to evaluate adequacy, only 6 of 18 channels met the water supply requirement.

Note that the water supply rates were calculated using acreage figures that are probably under-estimates of irrigated area. Therefore, true water supply rates were probably lower than those calculated in this analysis.

Stage II. Figure 6 shows the water supply hydrograph for the Stage II sluice of Kaudulla. A comparison of Figures 3 and 6 seems to indicate that the supply from the sluice is not adequate to meet evapotranspiration rates. As an example Table 2 is presented.

All four adequacy ratings are close to 1. If losses or an overall system efficiency of 50 percent are applied to the evapotranspiration rate, then the system cannot adequately meet water requirements. For 20 of the channels measured on Julian day 172 (21 June), the average weekly supply rate was 12.7 mm/day with a CV of 0.37. Other days show similar patterns. Assuming a water supply requirement of 13.5 mm/day (as approximated above) only 14 of the 36 channels studied received an adequate average weekly water supply for 1986 yala.

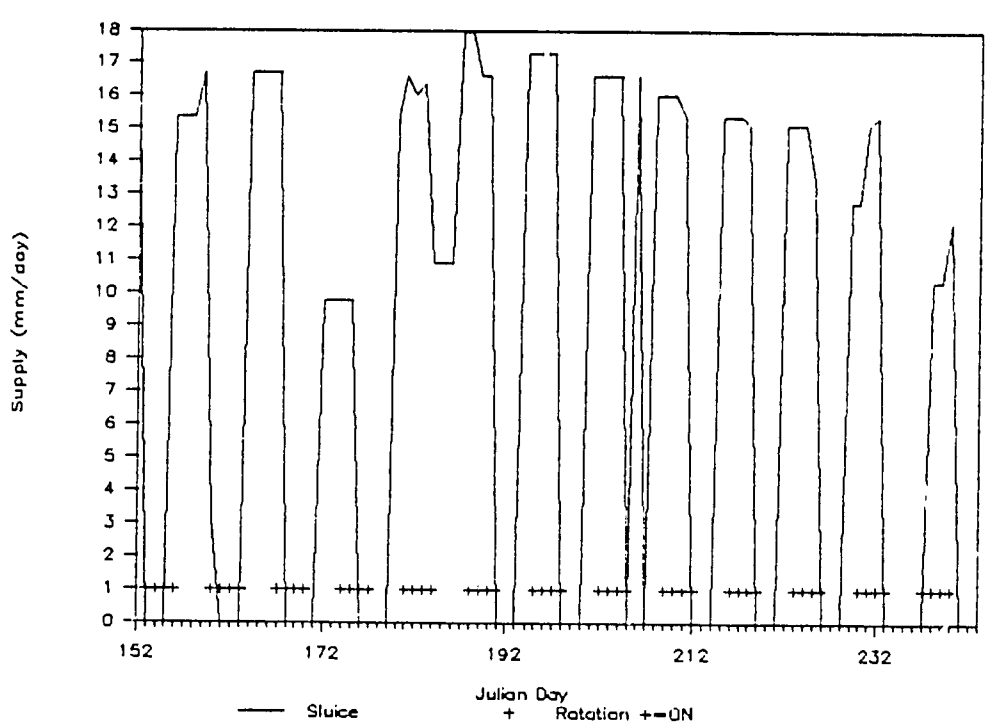

Figure 6. Kaudulla Stage II -- sluice supply (1986 yala).

Table 2. Example evapotranspiration and supply rates for Stage II, Kaudulla, 1986 *yala*.

Julian Day	Rice ET (mm/day)	Weekly Average Supply (mm/day)	Adequacy (supply/ET) (mm/day)
165	8.4	7.6	0.9
186	10.1	13.9	1.4
207	9.0	11.9	1.3
228	7.8	8.4	1.1

b. Dependability

Stage I. Figures 7 to 11 are the water supply hydrographs for several channels in Stage I. The graphs show the variation in supply rate with time. The plus signs near the bottom of the graphs indicate days when the rotation was to be "on." Apparently, supplies fluctuated widely. The rotation schedule partly contributed to the fluctuations. Note that the "peak" heights varied greatly during the study period. The variation in peaks indicates an undependable water supply.

The weekly average supply rates are the more meaningful values of supply to analyze since the week corresponds to a rotation. The daily

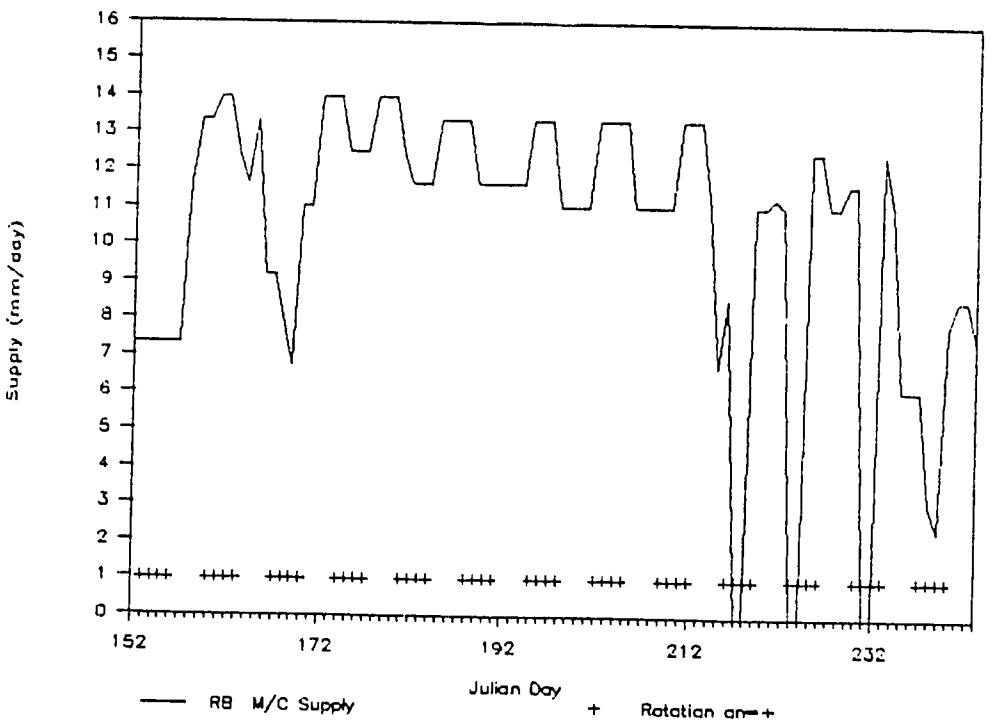

Figure 7. Kaudulla Stage I -- main channel supply near channel RB (1986 *yala*).

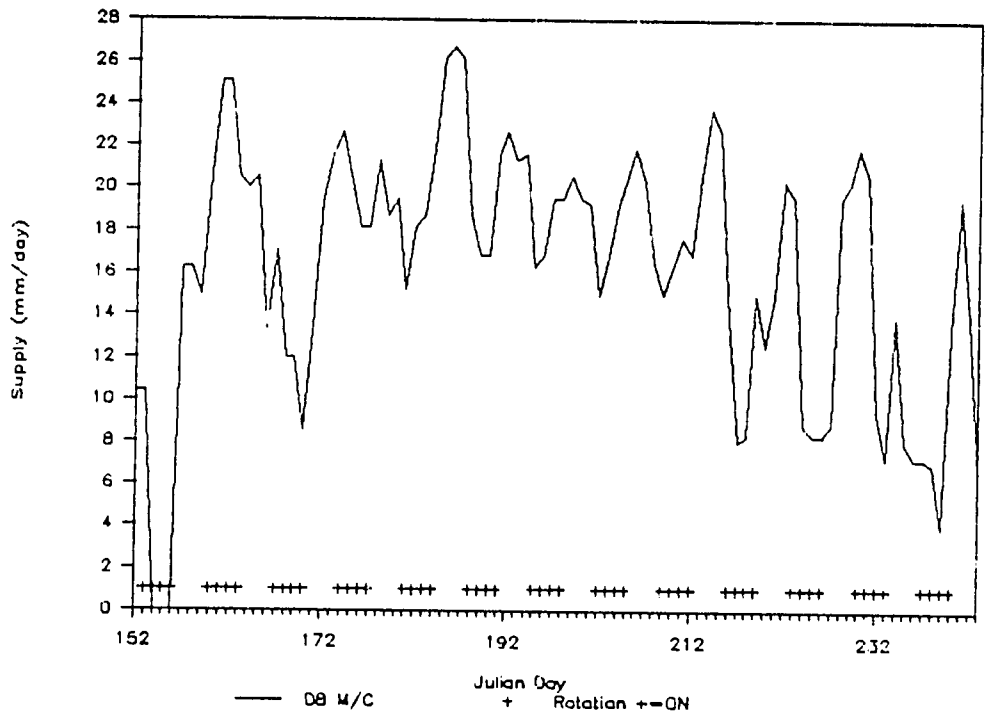

Figure 8. Kaudulla Stage I -- main channel supply downstream of D8 (1986 yala).

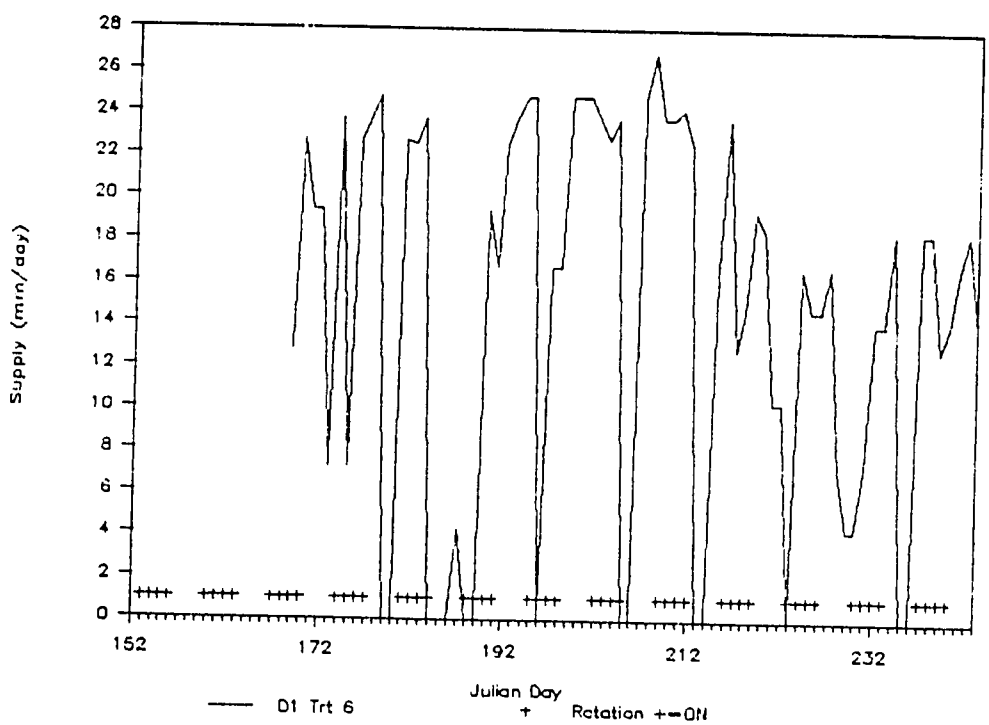

Figure 9. Kaudulla Stage I -- supply to D1, tract 6 (1986 yala).

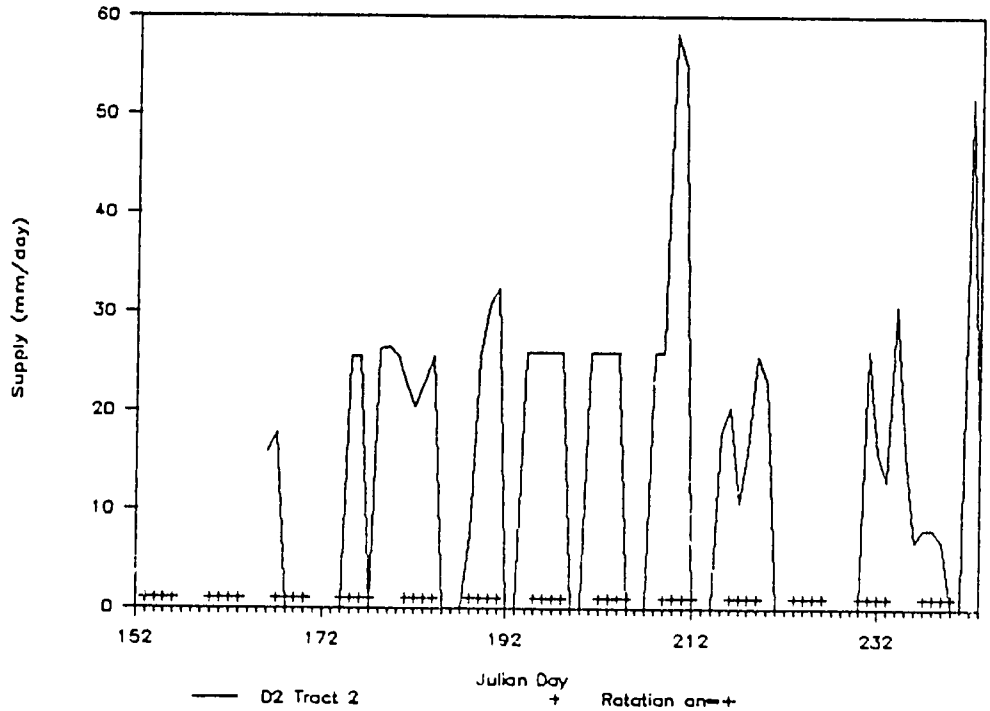

Figure 10. Kaudulla Stage I -- supply to D2, tract 2 (1986 yala).

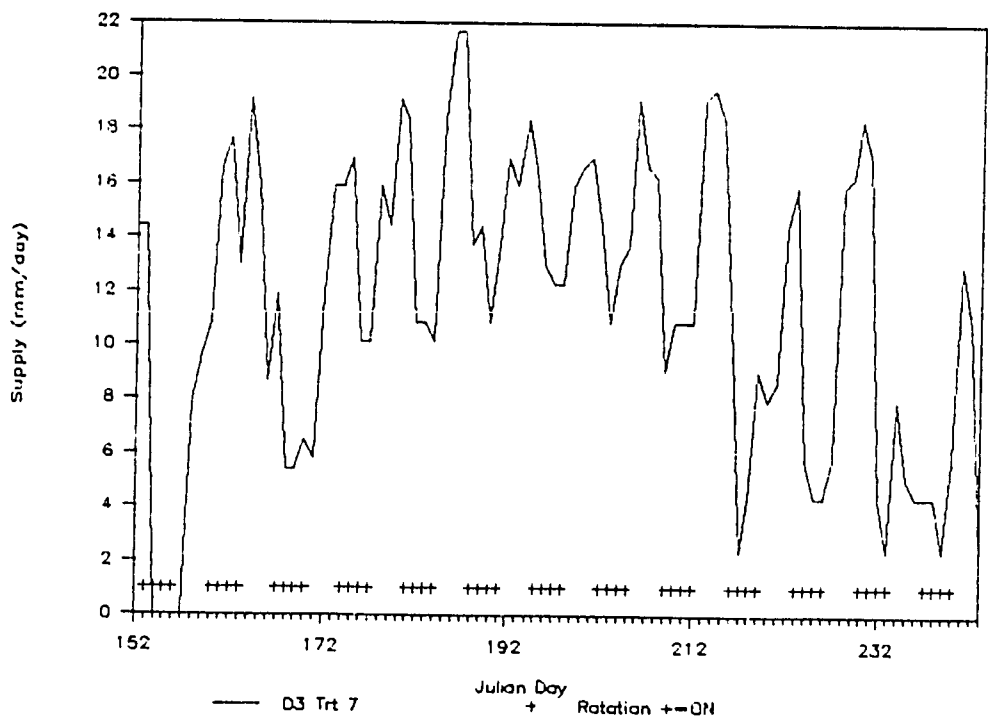

Figure 11. Kaudulla Stage I -- supply to D3, tract 7 (1986 yala).

rates vary also, but the daily variation is compounded by the zero or decreased supplies on the "off" rotation days.

Review of the Stage I hydrographs indicates a poor adherence to the rotation schedule. Therefore, the main channel has an almost continuous flow, although the flow decreases during the "off" periods of the rotation.

Review of Figures 9-11, which are supply hydrographs for three D-channels on the Kaudulla Scheme, Stage I, indicate undependable water supplies. Judging from the hydrographs, farmers would have a difficult time predicting when their D-channels would provide water.

Stage II. The water supply hydrographs for the sluice and other channels in the Kaudulla Scheme, Stage II, are shown in Figures 6 and 12 to 14. It is immediately apparent that there are wide fluctuations in supply rate. Part of the fluctuation is caused by the rotation. As in Stage I, the "peak" heights are erratic.

The variation in peak heights becomes greater towards the tail of the system. Figure 14, which depicts the supply rate from a channel at the tail of Stage II, shows the erratic nature of the peak heights. The implication is that supplies become more erratic towards the end of the system. Variation with distance is discussed in more detail in the equity subsection of this report.

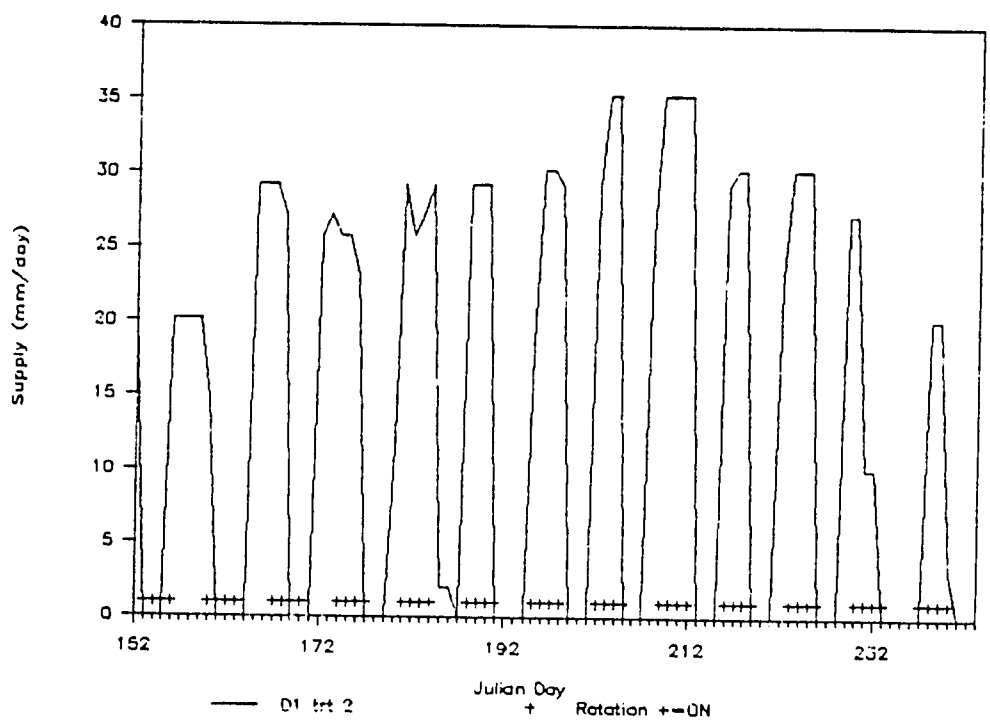

Figure 12. Kaudulla Stage II -- supply to D1, tract 2 (1986 yala).

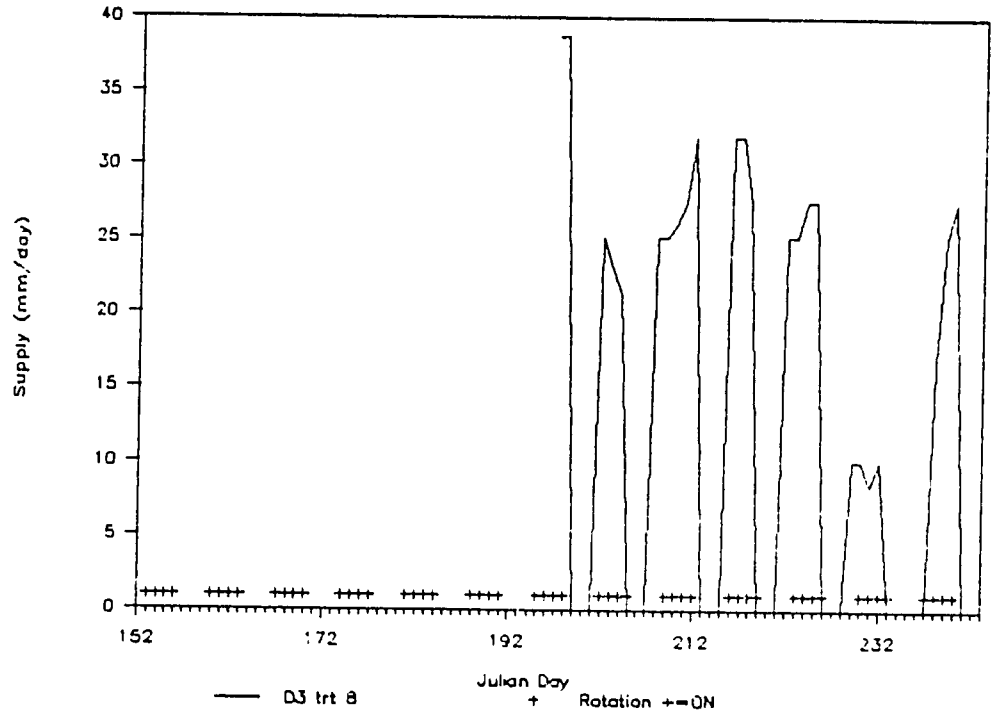

Figure 13. Kaudulla Stage II -- supply to D3, tract 8 (1986 yala).

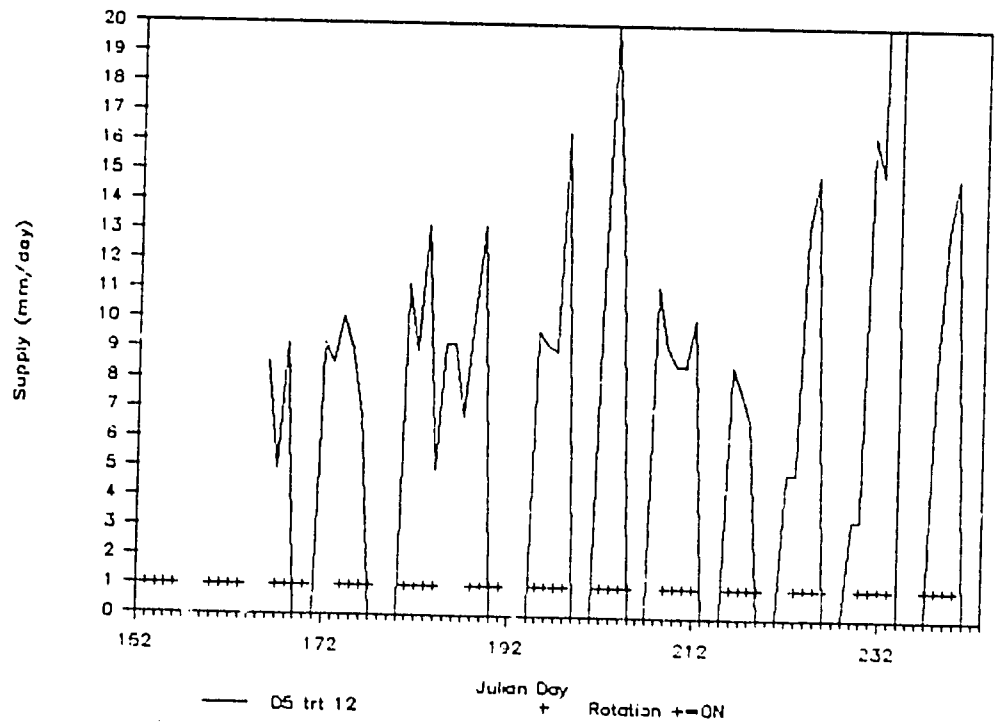

Figure 14. Kaudulla Stage II -- supply to D5, tract 12 (1986 yala).

Judging from Figure 6, a rotation was followed at the sluice and along the main canal. The D-channels also seemed to follow the rotation in most cases. However, the rotation did not correspond to the Irrigation Department's reported rotation schedule, which is displayed with plus signs along the horizontal axis of the graph. Whether this rotation was due to farmer tampering or Irrigation Department sanction was not known when this report was written.

c. Equity

Equity may be the most controversial of the parameters. The only intent here is to quantify the distribution of water supplies over the system. However, an assumption was made that D-channels and field channels, and subsequently, farmers, receive proportional allocations of water based on area. This assumption is probably valid given that the Kaudulla Scheme is essentially a one-crop system. The problem as stated above is to accurately and fairly determine commandable area.

Stage I. An examination of Figure 5 shows a large amount of variation in supply over the system. The CV of the weekly average supply was calculated and plotted against distance in Figure 15. The graph shows a wide variation in CV over the system, but indicates no pattern to the variation. The CVs for the channel supply rates of Stage I range from 0.23 to 0.65, with the average system CV equal to

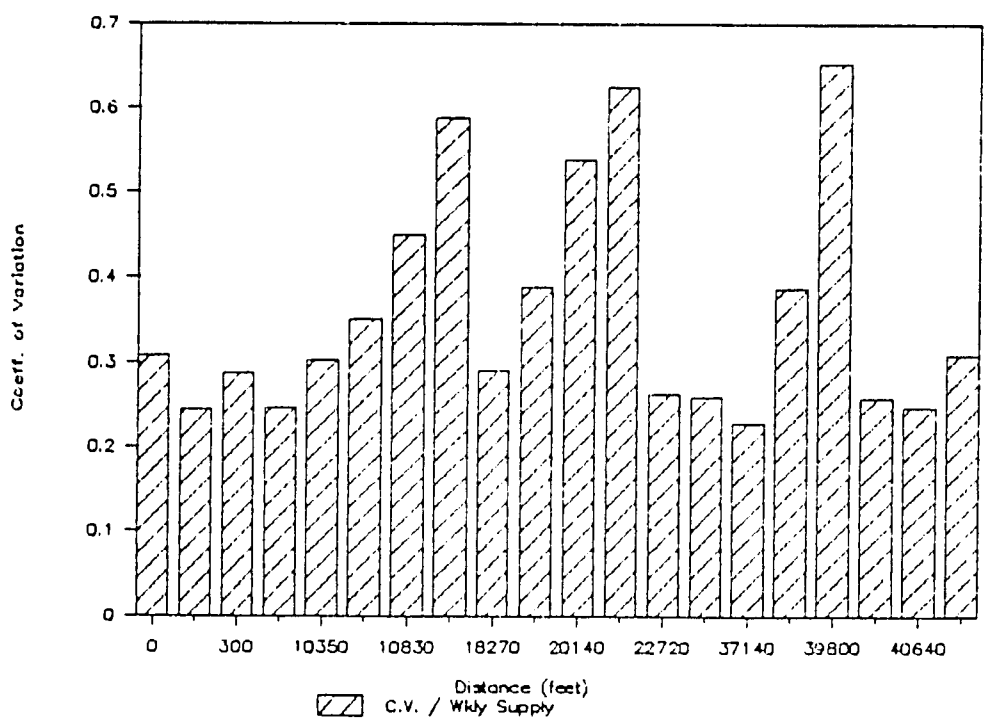

Figure 15. Kaudulla Stage I -- coefficient of variation for weekly average supply versus distance (1986 yala).

0.36. The above indicates that there is inequity in the system, but no pattern to the inequity (i.e., no head to tail differences).

Although no pattern of supply rates (i.e., head and tail differences) were apparent, regression analyses were performed to test for relationships between supply rates and distance from the sluice gate. The regressions performed are tabulated in Table 1 (Appendix C) for Stage I. Four regressions were performed: weekly average supply versus distance, coefficient of variation for average weekly supply versus distance, coefficient of variation for average daily supply versus distance, and the standard deviation of the average weekly supply versus distance. The r^2 value presented in each quadrant of the table is small. The r^2 indicates the strength of the relationship tested. In this case, the r^2 confirms that there was no apparent pattern to the variations in supply.

Stage II. Review of Figures 16 and 17 -- which represent the variation in daily supply with distance and the coefficient of variation in weekly average supply, respectively -- show wide variations, but no consistent pattern.

Tables 1 and 2 (Appendix B) show a range of CVs from 0.06 to 1.47 with 0.40 being the average system-wide CV for the weekly average supply rate.

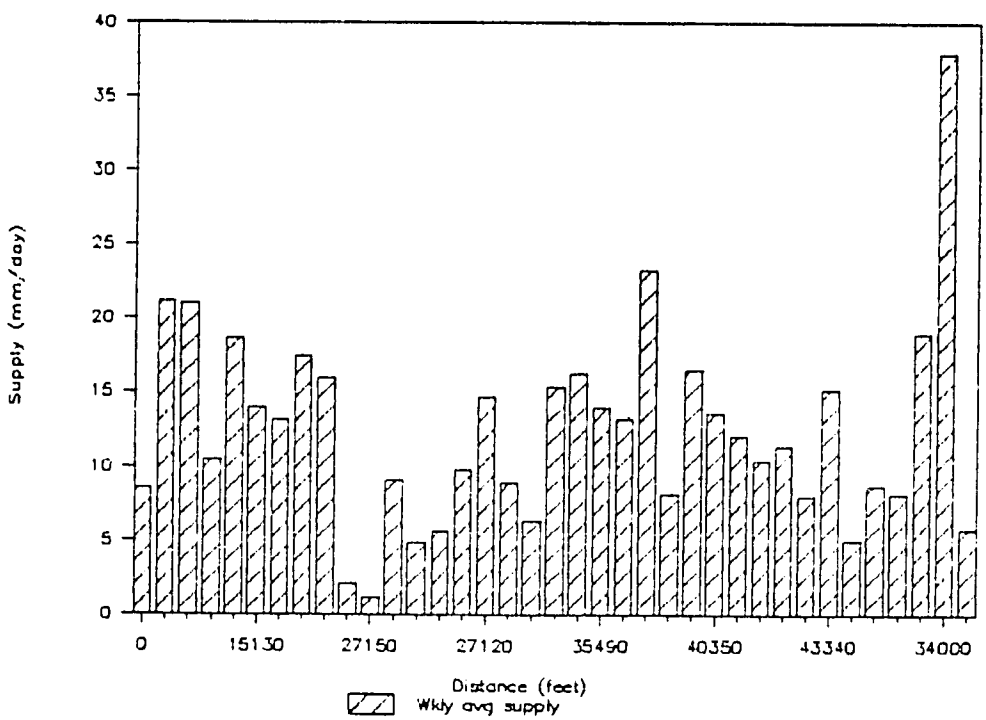

Figure 16. Kaudulla Stage II -- average daily supply versus distance (1986 yala).

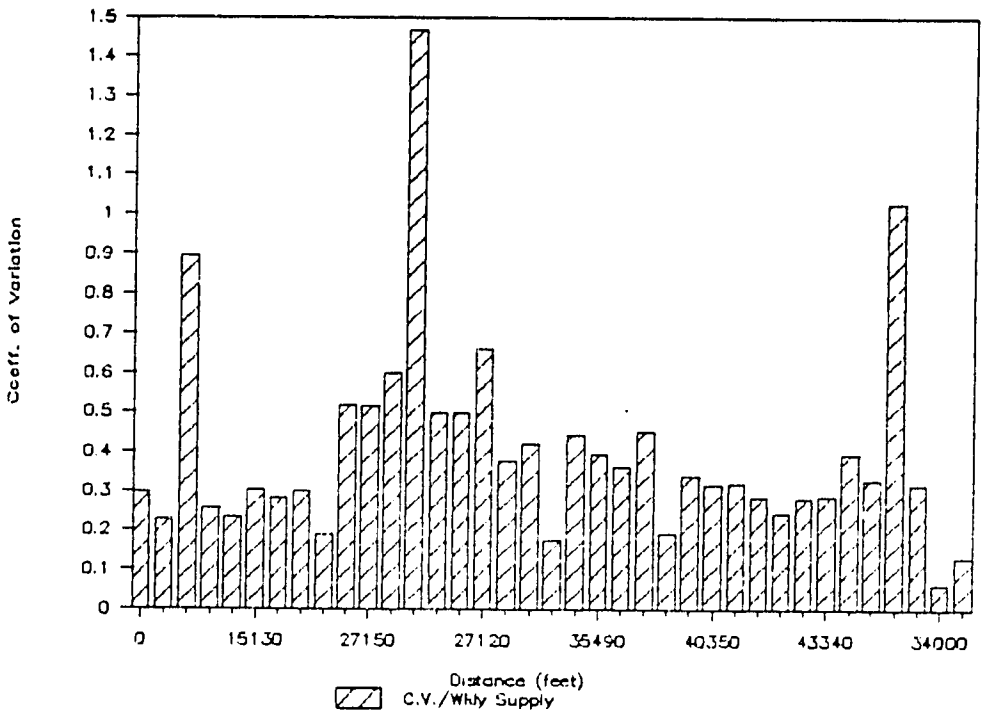

Figure 17. Kaudulla Stage II -- coefficient of variation for average weekly supply versus distance (1986 yala).

Table 2 (Appendix C) presents the regression analyses for Stage II. The same cases were tested as in Stage I. The r^2 values in the four quadrants of the table are all low, which indicates no pattern of inequity, although supply varied throughout the system.

4. CONCLUSIONS AND RECOMMENDATIONS

The average weekly supply to both stages of the Kaudulla Scheme was 12.5 mm/day. The average daily evapotranspiration rate for rice in the Polonnaruwa region was 7.92 mm/day. Therefore, the supply rate of the system appeared to be adequate to meet crop water requirements, given the acreage figures presented by the Irrigation Department. However, if higher acreage figures were used and system losses were added, the water supply would be inadequate. Even if losses were added to the evapotranspiration rate, though, the system could probably still handle increased demand by extending the rotation. The factors which constrain extended rotation are the Kaudulla Tank's storage capacity and undependable replenishment flows from the Mahaweli River via Minneriya Scheme.

On neither of the two stages was the rotation implemented completely. On Stage I, the flow was almost continuous with periodic reductions. Stage II was operated with an "on-off" arrangement, but the period of rotation was not consistent.

Inconsistent rotations influence dependability and equity in a system. Data indicate high amounts of variation in supply rates among the D-channels and within the D-channels of Kaudulla. These variations show supplies as being undependable and inequitable over the system.

Although the Kaudulla Scheme seemed able to meet the crop water requirement, the concept of the rotation should be examined. While implementing the rotation from the sluice is simple, this type of rotation is highly inefficient. Operational losses are high, and tail D-channels can experience highly erratic flow rates.

B. ON-FARM ENGINEERING

1. INTRODUCTION

If irrigation water use is to be improved in Sri Lanka, the water delivery system and the on-farm irrigation system must be viewed as an integrated whole. To take full advantage of water supplied, farm irrigation systems need to be properly designed, and farmers must be helped to improve their skills of irrigation scheduling and water application. Good water management on the farm requires that a dependable supply be available to irrigators when they need it and in the amount they need. If the on-farm water delivery system fails to meet this requirement, it imposes constraints that hinder agricultural production.

Existing on-farm irrigation systems can be evaluated by studying their performance in the field. After defining system boundaries, measurements of system parameters are made. When the field data are summarized and analyzed, they provide descriptive information on the system as it exists and operates in the field. However, the adequacy of the system cannot be appraised unless system objectives have been clearly defined. With system objectives in mind, the investigator can initially identify the primary problems that might be preventing the objectives from being met. This diagnostic analysis of the system is a prerequisite to considering alternatives for system renovation.

a. Objective of On-Farm Water Delivery

The purpose of any scheme of irrigated agriculture is to produce a bountiful harvest for the benefit of man -- the farm family and the wider market it serves. An on-farm water delivery system serves this purpose by supplying the required amount of water at the appropriate rate, at the appropriate time, and at the appropriate place. This implies several objectives for the system.

The first objective is adequacy: the flow must be the needed amount delivered at the right rate and at the right time. The flow rate must be large enough to deliver the water required by the crops during the time available for irrigation. The amount of water needed in an irrigation system varies with location and time as a function of crop type, stage of crop growth, soil properties, climatic conditions, and other factors. If the water supply is inadequate, crops may suffer stress, resulting in unacceptable reduction in crop yields.

A second objective of the on-farm water delivery system is equity. The spatial variance of water deliveries along the canal network should be minimized so that each irrigator receives a fair share.

Efficiency is a third objective of the system. In a region like the Dry Zone of Sri Lanka, where water at times limits production, irrigation should be practiced in a manner that conserves valuable water resources.

Reliability, the fourth objective, is closely related to the first two. Reliability means that water is delivered to farms in a quantity and on a schedule that are pre-set and known by farmers and system operators. It has been argued that this objective is the most important, for without reliability the farmer cannot plan his irrigations intelligently and use the water effectively. Also, an unreliable water supply hinders other critical farming practices (cultivation and application of fertilizers and herbicides, among others) which must be scheduled around or in conjunction with irrigations.

2. METHODOLOGY

The following sections of this report describe the procedures, results and conclusions of a diagnostic analysis of on-farm water delivery in the Kaudulla Scheme in Polonnaruwa District of Sri Lanka. The aims of this study were to derive indicators of system performance from field data, use these indicators to evaluate the system in light of its objectives, and identify any major problems in the system along with the factors contributing to those problems. The performance indicators selected for this study were associated with the four objectives of the on-farm water delivery system mentioned above. Table 3 lists these objectives along with the field data required, as discussed below.

The relative water supply (RWS) was used to indicate how well the system met the objective of providing an adequate water supply. Relative water supply was defined as the ratio of water supplied to water required:

$$RWS = IR/(ET + S + P - RN)$$

where

IR = irrigation water delivered (L^3),
ET = evapotranspiration of the crop (L^3),
S = lateral seepage flow across the boundaries surrounding the command area to adjacent sites and seepage from field conveyance channels (L^3),
P = subsurface percolation to groundwater (L^3), and
RN = effective rainfall (L^3).

In submergence agriculture, where the soil profile is maintained at or near saturated conditions, seepage and percolation losses are considered unavoidable and, hence, a part of the water requirement. When the value of RWS was less than 1.0 for any given time period, the water delivery during that time period was considered inadequate.

Equity was evaluated by studying the spatial distribution of water supply relative to water requirements within a network. A suitable performance indicator is the spatial coefficient of variation ($CV(\bar{x})_{RWS}$) in RWS over the domain of a distributary canal network defined as:

$$CV(\bar{x})_{RWS} = STD(\bar{x})_{RWS}/MEAN(\bar{x})_{RWS}$$

Table 3. Objectives of the on-farm water delivery system, associated performance indicators, and field data required for determination.

System Objectives	Performance Indicators	Data Required
Adequacy	Relative water supply (RWS) (ratio of water supplied to water required).	Amount of water required; (evapotranspiration + losses - rainfall); Amount of of water supplied.
Equity	Coefficient of variation between delivery points within a network.	Spatial distribution of amount of water required and amount of water supplied.
	Trends in spatial variability (dependence on position of delivery points along network).	
Efficiency	Water use efficiency (WUE) (ratio of water required to water supplied).	Amount of water required; (evapotranspiration + losses - rainfall); Amount of water supplied.
Reliability	Coefficient of variation in RWS over time at delivery points.	Temporal distribution of amount of water required and amount of water supplied.

where

$STD(\tilde{x})_{RWS}$ = sample standard deviation of the distribution of RWS at delivery points within a distributary canal network.

$MEAN(\tilde{x})_{RWS}$ = sample mean of the distribution of RWS at delivery points within a distributary canal network, and

$\tilde{x}$ indicates that the sample was taken over points in space at a given point in time.

The coefficient of variation is a dimensionless quantity that is normalized relative to the mean value of the observations. Hence, it

was a suitable measure for comparing the spatial variability occurring at different points in time or in different canal systems.

A distributary canal network that meets water requirements with perfect equity would have a value of $CV(\bar{x})_{RWS}$ equal to 0. The higher the value of $CV(\bar{x})_{RWS}$ for any period of time, the higher the spatial variability, and hence the inequity, in water delivery.

Spatial variability in on-farm water delivery often exhibits trends within a distributary canal network. That is, the degree to which the water requirement is met at a given delivery point may depend on the location of that delivery point within the canal network. An indication of such trends may be obtained by comparing the values of RWS over an irrigation season at delivery points located upstream in a system (at the head of the canal or farm channels) with the values at points located downstream (at the tail of the canal or farm channel).

The performance indicator to use to assess the efficiency of the on-farm water delivery is water use efficiency (WUE). This parameter is commonly used to evaluate lowland flooded paddy and is defined as:

$$WUE = (ET + S + P - RN)/IR$$

The term expresses the ratio of system output (in this case, useful water consumed as crop evapotranspiration and unavoidable losses, adjusted by rainfall supply) to system input (irrigation water supplied). Hence, the higher the value of WUE is, the more efficiently the system supplies the water demand. In cases where the water delivered was insufficient to meet the requirement, the WUE was assigned a value of 1.0.

A measure of system reliability is the coefficient of variation ($CV(\bar{t})_{RWS}$) in the relative water supply over time at a given point in the system:

$$CV(\bar{t})_{RWS} = STD(\bar{t})_{RWS}/MEAN(\bar{t})_{RWS}$$

where

$STD(\bar{t})_{RWS}$ = sample standard deviation of RWS over observations made at several points in time,

$MEAN(\bar{t})_{RWS}$ = sample mean of RWS at a given delivery point in the system made at several points in time, and

$\bar{t}$ indicates that the sample was taken over time at a given point in space.

At a given location in the system, if the amount of water supplied relative to the amount required is consistent over time, the value of $CV(\bar{t})_{RWS}$ will be 0. In this case, the system performance may be considered reliable (although not necessarily adequate) since the farmer knows what to expect in terms of relative water supply.

Accordingly, the higher the value of $CV(\bar{t})_{RWS}$, the more temporally variable, and hence unreliable, the relative water supply.

To calculate each of the performance indicators defined above, data were collected on the timing and amount of water required and the water supplied at a sample set of delivery points at the farm level within Kaudulla Scheme. The rationale and methods employed are briefly discussed in this section.

a. Site selection

To evaluate farm water delivery, data were collected at the head of selected field channels and at the turnouts to selected farm allotments. Data were collected at delivery points along three distributary canals within Stage I of Kaudulla Scheme (D1, tract 1, near the head of the system; D8, tract 4, at the middle of the system; and D1, tract 8, near the tail of the system) and along three distributary canals within Stage II (LB main, tract 1, at the head of the system; D1, tract 4, at the middle of the system; and D2A, tract 12, near the tail of the system). The sample set comprised 58 delivery points (27 farm channels and 31 allotments). A map showing the general location of study sites is given in Figure 18. Appendix D lists and describes the measurement sites.

The number and location of delivery points sampled were determined by several factors. Farmer cooperation, ease of access, ease of equipment installation, and availability of manpower and equipment. Also, the decision was made to sample locations at the head, middle, and tail of the distributary canals to detect suspected trends in spatial variability of water supply.

b. Field measurements

Command Area Surveys. Field surveys were conducted using theodolite surveying instruments to determine the cropped area commanded by each delivery point. Areas of both paddy and other field crops were determined in the surveys.

Water Requirements. Water requirements were evaluated by determining crop evapotranspiration, seepage and percolation losses and rainfall for each of the study sites. Since subsidiary crops were only about 4 percent of the cultivated area in the study region, water requirements were computed assuming all crops to be paddy.

Potential evapotranspiration (ET_o) in Kaudulla Scheme was calculated using the method of Jensen and Haise (Jensen, 1980). In this method, ET_o is computed by the following empirically derived equation:

$$ET_o = Ct(T-Tx)Rs$$

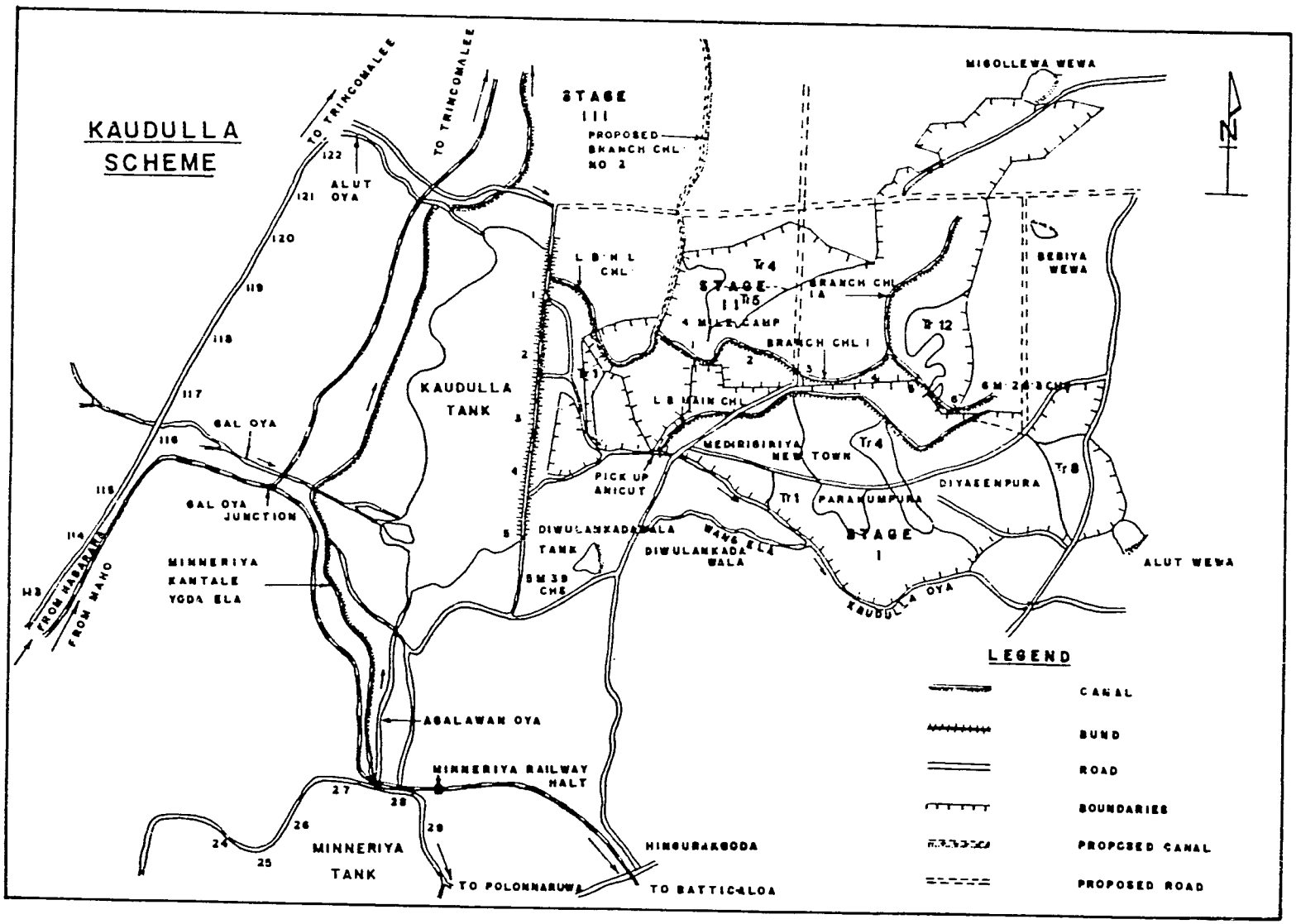

Figure 18. The Kaudulla Scheme showing location of on-farm engineering diagnostic analysis sites for 1986 yala.

where

Ct = 1/(Cl + 7.3CH)
CH = 50/(e2 - el)
Tx = -2.5 - 0.14(e2 - el) - (E/550)
E = elevation of site (meters)
e2 = saturation vapor pressure of water at the mean monthly maximum air temperature of the warmest month in the year (long term climatic data) (mb)
el = saturation vapor pressure of water at the mean monthly minimum temperature of the warmest month in the year (mb)
T = mean daily temperature (Celsius)
Rs = total daily solar radiation (Langleys).

Long-term climatic data needed for determining el and e2 were obtained from the weather station in Aralaganwila located about 48 km southeast of Kaudulla Tank. Daily temperature and solar radiation were measured at the Diyasenapura weather station (maintained by the Irrigation Department) using a Datapod™ (model DP219) potential evapotranspiration monitor. The device was fitted with a Licor™ (model L1200S) pyranometer for measuring solar radiation and an Omindata™ (model TP 10V) temperature probe. Readings were recorded by the Datapod™ once every 10 minutes.

Actual crop evapotranspiration was computed from:

$$ET = K_c ET_o$$

Where K_c is the crop coefficient dependent on the type of crop and its growth stage. For rice in the region, K_c was taken as 1.15 during the initial growth stage (approximately May 15 to July 15), 1.10 during mid-season (approximately July 15 to August 15), and 1.00 during the mature stage (approximately August 15 to September 15) (Doorenbos and Pruitt, 1977).

Seepage and percolation losses from paddy fields were estimated by conducting water balance studies in the field. The depth of standing water was recorded at specified time intervals in a few selected liyaddas (small bunded subdivisions of farm allotments) around the scheme. Cracks and crab holes in the liyadda bunds were sealed off and the depth of water was measured by a sloping gauge -- a simple instrument made of a measuring tape fixed onto a wooden frame set at a slope of approximately 1 vertical to 5 horizontal. Readings were taken hourly for about 8 hours. The rate of seepage and percolation was calculated as the difference between the observed rate of water depletion in the liyadda and the rate of evapotranspiration calculated for that day.

Seepage from field channels was determined from channel ponding tests conducted at 10 selected sites. Water was impounded between two temporary earthen dams constructed at both ends of a selected reach of

channel. The change in water depth was measured using a sloping gauge and recorded hourly as in the liyadda studies. The width of the water surface at each depth was also recorded. The seepage rate was calculated as the difference between the observed rate of water depletion in the channel and the rate due to evaporation for that day. The evaporation rate was assumed to be equal to the calculated value of potential evapotranspiration.

Rainfall was measured by the Irrigation Department using rain gauges located at five stations in the field: Ambagaswewa station for tract 8, Stage I, and tract 12, Stage II; Diyasenapura station for tract 4, Stage I; Fourth Mile Camp station for tract 4, Stage II; Headworks station for tract 1, Stage II; and Low Level Sluice station for tract 1, Stage I (Appendix E).

Water Deliveries. Flows at each of the delivery points were measured using either cutthroat (4 in, 8 in, or 12 in) flumes or long-throated (100 mm or 150 mm) flumes. Previous studies in nearby regions indicated that readings twice daily would be adequate for estimating the mean daily (24 hr) flow rates. Thus, measurements of flow depth in the flumes were recorded at approximately 8:00 a.m. and 5:00 p.m. each day.

The first issue of water to Stages I and II for the 1986 yala occurred on April 20. To facilitate land preparation, water was supplied continuously to Stage I from April 20 to May 20 and to Stage II from April 20 to May 25. The rotation schedule commenced on May 20 for Stage I and on May 25 for Stage II. Flow measurements were started sometime between May 6 and May 20 at most of the sites and ended on about August 31.

Rating equations used to calculate free and submerged flow through the cutthroat flumes are given in Skogerboe et al. (1972). Rating equations for long-throated flumes, which were calibrated only for free flow conditions, are given in Bos et al. (1984).

Physical Conditions of the Field Channels. At selected sites, surveys were conducted to determine channel cross sections and bed slopes. These data were collected to evaluate the conveyance characteristics of the channels and their effect on water supply.

An attempt was made to study the roughness of the channel banks towards the end of the season. In the calculations, bed slope of the channel was used in place of hydraulic gradient because in the design, uniform flow was assumed and bed slope was used in the Manning's equation. Due to time limitations, only 4 field channels were studied. Three of them gave acceptable results.

Land Leveling by Farmers. To make optimum use of water, land should be leveled as much as possible. When the surface is uneven, additional water is required to cover the high spots of the liyadda. The evenness of liyadda surface achieved by the farmer is an indication of his efficiency.

Data from 22 liyaddas distributed throughout the study area of Kaudulla Scheme were used for the analysis. Each liyadda was divided by grids into approximately rectangular sections, and spot levels were taken at the center of each grid section.

Locations of Pipe Outlets. The pipe outlets of Kaudulla were designed and constructed long ago. It was observed that some farmers did not use these pipe outlets. A pipe outlet that is not correctly located hampers the water supply to the farm. Hence, to study the condition of pipe outlets, the elevations of canal beds and farms were taken with respect to pipe outlets. These measurements were made in 24 locations.

3. RESULTS AND DISCUSSION

Field data were compiled and analyzed to determine the various performance indicators of interest. In the following sections the results are presented and discussed.

a. Relative Water Supply

Measured values of mean daily temperature and solar radiation are given in Appendix A. The elevation of the site was 70 m. Values of e1 and e2 computed from long-term climatic data collected at Aralaganwila were 23.92 mb and 35.23 mb respectively. A plot of paddy evapotranspiration at Kaudulla during 1986 yala is given in Figure 19. Calculated values of ET ranged from a low of 4.95 mm/day to a high of 10.20 mm/day.

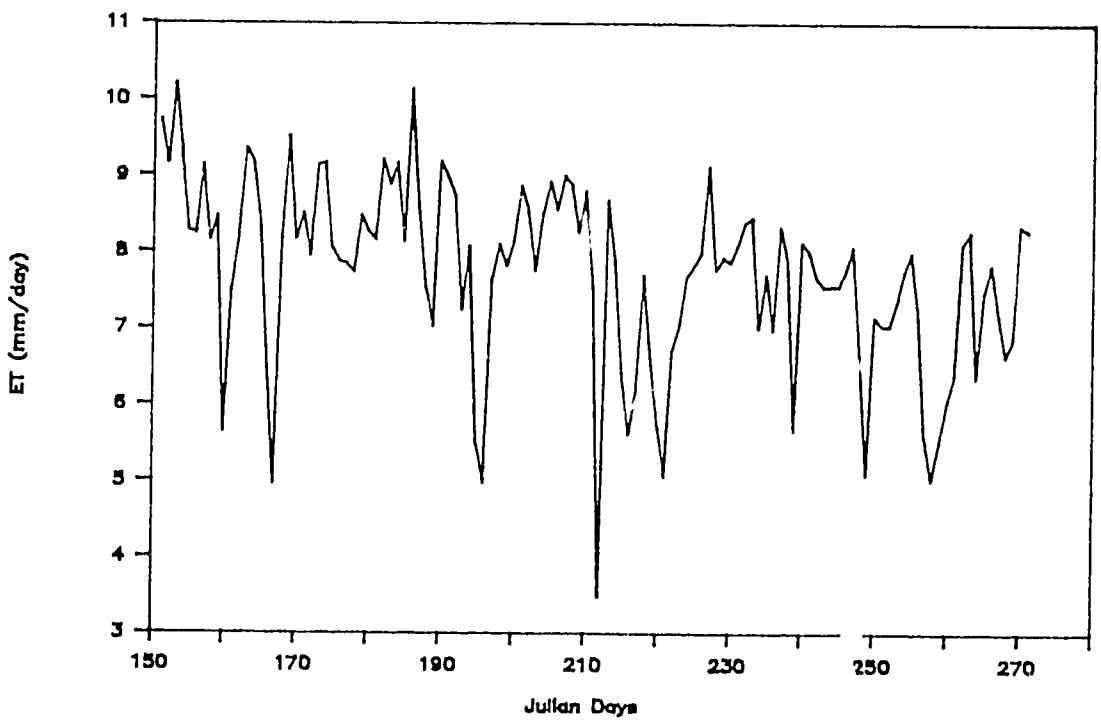

Figure 19. Evapotranspiration rate of paddy in Kaudulla Scheme, 1986 yala.

Rainfall observed at each of the gauge stations in Kaudulla is summarized in Appendix E. From June 1 to August 31, a total of 66.7 mm was supplied by six rainfall events at tract 1, Stage I. Over the same period 78.6 mm in six events (tract 4, Stage I), 15 mm in one event (tract 8, Stage I), 174.3 mm in eight events (tract 1, Stage II), 111.4 mm in four events (tract 4, Stage II) and 15 mm in one event (tract 12, Stage II) were observed.

Results of liyadda water balance studies conducted at five sites to determine seepage and percolation are summarized in Table 4. Spatial variability of seepage and percolation was expected to be significant within the study region (coefficient of variation among the liyadda measurement sites was found to be 1.1). However, data were insufficient to describe this variability on larger allotments and field channels where delivery analysis was conducted. Thus, seepage and percolation for the allotment and field channel command areas were assumed uniform over the region as the mean of the liyadda observations: 2.6 mm/day. This value was conservative compared to the value of 5.1 mm/day adopted by the Irrigation Department of Sri Lanka for design and operational purposes (Irrigation Department, 1981). Abernathy (1985) reported values for field seepage of 1.9, 0.3, 0.2, 1.1, and 2.5 mm/day for five annual water balance studies of the entire irrigated area at Kaudulla.

Table 4. Liyadda water balance tests for seepage and percolation, Kaudulla Scheme, yala 1986.

Site	Date	Depletion (mm/day)	ET (mm/day)	S+P* (mm/day)
D1, tract 4, Stage II	Jul 28	11.1	8.3	2.8
D1, tract 4, Stage II	Jul 28	15.5	8.3	7.2
D2A, tract 12, Stage II	Aug 4	5.6	5.6	0**
D2A, tract 12, Stage II	Aug 4	4.9	5.6	0**
Field channel 9, D1, tract 4, Stage II	Aug 8	8.7	5.7	3.0

*Seepage and percolation.
**When the measured depletion rate was less than the calculated ET, the value of (S+P) was assumed to be zero.

Results of ponding tests conducted to determine seepage from field channels are summarized in Table 5. Measured test parameters included the length of the channel section in which the test was conducted, the duration of the test, the range (initial and final readings) of observed water depth over the test duration, and the range of the observed width of the water surface in the channel over the test duration. Seepage from field channels at the Kaudulla site was found to be about 0.031 (± 0.016) $m^3/m/day$. This was equivalent to less than

Table 5. Ponding tests for seepage from field channels, Kaudulla Scheme, 1986 *yala*.

Location	Date	Test Parameters: Section Length (m)	Duration (hrs)	Water Depth Range (cm)	Width at Water Surf. Range (cm)	Evaporation (mm/day)	Seepage Rate (m^3/m)
FC2, Tr 4, St 2*	Sept 4	1.6	2	18 - 16.9	40.5 - 12.4	8.1	0.032
RC1, Tr 4, St 2	Sept 4	1.56	2	16 - 15.3	53 - 40.8	8.1	0.034
FC3, Tr 1, St 1	Sept 5	1.64	3	13 - 12.1	71.5 - 23.9	6.7	0.032
FC9, Tr 1, St 1	Sept 5	1.72	4	14 - 9.8	113 - 84	6.7	0.041
LB3, Tr 4, St 1	Sept 6	1.44	4	13.7 - 12.7	136 - 86	5.1	0.062
LB2, Tr 4, St 1	Sept 6	1.67	4	15.3 - 14.5	78 - 46	5.1	0.026
LB3, Tr 4, St 1	Sept 7	14.3	4	15.2 - 14.1	79.9 - 48.8	7.2	0.036
LB2, Tr 4, St 1	Sept 7	6.1	4	13.4 - 12.7	122 - 81.4	7.2	0.032
FC27, Tr 12, St 2	Sept 10	7.4	4	11.5 - 10.9	61.8 - 40.2	7.4	0.016
-- , Tr 1, St 2	Sept 20	7.8	4	12.8 - 12.7	111 - 101	8.3	0

*FC = Field channel, Tr = Tract, St = Stage, LB = Left bank.

0.5 mm/day (over the command area) for most sites. Hence, field channel seepage was neglected in determining command area water requirements.

Flume data were analyzed to determine flow hydrographs at each of the measurement points. Observed flow rates ranged between 0 cfs and 8.06 cfs (228 L/s) at the head of farm channels, and between 0 cfs and 0.89 cfs (25 L/s) at turnouts to allotments. Example hydrographs for two field channels and two allotments within the scheme are shown in Figures 20 through 23. These graphs illustrate the variation in flow rates that occurred over time at the given delivery point. When the flow rates were zero indicates off periods in the rotation schedule. Due to leakage of the main sluice gates, some points in the scheme had a small supply of water available even during "off" periods.

For purposes of comparison, the design supply rates for the field channels in Figures 20 and 21 were plotted as straight lines. The design supply rate for Kaudulla Scheme was 1 cfs/40 ac of command area. This flow rate was used to design the channel capacities assuming that the total cultivated area was in lowland paddy. The fact that the hydrographs in Figures 20 and 21 at times rose significantly above the design supply rate indicates the degree to which the system was operating above design capacity. This over-capacity operation was necessary since the system, which was designed for continuous flow, is now operated on a rotation schedule.

Flow rates at each of the measured delivery points were converted to command area water supply by dividing by the area of cropped land served downstream of the measurement point. The cropped areas measured for each of the delivery points are given in Appendix D. The seasonal mean water supply millimeters/day is given in Table 6 for each of the measured delivery points.

Water supply and water requirement data were simultaneously collected only during June 1 to August 31, 1986. Relative water supply was computed for weekly periods within this time frame by dividing weekly average values of water supply by weekly average values of water required. Plots of the results are given in Figures 24 through 35. Note that in tract 1, Stage II, of the scheme (Figure 30), a large rainfall event occurred during the week of July 6 to July 12 causing the water requirement to be zero. Thus, the value of RWS was undefined for that week for canal LB main/tract 1/Stage II.

A relative water supply of 1.0, corresponding to the required supply, was plotted as a straight line in Figures 24 through 35. At any point in time when the value of RWS fell below this line, the supply was inadequate. Relative water supply varied considerably both from point to point within the system and over time at any given point. A further analysis of this variability is presented below.

The seasonal mean of RWS for each of the measurement points was computed as the mean of all of the weekly values of RWS. The results, summarized in Table 6 and in Figures 36 through 41, show that the supply was inadequate (RWS < 1.0) at about 25 percent of the locations

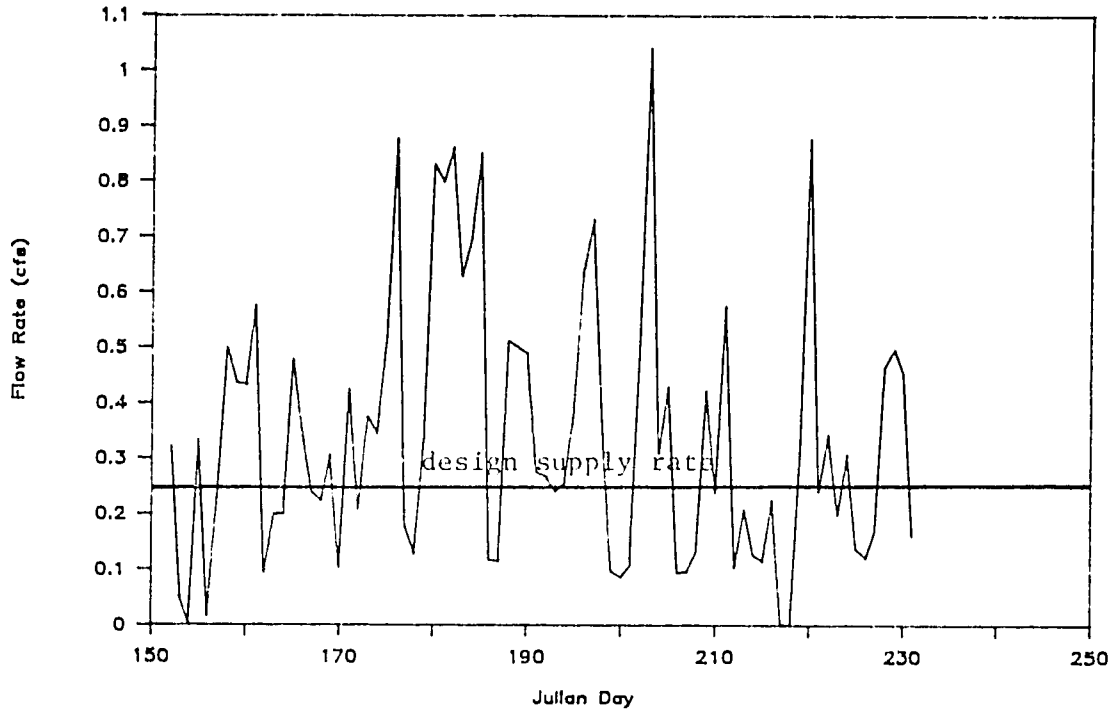

Figure 20. Hydrograph of flow rate delivered to head of field channel 9, D1, tract 1, Stage I, Kaudulla, during 1986 yala.

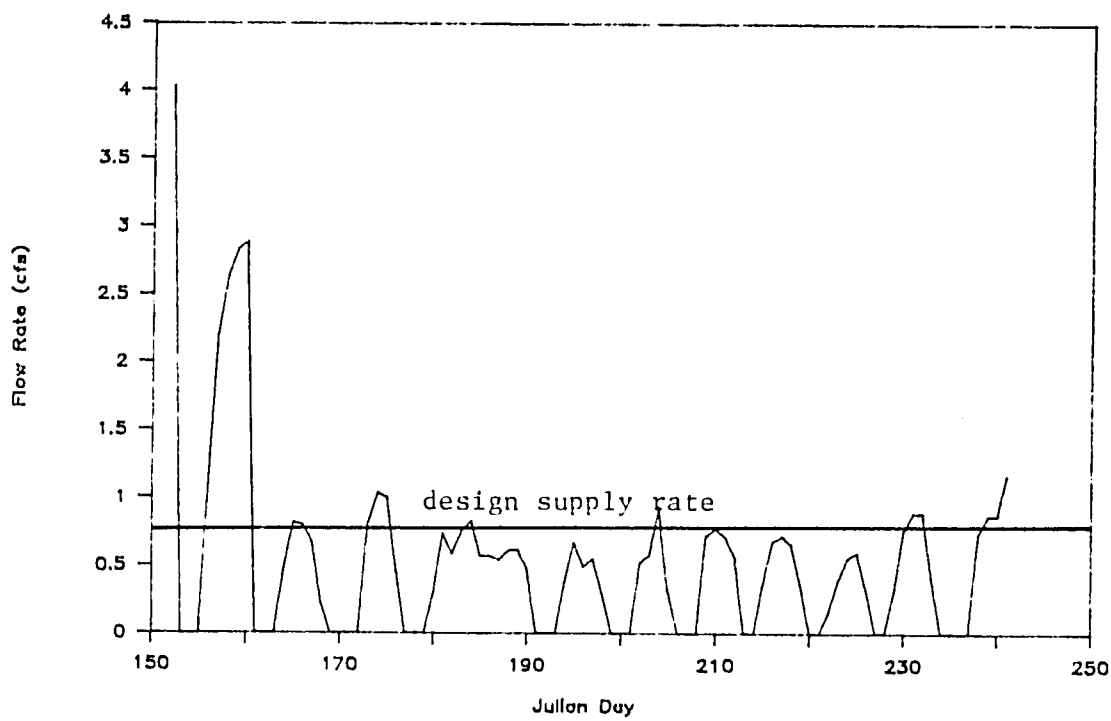

Figure 21. Hydrograph of flow rate delivered to head of field channel 26, D24, tract 12, Stage II, Kaudulla, during 1986 yala.

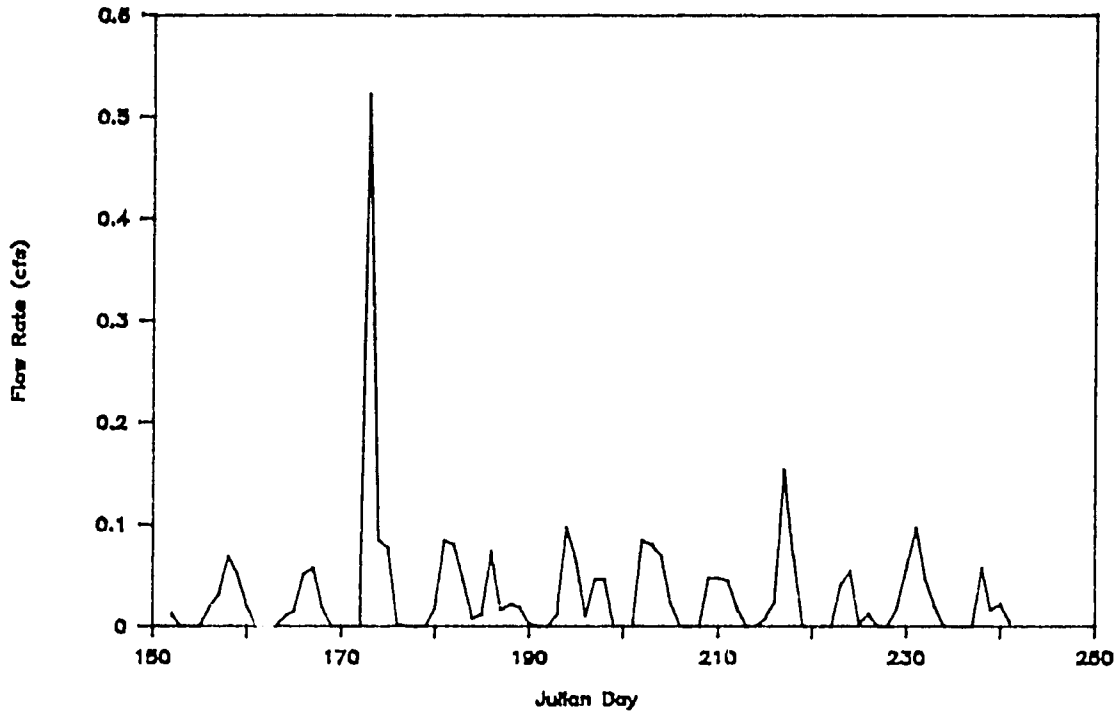

Figure 22. Hydrograph of flow rate delivered to allotment 232 on field channel 27, D2A, tract 12, Stage II, Kaudulla, during 1986 yala.

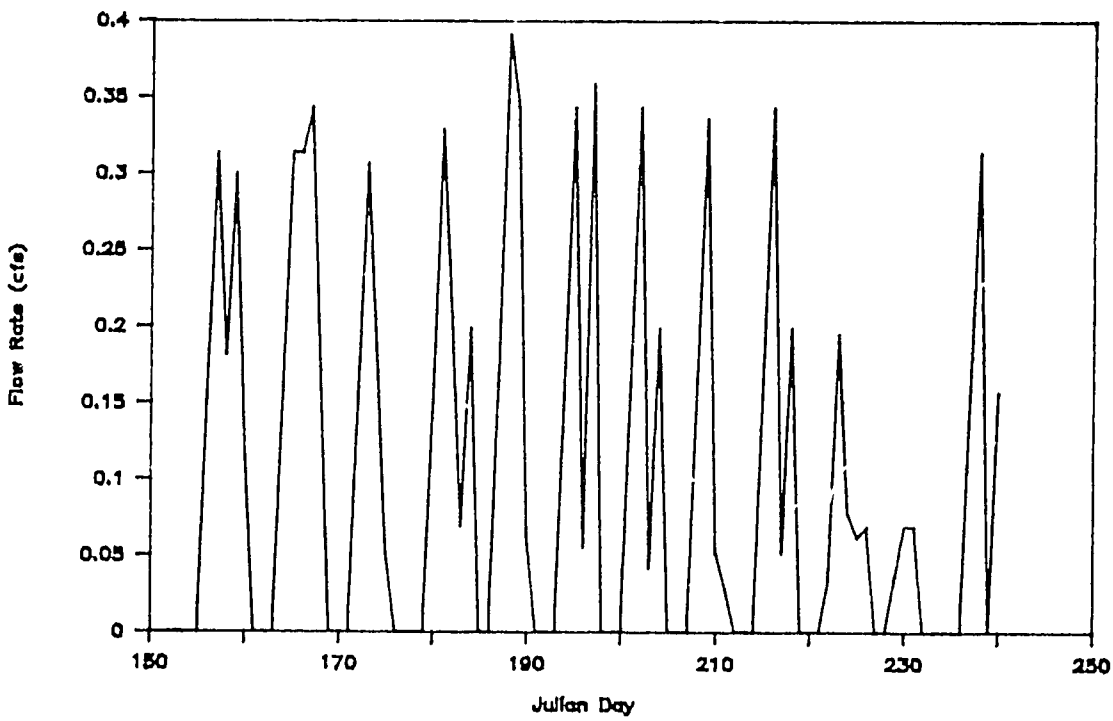

Figure 23. Hydrograph of flow rate delivered to allotment 103 on field channel 7, LB main, tract 1, Stage II, Kaudulla, during 1986 yala.

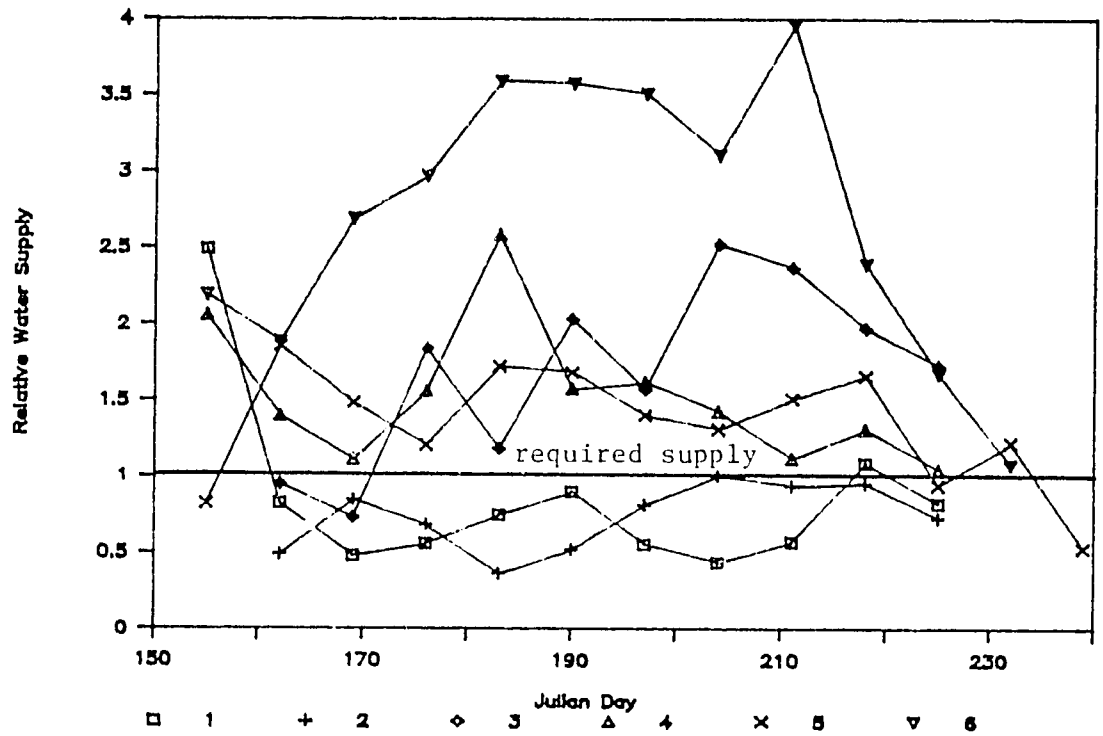

Figure 24. Relative water supply at sites 1-6 of D1, tract 1, Stage I, Kaudulla, during 1986 yala.

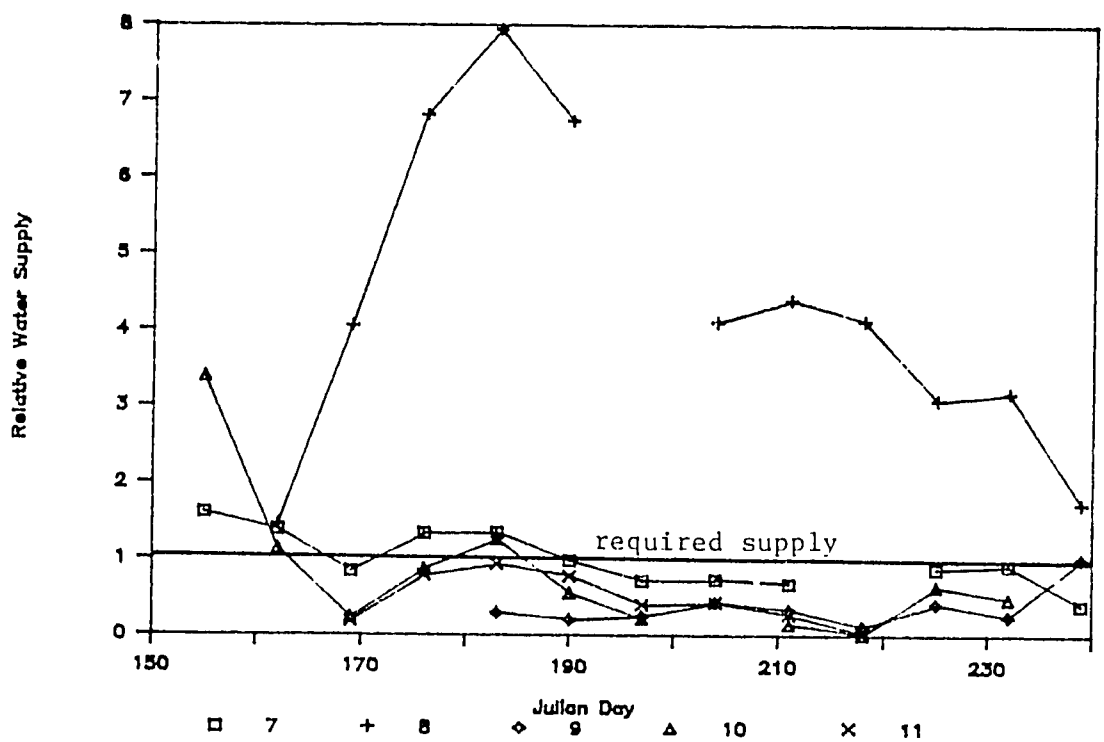

Figure 25. Relative water supply at sites 7-11 of D1, tract 1, Stage I, Kaudulla, during 1986 yala.

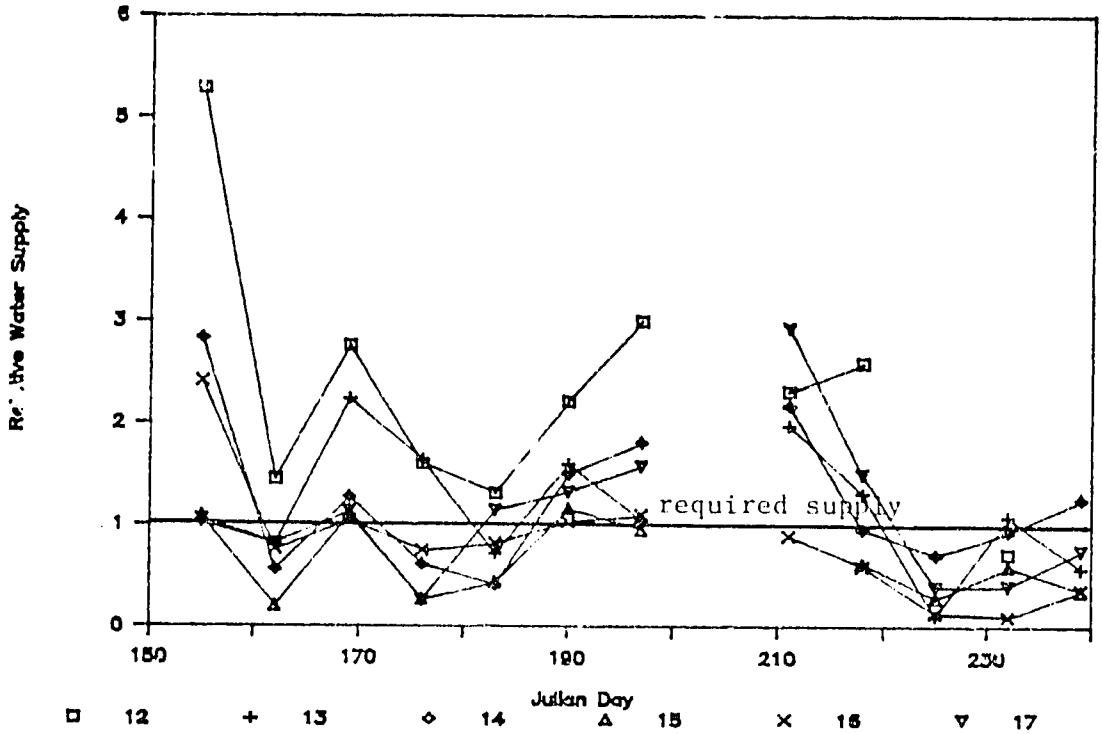

Figure 26. Relative water supply at sites 12-17 of D8, tract 4, Stage I, Kaudulla, during 1986 *yala*.

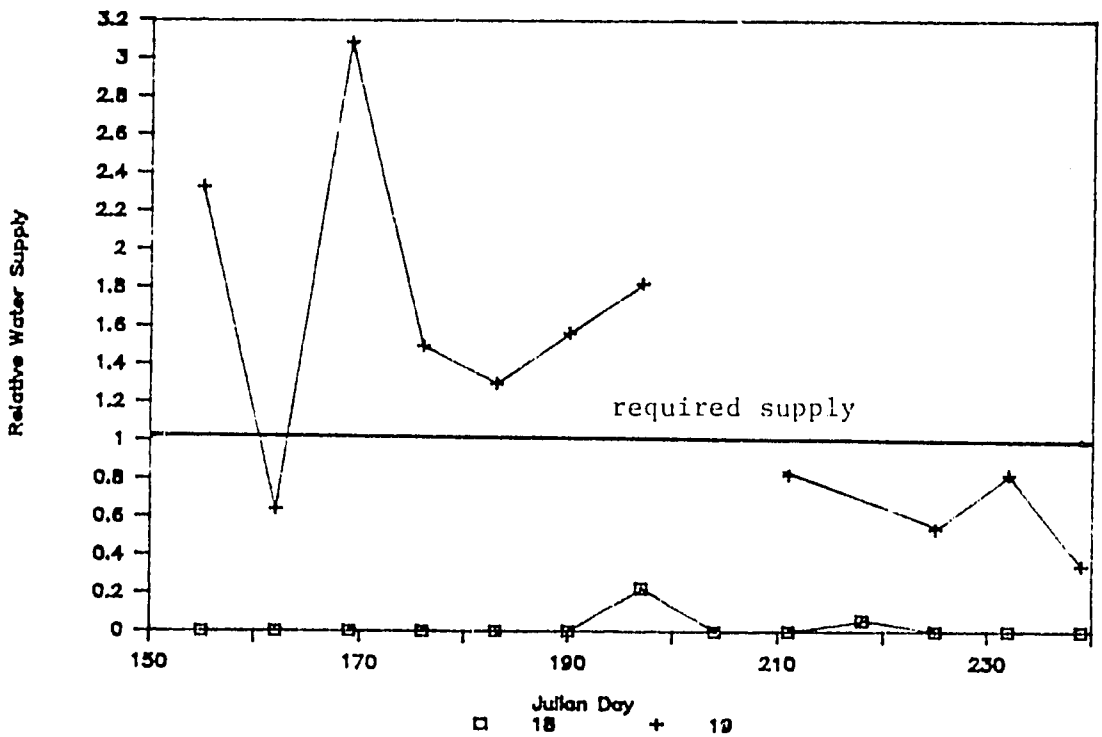

Figure 27. Relative water supply at sites 18 and 19 of D8, tract 4, Stage I, Kaudulla, during 1986 *yala*.

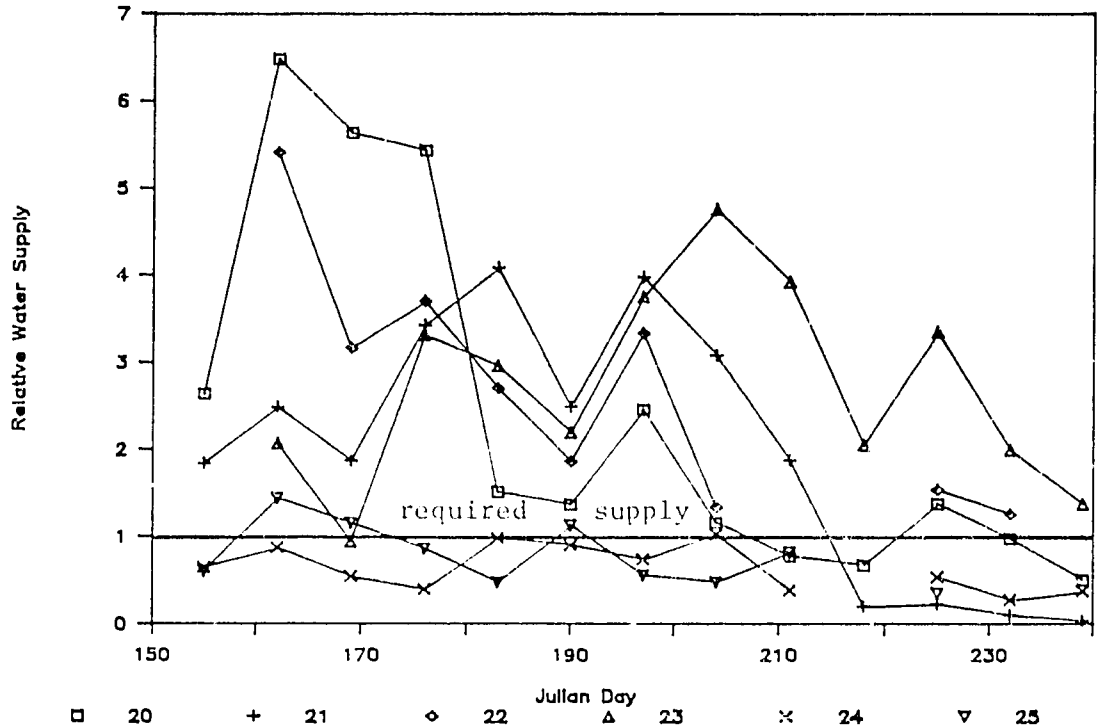

Figure 28. Relative water supply at sites 20-25 of D1, tract 8, Stage I, Kaudulla, during 1986 yala.

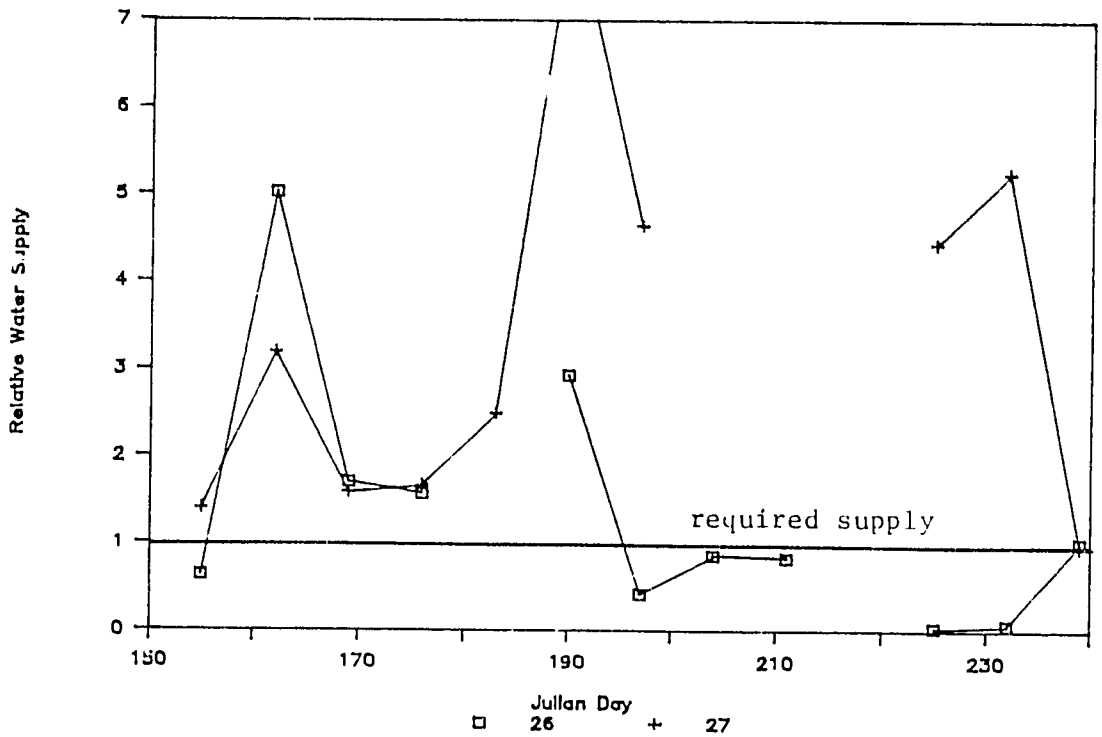

Figure 29. Relative water supply at sites 26 and 27 of D1, tract 8, Stage I, Kaudulla, during 1986 yala.

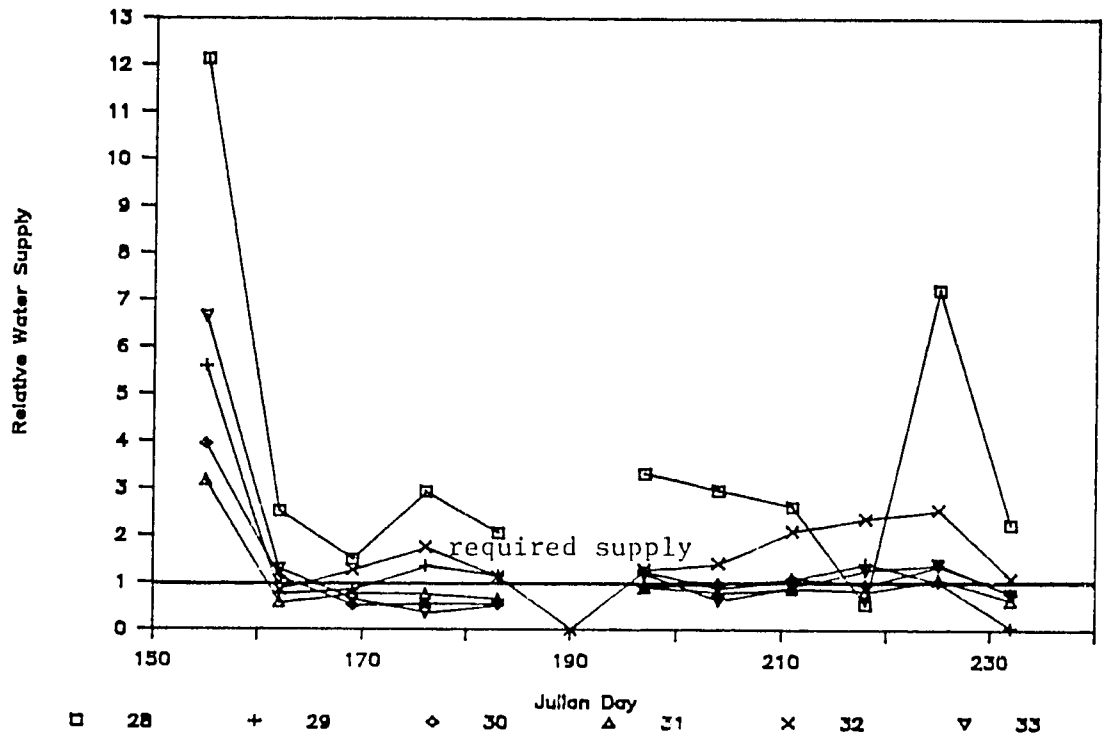

Figure 30. Relative water supply at sites 28-33 of LB main, tract 1, Stage II, Kaudulla, during 1986 yala.

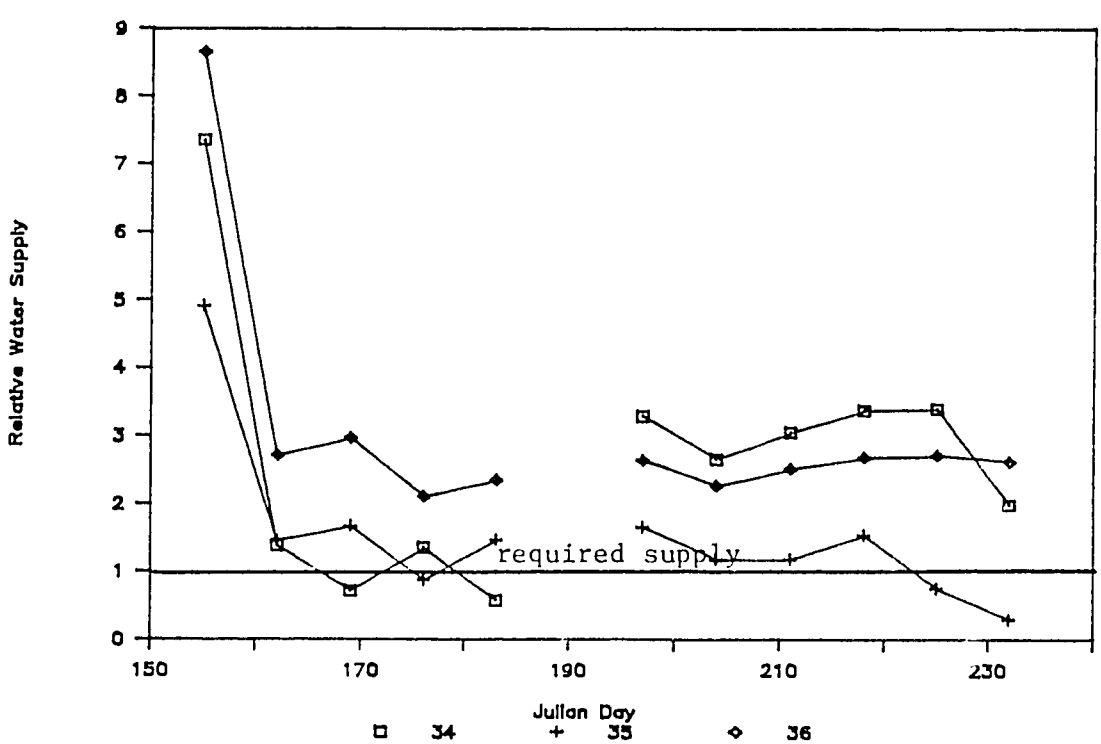

Figure 31. Relative water supply at sites 34-36 of LB main, tract 1, Stage II, Kaudulla, during 1986 yala.

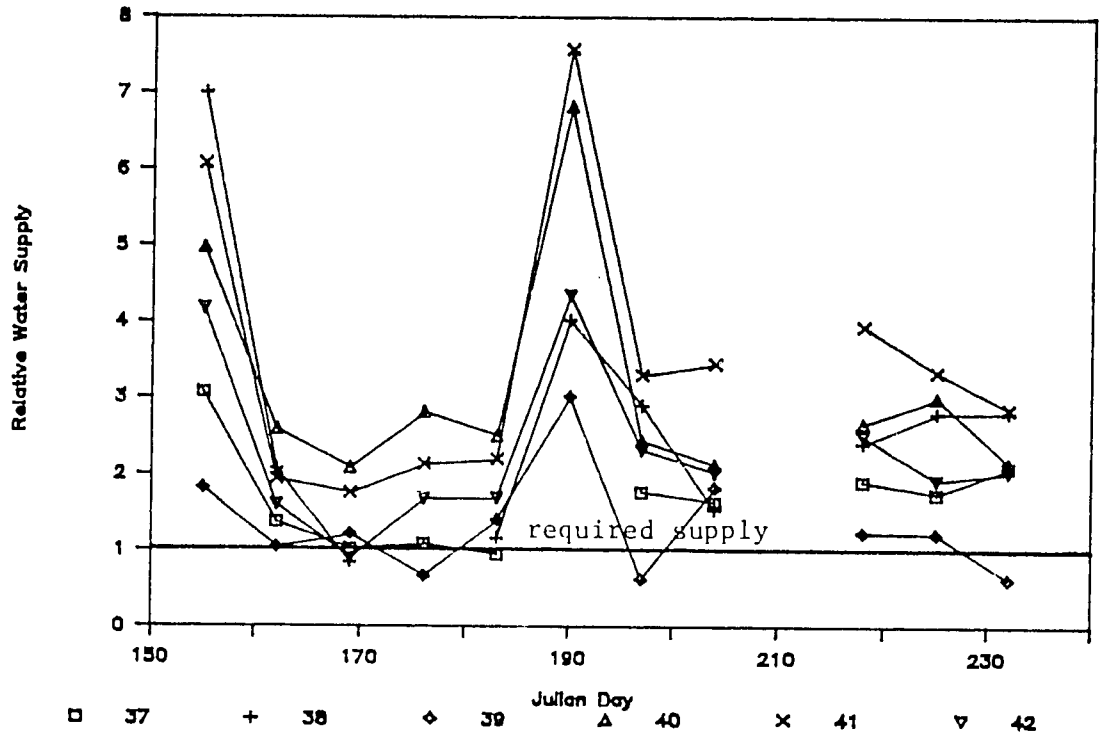

Figure 32. Relative water supply at sites 37-42 of D1, tract 4, Stage II, Kaudulla, during 1986 yala.

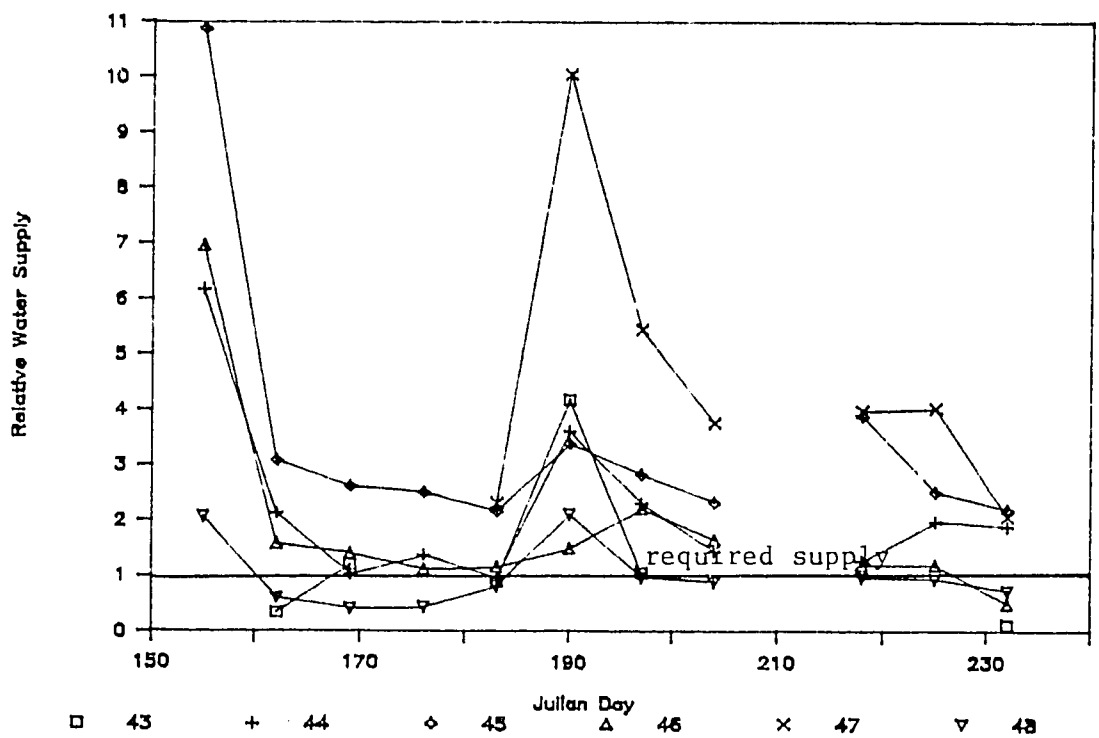

Figure 33. Relative water supply at sites 43-48 of D1, tract 4, Stage II, Kaudulla, during 1986 yala.

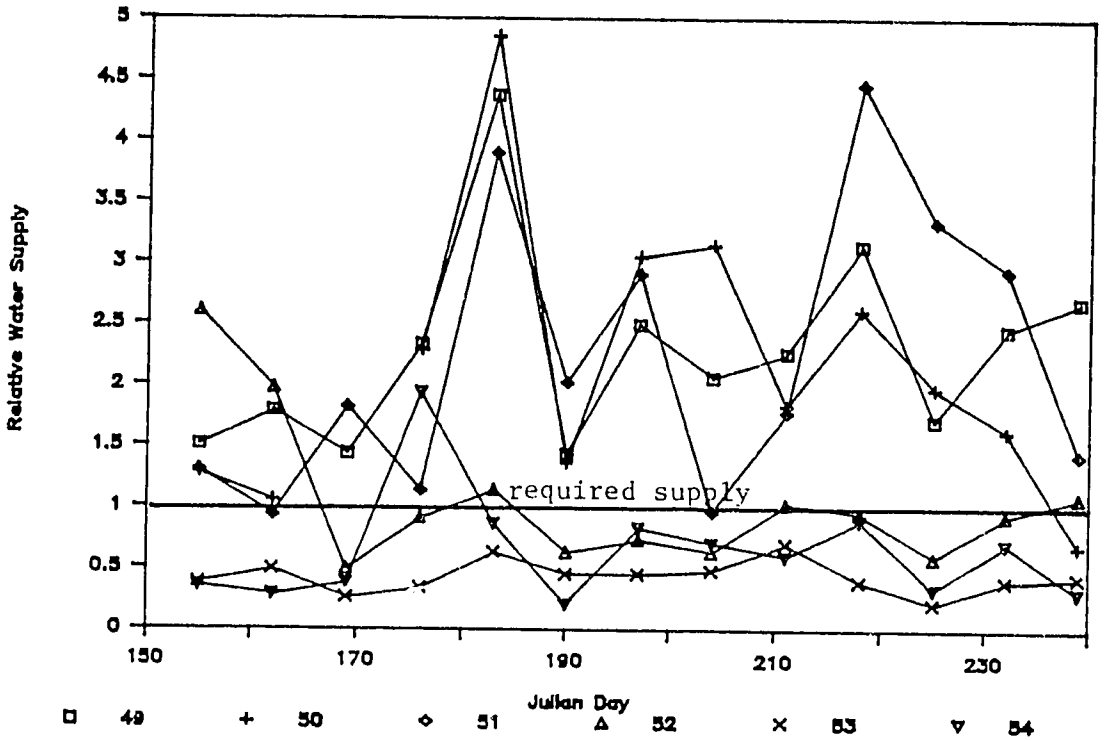

Figure 34. Relative water supply at sites 49-54 of D2A, tract 12, Stage II, Kaudulla, during 1986 yala.

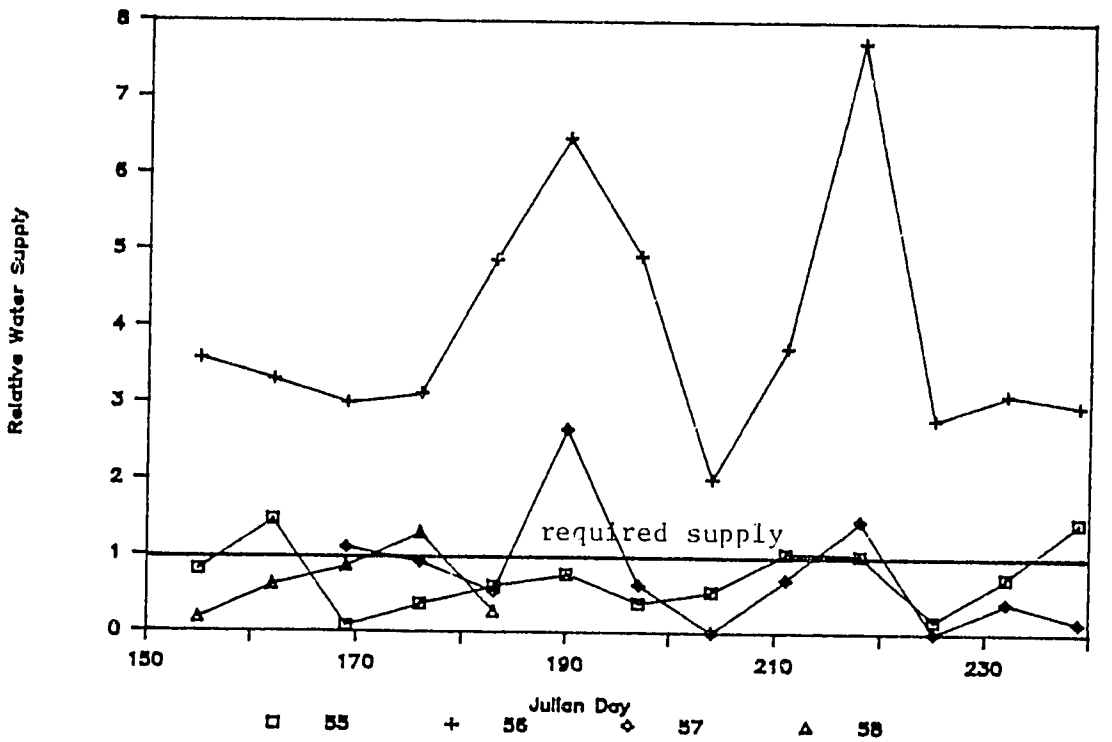

Figure 35. Relative water supply at sites 55-58 of D2A, tract 12, Stage II, Kaudulla, during 1986 yala.

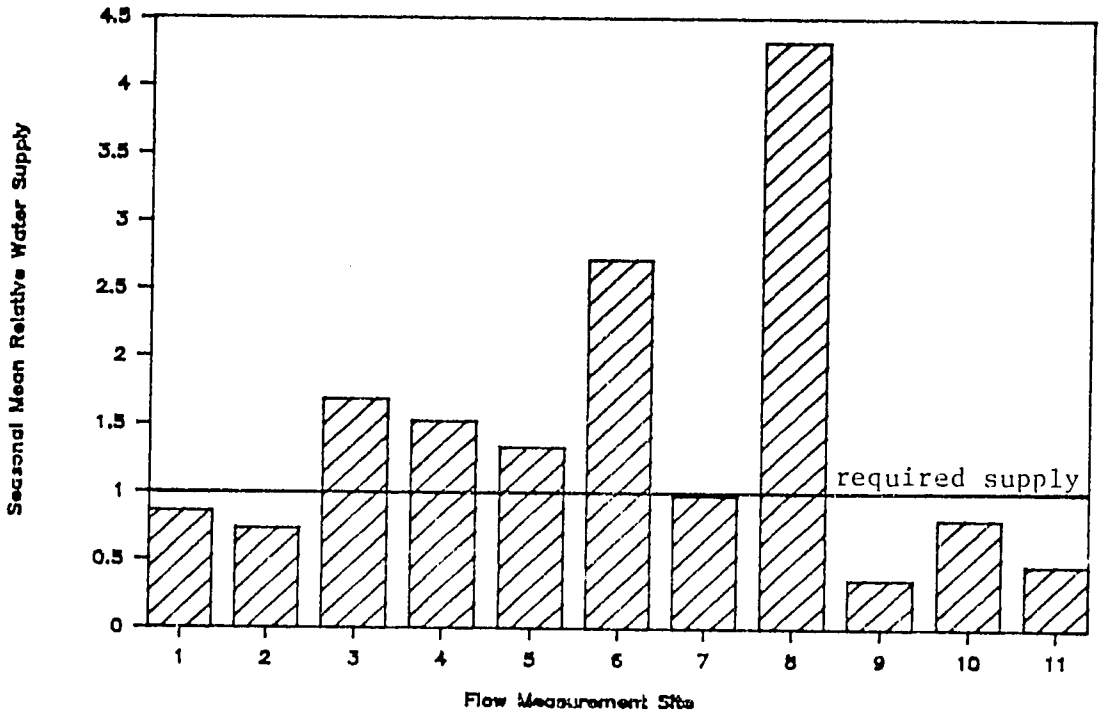

Figure 36. Seasonal mean relative water supply at sites on D1, tract 1, Stage I, Kaudulla, during 1986 yala.

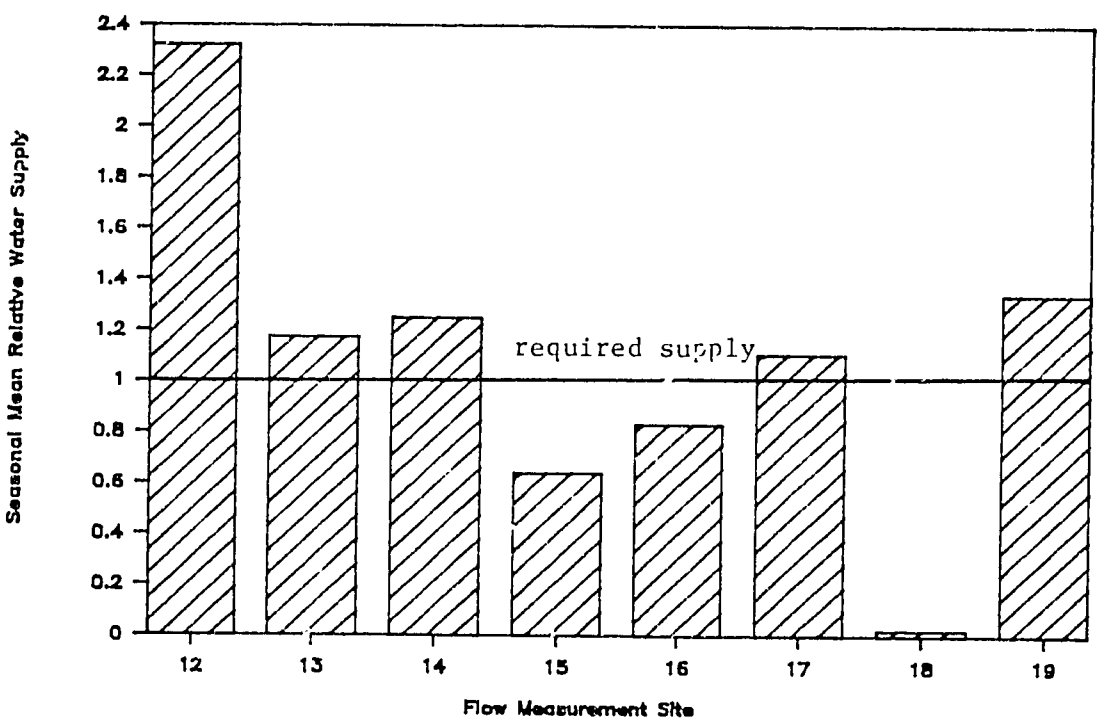

Figure 37. Seasonal mean relative water supply at sites on D8, tract 4, Stage I, Kaudulla, during 1986 yala.

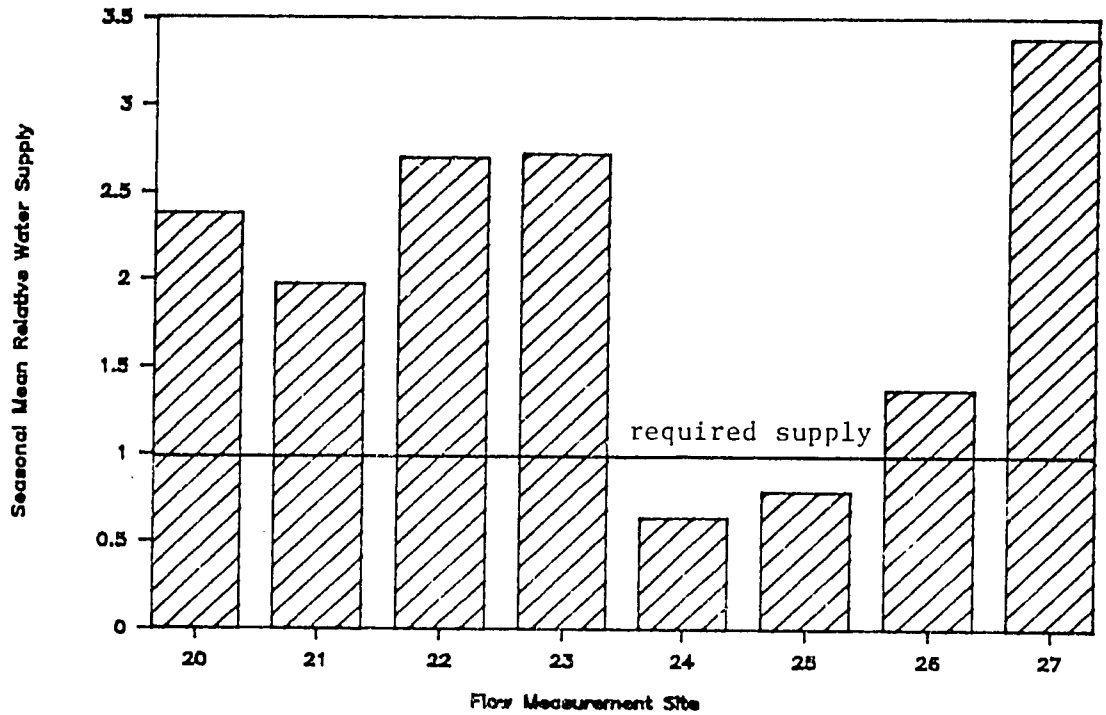

Figure 38. Seasonal mean relative water supply at sites on D1, tract 8, Stage I, Kaudulla, during 1986 yala.

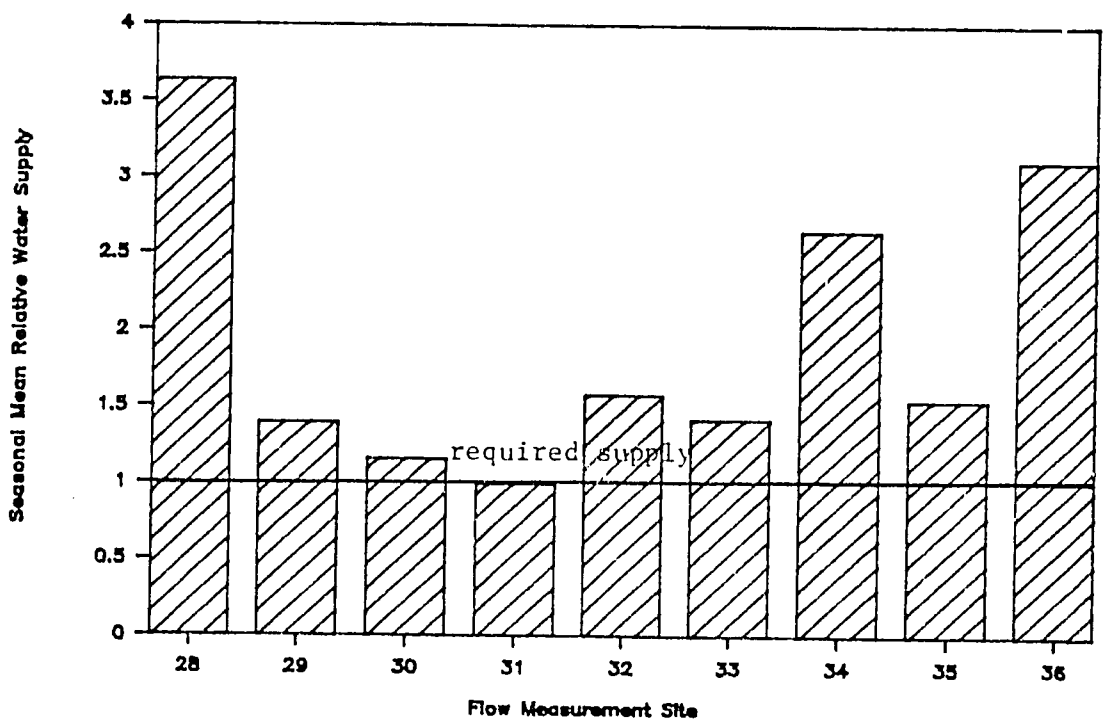

Figure 39. Seasonal mean relative water supply at sites on LB main, tract 1, Stage II, Kaudulla, during 1986 yala.

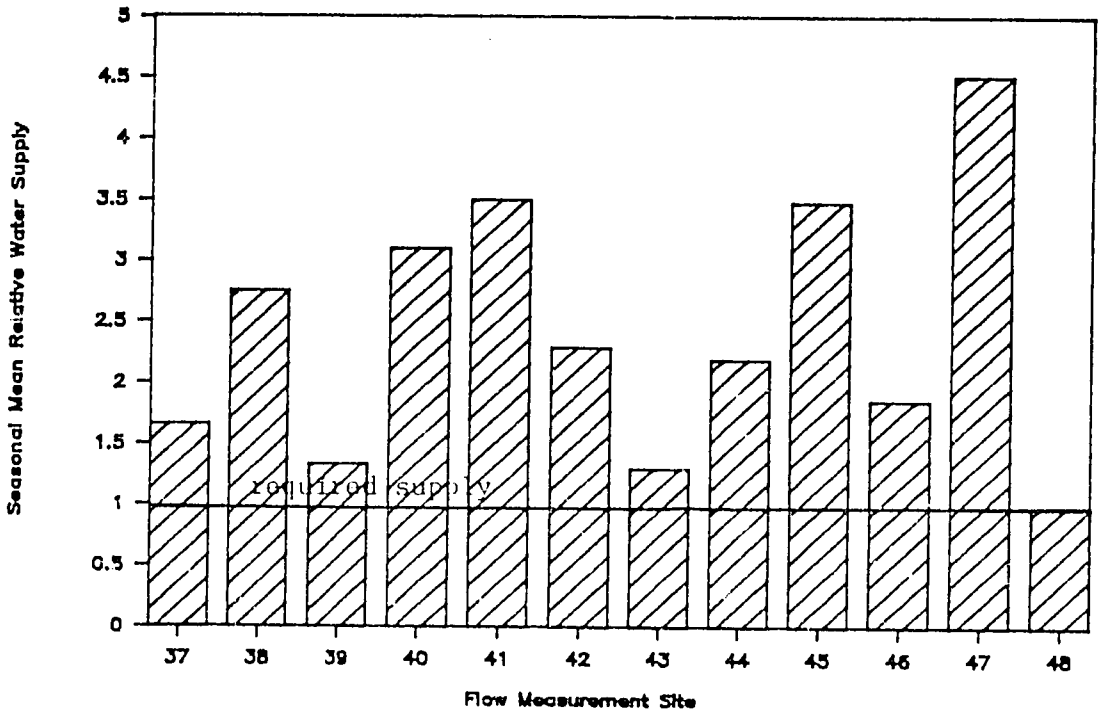

Figure 40. Seasonal mean relative water supply at sites on D1, tract 4, Stage II, Kaudulla, during 1986 yala.

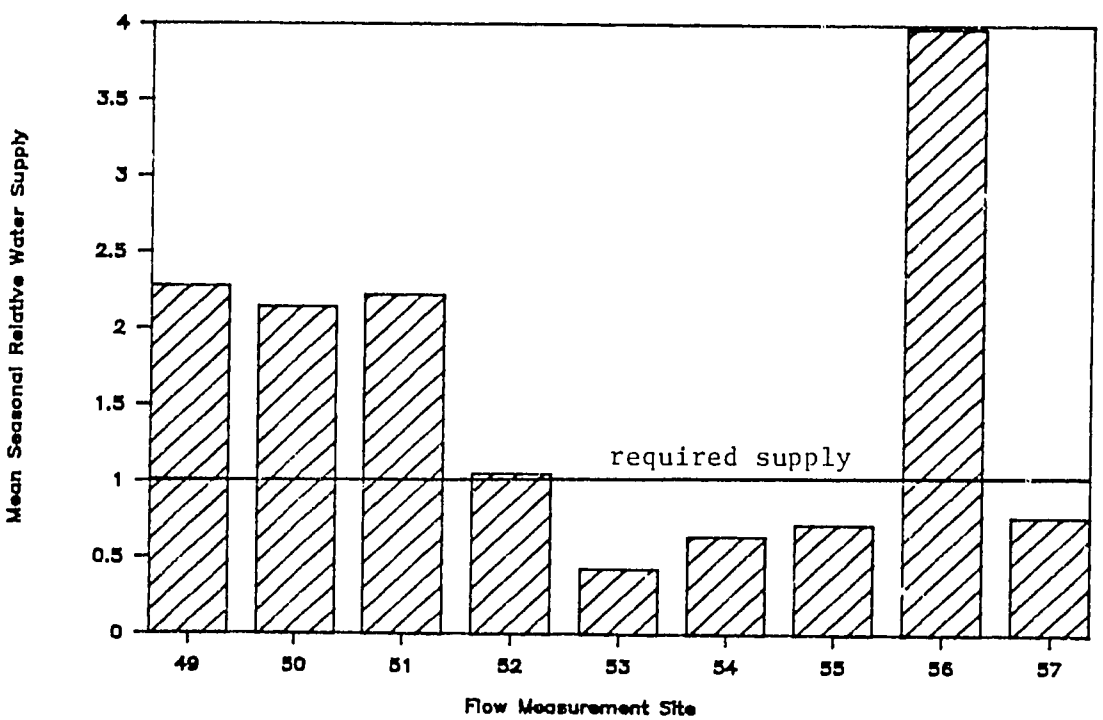

Figure 41. Seasonal mean relative water supply at sites on D2A, tract 12, Stage II, Kaudulla, during 1986 yala.

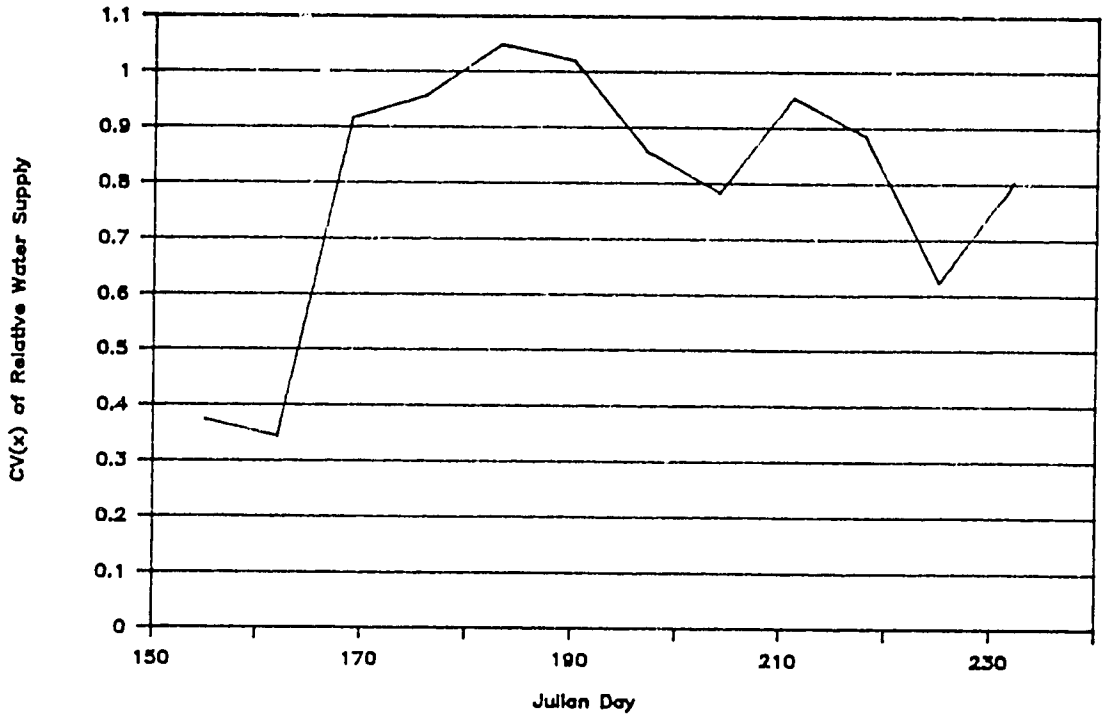

Figure 42. Spatial coefficient of variation in relative water supply among sites on D1, tract 1, Stage I, Kaudulla, during 1986 yala.

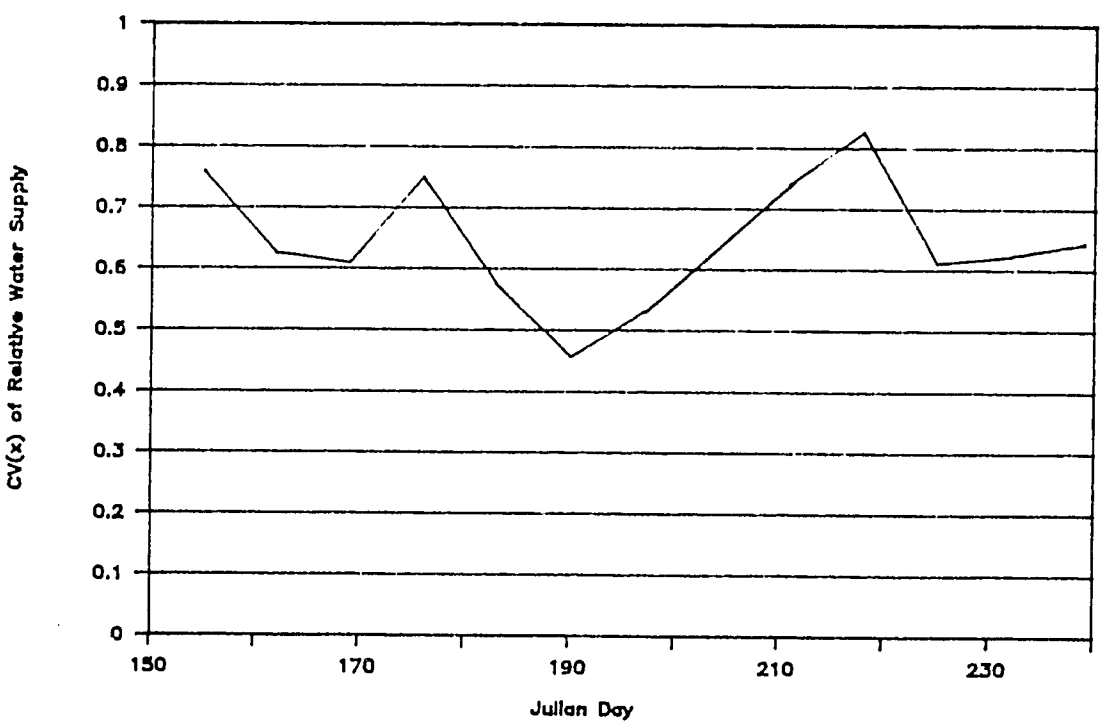

Figure 43. Spatial coefficient of variation in relative water supply among sites on D8, tract 4, Stage I, Kaudulla, during 1986 yala.

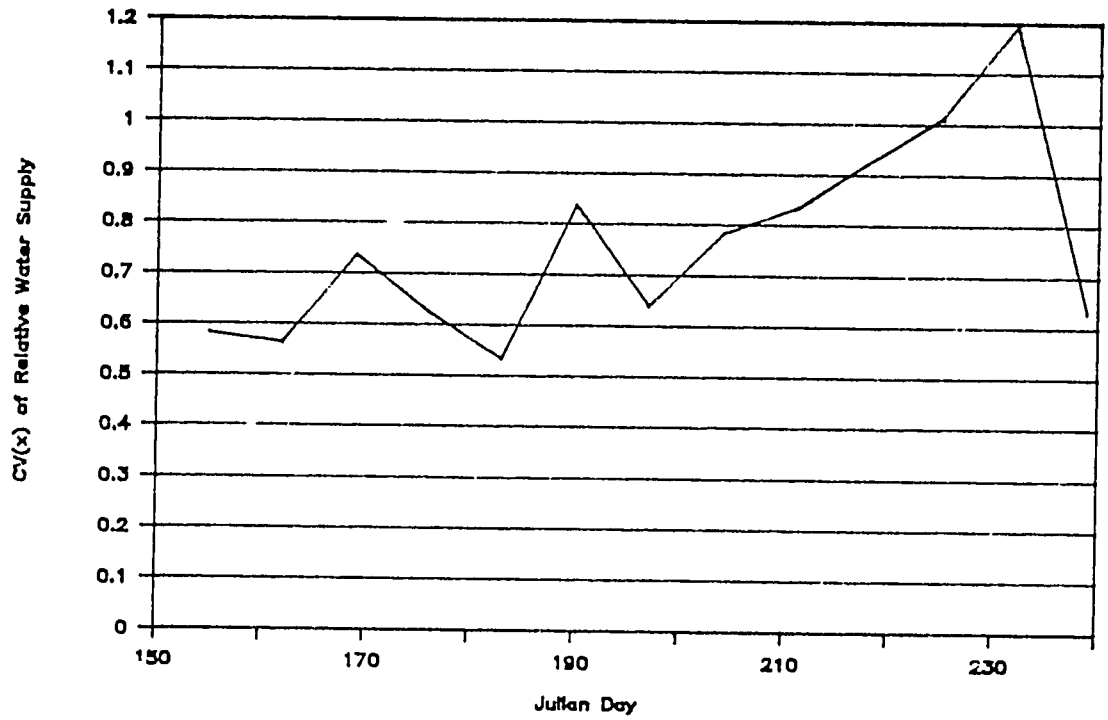

Figure 44. Spatial coefficient of variation in relative water supply among sites on D1, tract 8, Stage I, Kaudulla, during 1986 yala.

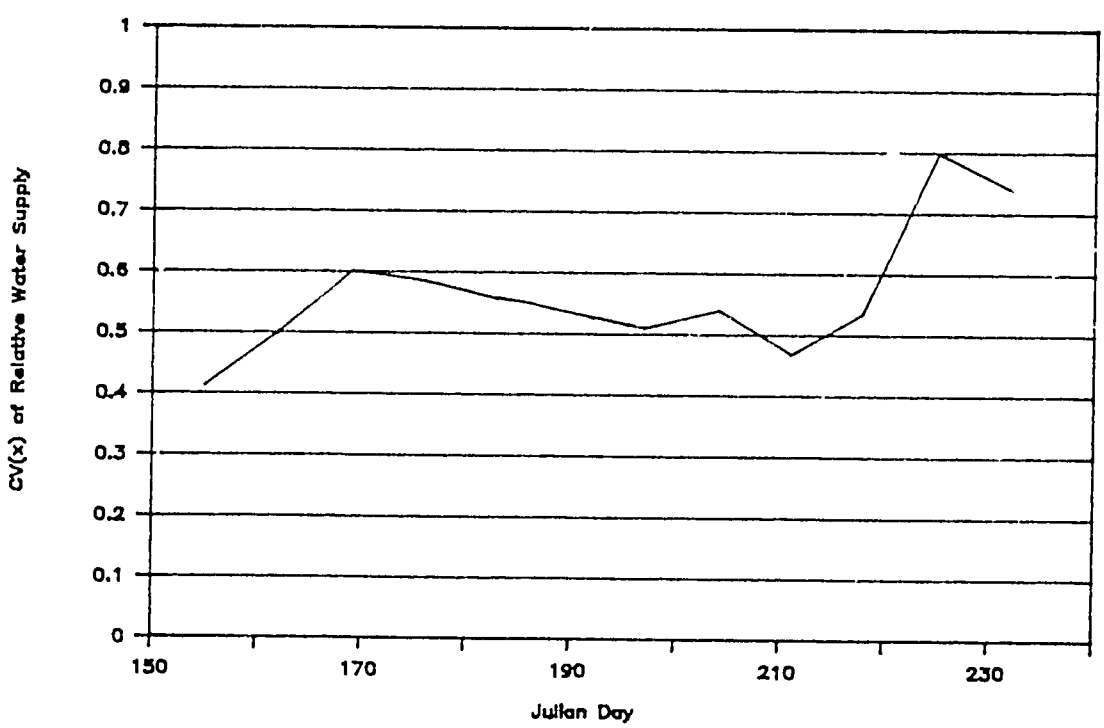

Figure 45. Spatial coefficient of variation in relative water supply among sites on LB main, tract 1, Stage II, Kaudulla, during 1986 yala.

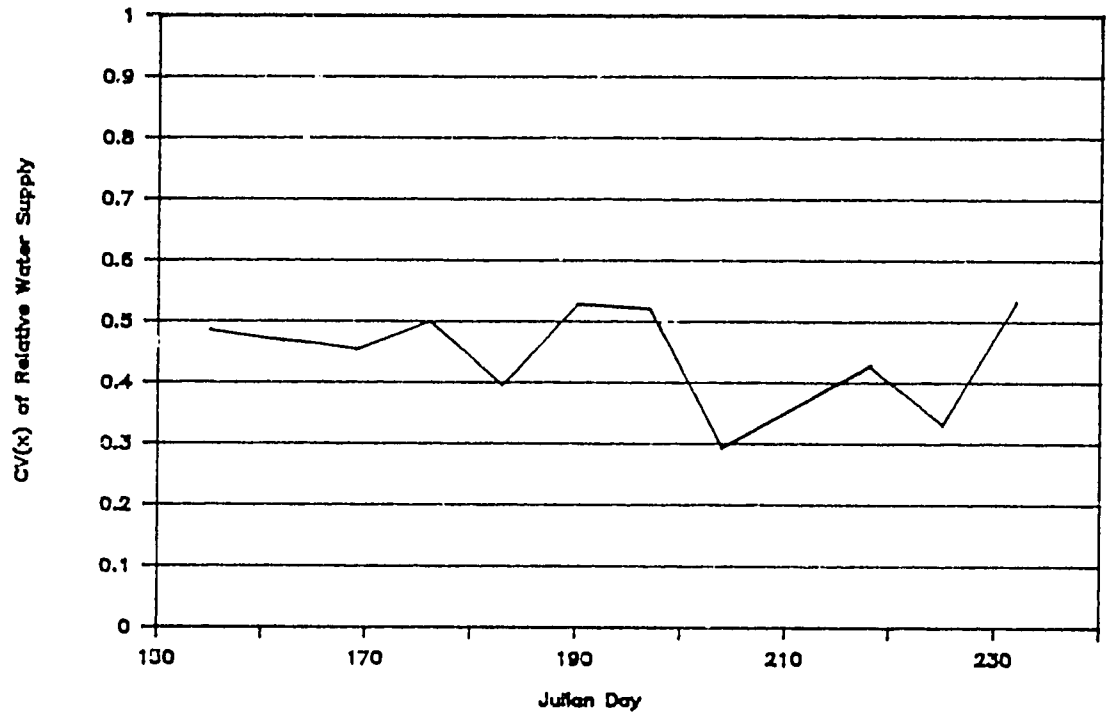

Figure 46. Spatial coefficient of variation in relative water supply among sites on D1, tract 4, Stage II, Kaudulla, during 1986 yala.

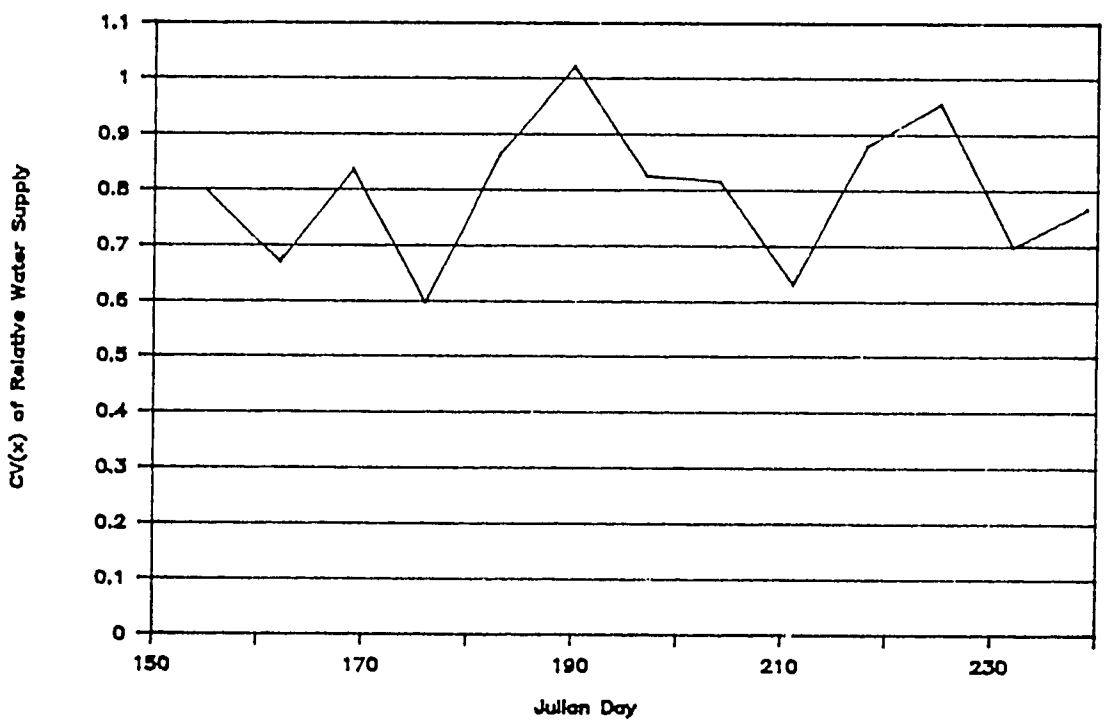

Figure 47. Spatial coefficient of variation in relative water supply among sites on D2A, tract 12, Stage II, Kaudulla, during 1986 yala.

Table 6. Statistics of seasonal water supply for Kaudulla Scheme, 1986 *yala*.

Measurement Site	Mean Supply (mm/day)	RWS Mean	RWS CV(t)	Mean WUE
1	7.39	0.86	0.64	0.94
2	7.45	0.73	0.28	1.00
3	17.19	1.69	0.33	0.64
4	14.67	1.53	0.28	0.70
5	13.24	1.33	0.28	0.75
6	26.78	2.72	0.31	0.42
7	9.45	0.98	0.35	0.90
8	44.73	4.33	0.46	0.30
9	3.72	0.36	0.68	1.00
10	6.64	0.81	1.12	0.91
11	4.97	0.47	0.64	1.00
12	19.43	2.32	0.52	0.52
13	11.05	1.17	0.50	0.82
14	10.66	1.25	0.56	0.80
15	5.86	0.64	0.55	0.97
16	7.00	0.83	0.69	0.94
17	10.04	1.11	0.62	0.84
18	0.23	0.02	2.67	1.00
19	12.32	1.34	0.59	0.76
20	25.22	2.38	0.84	0.64
21	20.92	1.98	0.71	0.58
22	28.71	2.70	0.48	0.46
23	27.87	2.72	0.40	0.44
24	6.81	0.64	0.39	1.00
25	8.26	0.79	0.43	0.94
26	14.47	1.37	1.02	0.80
27	35.84	3.39	0.64	0.44
28	29.64	3.64	0.86	0.42
29	10.21	1.40	0.98	0.84
30	8.62	1.16	0.79	0.89
31	7.93	1.00	0.70	0.93
32	15.27	1.58	0.35	0.70
33	9.72	1.42	1.19	0.84
34	21.28	2.65	0.68	0.52
35	12.60	1.54	0.74	0.74
36	26.16	3.11	0.57	0.37
37	14.68	1.66	0.36	0.67
38	20.88	2.75	0.61	0.49
39	11.29	1.33	0.50	0.78
40	25.62	3.10	0.45	0.37
41	28.41	3.50	0.50	0.35
42	18.72	2.29	0.44	0.51
43	9.98	1.30	1.04	0.84
44	16.82	2.19	0.66	0.60
45	27.04	3.48	0.69	0.35

Table 6. (Continued)

Measurement Site	Mean Supply (mm/day)	RWS Mean	RWS CV($\bar{t}$)	Mean WUE
46	13.96	1.85	0.90	0.70
47	38.69	4.52	0.55	0.28
48	7.86	0.99	0.56	0.91
49	23.54	2.28	0.34	0.48
50	22.35	2.14	0.51	0.57
51	22.68	2.22	0.50	0.57
52	11.06	1.05	0.54	0.90
53	4.44	0.43	0.30	1.00
54	6.68	0.64	0.68	0.96
55	7.42	0.73	0.58	0.95
56	40.59	3.97	0.39	0.29
57	7.85	0.78	0.95	0.91
58	-	-	-	-

measured. Water supply was severely inadequate (RWS < 0.8) at about 20 percent of the measurement points. When crops suffer this degree of water shortage, yield reductions usually occur. However, the magnitude of the reductions depends on other agricultural practices and the stage of crop growth.

b. Spatial Variability of Delivery

Coefficient of Variation in RWS. Values of $CV(\bar{x})_{RWS}$ were computed for weekly time periods and plotted in Figures 42 through 47 for each of the distributary canals. The lines plotted in these figures give the values of $CV(\bar{x})_{RWS}$ over time for a particular distributary channel. The range of values is given in Table 7.

A variability of $\pm$ 10 percent from the spatial indicated that relative water supply was considered acceptable in this analysis. Results showed in all cases that the spatial variability in RWS significantly exceeded this allowance (i.e., $CV(\bar{x})_{RWS} > 0.10$) along each of the distributary canals throughout 1986 *yala*. These high values for $CV(\bar{x})_{RWS}$ meant that all points in the system were not receiving the same relative supply of water within an acceptable margin of variability. Hence, the water supply was not equitable throughout the system.

Trends in Variability. A study of Figures 36 through 41 did not clearly indicate the existence of any spatial pattern or trend in the relative water supply. For instance, a field channel located near the tail of D1, tract 1, Stage I, had a RWS of about 4.3, while a field channel at the head of the same canal had a RWS of only 0.85. On the other hand, another field channel near the end of D1, tract 1, Stage I, had a similarly low RWS of about 0.80. On canal D1, tract 4, Stage II, all of the measured points at the head and at the tail received adequate water.

Table 7. Range in coefficient of variation in relative water supply over time for study sites in Kaudulla Scheme, 1986 *yala*.

Site	$CV(\bar{x})_{RWS}$
Stage I	
D1, tract 1	0.34-1.05
D8, tract 4	0.53-0.83
D1, tract 8	0.53-1.20
Stage II	
LB main, tract 1	0.41-0.80
D1, tract 4	0.29-0.53
D2A, tract 12	0.60-1.02

Abernethy (1985) reported that tracts at the tail of Kaudulla Scheme appeared to have a higher temporal variability of water delivery, but did not sufrer from water shortages. In the diagnostic analysis, it was observed that 45 percent of the points measured on Canal D2A, tract 12, Stage II, located at the tail of the scheme, had inadequate water. However, in general the results do not show shortages to be characteristically unique to the end reaches of the system.

Water Use Efficiency. Values of seasonal mean water use efficiency computed for each of the observation points are given in Table 6. Values ranged from 0.28 to 1.0, and for about 60 percent of the sites they were relatively high (> 0.70). However, at many of these sites, high efficiency was gained at the expense of inadequate supply to meet the water requirements. At the remaining 40 percent of the sites, a considerable amount of water was lost apparently by surface runoff. Large surface runoff losses were also noted by Abernethy (1985).

In addition to the above, the degree of levelness of farms was also studied. For each *liyadda*, the range of levels (difference between maximum and minimum levels) and the area of the level differences were calculated. The mean excess heights varied from 0.04 ft to 0.29 ft. The minimum mean excess depth of 0.04 ft occurred in one *liyadda* in Kaudulla Scheme (Table 8).

Seasonal Variability of Water Supply. Values of $CV(\bar{t})_{RWS}$ computed over weekly values of RWS are summarized in Table 6. Values were considered excessive when they were outside an acceptable range of variability of $\pm$ 10 percent from the mean (i.e., $CV(\bar{t})_{RWS} > 0.10$). Values were relatively high (> 0.10) for each of the points of observation, indicating significant temporal variability in relative water supply in Kaudulla Scheme. This variability constituted poor system reliability since farmers could not expect a consistent level of water supply.

Table 8. Mean excess heights and frequency of occurrence in Kaudulla study liyaddas, 1986 yala.

Range of Liyadda Sizes (ft^2)	Mean Excess Heights (ft)					
	0.0-0.05	0.05-0.10	0.10-0.15	0.15-0.20	0.20-0.25	0.25-0.30
<3000	1	5	2	2	1	1
3000-6000	0	6	1	1	0	0
6000-9000	0	0	1	1	0	0
9000-over	0	0	0	0	0	0

c. Channel Conveyance Characteristics

Data on channel cross sections and bed slopes indicated that channel conveyance characteristics differed significantly from the design profiles given by the Irrigation Department (1981). In many cases, bed widths were larger and channel slopes were steeper than originally designed. The most frequently found adverse physical features of the field channels are identified and tabulated in Table 9 in order to identify their effect on adequacy and equity.

Studies were conducted on five field channels for roughness. Four field channels gave reliable results. The estimated values of Manning's 'n' are given in Table 10. However, further studies on canal roughness and other flow control characteristics are recommended, as they would be useful in future consideration of system rehabilitation.

Note that the channels selected in this study for water supply measurement had relatively steep slopes since such conditions facilitated the setting of the flumes under free flow conditions.

The pipe outlet elevations seem to vary considerably with respect to both the farm and the channel bed. The results are given in Table 11, and the implications are discussed in the on-farm engineering results.

4. CONCLUSIONS: SYSTEM PERFORMANCE, PROBLEMS, AND CONTRIBUTING FACTORS

a. Adequacy

This study revealed that many points in Kaudulla Scheme received inadequate water supply from the delivery system. There seemed to be several inter-related factors that contributed to this problem.

The canal network in Kaudulla apparently was designed to deliver water continuously. However, in 1986 yala the system operated on a rotation schedule in which most distributary canals received water 4

Table 9. The relationship between water supply and physical features of the canals on Kaudulla, 1986 yala.

Field Channel	Gradient (Bed slope)	Adverse Feature Present*	Seasonal Mean RWS**				CV_t***			
			Intake	Head	Middle	Tail	Intake	Head	Middle	Tail
Stage I Tr1										
FC3	NA	a, e	0.86		0.73	1.69	0.64		0.28	0.33
FC9	0.0006	e, t	1.53				0.28			
FC10A	NA	t	1.33				0.28			
FC37	NA	e, g	2.72				0.31			
FC38	0.0026	c, g	0.98		4.33	0.36	0.35		0.46	0.68
FC36(tail)			0.81			0.47	1.12			0.64
Stage I Tr4										
LB1	0.0009	c, e, f	2.32	1.17		1.25	0.52	0.50		0.56
LB3	0.0024	a, c, e, f	0.64				0.55			
LB5	0.007	a, d	0.83		1.11	0.02	0.69		0.62	2.67
LB7	0.0023	a	1.34				0.59			
Stage I Tr8										
FC1	0.0024	a, d, e	2.38	1.98	2.7		0.84	0.71	0.48	
FC10	0.00018	b, c, e	2.72****				0.40			
FC11	0.00065	c, e	0.64				0.39			
FC16	0.00045	e	0.79	1.37	3.39		0.43	1.02	0.64	
Stage II Tr1										
FC3	0.0089	a, d, e, g	1.16		1.00	1.58	0.79		0.70	0.35
FC4	0.01	a, c, g	1.42				1.19			
FC7	0.00019	b, c, e, f	2.65		1.54		0.68		0.74	
Stage II Tr4										
FC2	0.0039	a, c, e, g	1.66	1.33	2.75		0.36	0.50	0.61	
FC1(tail)	0.0023	a, e, f	3.10				0.45			
FC9	0.0006	c, f	3.5	2.29		1.3	0.50	0.44		1.04
FC21	0.005	a, e	2.19				0.66			
FC17	0.004	a, g	3.48		1.85	4.52	0.69		0.90	0.55
FC23	0.0014	a, e	0.99				0.56			
Stage II Tr12										
FC22	0.0011	a	2.28	2.14		2.22	0.34	0.51		0.5
FC26	0.0044	a, d	1.05	0.64		0.73	0.54	0.68		0.58
FC27	0.0037	c, e, g	0.43				0.30			
FC25	negative 0.0029	c, e	3.97		0.78		0.39		0.95	

*a = Average canal bed slope larger than specified.
b = Average canal bed slope smaller than specified.
c = Average canal bed slope larger in the tail region.
d = Average canal bed slope larger in the head region.
e = Canal bed and canal bunds uneven.
f = Canal bed rises above intake sill level.
g = Sub-field channel.
**RWS = Relative water supply.
***CV_t = Coefficient of variation over time.
****2.72 becomes 1.95 when uncommanded areas are included.

Table 10. Summary of roughness coefficients (Manning's n) for Kaudulla study sites, 1986 *yala*.

Field Channel	Rel. Slope	Manning's n	Discharge (cfs)
10/Stage I/tract 4	0.00195	0.044	0.60
7/Stage II/tract 1	0.00095	0.0293	3.75
1/Stage II/tract 1	0.00113	0.0538	2.80

Table 11. Elevations of field channel bed and farm with respect to farm pipe outlet sill, Kaudulla, 1986 *yala*.

Field Channel	Allotment	FC Bed Elev. (ft) Above	FC Bed Elev. (ft) Below	Farm Elev. (ft) Above	Farm Elev. (ft) Below
Stage I, tract 1					
3	1	0.06			0.06
	2		0.00		0.03
36	1		0.23	0.90	
	2		0.26		0.34
38	1		0.17		0.80
	2		0.00		1.10
9	1		0.08		0.58
	2		0.02		0.42
10A	1	0.04			0.77
	2		0.02		0.17
	3		1.99		1.35
Stage I, tract 4					
LB7	1	0.05			0.00
	2				
LB5	1		1.00		0.93
	2		0.95		0.93
LB1	1		0.75		1.10
	2	0.05			0.20
Stage I, tract 8					
1	1	0.10			0.68
10	1	0.08			1.50
	2	0.20			0.09
11	1	0.11			2.04
	2	0.04			0.06
Stage II, tract 1					
1	1	0.00			1.19
	2	0.00			1.29

days/week. Since the duration of water supply was reduced by a factor of 4/7, the flow rates must be increased by a factor of 7/4 over those required for a continuous flow system. This would require correspondingly larger carrying capacities in the canals and field channels than were originally designed.

In some parts of the system, increased flow did not pose a serious problem since adequate freeboard existed in the original design and since, in many instances, channel cross-sections and bed slopes have increased over time. However, where channel cross-sections have deteriorated due to sloughing banks, silting and deposition, and uncontrolled growth of weeds and aquatic plants, the problem of low capacity was compounded and adequate flows could not be delivered.

Longitudinal sections of some field channels show that the channel bed rises to an elevation above the offtake sill immediately after the offtake due to silt deposition. The silt deposition is a likely result of reduced flow velocity due to expansion immediately after the offtake. The change in elevation reduces the offtake discharge because the effective head in the distributary channel is reduced.

Some of the field channels selected for the study were sub-field channels, most of which branched off at a right angle to the parent field channel. Hence, the supply to the sub-field channel depended on the availability of a regulating structure in the parent field channel. Most sub-field channels had comparatively lower relative water supply. The lack of regulating structures probably contributed to this.

Similarly, the condition of the regulating structures in the distributary channels affected the flow into the field channels. A comparison of LP014 and LP016, which take off from the same distributary channel and have more or less identical conditions at the intake, demonstrates this effect. Although LP016 was downstream of LP014, the former had a greater RWS. This is because a well-functioning drop structure to regulate the flow was present downstream of LP016.

The Manning's n values calculated are considerably higher than the values assumed in the design. However, further study on the subject is suggested. It was observed that some of the channel beds and bunds were uneven. This reduces the channel capacities and results in wastage of water.

There are other possible causes of inadequacy. Unauthorized land cultivation has increased over the last several years resulting in a total command area that was about 4 percent to 7 percent greater than that for which the system was designed to serve (Abernethy, 1985). There were inadequate hydraulic structures for controlling and monitoring the distribution of flows within the system. Canal banks leaked heavily in some places due to heavy vehicular traffic. Also, there was no explicit operational agenda by which farmers and irrigation officials were organized to manage the allocation of flows.

Although water supplies were inadequate at several points in the system, farmers often acquired the water they needed from drains, from runoff from adjacent allotments outside the command area, or from illegal extraction of water from the distributary canals.

The estimate for seepage and percolation from paddy lands constitutes what is, perhaps, the largest source of error in the determining field water requirements. Since the spatial variability of this phenomenon is significant and may make up a large part of the total water requirement at any given site, more research needs to be conducted in its determination.

b. Equity

There was a fairly high degree of spatial variability in the water supply, with some points receiving excess water and others suffering from severe shortages. This inequity did not appear to follow the often observed pattern where field channels near the head of the system receive more water than those near the tail.

The bed slopes of field channels varied in magnitude by a considerable amount. The variation was not only between field channels, but within the field channel itself. Some of the field channels showed very high gradients, probably due to poor maintenance of channel structures. Some had very mild slopes, which were evident in channels with no structures for a considerable length.

Within the field channel itself, variation of the bed slope was observed. In some cases, the slope at the tail region was higher than that at the head. This might contribute to the farmer at the head getting a higher supply.

The pipe outlets seemed to be located at varying elevations with respect to the channel bed and farm surface. Sometimes the farm seemed to be at a higher elevation than both the pipe outlet and the channel bed. These farms experienced water shortages, and many farmers resorted to illicit tapping at a more convenient location on the channel. Illicit tapping affects the water control and, subsequently, the equity of water distribution.

There are several other factors which influence equity of water distribution: inadequate water measuring structures, unauthorized placement of temporary dams and obstructions in channels to control water levels, inadequate cooperation among farmers for scheduling irrigations along field channels, and illegal extraction of water from the system.

c. Efficiency

Overall, the water use efficiency was fairly high. This was due in a large part to inadequate water supply. However, at several points in the system the water use efficiency was quite low, indicating loss to surface runoff. These losses were, to some extent, a consequence of the spatial variability in water supply since some points in the system

received more water than needed. Much of the runoff water was reused from drains by less fortunate farmers, but not without exacting a cost of time and labor.

The results of the study of farmer's land leveling show that there was no significant relationship between the mean excess heights and liyadda sizes. The most and the least degrees of evenness were achieved within the same range of liyadda sizes. However, mean excess heights as low as 0.04 ft have been achieved, and a significant number of farmers have achieved less than 0.1 ft of mean excess height. The distribution of excess heights through liyaddas show that there is no appreciable gradient across liyaddas. Farmers' land leveling could be improved further, which would result in water savings and improved water use efficiency.

d. Reliability

The high values of $CV(\bar{t})_{RWS}$ observed in the system revealed significant temporal variability and thereby, poor reliability, of water supply. Such a condition was probably due in part to the unscheduled accommodations of extra water supply made by the Irrigation Department to some parts of the system and to a lack of scheduling along field channels. Also, as with inequity, the structural and operational facilities required for precise flow control were not in place.

In Kaudulla Scheme, the rotation was implemented directly from the head sluice. Trying to accommodate for local deficiency on the system by adjusting the head sluice is difficult because the transient time to effect a change in discharge at the required location can take more time than available in a rotation period. Furthermore, changes in operation to benefit a small section of the command area can affect the whole system.

C. AGRONOMY

1. INTRODUCTION

The agronomy component was responsible for providing a description of the irrigated cropping system, including assessing the major variable affecting crop production on Kaudulla Scheme. This assessment involved a description of the soils, crops, and management practices of the cultivators.

2. METHODOLOGY

The 1984 Diagnostic Analysis of Farm Irrigation Systems Workshop and a six-day reconnaissance survey in January 1985 provided the background information used to plan the detailed agronomic studies. Observations made during these two activities indicated that the cropping system was essentially a paddy monoculture of sufficient complexity to warrant daily or near daily examination. Several variables thought to affect paddy production within the field channel were identified as particularly important: size of the cultivation unit; variety of paddy; method of plant establishment; availability of water; amount, time, and type of fertilizer applied; and degree of weed and pest infestation.

a. Site Selection

Six distributary channels (three in Stage I and three in Stage II) were selected as common study sites for the diagnostic analysis (Table 12). The three distributary canals in Stage I and Stage II were selected to represent expected hydrological differences. For sampling purposes, the distributary channels were further divided into head, middle, and tail regions, from which one or more field channels were selected for detailed investigation. The field channels also represented expected hydrological differences along the distributary channel.

b. Field Personnel

Six Agricultural Diploma holders were employed as data collectors, with each assigned to one of the six distributary channels. Each diploma holder was responsible for daily collecting agronomic data in three or four selected field channels in the distributary channel study site. The Agriculture Diploma holders resided near the study site and were provided with bicycles for traveling between field channels.

An agricultural graduate from the University of Peradiniya was employed to assist the Agriculture Diploma holders in collecting and analyzing data. The agricultural graduate was provided with a motorcycle for traveling to and from the field study sites.

Table 12. Agronomy field site characteristics for Kaudulla (1986 *yala*).

	Stage I									
	Tract 1			Tract 4					Tract 8	
D-Channel	1			8					1	
Distance to sluice (mi)	1.8			6.8					10.5	
Field channels	FC3	FC38	FC36	LB1	LB5	LB7	RB2	FC1	FC11	FC16
Allotment	4	6	8	3	3	2	3	14	6	10
Total area (ac)	12	20	25	8	9	6	7	27	15	20
Cultivators	7	6	11	4	3	3	3	19	7	12

	Stage II									
	Tract 1			Tracts 4&5			Tract 12			Total
D-Channel	LB Main			D1			D2A			
Distance to sluice (mi)	1.1			4.5			0.2			
Field channels	FC1	FC3	FC4	FC2	FC98	FC17	FC22	FC25	FC27	
Allotment	15	4	2	6	9	5	11	10	7	148
Total area (ac)	26	8	4	11	16	10	24	20	14	275
Cultivators	17	4	2	9	11	9	13	11	11	159

c. Data Collection

Agronomic investigations of Kaudulla were initiated with the first water issue (April 20) and culminated with crop cuttings in September-October of 1986. Each data collector was responsible for obtaining data from all of the separately cultivated fields along the selected field channels in the study sites. (On-farm engineering measurements were conducted on the same field channels.)

During the first two weeks of the agronomic study, the data collectors met with individual cultivators to explain the purpose of the investigations and to initiate data collection. During this period

the diploma holders prepared a list of all of the cultivators in the study area. Included in this list was the address of the cultivator, his allotment number, the allotment size, the name and relationship of the legal title holder, and the names of other individuals cultivating on the same allotment during the 1986 yala. The sociology and economics components of the diagnostic analysis used this list to select cultivators for interviews.

The diploma holders also prepared field channel sketches showing drainage channels, access roads, allotments, and cropping patterns. In addition, informal discussions were held with individual cultivators to obtain information on the date of the start of land preparation, number of plowings and harrowings used, type of power used, completion date of land preparation, dates of planting, method of planting, crop variety, area sown, and any plant protection measures used.

Throughout the remainder of the irrigation season, data collectors were responsible for observing specific practices of the individual cultivators. Field observations were made daily or on alternate days in each of the selected field channels. Observations were often supplemented with informal conversations with the farmer when more detailed information, such as the amount of fertilizer or insecticide applied, was not observed. The observational data collected included date of fertilizer application, amount and type of fertilizer applied, date of insecticide application, amount and type of insecticide applied, the reason for applying the insecticide, the degree of control obtained, date of weeding, method of weeding, amount and type of weedicide applied, degree of control obtained, disease infestations, and dates of panicle initiation, flowering, and harvest.

In addition, an attempt was made to determine the relative availability of water. On alternate days (sometimes 3-4 days) the data collectors walked an established route along the bunds of the paddy fields. The route was, as near as possible, a straight line following the slope of the land. The route began in the head region of the field channel and ended at or near the drainage channel in the tail region of the field channel. The relative availability of water was recorded for each liyadda using the following scale:

0 = Below field capacity, soil surface dry, many large cracks.

1 = Field capacity or above, soil surface moist to wet with none to few cracks.

2 = 1-5 cm of standing water.

3 = > 5 cm of standing water.

Data on relative availability of water were recorded for approximately two months beginning during the vegetative period of rice growth and concluding when weed growth on the bunds impaired movement in the fields.

Other data collected in each field channel included:

* Soil pH using a colorimetric pH test kit.

* Soil fertility measured indirectly using colorimetric N-P-K plant tissue test kits. Tissue tests were conducted at or soon after panicle initiation.

* Populations of plants, productive and nonproductive tillers, and weeds were determined using a 50-cm diameter plastic ring. The ring was randomly placed in the field and the number of plants, productive and nonproductive tillers, and weeds were counted. Five replications were done.

Yala paddy yields were estimated from crop cutting surveys conducted at the end of the season. A 1-m^2 sample, replicated five times, was selected as the sampling unit. Crop cuttings were collected from sampled fields in each study site. Additional crop cuttings were conducted on fields where the cultivator planted more than one variety. Each crop cutting was conducted as follows.

One-meter square, wooden frames were randomly tossed into the field. All plants falling inside the frame were carefully harvested and placed in a burlap bag. Five crop cutting samples were collected from each field. The harvested samples were carefully removed to an appropriate place for threshing. Samples were separately threshed by foot on an 8-ft, square tarpaulin. Each sample was winnowed by hand using a kulla. The cleaned paddy was placed in separate plastic sample bags, labeled, and brought to Polonnaruwa for weighing using a triple-beam laboratory balance. Seed moisture of the paddy was determined using a seed moisture meter. After weighing, the paddy samples were returned to the cultivator.

At the end of yala, the Soil Survey Division of the Irrigation Department was contracted to conduct a detailed soil survey of the selected study sites. Upon completion of the survey, soil survey maps of each field channel were prepared.

d. Data Analysis

The initial reduction and tabulation of field data was accomplished in the field by the field assistant. Tabulated data were analyzed using either Lotus 1-2-3™ or Microstat™ software programs on a Compaq™ microcomputer. Statistical analyses included mean, frequency, and standard deviation.

3. RESULTS AND DISCUSSION

a. Unit of Cultivation

It is commonly assumed that a single farm family is associated with a 2- or 3-ac allotment at Kaudulla Scheme. However, a number of

factors have influenced the actual unit of cultivation. These include original acreage allotted, encroachment, and land fragmentation.

On Stage I of Kaudulla Scheme, the original allottees were provided with approximately 3 ac of lowland and 2 ac of highland. On Stage II of Kaudulla Scheme, original allottees were provided with approximately 2 ac of lowland and 1 ac of highland. The lowland acreage was designated for irrigated paddy production and the highland for use as a homestead. Blocking out plans prepared during the settlement periods indicated that the original lowland allotments actually varied in size from 2-6 ac in Stage I and from 1-4 ac in Stage II. Similar differences in allotted acreages for the highland homestead were noted. While topographical features might make it difficult to provide allotments of uniform sizes, there was no apparent reason for the wide variation in size of the original allotments.

Engineering surveys of the field channel study sites (Appendix F) tended to confirm the allotment boundaries shown in the original blocking out plans. Noticeable exceptions to this were allotments that bordered field channels, drainage channels, and field channel access road easements. Almost all of these allotments had increased in size as a result of encroachment onto reserved areas. In Stage I, nearly 26 percent of the allotments were greater than 3.5 ac in area. The increased area associated with these allotments primarily resulted from encroachment onto reserved areas. Similarly, nearly 30 percent of the allotments in Stage II were greater than 2.5 ac as a result of encroachment onto reserved areas.

In most of the allotments not increased in area by encroachment, the original allottee is certainly economically disadvantaged. Of 77 surveyed allotments in Stage I, approximately 26 percent were less than 2 ac in area. Similarly, over 10 percent of 120 surveyed allotments in Stage II were 1 ac or less.

The unit of land available to the individual cultivator has also been decreased by the subdivision of allotments. Twelve of 59 allotments in Stage I were subdivided by a total of 27 individuals. Approximately 70 percent of these individuals cultivated 1 ac or less. In Stage II, 14 of 66 allotments were subdivided by 31 individuals. Nearly 87 percent of these individuals cultivated 1 ac or less.

The overall effect of encroachment, original allotment size, and subdivision of allotments in Stage I and Stage II suggests that while a few individuals benefitted by encroaching onto reserved areas, inequalities in the size of the original allotments and increased population pressure on the land have reduced many of the cultivators on Kaudulla to subsistence farming. It was also apparent from data presented in the sociology section of this report that the problem of subdividing allotments will increase as second- and third-generation families begin to inherit these lands.

b. Soils

The Soil Survey Division of the Irrigation Department was contracted to conduct a detailed soil survey of the field channel study sites to obtain basic soils information for Kaudulla. In addition to mapping soils, the survey team was requested to characterize a typical soil profile for each soil type. The soil survey was initiated during the irrigation closure period between the 1986 yala and 1986-87 maha and was completed in early December of 1986.

Two major soil groups -- reddish-brown earth (RBE) and low, humic gley (LHG) soils -- were identified by the soil survey team (Appendix F). RBE soils were identified as Rhodustalfs in the Seventh Approximation system of soil classification. RBE soils, which are predominant in the Dry Zone, were largely formed in place on the knolls and upper to middle slopes of the rolling topography. These soils, which are light in texture, are generally regarded as good agricultural soils if rainfall is supplemented by irrigation. However, they are structurally weak and thus are susceptible to water erosion. In addition, RBE soils located in the middle to lower slopes of the rolling topography are often affected by high water tables during heavy rains.

The LHG soils are primarily alluvial and were found in the lower slopes and valleys. LHG soils are equivalent to Haplustalfs in the Seventh Approximation system of soil classification and Gleyic Luvisols in the FAO system of soil classification. These heavy-textured soils have poor drainage characteristics and thus are susceptible to waterlogging. Because of this, LHG soils are only suitable for paddy cultivation. A more detailed background description of each soil group, tables of the physical and chemical properties, and general soil profile descriptions for both soil groups are presented in Appendix F.

A summary of the soil types and their approximate area, expressed as a percentage of the total area of the field channels, is shown in Table 13. Of the two soil groups identified, RBE soils were the most extensive, occupying nearly 64 percent of the total study area. Within study sites, RBE soils comprised 35-84 percent of any particular study site.

The RBE soils were subdivided into three drainage classes: well-drained, moderately well-drained, and imperfectly drained (Appendix F). All three drainage classes were observed in the field channel study sites. Imperfectly drained RBE soils accounted for an average of 42 percent of the total field channel area. Within study sites, imperfectly drained RBE soils comprised from 38-57 percent of any particular study site.

With the exception of Stage II, Tract 4, and Stage I, Tract 8, very little of the area was occupied by well-drained or moderately well-drained RBE soils. According to the soil survey team leader, much of the area now identified as imperfectly drained RBE soil was, prior to irrigation, well-drained RBE soil. That these soils have become

imperfectly drained has important water management implications for their use in the cultivation of other field crops.

The LHG soil group occupied approximately 36 percent of the study area (Table 13). Within study sites, LHG soils occupied from 19-65 percent of any particular study site. LHG soils were subdivided into drainage classes -- poorly drained and very poorly drained. However, within the field channel survey, only poorly drained LHG soils were observed. Because these soils were poorly drained, they were only suitable for irrigated paddy production.

Table 13. Approximate area of each soil type, expressed as a percentage of the total surveyed area (Kaudulla, 1986 yala).

	Stage I			Stage II			Total
	Tract 1	Tract 4	Tract 8	Tract 1	Tracts 4&5	Tract 12	Overall Average
Reddish-brown earth, shallow	0	0	0	37	0	0	12
Reddish-brown earth, well-drained	0	3	27	0	46	0	8
Reddish-brown earth, moderately well-drained	0	0	0	0	9	0	2
Reddish-brown earth, imperfectly drained	57	56	38	38	54	35	42
Low humic gley, poorly drained	43	41	19	25	7	65	36

The pH of the RBE and LHG soils was determined during the cropping season. Measured pH values for the RBE soils ranged from 6.1-7.4, while pH values of the LHG soils ranged from 6.8-7.6. These pH values were within the expected range for each soil group. In addition, visual observations of crop performance were used to assess problem soils (specifically, iron toxicity and salinity). These observations indicated no serious soil problems in the field channel sites. However, similar observations made during the reconnaissance survey of Kaudulla suggested that a few low lying areas exist that have salinity problems.

c. Cropping Pattern

During the 1986 yala, less than 5 percent of the study area was fallow. Approximately 2.75 ac of the 146.5 ac surveyed in Stage I, and

10.4 ac of the 132.4 ac surveyed of Stage II, were fallow. This land was fallow primarily because it could not be commanded by the irrigation system.

Data on soils presented in the previous section indicated a potential for cultivating crops other than paddy on approximately 35-40 percent of the irrigated command area of Kaudulla during yala. However, during the 1986 yala, only 3.9 percent of the study area was cultivated with crops other than paddy. Interestingly, only chili was cultivated. In Stage I, 4 individuals cultivated chili on a total of 1.25 ac. In Stage II, 18 individuals cultivated chili on a total of 10.4 ac. With the exception of one cultivator in Stage II, Tract 12, all of the individuals who grew chili also cultivated paddy.

While most cultivators understood that potential profits from other field crops, such as chili, were much higher than paddy, they were unwilling to risk the higher investment costs associated with these crops. Their preference for paddy over other crops was explained by:

* lower investment costs.
* availability of good quality seed.
* knowledge of, and less intensive, cultivation practices.
* shorter cropping period.
* fewer problems with theft.
* fewer storage problems.
* less severe price fluctuations.
* a more organized marketing system.

d. Cultivation Season

In mid-September, the 1986 yala kanna meeting for Kaudulla was held in Medirigiriya. The kanna meeting was chaired by the government agent and supported by the district department heads responsible for agriculture and settlement. While the major purpose of the kanna meeting was to finalize the 1985 yala irrigation schedule, it also served as a platform for the cultivators to air grievances and for the departments to disseminate information on relevant topics. However, the meeting was attended by less than 200 persons, most of whom were vel vidanes, rather than average cultivators.

The final 1986 yala irrigation schedule was based on the cultivation of short-season (3 to 3-1/2 month) varieties of paddy, which the farmers were requested to grow. Some of the more important dates established for the 1986 yala schedule were:

April 20	First water issue
May 20	Completion of land preparation
May 21	First rotational water issue
August 23	Closure of canals

This schedule provided irrigation water for 125 days, of which 30 days were for land preparation and 95 days were for crop growth. Although the schedule appeared reasonable, continuous water issues were extended until the first week of June, and the entire irrigation season was extended to the first week of September. An attempt is made to document some of the reasons for the extensions in subsequent sections of this report.

e. Land Preparation

Land preparation is one of the most important management components in paddy cultivation. Poor and untimely land preparation may result in unlevel fields, poor stand establishment, and early weed infestation. All of these problems affect the performance of the crop and often increase production costs. More importantly, extended land preparation may delay the completion of the cropping season.

Data concerning the start and completion of land preparation, power sources used, the number of plowings, and the number of harrowings were obtained through field observations and informal interviews with the cultivators. In addition, observations on the quality of land preparation were made. The quality of land preparation was evaluated by the degree of weed control obtained, availability of water, and by the degree of tilth and leveling obtained.

The date that cultivators started land preparation was compared with the date of the first scheduled water issue to determine the time required to initiate land preparation. The time required for land preparation was defined as the period between the start and completion of land preparation. The overall time required for land preparation was defined as the period between the date of the first scheduled water issue and completion of land preparation.

According to the Agriculture Department, 14-21 days is generally sufficient to complete land preparation. Land preparation periods greater than 21 days should only be necessary where irrigation water is limited, or in poorly maintained fields with large accumulations of organic residues.

Proper land preparation for paddy requires that the field be soaked for 2-5 days before the first plowing and maintained at or near saturation throughout the plowing period. During this period the bunds around the paddy are cleaned and repaired. Normally, two plowings are needed to turn the soil, weeds, and organic residue under. Approximately 7 days between plowings is needed to decompose the incorporated organic residue. Between plowings the bunds around the field are repaired and plastered.

Once the organic residue decomposes, the field is flooded with 2-5 cm of water, harrowed, and roughly leveled. Prior to planting, the field is again flooded with 2-5 cm of water, harrowed, and leveled. The field is then drained to 1-2 cm of standing water for planting.

Based on these recommendations, the Kaudulla 1986 yala irrigation schedule developed by the Irrigation Department provided 30 days of continuous water issue for land preparation. Even though this schedule appeared reasonable, land preparation was not completed on schedule. As a result, the Irrigation Department extended continuous water issues for two weeks. This extension increased the amount of water issued for land preparation by nearly 50 percent and contributed to the delay in completing the cropping season. Because this problem was common in both yala and maha, it was considered important to determine the factors which contributed to delays and subsequent extensions of the irrigation season.

Overall, the time required to initiate land preparation once scheduled water issues began ranged from the day of the first water issue to 54 days after the official first water issue, and averaged 17 days. Only 25 percent of the cultivators initiated land preparation within the first 10 days after the first official water issue (Table 14). Another 20 days was required before nearly 94 percent of the Kaudulla cultivators initiated land preparation activities. With the exception of Stage I, Tract 8, no apparent hydrological differences in the initiation of land preparation were observed. In Stage I, Tract 8, land preparation was not initiated until 20 days after the first official water issue. This initial delay may have occurred as a result of inadequate water deliveries in the tail of Stage I.

Table 14. The time between the first scheduled water issue and the initiation of land preparation as reported by Kaudulla cultivators, 1986 yala (n=156).

Number of Days	Stage I Tract 1	Stage I Tract 4	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Stage II Tract 12	Cum %
	number of responses						
0	0	0	0	0	3	0	1.9
5	0	4	0	2	2	7	11.5
10	5	4	0	1	6	5	25.0
15	6	2	0	11	2	7	42.9
20	6	1	7	5	11	7	66.7
25	0	1	18	0	5	6	85.9
30	3	0	8	2	0	0	94.2
35	0	0	4	0	0	1	97.4
40	0	0	0	0	0	0	97.4
45	0	0	0	0	0	0	97.4
50	3	0	0	0	0	0	99.4
55	0	0	0	0	0	0	99.4
60	1	0	0	0	0	0	100.0

Although observations on land preparation were made, data collectors did not obtain information on reasons for delaying the start of land preparation. However, two possible reasons for delays in starting

land preparation were suggested. First, inadequate water delivery during land preparation may have caused many cultivators to delay the start of land preparation. Second, problems in obtaining credit, power sources for land preparation, and labor for planting may have caused some cultivators to delay land preparation.

Once land preparation was initiated, the time between the start and completion of land preparation ranged from 6 days to 48 days, and averaged 20 days. Nearly 80 percent of the cultivators completed land preparation activities within 20-25 days (Table 15). The majority of cultivators (nearly 94 percent), regardless of their hydrological location, completed land preparation within 35 days. Thus, it was apparent that once land preparation was initiated, it was possible for cultivators to complete land preparation within 30-35 days.

Table 15. The time between the first plowing and the completion of land preparation as reported by Kaudulla cultivators, 1986 *yala* (n=157).

Number of Days	Stage I			Stage II			Cum %
	Tract 1	Tract 4	Tract 8	Tract 1	Tracts 4&5	Tract 12	
	number of responses						
10	3	0	4	2	5	0	8.9
15	8	2	11	6	7	4	33.1
20	9	0	13	8	7	8	61.8
25	2	3	8	2	5	3	79.6
30	1	3	0	3	0	8	89.2
35	1	0	0	0	4	2	93.6
40	0	3	0	0	0	1	96.2
45	0	2	1	0	1	0	98.7
50	0	0	0	0	0	2	100.0

Overall, the time between the first scheduled water issue and the completion of land preparation ranged from 18-70 days, and averaged 37 days. Only 27 percent of the cultivators completed land preparation within the scheduled period (Table 16). An additional 20-25 days was required before more than 97 percent of the cultivators completed land preparation.

Table 17 shows the different power sources that Kaudulla cultivators used for land preparation. Overall, nearly 53 percent of the cultivators used two-wheel tractors for land preparation. Approximately 42 percent of these cultivators used only two-wheel tractors for land preparation, with another 11 percent using a combination of two-wheel tractors and animal power. The majority of these cultivators were located in Stage I, where landholdings were larger. Those cultivators who did not use two-wheel tractors (47 percent) were primarily located in Stage II and used a combination of animal power and hand labor to prepare land.

Table 16. The time between the first scheduled water issue and the completion of land preparation as reported by Kaudulla cultivators, 1986 *yala* (n=157).

Number of Days	Stage I Tract 1	Stage I Tract 4	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Stage II Tract 12	Cum %
	number of responses						
20	0	0	0	0	2	1	1.9
25	4	0	0	2	3	1	8.3
30	5	1	1	7	11	5	27.4
35	4	4	4	8	6	3	45.9
40	3	0	14	3	4	11	68.2
45	2	2	11	1	0	7	82.8
50	2	6	5	0	1	0	91.7
55	2	0	1	0	2	4	97.5
60	1	0	1	0	0	1	99.4
65	0	0	0	0	0	0	99.4
70	1	0	0	0	0	0	100.0

Table 17. Power sources used by Kaudulla cultivators during land preparation (1986 *yala*).

Power Sources	Stage I Tract 1	Stage I Tract 2	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Cum %
	percent of cultivators					
2-wheel tractor	58	58	54	14	26	42
2-wheel & animal	13	17	11	14	0	11
Animal & hand labor	29	25	35	72	74	47

Table 18 shows the land preparation operations used by Kaudulla cultivators. With the exception of Stage II, Tracts 4 and 5, and Stage II, Tract 12, the majority of cultivators ploughed two or more times and harrowed and leveled one or more times to prepare their fields. In Tracts 4 and 5 and Tract 12, the majority of cultivators ploughed twice and levelled one or more times to prepare their fields. Cultivators in Stage I, Tract 1 (38 percent), preferred to use the rototiller rather than a moldboard plow attachment.

Data collectors evaluated the quality of land preparation in paddy fields throughout the study area. Included in their assessment of land preparation were availability of water for land preparation, degree of tilth and leveling obtained, and degree of weed control obtained. Land preparation was rated as average or poor in nearly all of the Kaudulla fields (Table 19). Only one field in Stage II, Tract 12, received a

good rating. Overall, land preparation was rated better in Stage I than in Stage II. This higher rating is probably explained by the greater usage of two-wheel tractors in Stage I.

Table 18. Land preparation operations used by Kaudulla cultivators during the 1986 *yala*.

Operation	Stage I			Stage II		
	Tract 1	Tract 2	Tract 8	Tract 1	Tracts 4&5	Tract 12
	percent of cultivators					
Rototilling & leveling	38	0	0	0	0	0
Ploughed once & leveled one or more times	12	0	8	0	3	30
Ploughed twice & leveled one or more times	0	0	0	0	93	61
Ploughed two or more times & harrowed and leveled one or more times	50	100	92	100	3	9

Table 19. Visual assessment of the quality of land preparation in paddy fields of Kaudulla Scheme (1986 *yala*).

Quality	Stage I			Stage II		
	Tract 1	Tract 2	Tract 8	Tract 1	Tracts 4&5	Tract 12
	percent of fields					
Good	0	0	0	0	0	3
Average	58	93	59	24	28	45
Poor	42	7	41	76	72	52

f. Planting

As previously mentioned, the 1986 yala kanna meeting established an irrigation season for Kaudulla of 125 days -- the first 30 days of which were designated for land preparation. To meet this schedule, farmers were requested to grow short-season, improved varieties of paddy. No recommendations on the method of planting were given. Generally, it was assumed that the majority of cultivators on Kaudulla would broadcast yala paddy. Since short-season paddy varieties only require irrigation water for 80-95 days and mature within 90-105 days, it appeared that the irrigation schedule established during the kanna meeting was reasonable.

Data collected on planting in each study site included paddy varieties, method of planting, and dates that planting was started and completed. Most of this information was collected through informal interviews with the cultivators. Whenever possible, information obtained through informal interviews was confirmed by field observations.

Paddy Varieties. According to the cultivators, 14 different paddy varieties were grown in the study sites. Of these, 7 were short-season varieties and 6 were long-season varieties. Two paddy varieties -- BG-90-4 and BG-330 -- were not on the Agricultural Department's list of recommended varieties, and one paddy variety -- BG-94-2 -- had been removed from the list of recommended paddy varieties (Table 20).

Table 20. The percentage of each study site planted with different paddy varieties as reported by Kaudulla cultivators (1986 yala).

Paddy Varieties	Stage I Tract 1	Stage I Tract 4	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Stage II Tract 12	Total %
	relative percent						
Short-Season							
BG-34-8	75	33	89	48	44	69	65
BG-276-5	7	3	0	3	0	3	3
BG-94-2	0	0	0	13	24	0	5
BG-94-1	5	0	0	9	0	19	6
BG-34-6	0	0	0	0	22	0	3
BG-90-4	4	5	5	0	0	0	2
BG-330	0	5	0	0	0	0	1
Long-Season							
BG-379-2	5	12	0	0	8	2	4
BG-400-1	2	0	3	0	0	0	1
BG-380	0	5	3	0	3	0	2
BG-11-11	0	24	0	0	0	7	4
BG-90-2	2	0	0	27	0	0	4
BG-450	0	12	0	0	0	0	1

Interestingly, approximately 10-15 percent of the cultivators were either unable to name or incorrectly named the variety of paddy they had planted. The farmers' lack of knowledge was significant and was unexpected by the Agriculture Department.

Data collectors were also unsuccessful in identifying some varieties of paddy. Variety misidentification occurred for approximately 10 percent of the sample. Even so, the data collected were still of value for evaluating the farmers' preference for certain paddy varieties.

Overall, BG-34-8 -- a short-season, improved variety -- was most common. Nearly 65 percent of the entire Kaudulla study area was planted with this variety. The other six short-season paddy varieties occupied an additional 20 percent of the study area. Of these, significant acreages of BG-94-2, BG-94-1, and BG-34-6 were reported on only some of the study sites (Table 20).

Long-season paddy varieties were reported by cultivators to grow on approximately 16 percent of the study area (despite recommendations given at the kanna meeting). Three of the long-season paddy varieties -- BG-379-2, BG-11-11, and BG-450 -- were reported on significant areas of some of the study sites.

Records of planting and harvesting dates kept by the data collectors suggested that long-season paddy varieties were grown on as much as 35 percent of the study area. The high proportion of long-season paddy varieties contributed significantly to the need to extend the 1986 yala irrigation season past the schedule originally established.

Planting Methods. Two planting methods -- broadcast sowing and transplanting -- were used by Kaudulla cultivators during the 1986 yala. Both methods were recommended by the Agriculture Department. In general, most Kaudulla cultivators preferred transplanting over broadcasting as they perceived that transplanted fields usually produced higher yields. Although agricultural research has indicated that similar yields can be obtained from either planting method, it was recognized that transplanting offered several advantages over broadcasting when other management practices were less than optimum.

When transplanting under the conditions existing at Kaudulla, it is easier to control the plant environment in a small nursery during the critical periods of germination and initial seedling growth than is possible for seedlings in a broadcast field. A cultivator is more assured of obtaining a uniform stand when paddy is transplanted, and transplanted seedlings are able to compete with weeds more effectively than broadcast seedlings can. Finally, transplanting effectively reduces the period of field irrigation and potential exposure to unfavorable field conditions by 25-30 days. While these advantages certainly improve the potential for obtaining higher paddy yields with transplanted paddy, transplanting involves a major investment in labor, time, and capital.

Because of this investment, broadcasting was often used by Kaudulla cultivators who wanted to decrease the financial risks associated with producing a paddy crop and by those who lacked capital or had trouble scheduling planting crews. In general, most cultivators considered yala to be more risky than maha because of the uncertainty of irrigation deliveries. Therefore, they were less willing to invest in transplanting during yala.

Approximately 76 percent of the paddy acreage in the study area was broadcast (Table 21). Within study areas, broadcast paddy ranged from 60-95 percent of the paddy acreage. The high proportion of broadcast paddy indicated that most cultivators were unsure of the yala water deliveries.

Table 21. The percentage of each study site broadcast or transplanted with either long-season or short-season varieties (Kaudulla, 1986 yala).

Planting Method and Varietal Type	Stage I			Stage II			Total
	Tract 1	Tract 4	Tract 8	Tract 1	Tracts 4&5	Tract 12	%
	relative percent						
Broadcast, short-season	68	41	90	47	59	67	66
Broadcast, long-season	5	19	5	13	30	2	10
Transplanted, short-season	22	2	2	22	8	24	14
Transplanted, long-season	4	39	3	18	3	7	10

In three of the study sites (Stage I, Tract 4; Stage II, Tract 1; and Stage II, Tracts 4 and 5) a significant proportion of the acreage was broadcast with long-season paddy varieties. Because broadcasting and long-season varieties resulted in a longer period of plant growth, these cultivators required an extension of the irrigation schedule by approximately 3 weeks. The use of long-season varieties in combination with broadcasting appeared to be somewhat risky given the possibility that irrigation deliveries could have stopped before the crop matured. However, cultivators indicated that they broadcast long-season paddy varieties because long-season paddy varieties had greater yield potential and were less sensitive to the timing of management activities, such as weeding or agro-chemical application.

Transplanted paddy only accounted for approximately 24 percent of the total paddy acreage in the study sites (Table 21). Within study areas, significant acreages of transplanted paddy were observed in Stage I, Tracts 1 and 4 and in Stage II, Tracts 1 and 12. The fact

that significant acreages were transplanted in these study sites indicated that the cultivators were reasonably confident of yala water deliveries.

Overall, cultivators initiated planting activities as early as 4 days before the scheduled completion of land preparation and as late as 54 days after the scheduled completion of land preparation. Early planting was primarily observed in the Stage II study areas. Interestingly, cultivators who delayed planting were primarily located in the head of the system. For 156 cultivators, the average time required for broadcasting and transplanting was 3 days.

According to the yala irrigation schedule for Kaudulla, all planting should have been completed within 35 days after the first scheduled water issue. However, by the 35th day after the first scheduled water issue, only 35 percent of the paddy had been planted in the study area (Table 22). An additional 20 days passed before planting was completed on 95 percent of the study area. Although there were a few instances where extended planting periods contributed to extensions in the irrigation issues, delays in land preparation were the major factor that caused cultivators to extend planting beyond the period established in the irrigation schedule.

Table 22. The number of days between the first scheduled water issue and completion of planting as reported by Kaudulla cultivators (1986 yala).

Number of Days	Stage I			Stage II			Cum %
	Tract 1 (n=24)	Tract 4 (n=20)	Tract 8 (n=35)	Tract 1 (n=21)	Tracts 4&5 (n=33)	Tract 12 (n=32)	
21-25	1	0	0	2	6	1	6.1
26-30	3	1	1	5	7	5	19.4
31-35	2	6	0	4	9	4	34.5
36-40	5	2	10	1	6	5	52.1
41-45	2	2	17	6	0	8	73.3
46-50	2	8	7	2	3	3	88.5
51-55	1	1	0	0	2	6	94.5
56-60	3	0	0	0	0	0	96.4
61-65	3	0	0	0	0	0	98.2
66-70	1	0	0	0	0	0	98.8
71-75	0	0	0	1	0	0	99.4
76-80	0	0	0	0	0	0	99.4
81-85	1	0	0	0	0	0	100.0

g. Fertilizer Application

Soil fertility and management are critical aspects of paddy production. Paddy yields of 150 bu/ac or more are only possible when soil fertility is properly managed throughout the growing season. To assist the farmer, the Agriculture Department provided detailed fertilizer recommendations for paddy cultivation in the low country Dry Zone. These recommendations specified the timing, type, and amount of fertilizer required for transplanted and broadcast short-season and long-season paddy varieties (Table 23). Data collected on the type, amount, and timing of fertilizer applications was used to determine how closely the cultivators in the study areas followed the Agriculture Department's recommendations. In Stage II, Tract 8, data collection was interrupted by the replacement of the data collector. Consequently, data on top dressing applications was incomplete and is not used in this report.

Basal Fertilizer Application. The Agriculture Department recommended that a basal fertilizer dressing of V-mixture (5-15-15) be applied and incorporated into the soil immediately prior to planting paddy (Table 23). The basal fertilizer application was recommended in order to improve initial seedling growth and plant tillering.

Eighty-four percent of the cultivators in the study area applied a basal fertilizer (Table 24). All of the cultivators who applied a basal fertilizer applied V-mixture. Approximately 33 percent of the cultivators applied V-mixture at or above the recommended rate (150 lbs/ac), and 51 percent applied V-mixture below the recommended rate.

Within study sites, all of the cultivators in Stage II, Tract 1, applied a basal dressing of V-mixture. Approximately 76 percent of the cultivators in this study area applied V-mixture at or above the recommended rate. In Stage I, Tract 1, nearly 54 percent of the cultivators did not apply a basal fertilizer. Many of these cultivators indicated that they preferred not to apply basal fertilizer because it encouraged excessive weed growth.

The majority (92 percent) of basal fertilizer applications in the study area were applied within 1-5 days before planting. It is probable that most of these fertilizer applications were incorporated into the soil. By incorporating the fertilizer into the soil, cultivators minimized the amount of nitrogen lost by volatilization. However, basal fertilizer applications in approximately 8 percent of the fields were applied after planting. Because fertilizers probably were not incorporated into the soil, the effectiveness of nitrogen in these fertilizers may have been reduced.

Top Dressing 1. The Agriculture Department recommended that a first top dressing of urea be applied and incorporated into paddy fields two weeks after planting (Table 23). The purpose of the initial top dressing was to improve early plant tillering and growth of the paddy. Incorporating this fertilizer into the soil minimizes nitrogen losses to the atmosphere.

Table 23. Fertilizer recommendations for paddy cultivation, Kaudulla 1986 *yala*.

Fertilizer Application	Planting Method*	Age Class (Months)	Fertilizer Type	Amount** (lbs/ac)	Time Applied***
Basal	B	3	V-mixture	150	Final Harrowing
		3.5	"	150	"
		4-4.5	"	150	"
	T	3	V-mixture	150	Final Harrowing
		3.5	"	150	"
		4-4.5	"	150	"
Top dressing 1	B	3	Urea	55	2 WAS
		3.5	"	55	"
		4-4.5	"	55	"
	T	3	Urea	82	2 WAT
		3.5	"	82	"
		4-4.5	"	55	"
Top dressing 2	B	3	Urea	27	5 WAS
		3.5	"	27	"
		4-4.5	"	55	6 WAS
	T	3	TDM	82	5 WAT
		3.5	"	82	6 WAT
		4-4.5	Urea	55	4 WAT
Top dressing 3	B	3	TDM	110	7 WAS
		3.5	"	110	8 WAS
		4-4.5	"	110	10 WAS
	T	3	---	---	---
		3.5	---	---	---
		4-4.5	TDM	110	8 WAT

*B - Broadcast, T - Transplanted
**V-mixture - Paddy fertilizer mixture (N-P-K = 5-15-15)
TDM - Paddy top dressing mixture (N-P-K = 30-0-20)
Urea - Ammonium nitrate (N-P-K = 46-0-0)
***WAS - Weeks after sowing
WAT - Weeks after transplanting

Table 24. The relative application rates of V-mixture applied by cultivators in the study area (Kaudulla, 1986 *yala*).

Rate of Application	Stage I Tract 1	Stage I Tract 2	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Stage II Tract 12	Total %
	Relative %						
Above recommended	0	0	11	0	48	15	12
At recommended	4	46	8	19	28	18	21
Below recommended	42	46	70	71	24	55	51
Did not apply	54	8	11	10	0	12	16

Sixty percent of the cultivators in the study sites applied the first top dressing (Table 25). All of the cultivators who applied the first top dressing applied urea. Sixty percent of the cultivators applied urea at 2-4 times the recommended rate. However, the overall efficiency of this fertilizer application may have been reduced since none of the cultivators incorporated the urea into the soil. Sixteen of 29 cultivators (55 percent) in Stage II, Tracts 4 and 5, and 6 of 32 cultivators (19 percent) in Stage II, Tract 12, did not apply a first top dressing.

Table 25. The relative application rates of urea applied by cultivators in the study area (Kaudulla, 1986 *yala*).

Rate of Application	Cultivators: Stage I Tract 1	Stage I Tract 2	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Stage II Tract 12	Total %
Above recommended	20	6	-	15	11	22	60
At recommended	3	2	-	4	2	4	13
Below recommended	1	4	-	1	0	0	7
Did not apply	0	1	-	1	16	6	20

Only about 28 percent of the cultivators applied the first top dressing during the second week after planting, as recommended. Overall response to urea applications may be reduced when urea applications are made later than the fourth week after planting.

Top Dressing 2. The Agriculture Department recommended a second top dressing of urea on short-season, broadcast varieties (5-6 weeks after planting) and long-season, broadcast (5 weeks after planting) and transplanted varieties (4 weeks after planting) (Table 23). The application was recommended to improve plant tiller development and increase grain formation. For short-season, transplanted varieties, the Agriculture Department recommended the application of TDM mixture (5 weeks after planting) as a final top dressing to increase grain weight and encourage normal seed development.

The second top dressing was applied on 68 percent of the fields in the study area (Table 26). Approximately 24 percent of the fertilizer applications were urea. Generally, urea was applied to broadcast short-season and broadcast or transplanted, long-season paddy varieties. Nearly all of the urea applications were 2-3 times the recommended rates.

Table 26. Top dressing 2 applied by cultivators in the Kaudulla study sites (1986 *yala*).

	Number of Cultivators						
	Stage I			Stage II			
Fertilizer Type	Tract 1	Tract 2	Tract 8	Tract 1	Tracts 4&5	Tract 12	Total %
Urea	3	5	-	0	15	6	24
TDM	12	2	-	15	12	11	44
No fertilizer	9	6	-	6	2	15	38

Approximately 44 percent of the cultivators applied TDM as a second top dressing. Only 30 percent of the cultivators who applied TDM as a second top dressing applied it as the final fertilizer application on transplanted, short-season paddy varieties. The majority of these applications were made at less than the recommended rate. All other TDM applications were on broadcast, short-season and broadcast or transplanted, long-season paddy varieties.

The time of application varied considerably within and between study sites, ranging from 5 to 10 weeks after planting. The efficiency of fertilizer use was certainly affected by late applications. Interestingly, a majority of cultivators in Stage II, Tracts 4 and 5, applied the second top dressing (based on time of application), although few applied a first top dressing.

Top Dressing 3. The Agriculture Department recommended the application of a third top dressing of TDM mixture for long-season paddy varieties and broadcast, short-season varieties (Table 23). This top dressing was recommended to improve yields and grain development.

Only 40 percent of the cultivators in the study area applied a third top dressing (Table 27). Of those who applied a third top dressing, all except one applied TDM. Forty-nine percent of the TDM applications were at or above the recommended rate. However, the effectiveness of these applications was reduced since none of the cultivators incorporated the fertilizer into the soil. More importantly, nearly 56 percent of the applications were made too late in the season to benefit the paddy.

Table 27. Top dressing 3 applied by cultivators in the Kaudulla study sites (1986 yala).

Fertilizer Type	Cultivators						Total %
	Stage I			Stage II			
	Tract 1	Tract 2	Tract 8	Tract 1	Tracts 4&5	Tract 12	
Urea	0	0	-	0	1	0	1
TDM	3	8	-	5	13	17	39
No fertilizer	21	5	-	16	15	15	60

When all four fertilizer applications were evaluated, less than 10 percent of the cultivators followed the Agriculture Department's fertilizer recommendations. Generally, cultivators applied V-mixture at rates that were lower than the recommended rates. In contrast, urea applications were much higher than the recommended rates. More importantly, a significant percentage of the cultivators did not apply a third top dressing. Instead, they applied higher than recommended rates during either the first or second top dressing. This suggested that the number of top dressings recommended by the Agriculture Department may not be necessary. Fewer top dressing applications with higher rates of fertilizer would reduce problems cultivators encounter trying to apply fertilizer at the correct time.

Field tissue tests for N-P-K in selected fields throughout the study area tended to support observations made on fertilizer applications. These tests, with a few exceptions, indicated that tissue levels of nitrogen and phosphorus were adequate to excessive, and tissue levels of potassium were low in many of the sites. Low potassium levels may have reduced the overall effect of nitrogen fertilizers and may have contributed to less than optimum paddy yields.

h. Relative Availability of Water

Research by De Datta (1981) indicated that plant growth and yields of paddy were affected by soil moisture conditions. This research

reported yield reductions of 8 to 21 percent when soil moisture levels decreased to near field capacity during critical growth stages. In addition, more serious yield reductions were reported as the duration of soil moisture stress increased. De Datta (1981) reported that moisture conditions were most critical for the following plant growth stages of paddy: mid- to late tillering, panicle initiation, and grain head formation.

During 1986 yala, field observations were made in selected liyaddas to evaluate soil moisture conditions in paddy fields throughout the study area. Soil moisture conditions were observed on alternate days in a series of liyaddas located on either side of a line parallel to the field channel and perpendicular to the drainage channel. A scale was used to classify the soil in the liyaddas as follows:

0 - dry, cracked soils

1 - wet soils

2 - 1-5 cm of standing water

3 - > 5 cm of standing water

Within study sites, observations of soil moisture conditions began during the vegetative period on the first and third weeks of June and continued through the grain filling period in late August to early September. With the exception of Stage I, Tract 1 (where observations were made on alternate days), soil moisture observations were made on variable schedules of 2-6 days.

Observations of soil moisture conditions indicated that periods of soil moisture stress occurred in all of the study areas with the exception of the tail study area in Tract 11 (Table 28). Overall, soil moisture stress appeared to be a greater problem in Tract 11 than in Tract 1. In fact, the most serious soil moisture stress conditions were observed in Stage II, Tracts 4 & 5. Over 27 percent of the observations in this study site indicated dry, cracked soils.

Because observations were not conducted on alternate days in all of the study sites, it was difficult to determine the duration of soil moisture stress. However, it appeared that periods of soil moisture stress usually lasted for at least two days in most of the study areas. It is probable that longer periods of soil moisture stress developed in Tracts 4 and 5. Thus, soil moisture stress probably contributed to yield reductions in all but the tail study site of Stage II.

Table 28. Observations of soil moisture conditions as a percent of total observations in selected *liyaddas* in Kaudulla study sites (1986 *yala*).

Observation	Stage I Tract 1	Stage I Tract 4	Stage I Tract 8	Stage II Tract 1	Stage II Tract 4&5	Stage II Tract 12
Dry, cracked soil	2.2	0.9	1.6	4.2	27.1	0
Wet soil	30.7	18	34.6	23.6	39.2	21.8
1-5 cm standing water	49.9	49	58	51.3	29.1	74.5
> 5 cm standing water	17.1	35	5.8	25	4.6	0

NOTE: *Stage I, Tract 1*. Observations on 35 *liyaddas* (4 allotments) for 46 days over a 91-day period, beginning on June 2.
Stage I, Tract 4. Observations on 119 *liyaddas* (12 allotments) for 11 days over a 92-day period, beginning on June 2.
Stage I, Tract 8. Observations on 20 *liyaddas* (5 allotments) for 12 days over a 77-day period, beginning on June 18.
Stage II, Tract 1. Observations on 27 *liyaddas* (4 allotments) for 21 days over a 70-day period, beginning on June 21.
Stage II, Tracts 4 & 5. Observations on 33 *liyaddas* (3 allotments) for 22 days over a 69-day period, beginning on June 21.
Stage II, Tract 15. Observations on 51 *liyaddas* (6 allotments) for 15 days over a 76-day period, beginning on June 19.

i. Weed Control

Environmental conditions in paddy fields favor the growth of many aquatic and semi-aquatic weeds that directly compete with rice plants for nutrients, sunlight, and space. Many of these weeds also serve as alternate hosts for disease and insects that attack paddy. Thus, when weeds are not controlled, substantial reductions in paddy yields usually occur. In addition, the quality of the harvested grain is often reduced by the presence of weed seed.

Weed control should begin with land preparation. Thorough land preparation can reduce initial weed infestations in newly planted fields; thus decreasing the amount of time and effort required to control weeds after planting paddy. Earlier in this report, the quality of land preparation in all of the study areas was rated as poor to average. Most fields would have developed serious weed problems after planting.

The method of planting the cultivator uses also affects weed populations. It is recognized that transplanted paddy, because of its age and size at planting, is better able to compete with initial weed infestations than broadcast paddy. In general, weed infestations in transplanted fields (24 percent of the Kaudulla study area) were lower than in broadcast fields.

While a cultivator may reduce weed problems with proper land preparation and by transplanting, it may still be necessary to control weed infestations after planting. Research has shown that maximum paddy yields were obtained from fields in which weeds were properly controlled within the first 20-30 days after planting (University of the Philippines, 1970). Accordingly, the Sri Lanka Agriculture Department recommends that weeds be controlled by hand or through herbicide applications within the first 30 days after transplanting or broadcasting paddy. Depending on the severity of weed infestation, 1 to 2 weed control operations were recommended.

Weed control was practiced in 71 percent of the paddy fields in the Kaudulla study area (Table 29). With the exceptions of Tract 4 and Tract 8 of Stage I, weed control efforts were high in all of the study sites. Kaudulla cultivators primarily used herbicides to control weeds in paddy. Hand weeding was only practiced in three of the study sites.

Table 29. The percent of fields in the Kaudulla study area in which herbicides, hand weeding, or no weeding were practiced (1986 yala).

Weeding Method	Stage I			Stage II			Total
	Tract 1 (n=24)	Tract 4 (n=13)	Tract 8 (n=37)	Tract 1 (n=21)	Tracts 4&5 (n=29)	Tract 12 (n=33)	% (n=157)
Herbicides	54	54	51	61	76	65	61
Hand weeding	0	38	0	24	0	0	10
No weeding	46	8	49	15	24	35	29

Two herbicides -- MCPA and 3,4 DPA -- were used by Kaudulla cultivators. While both herbicides control only sedge and broadleaf weeds, they are very effective when properly used. However, only 32 percent of the cultivators who applied herbicides obtained satisfactory weed control (Table 30). Within study sites, the percent of fields where weeds were adequately controlled by herbicides ranged from 14 to 54 percent. Lack of knowledge was the primary reason cultivators failed to control weed infestations with herbicides.

Table 30. The percent of fields in the Kaudulla study area in which herbicides or hand weeding were effective (1986 yala).

Weeding Method	Stage I			Stage II			Total
	Tract 1	Tract 4	Tract 8	Tract 1	Tracts 4&5	Tract 12	
Herbicides	54	0	32	62	27	14	32
Hand weeding	-	0	-	100	-	-	50

Ethnic disturbances on the borders of Kaudulla Scheme increased problems cultivators had in obtaining labor to hand-weed fields during the 1986 yala. This may the reason that only 10 percent of the cultivators attempted to control weed infestations by hand. Weed infestations were adequately controlled by hand weeding in Stage II, Tract 1. However, in Stage I, Tract 4, hand weeding was unsuccessful.

Overall, weed infestation was considered a major factor affecting paddy yields in nearly all of the study sites. Only in Stage I, Tract 1 were weeds controlled in a major portion of the fields.

j. Pest Control

The tropical climate of Sri Lanka favors the proliferation of insect pests. This problem is further accentuated on irrigation systems such as Kaudulla, where a crop (rice) is grown year-round. Failure to control insect pests usually results in substantial reductions in the quality and yield of paddy. For example, 24 separate experiments conducted over six cropping seasons at the International Rice Research Institute indicated that average paddy yields were reduced from 5.3 t/ha to 2.0 t/ha in plots with no insect control (De Datta, 1981). Although other management practices, such as weed control, are effective in helping to reduce insect infestations, controlling rice insects largely depends on the application of insecticides.

Generally, Kaudulla farmers reported armyworm, stemborer, and planthopper as the most important insect pests in paddy. Damage from armyworm and stemborer usually occurred during both maha and yala, whereas damage from planthopper occurred only during maha.

Insect infestations were observed in approximately 65 percent of the fields in the study area (Table 31). The insect pests were primarily stemborers, thrips, whorl maggots, leaf folders, armyworm, and paddy bugs. Kaudulla cultivators applied insecticides in approximately 76 percent of the fields infested by insects. Only in Stage II were there a significant number of fields in which insecticides were not applied. This was particularly true in Stage II, Tract 1, where insecticides were only applied in 41 percent of the fields.

Few cultivators applied insecticides more than once during yala (Table 32). Data collectors indicated that many of the cultivators also relied on old, superstitious practices such as placing palm fronds in the paddy fields to prevent or stop insect infestations. In addition, ethnic disturbances on the borders of the irrigation scheme may have affected the cultivators' decisions about spraying insecticides.

Kaudulla cultivators indicated that insect infestation during the grain-filling stage was more serious than in previous years. However, they were unwilling to apply insecticides to control these insects for fear of contaminating the paddy with insecticide residues. As a result, insect damage was considered a major factor in the lower than normal paddy yields.

Table 31. The number of fields in each study area where serious pest problems were observed and insecticides were applied (Kaudulla, 1986 yala).

Paddy Fields	Stage I Tract 1 (n=24)	Stage I Tract 4 (n=13)	Stage I Tract 8 (n=37)	Stage II Tract 1 (n=21)	Stage II Tracts 4&5 (n=29)	Stage II Tract 12 (n=33)	% Total
Insect infestations	23	12	6	17	22	22	65
Insecticides applied	22	11	6	7	17	15	76

Table 32. The number of fields in each study area where one, two, or three or more insecticide applications were made (Kaudulla, 1986 yala).

Number of Applications	Stage I Tract 1	Stage I Tract 4	Stage I Tract 8	Stage II Tract 1	Stage II Tracts 4&5	Stage II Tract 12	% Total
One	21	3	5	6	17	15	86
Two	0	6	1	1	0	0	10
Three or more	1	2	0	0	0	0	4

A wide variety of insecticides were used by Kaudulla cultivators. They included Azodrin (monocroptophus, Nuvacron), Osbac (Baycarb, Bassa), Bayrusil (Ekalux, Quinalphos), Diazinon (Basudin), Phenthoate (Elsan), Parathion (Alleron, Niran), Actellic, Dimethoate (Perfecthion), BHC, Carbofuran (Furadan Curaterr), Baytex (Fenthion, Lebaycid), Monitor (Methamidaphos, Tamaron), Malathion, and several others which were not identified. Although the use of Malathion was supposed to be restricted to the Government's anti-malarial program, Kaudulla cultivators preferred Malathion over other insecticides and were able to obtain it.

Observations of insecticide applications on Kaudulla indicated that the majority of cultivators were unaware of the potential health hazards associated with these chemicals. Insecticides were often mixed near drinking wells in the field using drinking water containers to mix the chemicals. In addition, cultivators sometimes mixed more than one insecticide together, unaware of the potential hazards associated with mixing incompatible chemicals. Sprayer applications were made without protective clothing, and usually when it was windy. The indifferent manner in which insecticides were handled was made more serious by the fact that several of the insecticides used by Kaudulla cultivators were classified as highly hazardous chemicals. A highly hazardous classification indicates that the chemical is extremely toxic (LD50 of 1-50

mg/kg) and should be handled with extreme care to avoid potential contamination through contact with the skin or from inhalation or ingestion of the chemical.

k. Harvesting

Harvest Period. Earlier it was mentioned that in the kanna meeting for the 1986 yala, a 125-day irrigation season was established. This schedule was based on the cultivation of broadcast and transplanted, short-season paddy varieties. The scheduled harvest season allowed approximately 20 days, beginning the second week of August, for all harvesting to be completed (between 125 and 145 days after the first water issue). The schedule allowed a minimum of nearly one month between the completion of the yala harvest and the first water issue of maha (tentatively scheduled for October 10). This one-month period was considered essential to properly maintain the canal system and to provide Kaudulla cultivators with an opportunity to market their paddy and make the necessary financial arrangements for the maha paddy crop.

Recall that the scheduled irrigation deliveries were extended by approximately two weeks. This extension was primarily due to delays in initiating land preparation and from broadcasting long-season paddy varieties.

The date when cultivators began harvesting was not obtained in the Kaudulla study area. However, the date of harvest completion was collected on 163 fields in the study area (Table 33). The first field harvested was located in Stage I, Tract 8, and was harvested on August 6, 109 days after the first water issue. This field was transplanted with a short-season paddy variety (BG-34-8) that required 60 days to mature from transplanting to harvest. The last field harvested was located in Stage I, Tract 1. It was harvested September 28, 161 days after the first water issue. This field was transplanted nearly three weeks after the scheduled planting date. Although the cultivator reported that he had planted a short-season variety, the crop was in the field for 104 days, which suggested that it was a long-season variety.

Overall, approximately 76 percent of the surveyed fields in the study area were harvested within the scheduled period (Table 33). Another two weeks were required before approximately 95 percent of the fields were harvested. In Stage I, Tract 1, the extended cropping season primarily resulted due to delays in completing land preparation. Extended cropping seasons in the other field channels resulted from a combination of long land preparation periods and broadcast sowing of long-season paddy varieties.

Paddy Yields. According to the Agriculture Department, the new, high-yielding paddy varieties have potential grain yields of approximately 150 bu/ac. However, potential yields are seldom achieved in actual field situations. More realistic potential yala paddy yields would probably range from 120 to 130 bu/ac.

During 1986 yala, paddy yields from 112 sampled fields in the Kaudulla study area (Appendix G) averaged 69 bu/ac; ranging from a low of 12.5 bu/ac to a high of 114 bu/ac (Table 34). The highest paddy yield occurred in a field located at the head of Stage I. This field was broadcast sown with a long-season paddy variety. The lowest paddy yield occurred in a field located in the middle of Stage I. This field was transplanted with long-season paddy varieties.

Table 33. The number of days required from the first water issue to the completion of harvest for 163 paddy fields in the Kaudulla study area (1986 yala).

Number of Days	Stage I			Stage II			Cum %
	Tract 1 (n=23)	Tract 4 (n=19)	Tract 8 (n=34)	Tract 1 (n=21)	Tracts 4&5 (n=33)	Tract 12 (n=33)	
110	0	0	2	0	0	0	1.2
115	0	0	0	0	0	0	1.2
120	0	0	0	0	0	0	1.2
125	1	0	0	0	0	0	1.8
130	0	0	1	0	4	2	6.1
135	4	3	7	8	5	3	24.5
140	2	0	7	9	8	9	46.0
145	3	7	9	4	11	14	75.5
150	4	0	8	0	3	3	86.5
155	1	9	0	0	1	2	94.5
160	1	0	0	0	0	0	95.1
165	4	0	0	0	1	0	98.2
170	2	0	0	0	0	0	99.4
175	1	0	0	0	0	0	100.0

Table 34. The maximum, minimum, and average paddy yields in the Kaudulla study area (1986 yala).

	Stage I			Stage II			Overall
	Tract 1	Tract 4	Tract 8	Tract 1	Tracts 4&5	Tract 12	
	bu/ac						
Maximum	113.8	95.5	102.6	103.2	103.4	101.9	113.8
Minimum	109.0	12.5	39.4	45.8	26.9	17.0	12.5
Average	86.0	58.3	65.8	66.7	70.5	61.9	69.1

The low average paddy yields obtained by Kaudulla cultivators were partially explained by the occurrence of periods of inadequate water supply, which affected the quality of land preparation, increased problems with weed control, and directly stressed some paddy fields during critical stages of plant growth. Deficiencies in several

management practices used by Kaudulla cultivators also contributed to low average yala paddy yields. Specifically, these practices were inefficient use of agro-chemicals to control weeds and insect infestations, low application rates of potassium fertilizers, and late applications of top dressings. In addition, the viability of paddy seed used by Kaudulla cultivators was also suspect. However, specific measurements to determine the quality of seed were beyond the scope of this study.

Kaudulla cultivators indicated that the 1986 yala paddy yields were lower than expected. Cultivators attributed the lower than normal yields to insect infestation and abnormally high winds, both of which occurred during the flowering stage. Cultivators indicated that they were afraid to use insecticides during this period in case the insecticides decreased grain formation. It is generally recommended that insecticides not be applied during pollenation, as insecticides cause pollen to become sterile. Dry, hot winds during pollenation may also cause sterility in paddy. Because dry, hot winds are common during this period in the Dry Zone, further investigation of the effects of dry, hot winds on pollenation of paddy would be appropriate.

Coefficients of variation in yala paddy yields ranged from 20 to 180 percent in the study area. Extreme variations in paddy yields (coefficient of variation greater than 50 percent) occurred in approximately 25 percent of the sampled fields and were fairly uniformly distributed over the study area. Thus, while yield variations were significant in all study sites, expected variations due to hydrological location were not apparent.

Data on threshing, drying, and storage of harvested grain was not collected. However, field observations during the harvest suggested that substantial losses, both in quality and amount of harvested grain, were incurred during threshing, drying, and transporting the harvested grain. It would not be unreasonable to expect as much as 15 percent of the harvested paddy to be lost during threshing, drying, bagging, and transportation of grain.

Note that bunds around the perimeter of the liyaddas reduced the actual cropped area by 5-10 percent. Thus, when losses associated with harvesting were added to reductions in cropped area, cultivators probably only realized about 75-85 percent of the grain yields estimated by the crop cuttings of the agronomy field investigations.

4. CONCLUSIONS

While it was commonly assumed that each farm family was associated with a 2-ac (Stage II) or 3-ac (Stage I) allotment on Kaudulla, several factors have influenced the actual unit of cultivation. First, allotment boundary surveys and the original blocking out plans indicated that the original allotment varied from 1-4 ac in Stage II and from 2-6 ac in Stage I. Second, most of the allotments bordering field channel and drainage channel easements have increased in area through encroachment. Finally, increased population pressure on the land has significantly decreased the unit of land available to an individual

cultivator. During the 1986 yala, the 125 allotments that comprised the study area (Stage I and Stage II) were cultivated by 157 individuals. Over 29 percent of these individuals cultivated 1 ac or less.

Soil surveys conducted by the Soil Survey Division of the Irrigation Department identified two major soil types in the study area. Reddish-brown earth soils occupied an average of 64 percent of the study site and covered from 35-84 percent of any particular study site. The majority of these soils were imperfectly drained as a result of the shallow, fluctuating water tables associated with irrigation. Although cultivation of these soils with crops other than paddy is possible, special management practices would be required to do so.

Low humic gley soils occupied approximately 36 percent of the study area and covered from 19-65 percent of any particular study site. All of these soils were poorly drained and only suitable for rice cultivation.

Although soil survey and climate information suggested that from 35-40 percent of the Kaudulla command area would support crops other than paddy, approximately 96 percent of the study area was planted with paddy during the 1986 yala. The other 4 percent was planted with chili.

The kanna meeting to finalize the 1986 yala irrigation schedule was attended by less than 200 people, most of whom were vel vidanes rather than Kaudulla cultivators. The irrigation schedule established during this meeting provided 30 days of continuous water issues for land preparation and 95 days of rotational issues for the cultivation of short-season paddy varieties.

However, during the 1986 yala irrigation season, it was necessary for the Irrigation Department to extend both continuous and rotational water issues by two weeks. The extensions were necessary because only 27 percent of the Kaudulla cultivators completed land preparation within the scheduled period. An additional 25 days passed before 97 percent of the cultivators completed land preparation. The longer land preparation period was primarily attributed to inadequate water deliveries during land preparation, which delayed the initiation of land preparation in a major portion of the fields by 20-30 days.

Nearly 70 percent of the cultivators in Stage I used two-wheel tractors for land preparation, whereas only 27 percent of the cultivators in Stage II used two-wheel tractors for land preparation. Overall, the quality of land preparation was better in Stage I than in Stage II.

All of the cultivators in the study area planted high yielding paddy varieties during 1986 yala. However, approximately 10-15 percent of the cultivators were unable to identify, or incorrectly identified, the variety of paddy they had planted.

Despite recommendations to plant short-season paddy varieties during yala, as much as 35 percent of the study area was planted with

long-season paddy varieties. More importantly, nearly 10 percent of the Kaudulla acreage was broadcast sown with long-season paddy varieties. Broadcast, long-season paddy varieties required an irrigation season of 110-120 days and, thus, also contributed to the need to extend the irrigation season.

Less than 10 percent of the Kaudulla cultivators followed the Agriculture Department's fertilizer recommendations for paddy. Although fertilizer applications in paddy fields were generally higher than expected, basal fertilizer applications were not made in 51 percent of the paddy fields. Instead, most cultivators applied a first top dressing of urea at 2-4 times the recommended rates. A significant percentage of cultivators incorrectly applied TDM as a second top dressing, and approximately 56 percent of the cultivators who applied the third top dressing applied it too late to benefit the paddy. These results suggest that the number and complexity of current top dressing recommendations need to be evaluated.

Periods of soil moisture stress occurred in all of the study sites. Although information on soil moisture stress was insufficient for evaluation, the data suggested that periods of soil moisture stress affected paddy yields in several of the sites.

The lack of weed control was regarded as a serious problem on Kaudulla. Weed control, using either herbicides or weeding by hand, was attempted in 61 percent and 10 percent of the fields, respectively. Herbicide applications were only effective in 32 percent of the fields, while hand weeding was only effective in 50 percent of the fields.

Infestations of armyworm, stemborer, thrips, whorl maggots, leaf folders, and paddy bugs were observed in 65 percent of the fields in the study area. Insecticides were applied in approximately 76 percent of the fields in which insect infestations occurred. The indifferent manner in which insecticides were mixed and applied was considered a very serious problem that not only threatened the health of the individual using the insecticide, but also other family members and neighbors.

The 1986 <u>yala</u> paddy yields for Kaudulla averaged only 69 bu/ac. Within study sites, average yields ranged from 58 bu/ac to 86 bu/ac. While average paddy yields in Stage II were slightly lower than average paddy yields in Stage I, expected differences in paddy yields as a result of hydrological position along the main channels were not observed.

D. ECONOMICS

1. INTRODUCTION

This section provides baseline economic data on the Kaudulla Scheme. Economic data collected during 1986 yala provides insight into the farmers economic and financial positions during this important cropping season. Such insight, together with the data collected by the other disciplines, will help in understanding the farmers' overall position. Such knowledge will also be useful in reaching judgments on the effectiveness of irrigation deliveries, support services, and financial institutions.

Specifically, the objectives of this section are to provide an understanding of the economics of the farmers' current agronomic practices, their efficiency in water use, and the equity of water distribution. Such knowledge should help the Ministry of Lands and Land Development (MLLD) identify farmers' interests and problems, and subsequently to set priorities for improvement. Such improvements could be implemented through the Irrigation Systems Management (ISM) Project, as well as by other means.

The economics report concentrates on the benefits and costs of paddy cultivation for 1986 yala. This season represents a "good" year in that water issues from the tank were said to be at design capacity, but also a "poor" year as far as farmers' feelings about paddy yields.

This section describes the methods the economics component used to gather and analyze data, presents and discusses the results, and draws conclusions. This format, as well as much of the text, follows that of the companion report on the 1986 yala survey of sample farmers on the Minneriya Scheme. In fact, through the use of word processing and spreadsheet analysis, the author produced the two reports "in carbon copy," except for the differing questionnaire results and their interpretations.

2. METHODOLOGY

The information contained in this section came mostly from interviewing 77 farmers (80 were selected, but 3 were not located or did not give the requested information). Of this total, 23 were from the head, 19 were from the middle, and 35 were from the tail of the system. Together, they held 1.3 percent of the scheme's irrigable area. Approximately half of these farmers were located within Kaudulla's Stage I development, and the other half were within Stage II.

To select these farmers, the diagnostic analysis team chose six locations: two each from the head, middle, and tail of the system. The two head locations were no more than 2.5 km downstream from the main sluice. The middle and tail locations were 8 to 12 km and 14 to 19 km, respectively, from the main sluice.

Irrigation Department staff suggested the specific locations, giving primary emphasis to problem areas at the tail of the system. Tail farmers may find themselves disadvantaged compared to other farmers when it comes to quantity and certainty of irrigation deliveries.

The team selected the other four locations to represent conditions typical of the head and middle sections. Next, the team identified field channels emanating from the head, middle, and tail sections of the distributaries. From a comprehensive list of the allotments pertaining to these field channels, the team selected two of every three farmers to interview.

A team of five to six field investigators, usually working in pairs, contacted farmers at their homesteads, which were usually separated from the lowland allotments. The field investigators based their formal interviews on a previously field-tested questionnaire of 330 items administered in two sessions of approximately two hours each. The responses were to be "closed form"; i.e., according to predetermined sets of possible answers instead of in "open-ended" form, where the responses are unrestricted. The field investigators conducted one interview following planting and another after harvest.

As is common with comprehensive, but infrequently conducted interviews of farmers, the results suffer from farmers' imperfect recall and potential bias. Problems of recall occurred when farmers were asked to estimate routine activities, such as the amount of time the family spent weeding. Problems of bias centered on farmers' reluctance to reveal personal items such as family income and land transactions -- some of which violated restrictions placed on the settlers. Notwithstanding, the team judged the responses of the 77 farmers as good. The economics team checked the reasonableness of several responses by comparing the results to information obtained from other sources: informal contacts, observations, and data collected by the other disciplines.

3. RESULTS AND DISCUSSION

The survey results include information on farmers' holdings, livestock, cropping patterns, cultural practices for paddy, water management, labor inputs for paddy, use of improved practices, costs of paddy production, paddy output and disposal, paddy yields, family income, net profitability from paddy production, cash flows for paddy, credit, and farmer attitudes.

a. Land Holdings

The 77 sample farmers owned 123 ac of lowlands, which they devoted almost entirely to paddy production, and 84 ac of highlands for a total of 207 ac. Of the lowland amounts, the farmers reported that they had received 82 ac as part their original allotments, 33 ac from authorized encroachments, and 8 ac through purchases. The respective highland amounts reported were 49 ac, 29 ac, and 6 ac.

Encroachment occurs when farmers move onto lands unauthorized as part of their original settlement, including lands set aside for other purposes, such as forestry. The lands become authorized when the government formally acknowledges the farmers' rights to their use. The data on landholding may be understated, due to government restrictions on land transactions and encroachment.

The average farmer owned 1.6 ac of lowlands and 1.1 ac of highlands. Tables 35 and 36 provide distributional averages of respondents' reported landholdings. Table 37 shows the combined lowland and highland holdings. The amount of land owned by the sample farmers was relatively small. Somewhat over 25 percent of the farmers owned less than 2 ac and about the same amount owned between 4 and 6 ac. The smallness of holdings indicates the degree of fragmentation, which resulted in part from the family practice of dividing land among its members. Upper limits are set by the government's colonization policy.

Table 35. Average lowlands owned as reported by sample farmers at Kaudulla, 1986 *yala* (n=77).

Location	Head (n=23)	Middle (n=18)	Tail (n=35)	Total (n=77)
	acres/farmer			
Allotments	1.2	1.1	0.9	1.1
Encroachment with permits	0.3	0.4	0.5	0.4
Purchases	0.1	0.1	0.1	0.1
Total	1.6	1.6	1.5	1.6

Table 36. Average highlands owned as reported by the sample farmers at Kaudulla, 1986 *yala* (n=77).

Location	Head (n=23)	Middle (n=19)	Tail (n=35)	Total (n=77)
	acres/farmer			
Allotments	0.7	0.6	0.6	0.6
Encroachment with permits	0.2	0.3	0.5	0.4
Purchases	0	0.1	0.1	0.1
Total	0.9	1.0	1.2	1.1

Table 37. Combined average lowland and highland ownership by size of holdings for Kaudulla sample farmers, 1986 *yala* (n=77).

Size (ac/farmer)	Number of Farmers				Percent of Total
	Head (n=23)	Middle (n=19)	Tail (n=35)	Total (n=77)	
< 1	6	3	5	14	18
1 - 1.9	2	2	3	7	9
2 - 2.9	2	4	5	11	14
3 - 3.9	7	6	9	22	29
4 - 4.9	1	2	13	16	21
5 - 6	5	2	0	7	9
Total	23	19	35	77	100

While the average holding may be small, individual lowland and highland holdings were reported to be predominantly undivided into smaller plots. Specifically, 18 percent of the farmers reported that their lowland and highland holdings were divided into two plots, and just 3 percent reported that their holdings were divided into three plots. The rest are single units of either lowland or highland, which makes the farming more efficient.

Of the total sample farmers, 26 said they were the original allottees, 9 said they were second generation owners, and 1 first generation person (the spouse of the original allottee) and 1 third generation person said they were owners. However, the majority (39) said they acquired land by other means -- possibly through purchase, mortgage default, or transfers from relatives other than direct family.

To augment their holdings, some of the sample farmers occupied encroached areas for which they have not yet received, or may not receive, Government approval. Some sample farmers have obtained additional land for cultivation through rentals or mortgages. Other sample farmers rent, lease or mortgage portions of their holdings to others. Most of the farmers reported money problems as their reason for giving up the use of these lands. Table 38 shows the reported amounts of unauthorized encroachment and lowland transfers. As for the highlands, the sample farmers reported additions to their ownership amounting to less than 3 ac total. Also, one farmer transferred 1.5 ac to his children. Thus, average highland cultivated areas were essentially the same as average highland ownership. Table 39 shows that after net additions to holdings, 13 percent of the sampled households cultivated less than 2 ac.

Subdivision of land among family members reduces the size of family holdings somewhat. Of the 77 sample farmers, 5 heads of households reported that they had subdivided the land with their sons and one reported dividing his allotment with his wife.

Table 38. Average net additional lowland transactions and total lowland areas cultivated by the sample farmers at Kaudulla, 1986 *yala* (n=77).

Location	Head (n=23)	Middle (n=19)	Tail (n=35)	Total (n=77)
	acres/farmer			
Net Additions				
Encroachments with permits	0	0	0	0
Net rentals or leases	0.5	0.3	0.1	0.3
Net mortgages	0	0.2	0.3	0.2
Given to children	0	0.1	0	0
Subtotal	0.5	0.6	0.4	0.5
Owned	1.6	1.6	1.5	1.6
Total	2.1	2.2	1.9	2.1

Table 39. Combined lowland and highland areas farmed by the sample farmers at Kaudulla, 1986 *yala* (n=77).

Size (ac/farmer)	Number of Farmers Head (n=15)	Middle (n=19)	Tail (n=35)	Total (n=77)	Percent of Total
< 1*	1	0	0	1	1
1 - 1.9	2	4	3	9	12
2 - 2.9	6	4	14	24	31
3 - 3.9	9	5	6	20	26
4 - 4.9	1	2	11	14	18
5 - 5.9	4	3	0	7	9
6 - 9**	0	1	1	2	3
Total	23	19	35	77	

*1 farmer reported farming 0.5 ac.
**1 farmer each reported farming 7.5 and 8.25 ac.

In 40 cases the sample farmers reported engaging in either leasing or mortgage transactions. For the 24 leasing cases, the size of the acquisitions averaged about 1.5 ac. For the 16 mortgage cases, the size of the acquisitions averaged slightly less than 1 ac. About half of these transactions were for a single season; the other half ranged between one and three years. Lease rates averaged Rs. 620/ac/season when cash was the means of payment and 20 bu/ac/season when payment was in kind. Mortgage amounts ranged from Rs. 600 to Rs. 11,000. The

survey did not obtain details on repayment requirements for these mortgages.

b. Livestock

In addition to landholdings and acquisitions, farmers also derived utility and income from various types of livestock. Of outstanding importance were the farmers' buffalo, which they used for power, transportation, and food. Slightly over one-half of the sample farmers owned two or more buffalo, which were a major alternative to tractor power. While four farmers reported owning one buffalo each, on average the sample farmer owned nearly three buffalo.

Of less significance among the farmers interviewed were the cattle and poultry. Nearly one-fourth of the sample farmers owned an average of about two cattle. The largest number of cattle owned by a single farmer was five. Eight farmers reported owning chickens -- one farmer owned 30 chickens. However, the average number of chickens owned was 11. While some of the farmers said they held cattle and poultry for commercial purposes, only two farmers reported receiving income from them (Rs. 900 for the season). A somewhat higher percentage of tail sample farmers reported owning cattle and poultry than did those farmers in the head and middle regions of the scheme.

c. Cropping Patterns

Travelling through Polonnaruwa District, one is struck by the dominance of paddy cultivation over other farming activities. Data gathered by field investigators supported this observation. All but one of the 77 sample farmers reported growing paddy on an estimated 153 ac. Twelve farmers reported growing chilies on 8 ac. Thus, of the two crops reported growing, 95 percent of the area was used for paddy.

The area reported devoted to paddy and chilies totaled 161 ac. Compared to the total lowland area of 153 ac, this means farmers must have used some of their highlands to cultivate these crops. Since both of these crops are likely to require irrigation during yala, some of the highlands must have been irrigated, even though highlands are not formally served by the irrigation system.

Farmers are known to convert the highlands into lowlands through excavation. The lowered surfaces can then receive irrigation deliveries. Farmers also sometimes siphon water to uncommanded areas from delivery channels. Another possible source, which the questionnaire did not cover, could be water supplied through pumping.

Eighty-four percent of the farmers said they preferred growing paddy, citing ease of production and higher profitability as their reasons for doing so. Higher profitability is somewhat surprising, given the studies (Skogerboe et al., 1984) that show chili production to be considerably more profitable than paddy production. A possible explanation is the farmers' unfamiliarity with chili production. Suitability of soils also accounted for some of the farmers' preference, depending on their location. Paddy production is favored by

the low humic gleys, whereas chili favors the better-drained, reddish-brown earth soils.

The data show that 78 ac were devoted to permanent crops, which approximates the acreage reported earlier as highlands under production. On these 78 ac, farmers reported the following average number of trees per acre: 18 coconut trees, 14 banana plants, 3 mango trees, 2 jack trees, and 2 papaya trees.

d. Paddy Activities

The diagnostic analysis team identified 18 basic activities associated with yala paddy production by the 76 farmers reporting on this crop. These activities began with field channel cleaning and ended with transporting paddy to market. While the questionnaires indicated that not all the farmers participated in all of the activities, the majority of them did. Below is the list of paddy activities studied in 1986 yala.

* cleaning field channels
* plowing
* harrowing
* preparing seedbeds
* making porulela
* cleaning and plastering bunds
* seeding
* applying fertilizers
* applying insecticides
* weeding
* managing water
* reaping
* bundling and collecting
* preparing the threshing floor
* threshing
* winnowing and bagging
* transporting from field to home
* transporting to market

Various aspects of these activities are discussed in more detail in the following sections. However, some general observations follow regarding a few of these activities.

Sixty-seven farmers broadcast seed on the lowlands an average of 1.0 ac/day. Twenty farmers transplanted seedlings on the lowlands at an average rate of 0.37 ac/day. Four farmers broadcast seed on the highlands at an average rate of 0.86 ac/day. None of the farmers reported transplanting in highland areas. Based on total area reported planted in paddy, 21 percent, 28 percent, and 17 percent of the respondents transplanted paddy in the head, middle and tail regions, respectively. All farmers reported using high-yielding varieties, with nearly 67 percent planting BG 8/34 -- a short-season variety. BG 2/379, BG 6/34, and a few other varieties were used in considerably fewer instances. Three-quarters of the farmers reported using their own seed, while another 20 percent acquired seed from their neighbors. Seeding rates averaged 2 bu/ac. Seed selection and seeding rates apply to all locations, whether head, middle or tail.

Sixty-nine farmers reported applying basal fertilizers, 75 used a first top dressing, and 70 used a second top dressing. Thus, fertilizer use is widespread. Amounts for each of these three applications

for head, middle and tail farmers all averaged close to 55 kg/ac according to respondents' reports.

Farmers reported using V_1, TDM, and urea for these three applications and obtaining their supplies from private traders. Half of the farmers stated they applied the recommended rate, and 45 percent of the farmers said they applied less than the recommended rate, leaving only a few who applied more than the recommended rate. Two-thirds of sample farmers at the head said they applied less than the recommended rate, one-half in the middle said they applied less than the recommended rate, and only one-quarter of farmers at the tail said they applied less than the recommended rate. Frequently, farmers gave money problems as the reason for applying less than the recommended rates. However, some said that their experience justified applying either more or less than the recommended amount.

Sixty-two farmers reported applying insecticides at an average rate of 1.1 bottles/ac. Head farmers applied 28 percent less than the average, middle farmers applied 38 percent more than the average, and tail farmers applied the average. As a percentage of total area planted to paddy, 56 percent, 74 percent, and 91 percent of the head, middle, and tail farmers, respectively, applied insecticides to their fields. Combining the application rates and the areas covered indicates that middle and tail farmers applied twice the amounts as did the head farmers.

Farmers reported applying insecticides to combat leaf folder and stemborers in 84 percent of the cases. Farmers reported the brown plant hopper, rice bug, leaf-eating caterpillar, and thrips as being less important. Nearly all said they applied the recommended amounts of insecticide. Those few who said they did not apply recommended rates, claimed they did not know what the recommended rate should be.

The majority of farmers reported using weedicides, manually weeding, or both. Seven farmers reported no weed control efforts. Five of these farmers had transplanted paddy. Rates of weedicide application were relatively similar among head, middle, and tail farmers, averaging 2.4 bottles/ac. The percentage of area receiving some form of weed control, and the rates of weedicide applied, showed substantial similarities among the head, middle, and tail farmers. The weed most frequently mentioned was gavari (a grass) followed by kuda metta (a sedge) and bagari (a grass).

Nearly all of the farmers reported that they applied the recommended weedicide rates. Few of the respondents supported the idea of mechanical weeding. Head, middle and tail farmers varied little in their responses to weedicide use, weed problems, recommendation rates, and weeding preferences.

On average, farmers estimated that they spent 14 hrs/week irrigating. This average is the combination of 3.3 days/week for 4.2 hrs/day. Significantly, head farmers estimated that they spent 5.2 hrs/day, compared with slightly less than 4 hrs/day for the middle and tail farmers. Thus, head farmers reported spending about one-third

more time on water management than did the others. A greater abundance of water available to the head could account for the greater time needed to apply it. When water is abundant, however, farmers are more likely to be less careful managing it. Farm size does not provide an explanation, since the size of the head farmers' holdings approximated the overall average. Consequently, no clearcut explanation for the difference in time spent on water management came from the data collected. Moreover, the questionnaire's report on man-days of activity for yala suggests that farmers spent less time on water management than reported here.

A slightly higher percentage of head farmers reported receiving less than their requirement for water (35 percent), compared to 21 percent of the middle farmers and 30 percent of the tail farmers. Overall, 50 percent of the farmers said they had water management problems. Apparently some of the farmers associated water management problems with something other than the general availability of water. The questionnaire did not provide information on farmers' use of drainage water, nor was information available on water supplied through capillary action. Drainage water and groundwater quality was generally considered good. These sources, together with occasional rainfall, somewhat diminished farmers' reliance on the delivery system.

Almost all respondents reported costs associated with reaping, bundling and collecting, preparing the threshing floor, and threshing. All of the farmers reported labor costs for winnowing and bagging, but only ten farmers reported costs for winnowing fans. Six of these farmers were from the head, while only two each were from the middle and tail sections.

About 80 percent of the farmers reported labor costs for transporting the paddy from the fields to their homesteads, and about 30 percent reported tractor costs for this purpose. The head farmers incurred somewhat fewer costs than average for both labor and tractors.

Only 12 of the 76 farmers reported spending time to market their paddy. Most of the farmers sell their paddy to private firms that come to the farmers' gate. Four farmers had not sold their marketable surplus by the time of the survey, and two others reported no marketable surplus.

e. Paddy Labor

This section concentrates on the amount of labor reported required to do the foregoing activities. Included are estimates of man-day requirements for each activity. Values are given for head, middle, and tail farmers; for family, hired and contract labor; and for male and female workers. To focus the reader's attention, we present labor requirements for the typical set of farming paddy activities. The section closes with a comparison of these requirements and the availability of family labor.

Requirements. The sample farmers met their labor requirements for paddy production through that available from their own household, and

by hiring laborers daily or through contracts to perform specific activities. We assumed that farmers exchange labor at times of special need. While we did not have specific information on such communal activities, we have assumed that the net effect was to even out farmers labor requirements rather than to increase or decrease the amount. Table 40 lists the average farmers' labor requirements overall according to their location at the head, middle, or tail of the system. The heaviest labor requirement was for transplanting; labor required for broadcasting was relatively small. Manual weeding also required considerable labor.

Comparisons among head, middle and tail farmers showed only minor differences in practices, as would be expected. An exception was the larger average labor requirement by tail farmers for transplanting. However, the number of cases where this was found was too small to draw conclusions about the significance of this finding.

The farmers' estimate of 6.9 man-days for water management does not agree with their responses to the days per week and hours per day spent on this activity. The 14 hrs/week mentioned earlier may be an upper limit and the 6.9 days/season reported here may represent the lower limit. Farmers may manage water while also performing other duties, and consequently did not think of water management as a separate activity.

Table 41 tells whether the labor was supplied by the farmer's family, hired daily, or provided through contract. The dominant supply of labor came from the family. Contract labor seemed to be reserved for transplanting, reaping, bundling, and collecting. The farmers' reliance on hired labor was surprising. Hired labor inputs were comparable to those of the family for reaping, bundling, collecting, threshing, winnowing, and bagging.

Table 42 shows the division of farmers' labor according to gender. Women undoubtedly perform a variety of farming activities when special needs arise, but the major contribution women were reported to make were transplanting and weeding and, to a lesser extent, reaping, bundling, and collecting.

To gain a fuller understanding of labor requirements, one must know more about the characteristics of farmers' practices. Table 43 provides a breakdown of the 76 sample farmers' responses based on whether they cultivate with tractors or buffalo and whether they transplanted or broadcast their paddy fields. The table also reveals the extent to which they applied weedicides and relied on insecticides, both of which reflect elements of modern agricultural practices. We do not show the breakdown of chemical fertilizer application, since all but two of the sample farmers reported their use.

The dominant practice is the combination of buffalo use and broadcast paddy. The table indicates that 41 percent of the sample farmers reported relying only on this approach. Nine farmers used buffalo, broadcast, and also transplanted their fields. Combined, the percentage of farmers using buffalo and broadcasting at least some of

Table 40. Average labor requirements for paddy production -- overall and by head, middle, and tail as reported by Kaudulla respondents, 1986 *yala* (n=76).

Activities	Head (n=23)	Middle (n=19)	Tail (n=34)	Total (n=76)
	man-days/farmer*			
Cleaning field channels	1.96	1.50(18)**	1.70(32)	1.73(73)
First plowing				
tractor	2.08(6)	1.85(5)	1.63(8)	1.83(19)
buffalo	5.24(17)	4.57(14)	5.94(26)	5.39(57)
Second plowing				
tractor	2.00(6)	2.46(6)	1.66(16)	1.90(28)
buffalo	5.24(17)	4.35(13)	7.38(17)	5.77(47)
Harrowing				
tractor	1.90(5)	2.00(3)	1.37(7)	1.67(15)
buffalo	4.08(18)	3.53(16)	3.46(27)	3.66(61)
Preparing seedbeds (for transplanting)	3.67(6)	2.29(7)	3.92(6)	3.24(19)
Making poru ela (for broadcasting)	6.33(20)	7.56(18)	6.26(29)	6.63(67)
Cleaning and plastering bunds	12.76	16.26	14.44	14.39
Seeding				
transplanting	30.86(7)	32.57(7)	46.50(6)	36.15(20)
broadcasting	2.08(19)	1.58(18)	1.75(30)	1.80(67)
Applying fertilizers	2.00(22)	1.97(19)	2.18(33)	2.07(74)
Applying insecticides	1.29(12)	2.25(16)	1.73(32)	1.78(60)
Weeding				
weedicides	1.69(16)	1.57(15)	1.84(25)	1.72(56)
manually	13.50(6)	14.77(13)	15.72(23)	15.11(42)
Managing water	7.13	7.05	6.65	6.90
Roaping	17.61	16.42	18.74	17.82
Bundling and collecting	11.39	11.32	9.97	10.74
Preparing the threshing floor	3.18(22)	2.77(13)	2.83(24)	2.95(59)
Threshing	9.91	9.11	9.56	9.55
Winnowing and bagging	5.87	4.79	5.97	5.64
Transporting from field to homestead	3.00(2)	1.80(5)	2.80(5)	2.42(12)

*Average area planted in paddy by location: 2.04 ac for head, 2.16 ac for middle, 1.92 ac for tail, and 2.01 ac overall.

**Values in () are numbers of farmers. Where no value is shown, the amount equals the value in the header.

Table 41. Average labor requirements for paddy production by source of supply on Kaudulla for 1986 *yala* (n=76).

Activities	Family	Hired	Contract	Total
	man-days/farmer*			
Cleaning field channels	1.62(70)**	1.44(9)	0	1.73(73)
First plowing				
tractor	--	--	--	1.83(19)
buffalo	4.09(43)	4.66(29)	0	5.39(57)
Second plowing				
tractor	--	--	--	1.83(29)
buffalo	4.00(36)	4.88(26)	0	5.77(47)
Harrowing				
tractor	--	--	--	1.67(15)
buffalo	2.79(48)	3.20(28)	0	3.66(61)
Preparing seedbeds (for transplanting)	3.13(19)	2.00(1)	0	3.24(19)
Making poru ela (for broadcasting)	3.37(59)	4.47(55)	0	6.63(67)
Cleaning and plastering bunds	8.07(67)	9.68(57)	0	14.39(76)
Seeding				
transplanting	10.06(17)	23.53(15)	39.00(4)	36.15(20)
broadcasting	1.63(66)	1.86(7)	0	1.80(67)
Applying fertilizers	1.93(74)	2.25(4)	0	2.07(74)
Applying insecticides	1.62(56)	2.00(8)	0	1.78(60)
Weeding				
weedicides	1.53(55)	1.79(7)	0	1.72(56)
manually	7.78(39)	16.55(20)	0	15.11(42)
Managing water	6.90(76)	0	0	6.90(76)
Reaping	14.50(76)	2.75(24)	6.41(29)	17.82(76)
Bundling and collecting	9.05(76)	2.35(26)	4.79(14)	10.74(76)
Preparing the threshing floor	2.24(54)	2.30(23)	0	2.95(59)
Threshing	3.49(71)	6.83(70)	0	9.55(76)
Winnowing and bagging	3.02(66)	3.54(65)	0	5.64(76)
Transporting from field to homestead	2.33(9)	2.67(3)	0	2.42(12)

*Average area planted in paddy is 2.01 ac.
**Values in () are numbers of farmers. Numbers across may not total since some farmers use more than one source of labor.

Table 42. Average labor requirements for paddy production by gender as reported by Kaudulla respondents, 1986 *yala* (n=76).

Activities	Male	Female	Total
	--------man-days/farmers*----------		
Cleaning field channels	1.73(73)**	0	1.73(73)
First plowing			
tractor	1.83(19)	0	1.83(19)
buffalo	5.39(57)	0	5.39(57)
Second plowing			
tractor	1.90(28)	0	1.90(28)
buffalo	5.77(47)	0	5.77(47)
Harrowing			
tractor	1.67(15)	0	1.67(15)
buffalo	3.66(61)	0	3.66(61)
Preparing seedbeds for transplanting	3.24(19)	0	3.24(19)
Making poru ela for broadcasting	6.63(67)	0	6.63(67)
Cleaning and plastering bunds	14.39(76)	0	14.39(76)
Seeding			
transplanting	13.50(16)	26.68(19)	36.15(20)
broadcasting	1.80(67)	0	1.80(67)
Applying fertilizers	2.07(74)	0	2.07(74)
Applying insecticides	1.78(60)	0	1.78(60)
Weeding			
weedicides	1.72(56)	0	1.72(56)
manually	7.33(20)	13.56(36)	15.11(42)
Managing water	6.90(76)	0	6.90(76)
Reaping	14.50(76)	6.46(39)	17.82(76)
Bundling and collecting	9.05(76)	3.88(33)	10.74(76)
Preparing the threshing floor	2.95(59)	0	2.95(59)
Threshing	9.55(76)	0	9.55(76)
Winnowing and bagging	5.64(76)	0	5.64(76)
Transporting from field to home	2.42(12)	0	2.42(12)

*Average area planted in paddy is 2.01 ac.
**Values in () are numbers of farmers. Numbers across may not total since some farmers use more than one source of labor.

Table 43. Cultural practices reported by the sample farmers in Kaudulla, 1986 *yala* (n=76).

Traction	Insect and Weed Control	Seeding Method: Transplant	Broadcast	Both	Total Responses
		-----Number of Responses-----			
Total farmers using tractors only		2	15	0	17
	Weedicides only	0	8		8
	Weedc./manual	0	6		6
	Manual only	2	0		2
	No weeding	0	1		1
	Insecticides	2	14		16
	No insecticides	0	1		1
Total farmers using buffalo only		5	31	9	45
	Weedicides only	0	12	4	16
	Weedc./manual	0	12	4	16
	Manual only	1	5	1	7
	No weeding	4	2	0	6
	Insecticides	4	23	8	35
	No insecticides	1	8	1	10
Total farmers using tractors and buffalo		1	11	2	14
	Weedicides only	0	6	1	7
	Weedc./manual	0	4	0	4
	Manual only	0	1	1	2
	No weeding	1	0	0	1
	Insecticides	1	8	2	11
	No insecticides	0	3	0	3
Total farmers		8	57	11	6

their fields was 53 percent of the total. The prevailing technology is labor-saving through the farmer's use of purchased inputs. The next most prevalent practice was that of tractor use and broadcasting.

Several reasons could explain the farmers' heavy reliance on buffalo, rather than tractors. In view of a tractor's relatively high cost, limited income and wealth must inhibit many farmers from purchasing them. The popular two-wheeled Japanese tractor, complete with attachments, reportedly costs Rs. 70,000. Considering that many families' annual net cash income may be no more than Rs. 5,000, and that most farmers do not have access to medium- or long-term bank credit, they are unable to purchase a tractor. Moreover, the farmers small holdings reduce the need for tractor power. While irrigation scheduling could be improved through more coordinated land preparation, the Irrigation Department accommodates buffalo plowing by lengthening the pre-planting irrigation beyond the 30 days nominally set during the pre-season planning (kanna) meetings.

Table 44 shows that the farmer who relied on buffalo, broadcast, and used fertilizers, pesticides, and weedicides averaged 101 man-days of labor during 1986 yala. The farmers used just over half this amount to clean and plaster bunds, reap, bundle, collect, and thresh. A representative farm family obtained 66 percent of its labor requirements from within the family itelf.

The female's contribution to farming activities for a "typical" farm as reported by sample farmers was 5.4 percent on farms that relied on weedicides only and 8.6 percent on farms that relied on weedicides and manual weeding. We estimated the larger percentage by assuming the representative farmer used weedicides one-half of the time and manually weeded the other half of the time.

This small contribution from women is surprising and may be the result of the way the questionnaire was constructed (in addition, men were interviewed to obtain this information). The farmers were asked to list female labor for only transplanting, weeding, reaping, bundling, and collecting. Since the most representative farmer broadcast rather than transplanted, and often relied on weedicides instead of manual weeding, women's labor contribution in many of these cases may have been limited to reaping, bundling, and collecting. However, to the extent that women engaged at least marginally in other activities, their overall contribution would be larger than the percentages stated above. In fact, the farm women interviewed by the women in development component reported much higher agricultural participation.

The greatest seasonal labor requirements (145 man-days) were associated with plowing with buffalo, transplanting paddy, and weeding manually. The least labor requirements (92 man-days) were associated with farmers who used tractors, broadcast paddy, and relied on weedicides. Interestingly, the low labor alternative is strikingly close to the most representative case, differing only in the use of buffalo instead of tractors. Generally, farming activities and the associated

Table 44. Labor requirements for the typical Kaudulla paddy farmer by farming types in 1986 *yala*.

Activities	Most Common	Labor Intensive	Labor Saving
	--------man-days/season*----------		
Cleaning field channels	1.73	1.73	1.73
First plowing			
tractor	0	0	1.83
buffalo	5.39	5.39	0
Second plowing			
tractor	0	0	1.90
buffalo	5.77	5.77	0
Harrowing			
tractor	0	0	1.67
buffalo	3.66	3.66	0
Preparing seedbeds (for transplanting)	0	3.24	0
Making poru ela (for broadcasting)	6.63	0	6.63
Cleaning and plastering bunds	14.39	14.39	14.39
Seeding			
transplanting	0	36.15	0
broadcasting	1.80	0	1.80
Applying fertilizers	2.07	2.07	2.07
Applying insecticides	1.78	1.78	1.78
Weeding			
weedicides	1.72	0	1.72
manually	0	15.04	0
Managing water	6.90	6.90	6.90
Reaping	17.82	17.82	17.82
Bundling and collecting	10.74	10.74	10.74
Preparing the threshing floor	2.95	2.95	2.95
Threshing	9.55	9.55	9.55
Winnowing and bagging	5.64	5.64	5.64
Transporting from field to homestead	2.42	2.42	2.42
Total	100.96	145.24	91.54

*Based on overall values for 76 farmers as shown in Table 40, and on an average paddy area per farmer of 2.01 ac.

labor requirements were reasonably uniform for head, middle, and tail farmers.

Supply. The questionnaire did not provide information on family size or household labor available for paddy production. The Government's Consumer Finance and Social Economic Survey for 1981-1982, however, indicated that family size for the whole of Zone II, which includes Polonnaruwa, was 5.3 (Central Bank of Ceylon, 1984). Considering that rural families might be somewhat larger than urban families, Kaudulla farmers might have an average family size of 5.5 members. Thus, two full-time adult workers might be a reasonable estimate of available family labor. This estimate would allow for a male head of household, inputs from an elder son, and occasional inputs from the wife. Over the irrigation season (mid-April through August), the family would therefore have roughly 220 days of labor available. This estimate allows for one day of rest per week and a few days for holidays or other occasions when work is not done.

The cropping requirements for the typical situation, shown in Table 44, is 101 man-days. Considering that the sample farmers provided about two-thirds of this input (using data from Table 41, then the family's supply of labor exceeds its input by more than three times (220 divided by two-thirds of 10 = 3.3). This ratio seems reasonable when allowing for the non-uniformity of labor requirements throughout the season and farmers' other responsibilities and preferences. The sample farmers' reliance on hired labor, some custom services, and labor saving practices such as broadcasting and chemical weed control supports this conclusion. Were credit more abundant or the cost of tractors less, one could expect considerably more farmers to cultivate with tractors.

f. Paddy Costs

This section provides information on the costs of paddy production as reported by the 76 sample farmers. These costs concern purchased materials, hired and contract labor, the services of buffalo and equipment, and the family's own labor. For family labor and where the farmers used their own tractors and buffalo, the costs do not represent actual cash expenditures. Rather, the costs reported on the questionnaires represent what economists call "opportunity costs"; i.e., the value of an item in its best alternative use. For example, by assigning the standard daily wage of Rs. 30 for family labor, we assume that family laborer could earn this amount were he or she to hire out instead of participating in the family's paddy production. Similarly, where farmers own buffalo or tractors, the production costs represent what these assets could earn were the farmers were to rent them out instead of using them for their own paddy production. In a subsequent section we modify this approach as we investigate the sample farmers' economic and financial positions. At that time we take account of the sample farmers' various sources of income and costs other than those directly related to paddy production.

In reviewing the costs of paddy production, we found that the breakdown of farmer practices was reasonably consistent among head,

middle, and tail farmers. For example, the predominant system of buffalo traction and broadcasting occurred 41 percent of the time among head farmers, 37 percent of the time among middle farmers, and 44 percent of the time among tail farmers, compared with 41 percent overall. In view of this similarity, we chose to present paddy production costs for the sample group as a whole, rather than by head, middle, and tail groupings. Table 45 shows average costs by type of input for each activity. Since the area planted to paddy averaged 2.01 ac/family, the costs per acre are half those shown in the table.

To give these individual costs more meaning, we applied them to the most common set of paddy practices, which was using buffalo, broadcasting, and weedicides. This set of practices costs Rs. 7,011/farmer, as shown in Table 46, or roughly Rs. 3,490/ac. This result agrees closely with that obtained by the design team for the Irrigation Systems Management Project (Skogerboe et al., 1984). Their overall estimate for these same items came to Rs. 2,950/ac for a representative season in 1984. Adjusting for inflation brings these values close together, although individual costs occasionally differ significantly.

Somewhat less than half (43 percent) of total costs were for labor, for which the family accounted for two-thirds. The assumption that the value of family labor equals the market wage of Rs. 30/day is important in evaluating these costs. About two-thirds of equipment and buffalo were for plowing and harrowing. Many of the farmers used their own buffalo, which have been herein charged at the market rate of approximately Rs. 100/day. Fertilizers accounted for just over half of material costs. Combined, family labor, buffalo and fertilizers accounted for 64 percent of total costs. Note that when farmers owned buffalo the only cash expenditure was for fertilizers.

To evaluate the differences in costs between the predominant set of cultural practices and the labor intensive and labor saving methods, we need to focus on the relative costs of traction, seeding, and weeding methods. The three sets of cultural practices result in substantially different costs for seeding and relatively minor differences in costs for tractors and weeding. Of course, more is involved in the farmers' choices than just the costs per farm. Other factors include timeliness of land preparation, access to funds, availability of family and hired labor, variability of yields, and so on.

The labor intensive method averaged Rs. 1,289 more than the Rs. 7,011 cost for the predominant method, bringing the cost of the labor intensive method to Rs. 8,300. This cost is an 18 percent increase -- a sizeable amount. The labor intensive method incurs costs of Rs. 114 for preparing the seedbed, Rs. 1,286 for labor to broadcast, and Rs. 614 for manual weeding for a total of Rs. 2,014. The predominant method incurs costs of Rs. 230 for making poru ela, Rs. 102 for labor to broadcast, and Rs. 393 for chemical weed control for a total of Rs. 725. All other costs are roughly the same, including that for seed.

Table 45. Average variable costs of producing paddy on 2.01 ac as reported by the Kaudulla sample farmers in 1986 *yala* (n=76).

Activities	Type of Cost*		
	Labor	Materials	Equipment & Buffalo
	Rs./farmer		
Cleaning field channels	57(74)	NA	NA
First plowing			
tractors	**	NA	610(19)
buffalo	***	NA	523(57)
Second plowing			
tractors	**	NA	641(29)
buffalo	***	NA	562(47)
Harrowing			
tractors	**	NA	478(15)
buffalo	***	NA	354(61)
Preparing seedbeds (for transplanting)	114(19)	NA	NA
Making poru ela (for broadcasting)	230(67)	NA	NA
Cleaning and plastering bunds	512(76)	NA	NA
Seeding		396	NA
transplanting	1,286(20)		
broadcasting	102(67)		
Fertilizing	82(76)		NA
basal		328(69)	
first top dressing		312(75)	
second top dressing		346(70)	
Applying insecticides	63(62)	194(62)	45(60)
Weeding			
weedicides	61(57)	286(57)	46(57)
manually	614(43)	NA	NA
Managing water	207(76)	NA	NA
Reaping	633(76)	NA	NA
Bundling & collecting	368(76)	NA	NA
Preparing the threshing floor	106(59)	NA	NA
Threshing	334(76)	NA	314**(76)
Winnowing & bagging	195(62)	****	150(10)
Transporting from field to homestead	82(21)	NA	123**(62)

NA = not applicable.

*Numbers in () are numbers of farmers. Occasionally, minor differences occur between the number of farmers reported here and in Tables 40 to 42 due to incomplete reporting on the questionnaires.

**Fuel, lubricants, and operators contribute to tractor costs.

***Labor is included as part of buffalo costs.

****The questionnaire did not obtain information on bagging costs.

Table 46. Average variable costs of producing paddy for Kaudulla farmers who followed the dominant practice* in 1986 yala (based on an average farm size of 2.01 ac).

Activity	Type of Cost			
	Labor	Materials	Equipment & Buffalo	Total
	Rs./farmer			
Cleaning field channels	57	NA	NA	57
Two buffalo plowings	**	NA	1,085	1,085
Harrowing with buffalo	**	NA	354	354
Making poru ela for broadcasting	230	NA	NA	230
Cleaning and plastering bunds	512	NA	NA	512
Broadcasting seed	102	396	NA	498
Three fertilizer applications	82	986	NA	1,068
Applying insecticides	63	194	45	302
Weeding with weedicides	61	286	46	393
Managing water	207	NA	NA	207
Reaping	633	NA	NA	633
Bundling & collecting	368	NA	NA	368
Preparing the threshing floor	106	NA	NA	106
Threshing	334	NA	314	648
Winnowing and bagging	195	***	150	345
Transporting from field to homestead	82	NA	123	205
Total	3,032	1,862	2,117	7,011

NA = Not applicable.
*Farmers who used buffalo, broadcast, and applied weedicides.
**Labor is included as part of buffalo costs.
***The questionnaire did not obtain information on bagging costs.

Comparing the typical farmer who transplants with the one who broadcasts, however, reduces the above difference to Rs. 675, since five of the eight sample farmers who transplanted did not weed at all. Not weeding creates a savings of Rs. 614.

As noted, the predominant case comprised farmers who used only weedicides (46 percent). Of the remaining sample farmers who broadcast, 38 percent used a combination of weedicides and manual weeding, 11 percent relied only on manual weeding, and 5 percent reported no weeding costs. Comparing these additional conditions would, of course, alter the cost differences shown above, but broadcasting would remain the lower cost alternative.

The labor saving method costs Rs. 7,301, or Rs. 290 more than the predominant method. The only difference in costs between the two

methods resulted from the higher cost of tractors over buffalo. Table 45 shows Rs. 1,729 for two plowings and one harrowing with tractors, and Rs. 1,439 when these same activities are performed by buffalo. The daily rates for tractors, which ranged from Rs. 284 to Rs. 363, were higher than the daily rates for buffalo, which hovered around Rs. 100. Offsetting the higher daily rates for tractors was the lesser time they required. The average length of time to plow and harrow with tractors was approximately two days, while that for buffalo was approximately five days.

Thus, farmers following the dominant practice have opted for the least expensive means of production. This preference for a least cost solution might be misguided were it found that the value of higher yields from transplanting overrode the extra production costs of this practice. However, this is not the case, as will be shown shortly.

g. Paddy Production

According to information supplied by sample farmers, output on the 153 ac planted in paddy averaged 47 bu/ac. (The agronomy section of this report gives estimated yields from crop cuttings.) Yields ranged from an average high of 55 bu/ac for the head and middle sections to a low of 39 bu/ac for the tail sections. These results compare with a nationwide average of 70 bu/ac and a realizable potential of 110 to 120 bu/ac (USAID/Colombo, 1986). Consequently, the reported yields are well below the national average and seriously below the potential. Note that the sample farmers reported that yields during the 1986 yala were below those of the previous maha and the 1985 yala. The majority of the farmers attributed their low yields during 1986 yala to the prevalence of wind during pollination. They also cited pests in general and during pollination as contributing factors.

Table 47 provides the yields for head, middle, and tail farmers according to whether they transplanted or broadcast paddy. Because farmers reported the disposition of their output, yields per acre of harvested area had to account for losses during harvesting and initial post-harvest. In some cases, farmers were holding paddy to sell at a later date, as indicated by the difference between the amount they reported as their marketable surplus and sales to date. The marketable surplus is the harvested output less amounts set aside for seed and consumption or paid in kind to the vel vidane and for leases or mortgages.

Note the much higher yields for head and middle section farmers than for tail farmers (statistically significant at the one percent level). Aside from the low yield for one transplanting case in the middle section, the data do not show significant differences in yields between transplanting and broadcasting. Given the higher cost of transplanting, this result is somewhat surprising. A possible speculative explanation is that farmers traditionally transplanted paddy to control weeds. Only relatively recently have weedicides become available and accepted by farmers as a more cost-effective means of weed control. Because this newer technology is still in the introductory stage, some farmers still followed the traditional practice.

However, transplanting would appeal to those farmers wishing to limit their purchased inputs by using family labor to transplant. For this to be possible, family labor would have to be sufficient for the amount of land devoted to paddy.

Table 47. Average net paddy yields for sample farmers according to their location and method of seeding, Kaudulla, 1986 *yala*.

	Head		Middle		Tail		Overall	
	T*	B	T	B	T	B	T	B
Number of farmers**	4	16	1	12	3	29	8	57
Total production	340	1,675	91	1,221	333	2,062	764	4,958
Area planted (ac)	6.0	30.8	3.5	21.3	8.3	52.5	17.8	104.6
Yields (bu/ac)	56.7	54.5	26.0	57.3	40.1	39.3	42.9	47.4
Combined yields (bu/ac)	54.9		54.9		39.4		46.8	
Area harvested (% of planted)	96	96	100	100	94	93	96	95

*T - Transplanted; B - Broadcast
**Omitted are the results for 11 farmers who used both methods of seeding because yields could not be associated with only one of the two methods.

Farmers reported harvesting 146 of the 153 ac they reported as planted. At least part of the explanation for the difference would be for the same reasons farmers gave for the reduction in yields, noted above.

Coefficients of variation of 31, 41, and 37 percent for head, middle, and tail farmers, respectively, are all reasonably close, which indicates similar distribution of yields within the groups. In support of this conclusion, a test of the standard deviations for head and tail yields failed to show a difference at the five percent level of significance.

Though one could expect greater yield variability in the tail of a system, this does not appear to be true in Kaudulla. One possible explanation for this could be the tail farmers' access to good drainage water. Another possible explanation is that tail farmers may receive adequate amounts of water overall, although perhaps not at times

critical to plant growth. The main system and on-farm sections of this report cover water availability in detail.

Disposal of Output. Combining the average yield for each farmer (46.8 bu/ac) and the average land in paddy during 1986 yala (2.01 ac) produced an average output from each family of 94.1 bu. Of this total, the farmers paid out an average of 8.0 bu for leasing arrangements and 0.3 bu for the vel vidane, and kept 4.2 bu for seed; leaving a net output of 81.6 bu. Of this amount, the farmers set aside an average of 25.8 bu for consumption, sold 38.2 bu, and retained 17.6 bu for future sale.

Practically all of the farmers sold their paddy through local, private traders. Only one family reported selling to the cooperative. Farmers' preference for private traders over official sources such as the Paddy Marketing Board, Agricultural Service centers, or cooperatives resulted from the comparative ease with which farmers obtained payment from the private traders, the traders' acceptance of the farmer's paddy without penalties for low quality, and the low or no transportation costs associated with paddy sales. Concerning transportation costs, farmers said they paid less than an average of Rs. 1/bu sold.

The amount farmers reported set aside for consumption represents an average daily per capita consumption of 0.38 kg of rice per day. This result approximates the apparent combined consumption of rice and rice flour for Sri Lanka in the years 1978-82 as reported by the Ministry of Finance and Planning (1984). This estimate of the sample farmers' consumption derives from the following values and assumptions: 20.87 kg/bu, 0.68 conversion factor from paddy to rice, two paddy plantings each year so that each season's paddy set aside represents one-half of the year, and an average family size of 5.5 members.

Having a marketable surplus of some 55 bu/season, compared with the 26 bu set aside for consumption, means that these farmers are active participants in the market economy. Also, by holding 18 bu off the market, the sample farmers are better able to demand a more competitive price for their paddy than were they forced to sell all, or most, of their paddy immediately following harvest. Such activity probably explains the farmers' use of purchased inputs (pesticides and fertilizers) as well as their employment of labor and purchases of tractor and buffalo services. Given their current market activity, introducing improved practices to Kaudulla farmers ought to be an easier task than often occurs in developing countries. (Where small-scale agriculture is largely subsistence, farmers find it difficult to accept changes that require cash outlays.)

Table 48 divides these overall figures into those representative for the head, middle, and tail farmers. This locational breakdown reveals that head farmers held more for consumption than the other sample farmers and sold nearly all of their marketable surplus. In contrast, the tail farmers held less for consumption, which accords with their less favorable yields. Even so, they were able to withhold an average of 12.6 bu for future disposal, which shows some marketing

strength. With favorable yields compared with the head and tail farmers and low provision for consumption and rental payments, the middle farmers appeared to be in the strongest marketing position of all.

Table 48. Average disposition of paddy overall and by head, middle, and tail farmers, Kaudulla, 1986 yala.

Item	Head (n=23)	Middle (n=19)	Tail (n=34)	Overall (n=76)
	(bu/family)*			
Total production	106.3	103.7	79.3	94.1
Less amounts for				
rent	13.3	2.4	7.6	8.0
seed	5.2	5.1	3.0	4.2
vel vidane	0.8	0.1	0.1	0.3
Net output	87.0	96.1	68.6	81.6
Less amounts held for consumption	29.3	23.1	24.8	25.8
Marketable surplus	57.7	73.0	43.8	55.8
Sales to date	56.3	28.7	31.2	38.2
Retained	1.4	44.3	12.6	17.6

h. Family Income

During yala, family income derived principally from paddy sales because of moisture limitations on the highlands. However, the family also received income from additional means, such as from selling other crops that do receive sufficient moisture, leasing tractors to others, and obtaining off-farm sources. Below are survey findings for both paddy production and other income sources.

Value of Paddy Production. Table 49 reveals that the average net value of paddy production for the sample farmers as a group amounted to Rs. 5,761. This value is the product of the farmers' net output, as shown in Table 48, and the average farm gate price less any transportation costs. Before comparing this value with the cost of production, we must adjust for the cost of seed. In Table 46, the Rs. 396 for seed was imputed at the rate of Rs. 71/bu of paddy equivalent. However, farmers supplied 75 percent of this amount from stocks held over from previous harvests. Thus, seeding costs would double were we to use the costs from Table 46 and the net output from Table 48. To correct for this overlap, we deducted 75 percent of the seed cost from the total cost of production. This lowered total costs by Rs. 297 (0.75 x Rs. 396), giving an adjusted cost of production for comparison purposes of Rs. 6,714 (Rs. 7,011 - Rs. 297).

Table 49. Average values of paddy production overall and by head, middle, and tail farmers, Kaudulla, 1986 yala.

	Head (n=23)	Middle (n=19)	Tail (n=34)	Overall (n=76)
Net production (bu)	87.0	96.1	68.6	81.6
Farm-gate price (Rs./bu)	69.9	73.8	71.2	71.6
Less transportation charge (Rs./bu)	0.6	0.9	1.4	1.0
Net price (Rs./bu)	69.3	72.9	69.8	70.6
Value (Rs.)	6,029	7,006	4,788	5,761
Amount sold (%)	64.7	29.9	45.5	46.8
Assumed cash receipts (Rs.)	3,901	2,095	2,179	2,697

This value of production falls short of the adjusted cost of production by 14 percent (Rs. 5,761 is 86 percent of Rs. 6,714). The sample farmers all claimed that this season was worse than the previous maha and yala, so for an average year, the farmers might come close to or exceed their direct costs of production. However, that would not necessarily cover the costs of interest, tool and equipment purchases, and the like; nor would it give farmers a return on their land and management.

The paddy prices these income estimates are based on averaged Rs. 70.6/bu overall. The highest price, mentioned by one of the middle farmers, was Rs. 84/bu, and the lowest price, mentioned by one of the head farmers, was Rs. 62/bu. Supposedly, farmers can receive a guaranteed price of Rs. 70/bu from official sources such as the Paddy Marketing Board. However, the farmer's net price from official sources may be less because of deductions for excessive moisture, rejections due to poor quality, and associated transportation costs. For these reasons, farmers often feel they obtain as good a price from the local traders, even though these traders at times pay them less than the guaranteed price.

A slightly higher price combined with larger average sales gave the middle farmers the highest income from paddy. The tail farmers remained well below the average. Looking at individual farmers within the head, middle, and tail sections revealed pronounced extremes. The highest paddy incomes among head, middle, and tail farmers were Rs. 15,900, Rs. 35,500, and Rs. 23,650, respectively. These farmers' respective areas planted in paddy were 3, 5.5, and 3.5 ac. The lowest paddy income farmers for these same groupings were Rs. 1,380, Rs. 1,400, and Rs. 690. These farmers' respective holdings in paddy were 1.5, 0.5, and 0.5 ac.

Studying the cultural practices of these six farmers failed to produce any pattern that might help explain these differences. All broadcast at least part of their fields, most used buffalo, all used pesticides, and differences in rates of fertilizer application were equally great among the high income group as among the low income group. Consequently, size of holdings must play a key role in determining these farmes' income levels from paddy.

The cash receipts these farmers receive amount to their sales plus whatever portion of the retained amounts are sold. At the time of the survey, farmers had sold 47 percent of their net output for an average cash value approaching Rs. 2,700. We use these values later when discussing the farmers' financial position.

Other Income. Looking at the farmers as a group, income from sources other than paddy averaged Rs. 3,060 during 1986 *yala*. This amount is over half (53 percent) of that from paddy production (Rs. 5,761). These other sources, shown in Table 50, include the value of subsidiary crop and home garden production, off-farm wages and salaries to the farm families, pensions, tractor rentals, and revenues from livestock.

Table 50. Average other income accruing to the Kaudulla sample farmers during 1986 *yala*.*

Source	Head (n=23)	Middle (n=19)	Tail (n=34)	Total (n=76)
	Rs./farmer			
Subsidiary crops	2,420(4)	2,210(3)	1,670(8)	1,980(15)
Home gardens	510(11)	1,090(9)	300(6)	660(26)
Wage labor	810(5)	3,080(6)	820(19)	1,270(30)
Permanent jobs	6,980(2)	0	0	6,980(2)
Pensions	6,390(2)	0	0	6,390(2)
Other family earnings	2,530(8)	1,750(1)	4,200(1)	2,620(10)
Tractor rentals	5,330(3)	5,360(5)	5,330(3)	5,340(11)
Livestock	730(2)	450(1)	0	640(3)
Average	4,410(19)	4,000(16)	1,700(30)	3,060(65)
Highest value	17,000	8,300	11,000	17,000
Lowest non-zero value	250	540	160	160

*Values in () are the number of farmers.

Tractor rentals accounted for the largest source of income overall, averaging Rs. 5,340 for 11 farmers. The largest group of farmers benefitting from additional income were those who earned wages off the farm: 30 earned an average of Rs. 1,270 during the season. The largest individual incomes went to those who had permanent jobs, rented out tractors, or received income from other family members.

The other income exaggerates the spread in overall income for farmers. Other income for the three farmer groups for the season was Rs. 4,410 (head), Rs. 4,000 (middle), and Rs. 1,700 (tail). Thus, not only do head and middle farmers receive substantially more income from their paddy production than do the tail farmers, but their additional income is also substantially higher. When these two income sources are combined, as shown in Table 51, we find that the resulting average income for the tail farmers ranged between 59 and 62 percent of the averages for the middle and head farmers, respectively.

Table 51. Combined 1986 yala incomes for the 76 sample farmers at Kaudulla.

	Head	Middle	Tail	Overall
	Rs.			
Average value of paddy production	6,029	7,006	4,788	5,761
Average value of other income	4,410	4,000	1,700	3,060
Total income	10,439	11,006	6,488	8,821

We recognize that the value of paddy production applies to all 76 farmers, while the value for other income applies to 65 farmers, but the results provide a general picture of the farmers' relative positions. Considering that 11 of the farmers reported no additional income at all, and that three of the farmers in the head sections had additional incomes that ranged between Rs. 13,000 and Rs. 17,000 for the season, the spread in incomes among individual members is greater than that suggested by the averages. Further research might well explore these and other outlying cases to gain a more complete picture of income distribution within Kaudulla. Of particular interest would be those farmers at the low end of the income spectrum.

1. Farmers' Net Income

The sample farmer's average net income can be estimated by deducting those costs not directly related to paddy production from the foregoing estimates of total income. The results provide us with insight on the returns to family resources, including labor, and the family's financial position.

Additional Costs. The additional costs include land rentals and mortgages, interest payments on seasonal and longer-term credit, operation and maintenance (O&M) fees, costs of producing subsidiary crops and home gardens, tools and equipment purchases, and livestock maintenance. The questionnaire contained some information on these costs, but in other cases we have used our judgment to arrive at what we hope are realistic estimates.

Sixty percent (46 out of 76) of the farmers engaged in land rental or mortgage (14, 13, and 19 of the head, middle, and tail farmers, respectively). Subtracting cash inflows and outflows, the result yields an average net cost of Rs. 315 to the head farmers and Rs. 1,984 to the middle farmers. Tail farmers received a net cash inflow averaging Rs. 341. Thus, for the sample farmers as a whole, rentals and mortgages cost an average of Rs. 439 for the season. Recall that we have already accounted for rental payments in kind.

The majority of the farmers received credit during the season (42 of 76), with only 39 percent of the farmers at the head doing so compared to over 60 percent for middle and tail farmers. Three-fourths of the farmers received their credit from relatives and "others," rather than from banks, cooperatives, traders, or millers. Only six of the 42 farmers reported receiving credit from the bank. The reported loan averaged Rs. 2,360, which was all received in cash rather than in kind. Farmers said their principal reasons for not using bank credit related to missing identification cards, lack of ownership, or simply that other loans were easier to obtain. Farmers reported that 41 of the loans were for cultivation purposes, 4 were for consumption, and only 1 was for purchasing equipment. Annual equivalent interest rates ranged from zero, when funds were supplied by the family, to 240 percent. Below is the distribution of these rates, which reveals just how high these charges can be (Table 52).

Table 52. Interest rates reported by Kaudulla sample farmers, 1986 *yala*.

Annual Rate (%)	Number of Responses
0	8
6-12	10
48	2
100-120	4
140-180	5
240	13

Eight of the low interest loans offered by the bank were insured at an average premium of Rs. 250.

Nearly half (37 of 76) of the farmers said they paid the 1985 O&M fee of Rs. 100/year. Of those who did not pay, 18 said they were not the owners, 10 resisted paying because they felt service from the Irrigation Department was poor or that the rate was too high, 7 said they had money problems, and 4 felt they should not pay if others did not. None of the farmers had paid their 1986 O&M fee, but 30 of the 76 farmers said they planned to pay later.

As noted earlier, the questionnaire did not provide information on the costs of producing subsidiary crops and home gardens. Elsewhere, Alwis et al. (1983) reported the relative profitability of chilies compared to paddy. Less information is readily available on the

profitability of home gardens. For want of better information, we have assumed that the farmers' production costs for home gardens and subsidiary crops equal their value (as shown in Table 50). Such an assumption implies somewhat greater profitability for these crops than for paddy, since we have shown that paddy costs exceeded the value of output.

The questionnaire contained no information on the farmers' seasonal purchases of tools and only one reference about credit to obtain equipment. Given the relatively low income of the sample farmers and the high cost of equipment, we have left out costs associated with these purchases except for the interest charge already noted. This understates the farmers' seasonal costs, but not significantly. However, this is a subject that should be investigated in future studies.

Most farmers owned livestock in some form, with over half owning two or more buffalo. On balance, we do not believe that farmers use much money to maintain their livestock other than an occasional purchase. Considering the importance of buffalo to the family, however, this assumption may not be valid.

Table 53 summarizes the costs implied above. Except where the questionnaire provided data by farmers' location, we have not attempted to distinguish unit costs according to head, middle, and tail locations. In presenting these values, we recognize our heavy reliance on assumptions and, consequently, the potential weakness of the conclusions drawn. Nevertheless, we feel that the insight we have gained about the farmers' position justifies the risk of error.

We can now construct a composite of a representative farmer from the sample group. This composite will show central tendencies based on conditions experienced by many, if not always most, of the farmers. To do this, we selected appropriate values from previous tables. Even though only one-third (26 of 76) of the families reported income from home gardens, we chose to include this output as part of the family's income. Our reason was to count more than just wage labor as a source of other income, and income from home gardens seemed to be the most logical choice after wage labor. We have omitted subsidiary crops because too few farmers raised them; thus, we did not consider raising subsidiary crops to be representative of the composite farmer.

The estimate of interest payments resulted from the farmers' statements as to the amount borrowed, multiplied by the interest rate. To obtain the seasonal figure, we assumed that the average length of loan was 3 months. This estimate accounts for the farmers' needs for 986 credit to finance cash outlays over the growing season and for some reasonable amount of time to elapse between harvesting and sales.

Finally, other incomes and costs accrued to too few farmers to make them representative of the whole. However, their accrual to a few farmers serves to increase the spread in net incomes. Table 54 provides the compilation for the composite farmer.

Table 53. Summary of the Kaudulla sample farmers' costs that were additional to those involving paddy production, 1986 yala.*

Type of Cost	Head	Middle	Tail	Total
	Rs./farmer			
Net of land rentals and mortgages	315(14)	1,984(13)	-341**(19)	439(46)
Interest payments	621(9)	505(12)	544(21)	549(42)
O&M fees***	50(12)	50(9)	50(16)	50(37)
Subsidiary crops	2,420(4)	2,210(3)	1,670(8)	1,980(15)
Home gardens	510(11)	1,090(9)	300(6)	660(26)
Tools and equipment purchases	--	--	--	--
Livestock maintenance	730(2)	450(1)	0	640(3)

*Values in () are the number of farmers.
**Represents a cash inflow rather than a cost.
***Payments made for 1985 yala as reported by respondents.

Table 54. Net loss for the Kaudulla composite farmer, 1986 yala.

	Rs.
Income	
Paddy production	5,761
Home garden production	660
Wage labor	1,270
Total	7,691
Expenditures	
Paddy production	6,714
Home garden production	660
Rentals and mortgages	439
Interest	549
O&M fees	50
Total	8,412
Net loss	721

On these grounds, the typical Kaudulla farmer was not doing very well -- the family was not earning a "fair return" on its resources. This assumption was made assuming that family labor was worth Rs. 30/day and that the farmer's buffalo could earn Rs. 100/day. These are scarcely valid assumptions in most developing countries, where rural labor forces are usually large and employment opportunities are usually limited.

A more meaningful way to evaluate a family's position is to look at the returns to the family's resources to see how much income it generates as a unit. This result can then be compared to per capita income for the economy as a whole.

Returns to Family Resources. To calculate the returns to family resources, we must deduct costs of family resources from our earlier estimate of production costs. We begin by adjusting for paddy production, which includes removing the costs of family labor, buffalo, and seed. Then, we extend the concept, if not the detail, to home gardens.

As before, we subtract the cost of seed (75 percent of Rs. 396, which is Rs. 297) from total production costs (Rs. 7,011) to arrive at an adjusted cost of production of Rs. 6,714. We had also estimated that family labor was about two-thirds of the total labor costs for the set of predominant paddy practices. Applying this percentage to the total labor costs (Rs. 3,032) means that Rs. 2,021 can be deducted. We also found from the questionnaire that slightly over one-half of the farmers owned two or more buffalo. If we assume the typical farmer owns enough buffalo for plowing and harrowing, we can deduct costs associated with buffalo traction. These costs, as shown in Table 46, total Rs. 1,439. Now, if we subtract these two savings in costs, we have the value of purchased inputs (Rs. 3,254) (Rs. 6,714 less Rs. 2,021 and Rs. 1,439) and the return to family resources (Rs. 2,507) (Rs. 5,761 (value of production) less Rs. 3,254 (purchased inputs)). If we assume a slightly higher profitability for home garden production and the probable lesser purchase of inputs, the corresponding ratio for home gardens could be 50 percent. Applying this ratio to the value of home garden production, shown in Table 50, shows further returns to the family of Rs. 330 (Rs. 660 x 50 percent). Finally, by combining the original loss of Rs. 721 with these returns to family resources we arrive at the returns to the family for 1986 yala of Rs. 3,069.

For want of more precise information, we have assumed that net returns during maha are 25 percent greater than during yala. Using these values and an assumed family size of 5.5 members, we estimated per capita income as shown below:

Returns during yala	Rs. 3,069
Returns during maha at 25 percent more than yala	Rs. 3,836
Assumed total for the year	Rs. 6,905
Per capita income for family of 5.5	Rs. 1,255

This result is exceptionally low, being only 13 percent of the 1985 per capita income for Sri Lanka as a whole (Rs. 9,430) (The per capita national income was derived from a gross domestic product of Rs. 149 billion and a population of 15.8 million (Central Bank of Sri Lanka, 1984)).

While some percentiles within an economy may be this low, one would not expect this to occur among farmers who irrigate. Perhaps the answer lies with the farmers' understatement of other income sources, or low yields. At 47 bu/ac, the respondent's average yields were two-thirds the national average. By raising paddy yields by one-half to reach the national average of 70 bu/ac, the family's income might be expected to rise by 50 percent or more. This would bring the farmers' income to approximately 20 percent of the national average -- still a low value.

Such a finding suggests that farmer incentives for growing paddy would be low. However, because rice is the farmers' staple food and the traditional crop, they continue growing paddy even though benefits from doing so are minimal. This outcome calls for further study of the sample farmers' overall economic and financial positions to ascertain the validity of these findings.

Returns to Family Labor. The results of the economic analysis can be considered from another vantage point: returns to family labor employed in paddy production. By assuming that all of the returns from paddy production accrue to family labor and that the costs of rentals, mortgages, interest, and O&M fees are associated with paddy production, we found that the family's own labor would have earned a daily wage of Rs. 21.90 when we omit the costs of buffalo traction. When we include the costs of buffalo traction, the daily wage approaches zero. If we split the difference, we have a daily wage of Rs. 11/day, which is 37 percent of the standard market wage of Rs. 30/day. Such a result is low for many developing countries, but not unusual for heavily populated countries with limited agricultural holdings per capita as in Sri Lanka. Of course, imputing values to land, equipment, management, and the like would further reduce the imputed wage. On the other hand, part of these costs may be attributed to activities other than paddy production.

As shown in Table 55, we obtained the high and low values by dividing the net returns to paddy production -- with and without buffalo costs -- by the man-days of family input. Our sources were Tables 44, 46, and 54.

Financing Production. By paying usurious rates that are equivalent to 240 percent per year, farmers reveal an urgent need for credit. The length of time the loan is out, however, plays an important part in determining the true meaning of this rate. Were the lending period only one month, the farmer would pay 20 percent on the amount of the loan. A 20 percent charge for some critical period could be a reasonable amount for the farmer and a justifiable charge for servicing the loan and accounting for the lender's risk. The questionnaire did not clarify for how long farmers were borrowing money. However, an indication of the lending period can be gained from the farmers' outlays for hired and contract labor, materials, and tractor and buffalo services, as noted previously. We believe our assumption of three months for an average length is reasonable.

Table 55. Average high and low returns to family labor in Kaudulla in rupees, 1986 *yala*.

Alternative Without Buffalo Costs Included		
Value of paddy production		Rs. 5,761
Less costs of		
Purchased inputs	Rs. 3,254	
Rentals and mortgages	439	
Interest	549	
O&M fees	50	
Sub-total		4,292
Net		1,469
Man-days of family labor (2/3 x 101)		67
Imputed daily wage		21.90
Alternative With Buffalo Costs Included		
Net (from above)		1,469
Less buffalo costs		1,439
Net		30
Imputed daily wage		0.45

We can learn of the composite farmer's general financial position by looking at the family's cash inflows and outflows. Cash inflows would be primarily from actual and potential sales of paddy and income from wage labor. For want of better information, we assumed that cash from the sale of home gardens matched cash expenditures associated with their production. We also chose to omit cash transactions associated with subsidiary crop production because only a few farmers said they grew these crops during the season. Cash outflows other than for debt servicing would be primarily for paddy production, rentals, and the O&M fee.

Table 56 shows the composite farmer to be in a cash surplus position in his ability to cover interest payments on his debt. However, the farmer's cash requirements for household and other purposes add to his needs; and, more importantly, cash outlays for production come throughout the cropping season, whereas cash receipts come at the end of the season. These results show that the cash surplus generated during the season, even if all were reserved for

production, is insufficient to cover the crop's cash requirements for the following season. Thus, there is a need for seasonal credit.

Table 56. Net cash flow for the Kaudulla composite farmer for 1986 yala.

	Rs.
Cash inflows	
Paddy sales to date (38.2 bu x Rs. 70.60/bu)	2,697
Potential paddy sales (amount retained) (17.6 bu x Rs. 70.60/bu)	1,243
Wage labor	1,270
Total	5,210
Cash requirements	
Paddy production	3,254
Rent	439
O&M fees	50
Net cash inflow	1,467

Given the ratio of cash surplus to interest payments of nearly 2.67:1 (Rs. 1,467:Rs. 549), the farmers ought to be reasonably good risks to the lenders. On these grounds, lower-cost credit might be expected. On the other hand, occasional low crop yields or low paddy prices, together with occasional delays or nonpayment by farmers, could serve to keep interest rates high.

4. SUMMARY AND CONCLUSIONS

According to farmer responses, original allotments for the 77 sample farmers averaged 1.1 ac of lowland and 0.6 ac of highland. To this lowland amount sample farmers reportedly added 2.1 ac through encroachments, rentals, and purchases.

During yala, all but one of the 76 sample farmers reported growing paddy on an average of 2.01 ac/farmer. Farmers also reported growing an average of 0.11 ac of chilies, part of which was on highlands. These results, as well as farmers' statements, revealed that nearly all of the reported cropping was on lowlands. Farmers reported little difference in cropped area or cropping patterns regarding head, middle, and tail locations.

Buffalo traction and broadcast paddy formed the most common set of practices (31 of the 76 paddy farmers). Looked at individually, 45 farmers relied only on buffalo compared to 17 farmers who relied only on tractors; and 57 farmers only broadcast paddy compared to 8 farmers

who only transplanted. The remaining farmers combined their methods of traction and/or seeding.

Slightly over half of the farmers owned two or more buffalo, which means that most of them controlled their means of traction. The predominant type of tractor in use was a two-wheeler produced by the Japanese that, complete with attachments, cost about Rs. 70,000. This cost puts tractors beyond the reach of most of the sample farmers, based on their reported incomes. The smallness of the farmers' plots may help explain their heavy reliance on buffalo.

Nearly all of the farmers applied fertilizers, and the majority used weedicides and insecticides. Thus, the sample farmers appeared to be following good cultural practices, except possibly for relying on their own rather than on certified seed. (See the agronomy section for a more in-depth discussion of the actual usage of these agricultural inputs.)

When the current market rates were applied to the various inputs, the overall cost of production for the most common set of cultural practices came to approximately Rs. 3,500/ac. This result accords closely with that of the information found in Skogerboe et al. (1984). An analysis of alternative cultural practices shows that broadcasting costs less than transplanting, using buffalo costs less than using tractors, and weedicides cost less than manually weeding. Thus, farmers who follow the most common set of practices were employing the least-cost approach. The lack of superior yields from transplanting supports the farmers' preference for broadcasting.

The predominant cultural practice for paddy requires an average of 101 man-days/farmer for the season. This amount, which averaged 50 man-days/ac, came close to the most labor-saving method. By employing tractors, the families could reduce their labor input by 9 percent. Of the total labor requirements, the family supplied two-thirds; the rest came primarily from hired labor, with contract labor completing the requirement. The schedule set by the Irrigation Department for land preparation, water deliveries, and the resulting peak labor periods helped to explain the farmers' reliance on labor other than their own.

The overall yield for the season averaged 47 bu/ac, which was considerably lower than the national average of 70 bu/ac. In verifying the reasonableness of this difference, farmers commented that yields during 1986 <u>yala</u> were lower than in the previous year's <u>maha</u> and <u>yala</u>. As yet we cannot fully explain why yields were so far below average. Soils and water quality were supposedly good, and farmers reported that they used the recommended rates of fertilizers and pesticides (although we do not know from the data how they knew what the requirements ought to be). One might speculate that lack of water could explain the lower yields, but most of the farmers reported that they received enough water for their cultivation needs. Farmers blamed lower yields on winds and pests during the pollination period. In addition, they relied on their own and neighbors' seed, rather than on certified seed.

Yields by location showed that head and middle farmers produced an average of 55 bu/ac, whereas tail farmers averaged only 39 bu/ac. This difference, which is statistically significant at the one percent level, seems to be the result of something other than farmers' practices. In contrast, yield variabilities within head, middle, and tail regions were not statistically different at the five percent level. Our investigation of types and levels of inputs revealed no important difference according to farmers' location within the system. Consequently, we are unable to discern from the economics data the reasons for the differences in yields.

Farmers disposed of this output (which averaged 94 bu/farm) by setting 26 bu aside for family consumption, selling 38 bu, holding 18 bu for future disposal (probably for sale), and applying the rest for seed and for payments in kind for rent and the vel vidane's fee. The amount farmers withheld for consumption agrees closely with the apparent per capita rice consumption for Sri Lankans. By covering their consumptive needs, holding surplus paddy off the market, and eventually selling nearly 60 percent of their production, these farmers demonstrated considerable market activity and strength. Their market involvement undoubtedly explains the farmers' widespread use of improved technologies such as agricultural chemicals and their reliance on hired and contract labor. Were their incomes greater, they would undoubtedly use the two-wheeled tractors to a greater extent. From this, we concluded that these farmers would be open to other improvements in technology, including changes in water management practices.

The foregoing suggests that the farmers are relatively well off. However, although they are doing well in terms of being self-sufficient in paddy production; in other ways they are not. At full costing of variable inputs for the predominant set of cultural practices, paddy income failed to cover direct production costs. The cost of paddy production for the season, after adjusting for the value of paddy held out for seed, was Rs. 6,714 compared to the value of output available for family consumption and sale (Rs. 5,761). This results in a net loss of Rs. 953. when the farmer's earnings from wage labor are added and the costs of rentals, mortgages, interest, and O&M fees are subtracted, the composite farmer still has a net loss of Rs. 721 for the season.

In valuing the farmers' output, we used the average sales price of Rs. 71.6/bu. In nearly every case, the farmers made their sales through private traders rather than government sources. While government sources generally offered a guaranteed price of Rs. 70/bu, farmers often realize less than this amount because of adjustments for quality and for the costs of transportation. Thus, the sample farmers reported that by dealing with private traders they were able to do better than had they taken the Government support price.

The farmers' poor economic showing rests in part with the assumption that their opportunity cost of labor is Rs. 30/day and that their buffalo are worth Rs. 100/day -- both of which are the current market rates. Such assumptions are seldom valid for farmers with limited holdings such as in Sri Lanka.

Adjusting for the farmer's provision of his own seed and deducting for family labor and buffalo costs, the typical farmer would earn about Rs. 22/man-day, or about three-quarters of the market wage. However, this allows no return for the farmer's buffalo, land, management, or other inputs. Were the full cost of buffalo use deducted, the farmer's return to labor would approach zero. Taking an average of these two gives a shadow wage of 37 percent -- a value somewhat on the low side, but not out of the ordinary for Sri Lanka. Deducting the costs of land, management, tools, and the like would reduce the profitability to family labor even further. However, not all of these costs should be charged to paddy production.

Another indication of the family's poor situation is the return to their resources. This measure takes the total family's income (cash and imputed earnings) during yala, assumes values for a typical maha, and deducts the costs of purchased inputs. The result applied to an assumed family size of 5.5 members yields a per capita income of Rs. 1,255 -- which is only 13 percent of the national average (Rs. 9,430). In making these calculations, we limited off-farm income to the average Rs. 1,270 earned in wage labor by 30 families during yala. Some families' incomes were augmented far more than this from tractor rentals, pensions, and permanent jobs, but the few farmers who benefitted this way were atypical.

Comparing the farmers' seasonal cash inflows and outflows showed that they generated an average cash surplus of Rs. 1,467, nearly all of which came from off-farm wages. This overall surplus, however, is not enough to meet the seasonal cash requirements of Rs. 3,254. This amount also does not account for cash requirements for household needs, tools, equipment, or other purposes. This deficit in cash flow helps explain the farmers' heavy reliance on seasonal credit.

To close, the sample farmers appeared to follow practices that were cost effective through ample use of fertilizers and pesticides. Even so, their small holdings combined with lower than previous seasons' yields resulted in substandard incomes for the season. Because we are dealing with averages, approximately half of the farmers would have incomes below this level. Some of the sample farmers provided information indicating extremely low incomes. These low income levels for many of the sample farmers certainly call for closer scrutiny by future researchers.

E. SOCIOLOGY

1. INTRODUCTION AND METHODOLOGY

Sociology researchers who participated in the diagnostic analysis of Kaudulla Scheme conducted a comprehensive investigation during 1986 yala. These investigators used a sample household survey and a series of in-depth, qualitative interviews with technical assistants, work supervisors, patrol laborers, farmer representatives, vel vidanes, irrigation engineers, and project managers. This section of the report presents the findings of the sociology component of the diagnostic analysis.

The study focused attention on the following areas:

* Socio-economic background of the farm families interviewed.
* Issues relating to water supply and distribution.
* Farmers' irrigation behavior.
* The relationship between irrigators and irrigation officials.
* The role of farmer representatives and farmer organizations.
* System maintenance and the project committee system.

Eighty families were randomly selected from Stage I and Stage II of the settlement scheme for the sample. We were able to survey all the farmers selected. The respondent households were drawn from the original list of cultivators farming in each of the sites selected to represent different hydrological conditions within the system. The following table gives the distribution of respondents by location.

Table 57. Spatial distribution of respondents in Kaudulla Scheme, 1986 yala.

Location	Number of Respondents		
	Stage I	Stage II	Total
Head	12	11	23
Middle	7	13	20
Tail	20	17	37
Total	39	41	80

An attempt was made to ensure that the respondents came from different parts of a field channel area since hydrological conditions may vary as one moves along a field channel from head to middle to tail. Table 58 gives the distribution of the 80 respondents according to their location on their respective field channels. Note that the survey data was gathered during yala. Since use of inputs and agricultural practices may differ between seasons, the results in this report should not be related to maha activities.

Table 58. Location of respondents along field channels in Kaudulla, 1986 *yala*.

Location	Number of Respondents	Percent
Head	29	36
Middle	23	29
Tail	28	35
Total	80	100

Due to resource and time constraints, it was not possible to draw a larger sample for the study. The sample drawn was about 1.3 percent of the total number of families residing in Kaudulla. This is not a large sample, but since the respondents were from different hydrological locations scattered within the system it may be reasonable to claim that the respondents were representative of Kaudulla's irrigating farmers.

A structured questionnaire containing some open-ended questions was used to survey the sample. In addition, in-depth interviews were used to elicit qualitative data to supplement the information gathered through the household survey. These interviews also contributed to our understanding of the way people in different professional positions perceived the diverse issues associated with the irrigation system.

The household survey and most of the in-depth interviews were conducted by two experienced social science university graduates under the guidance and supervision of the sociology coordinator. Respondents in Kaudulla were cooperative and enthusiastic. Though the interview was directed mainly to the chief householder, the other family members were allowed to take part in the interview whenever relevant and necessary. Note that during the survey, bias may have been introduced by both the investigator and the respondent. It was generally felt that responses to sensitive questions -- particularly those relating to personal finances, land ownership, and tenurial arrangements -- may not be reliable.

The raw data gathered through the household survey was coded by the two investigators, and the sociology coordinator analyzed the coded data using a software statistical package on a microcomputer. The main statistical techniques used were frequency distribution and cross tabulation. The two social science researchers and the sociology coordinator also had an opportunity to observe the system while conducting the interviews. Therefore, their observations contributed to the description and analysis of the system.

2. RESULTS AND DISCUSSION

a. Socio-Economic Profile

As Table 59 shows, the respondents in Kaudulla were a relatively young population, with about 50 percent of the respondents between 20 and 40 years of age. This younger age grouping appeared to be related to the fact that families in Stage II settled as late as the 1970s (Table 60). Almost all the settlers arrived after 1956, which indicated that the rehabilitated Kaudulla Scheme has existed for less time than the other schemes in Polonnaruwa.

Table 59. Age distribution of respondents in Kaudulla, 1986 yala (n=80).

Age	Number of Responses	Percent
20-30	19	24
31-40	21	26
41-50	16	20
51-60	22	28
> 60	2	3

Table 60. Year of arrival of settlers in Kaudulla 1986 yala, (n=74*).

Year	Number of Responses	Relative Percent
1945	0	0
1945-55	2	3
1956-65	26	35
1966-75	31	42
1976-86	15	20

*The remaining six farmers in the sample were born in Kaudulla.

Most of the respondents in Kaudulla came from three districts: Nuwara Eliya, Kandy, and Kegalle. This was indicative of the general pattern of population movement in this part of the country as people from the central provinces migrated to the north central provinces. About 20 percent of the interviewees originated from within Polonnaruwa District. Some settlers were probably purana villagers.

Just over 50 percent of the Kaudulla respondents had less than 5 years of schooling. Another 28 percent had 6 to 8 years of education (Table 61). Though the literacy rate is high, a large number of farmers in Kaudulla have no direct access to printed media, such as newspapers. Only 28 percent of the farmers interviewed read daily newspapers. However, eighty-one percent of the respondents (65) had

radio sets in their houses, and 5 percent (4 respondents) owned television sets.

Table 61. Educational attainment of Kaudulla respondents 1986 *yala* (n=80).

Education	Number of Responses	Percent
No education	4	5
Grade 1-5	37	46
Grade 6-8	22	28
GCE (OL)*	14	18
GCE (AL)**	3	4

*GCE(OL) = General Certificate of Education - ordinary level (10 yrs).
**GCE(AL) = General Certificate of Education - advanced level (12 yrs).

Landholding. Even though the Kaudulla settlements were established much later than the other schemes in the region, only about 55 percent of the allotments were still held by the original allottees or their descendents (Table 62). A large percentage of the allotments have changed hands through various terms ranging from short-term lease to outright sale and mortgage. The farmers who cannot mobilize adequate resources to meet cultivation expenses often lease out their plots, either in part or whole. Some farmers have also encroached onto reserved land. As discussed later, these tenurial changes have significant implications for water distribution and management.

Table 62. Landholding status of respondents in Kaudulla, 1986 *yala* (n=80).

Status	Number of Responses	Percent
Original allottee	33	41
Second generation of original allottee	10	13
Spouse of original allottee	1	1
Other		
Lease	5	6
Purchase	6	8
Mortgage	3	4
Encroach	12	15
Wee porunduwa	10	13

As Table 63 shows, 26 percent of the respondents cultivated 1 ac or less of lowland. The largest proportion of the farmers cultivated about 2 ac of lowland. Only a few respondents reported cultivating over 5 ac.

Table 63. Extent of lowland cultivated in 1986 yala as reported by Kaudulla respondents (n=80).

Extent in Acres	Number of Responses	Percent
0-1.0	21	26
1.1-2.0	32	40
2.1-3.0	14	18
3.1-4.0	6	8
4.1-5.0	4	5
> 5.0	3	4

Apart from original allotments, parcels of land acquired through other means were also held by over 50 percent of the respondents in Kaudulla. The most common forms of such landholding were lease, wee porunduwa, ande, encroachment, and mortgage.

Only 6 respondents (8 percent) in Kaudulla reported that their allotments were already divided among family members. Yet, many farmers seemed to have given at least a portion of their allotments to others on various terms. Seventy-three percent of the respondents stated that land in the settlement scheme has passed into hands of non-allottees. Table 64 gives the various methods by which non-allottees were perceived to have acquired land. Among these, encroachment and purchase appeared to be the most common methods for acquiring land.

Table 64. Methods by which non-allottees have acquired lowland as perceived and reported by respondents in Kaudulla, 1986 yala (n=59).

Methods for Acquiring Lowland	Number of Responses*
Purchase	43
Encroachment	41
Ande/lease	17

*Multiple responses were possible.

Source of Income. Seventy-seven respondents in Kaudulla (96 percent) reported depending on paddy farming as their main source of income and subsistence. Only three respondents (4 percent) said that farming was not their primary source of income. Two of these respondents had permanent jobs, and the third person mostly depended on wage labor.

Fifty-eight (72 percent) respondents reported that they had access to secondary sources of income. The majority of these respondents cited wage labor and cultivation of subsidiary crops as secondary

income sources. Table 65 shows the secondary sources of income reported by Kaudulla farmers.

Table 65. Secondary sources of income reported by Kaudulla respondents, 1986 yala (n=58).

Sources of Income	Number of Responses	Relative Percent
Wage labor	26	45
Subsidiary crops	10	17
Trade	9	16
Permanent crops	5	9
Pension	5	9
Farming	3	5

Only 25 percent of the farmers interviewed in Kaudulla reported that their income from paddy cultivation was sufficient for subsistence. The apparent inability of a large proportion of the farmers in Kaudulla to generate an adequate income from farming may be one reason why a large number of Kaudulla respondents did not want their children to have farming as their main occupation. Thirty-four respondents (44 percent) said they did not want their children to continue with farming. Most of the respondents wanted their children to get a good education so that they could find white-collar employment with regular incomes.

Farmers also cited land fragmentation as a reason why children should not turn to agriculture. Since subdivided plots might not generate adequate income for subsistence, farmers did not want to further fragment their holdings. One way to avoid this is to find alternative sources of subsistence for their children.

Agricultural Practices and Inputs. Incomes and living conditions depend on many factors. Apart from ownership of productive resources, particularly land and water, agricultural practices also no doubt play an important role in determining income and living conditions. Therefore, some information collected by the sociologists relating to agricultural practices and inputs was included here because it may contribute to better understanding the behavior of Kaudulla farmers. However, for a more complete and extensive discussion concerning agricultural practices and inputs, the reader is referred to the agronomy and economics sections of this report.

Most of the respondents in Kaudulla reported that they used tractors during 1986 yala. The three farmers who reported not using tractors owned cattle or hired cattle. Those who reported using tractors used them for a variety of activities ranging from land preparation to threshing. Note that 63 respondents (79 percent) in Kaudulla reported using buffalo in conjunction with tractors. A majority of respondents (61 percent) reported using buffalo for land preparation. Sixty-one percent of the sample farmers using buffalo

reported that they owned the buffalo. None of the farmers reported owning four-wheel tractors, and only 16 respondents (20 percent) said they owned two-wheel tractors. Nineteen farmers (24 percent) reported that they owned agro-chemical sprayers.

Thirty-two percent of the respondents reported that they transplanted paddy during 1986 yala. Only 31 percent of the farmers reported using high-yielding varieties. However, all the respondents said that they used agro-chemicals, including chemical fertilizers. Many farmers cited insufficient water as the reason for resorting to chemical weed control.

The use of hired labor was widespread in Kaudulla. Eighty-five percent of the farmers reported that they had used hired labor. Other respondents reported using their own family labor or exchange (attam) labor.

Kaudulla respondents appeared to rely on local labor rather than on seasonal workers from outside the district. For instance, as the data in Table 66 indicate, 51 respondents (75 percent of those who had hired wage labor) relied on local workers. Only 8 respondents had relied on itinerant workers who migrate to the district from surrounding areas during the peak months of the agricultural cycle.

Table 66. Types of hired workers employed as reported by Kaudulla respondents, 1986 yala (n=68).

Types of Hired Workers	Number of Responses	Relative Percent
Local workers	51	75
Outside seasonal laborers	8	12
Both seasonal and local	7	10
Own village sends	2	3

Farmers' Disposition of Paddy. Seventy-four respondents (92 percent) said that they keep enough paddy for consumption after each harvest. However, 54 farmers (72 percent) reported that they had to sell at least part of their retained paddy to obtain needed capital. Lack of capital is one reason why Kaudulla respondents resort to other sources of income, such as wage labor, between seasons.

b. Irrigation Water Supply and Distribution

Though the farmers in a surface distribution system like Kaudulla usually get water to their fields from field channels, it is not uncommon for some irrigators to obtain water from other sources. According to the data in Table 67, 74 respondents reported that they had access to irrigation water from field channels. Thirteen respondents reported that they had access to water from sources such as adjoining fields and drainage channels. It was observed that some of the newly encroached fields had no access to existing field channels.

Table 67. Sources of water for crop cultivation as reported by Kaudulla respondents, 1986 yala (n=80).

Source	Number of Responses*
Field channel	74
Branch canal	0
Adjoining fields	9
Drainage channel	4

*Multiple responses were possible.

Water Supply. According to the household survey conducted in Kaudulla, most farmers perceived that they had not received adequate water during 1986 yala. Only 10 farmers (12 percent) felt that they had received an adequate supply. The majority of respondents who said they had not received an adequate water supply thought that not enough wate was released from the tank. One irrigator attributed inadequate supply to illicit tapping and damaged structures, and another farmer claimed that sufficient water was not distributed.

When respondents were asked where they believed water problems occurred most often within their field channel areas, the majority felt that the tail regions experienced water problems most often (Table 68). Respondents gave a number of explanations for water distribution problems based on their experience and observations. These are summarized in Table 69. Most of the farmers attributed water problems to faulty physical structures (canals, outlets) and to an inadequate water supply.

Table 68. Kaudulla respondents' perceptions of where water problems most often occur in field channels, 1986 yala (n=67).

Location	Number of Responses	Relative Percent
Head	1	1
Middle	1	1
Tail	58	87
Along field channel	7	10

Table 69. Reasons given by respondents for water distribution problems in Kaudulla, 1986 yala (n=67).

Reason	Number of Responses	Relative Percent
Bad construction of channels, and silting	23	34
Inadequate supply and duration	12	18
Field channel outlets faulty	10	15
Waste of water due to damaged structures	10	15
Non-maintenance of field channel	6	9
Expansion of command area	3	5
Illicit tapping	2	3
Improper water management	1	2

Water Rotation. Ninety-seven percent of the farmers in Kaudulla reported gettin water supplies on rotation. Only two respondents reported that they have access to continuous flow. Most farmers said they only knew the rotation changed when the canals dried up. Six farmers (8 percent) said they heard about rotation changes from the vel vidane, and 12 farmers (15 percent) said they find out about changes from the patrol laborer. Most farmers complained that they do not receive advance notice of rotational changes. Only 12 farmers (15 percent) said that they were informed in advance.

As the data in Table 70 indicate, many farmers in Kaudulla seemed to think that water users have little influence on decision-making related to water rotation. Their impression was that higher government authorities, such as the government agent and the irrigation engineer, tend to dominate decision-making. However, many respondents indicated that decisions regarding the rotation system are made at the kanna meeting, which is supposed to act as a forum to facilitate two-way communication between irrigators and the Irrigation Department. Yet farmers believed that the kanna meeting is increasingly used by officials to inform farmers of official decisions, rather than to provide for a free and informal dialogue between officials and water users. Irrigation officials, however, stated that they are always ready to listen to and seriously consider farmer suggestions at the kanna meetings. In Kaudulla, about 47 percent of the farmers interviewed reported that they had participated in the 1986 kanna meeting for 1986 yala. However, since farmers are charged with the responsibility of attending kanna meetings, the magnitude of this response may have been due to a "courtesy response." Some diagnostic analysis team members reported low attendance by farmers at most kanna meetings.

Table 70. Kaudulla respondents' report of who makes decisions regarding the irrigation rotation, 1986 *yala* (n=80).

	Number of Responses	Percent
Pre-cultivation (*kanna*) meeting	25	31
Government and irrigation engineer	22	28
Don't know	11	14
Government agent	10	13
Irrigation engineer	9	11
Mahaweli Authority	3	4

Equity. Equity is another important irrigation issue. Fifty percent of the respondents said that not all the farmers in Kaudulla had equal access to water for various reasons. The most commonly given reasons were the following:

* Canals do not carry sufficient water.
* Damaged structures.
* Illicit tapping.
* Faulty construction and positioning of outlets.
* Improper water management.
* Improper construction and leveling of canals.

Although many respondents perceived that farmers from tail regions of field channels encountered more water problems, farmers from head and middle regions reported that they experienced water problems as well (Table 71). Moreover, it was revealed that farmers' complaints of water shortages were more acute in Stage II of the system. Most Stage II farmers complained of water shortages regardless of their hydrological position within the system.

Table 71. Sample farmers' responses when asked if they experience water shortages (by hydrological position), Kaudulla, 1986 *yala* (n=79).

Do You Experience Water Shortage?	Number of Responses*			Total
	Head	Middle	Tail	
Yes	26(90)**	18(78)	25(93)	69(87)
No	3(10)	5(22)	2(7)	10(13)

*Location of allotment on field channel.
**() = Relative percent.

When water users are faced with problems, such as water shortage, most of the sample farmers said that they informed the irrigation officers directly, or through others such as the vel vidane and the ela niyojitha. Two farmers reported that when they faced water shortages, they resorted to illicit tapping. Though others did not openly admit to illicit tapping, it is likely, as indicated by reports of widespread illicit tapping, that many more do so.

Ninety-six percent of the respondents reported that they shared water during times of scarcity through joint agreements with neighboring farmers. When there is an inadequate water supply, farmers must cooperate with their neighbors in order to divert adequate water to individual allotments. For instance, if all the farm outlets are open, the water level is not high enough and no allotments will receive sufficient water. In such circumstances, the only way to divert water into these allotments is to close some outlets to raise the water level. This can be done by force (which could lead to disputes) or through informal agreements. Among other responsibilities, the vel vidane is charged with ensuring that all farmers in his area receive sufficient water. However, when the vel vidane attempts to rectify situations such as that described above, only three farmers reported that they follow his instructions.

In spite of the many informal joint agreements among farmers at the field channel level, disputes over water rights are not uncommon in Kaudulla. Seventeen percent of the sample farmers reported that they were involved in water disputes with their neighbors. Disputes have led to violent conflicts in four of those cases. Compared to land disputes, water disputes are more prevalent in Kaudulla. For example, only 6 percent of the respondents reported that they had disputes with neighbors over land rights. For adjudication of disputes, the main mediators mentioned by respondents were the vel vidane, work supervisors, the cultivation officer, and neighboring farmers.

c. Farmers' Irrigation Behavior

Farmers identified a range of issues which they felt affected their irrigation behavior. These included illicit tapping of irrigation water, damaged structures, encroachment, highland cultivation, and system maintenance.

Illicit Tapping of Irrigation Water. Significant tenurial changes have taken place in Kaudulla since land allotments were made. As a result of these changes, a large proportion of current cultivators were not original allottees or inheritors of allottees. Non-allottees held parcels of land on diverse terms, such as ande, wee porunduwa, lease, mortgage, and outright purchase.

Farmers and other key informants stated that those who temporarily cultivate someone's land are often motivated to gain as much as possible during a short time. Therefore, they do not necessarily feel obliged to attend to their duties as irrigators. On the other hand, many settlers continue to lease or mortgage parcels of their land to outsiders due to financial difficulties and for other reasons. Yet, it

was generally agreed by officials and irrigators that non-allottees think and act in terms of their personal interests and, therefore, contribute to water problems. Non-allottees reportedly tended to violate formal and informal rules that guide irrigation practices at the local level. Officials and other irrigators said that non-allottees were more likely to resort to illicit tapping.

Illicit tapping was perceived by most irrigators as a major problem in Kaudulla. Ninety percent of the farmers interviewed said that farmers in their locality resorted to illicit tapping (Table 72). Only 9 percent of the respondents said that illicit tapping does not occur in their locality. Illicit tapping was reported almost everywhere within the system, regardless of hydrological position.

Table 72. Kaudulla respondents' response to the question "Do farmers resort to illicit tapping in your area?" (1986 yala, n=80).

Response	Number of Responses	Percent
Yes	72	90
No	7	9
Don't know	1	1

As Table 73 shows, most illicit tapping of water occurred from field channels. Many respondents also reported that water was tapped from branch canals, D-channels, and the main canal. The methods used to tap water illicitly may also damage physical structures. In fact, 58 farmers reported that illicit tappers used methods that damaged structures. Some methods mentioned were the following:

* Cutting channel bund.
* Drilling holes in channel bund.
* Breaking outlet gates.
* Breaking outlet pipes.

Some farmers said that other methods used did not lead to structural damage, including pumping water using rubber hoses, and blocking the flow of water.

Table 73. Source of water for illicit tapping in Kaudulla as reported by respondents, 1986 yala (n=73).

	Number of Responses*
Field channel	70
Branch canal	50
Distributary channel	49
Main canal	2

*Multiple responses were possible.

Most respondents in Kaudulla clearly understood that illicit tapping was a punishable offence, with only one respondent saying that it was not. Most of the sample farmers also cited the kind of action taken against offenders. Forty-one respondents (51 percent) said that offenders were asked to pay damages and a fine. Four respondents said that offenders were denied water for a few days, and 14 respondents stated that offenders had to appear before a court of law for legal action. Most of the respondents (74 percent) said that the punishments were adequate.

Fifty percent of the respondents interviewed in Kaudulla said that they report illicit tapping to higher authorities. Table 74 shows the officers to whom farmers indicated that they reported illicit tapping.

Table 74. Kaudulla respondents' report of who they notify about illicit tapping, 1986 yala (n=40).

	Number of Responses*
Agrarian Service officers	22
Irrigation Department officers	17
Colonization officer	2
Ela niyojitha	1

*Multiple responses were possible.

However, 23 (58 percent) of the 40 farmers who responded reported that officers do not take action against offenders when reported. The rest of the 40 respondents said that officers do take action against offenders. Those respondents who said no action was taken gave diverse reasons for this, including the following:

* Officers had weaknesses and shortcomings, particularly negligence, favoritism, and absenteeism.
* Officers only warned offenders, but meted no real punishment.
* Farmers were reluctant to give evidence against neighbors.
* The scheme lacks effective rules and regulations.

The majority of respondents (90 percent) were dissatisfied with the present system of dealing with illicit tapping. About 50 percent of the respondents said that no rules and regulations were enforced. While some said existing laws were inadequate and ineffective, others said that officers did not perform their duties in keeping with rules and regulations.

As the data in Table 75 indicate, farmers' generally perceived that irrigation officers and Agrarian Service officers have the authority to take action against illicit tappers. When asked who should possess the authority to deal with illicit tapping, over 50 percent of the respondents said that it should be a special officer from the Irrigation Department appointed for the task (Table 76). Fourteen respondents said that Agrarian Service officials should have

authority, and others cited various people such as the government agent, the ela niyojitha, the colonization officer, and police.

Table 75. Kaudulla respondents' report of who possesses authority to deal with illicit tapping, 1986 yala (n=80).

	Number of Responses	Percent
Irrigation Department officers	24	30
Agrarian Services officers	42	53
Colonization officer	0	0
Don't know	14	18

Table 76. Kaudulla respondents' report of who should possess authority to punish illicit tappers, 1986 yala (n=80).

	Number of Responses	Percent
Special officer from Irrigation Department	43	54
Agrarian Services officials	14	18
Ela niyojitha	8	10
Government agent (police)	6	8
Don't know	6	8
Mahaweli Authority	2	3
Colonization officer	1	1

Damaged Structures. Damage to irrigation structures are caused by humans and natural events. Whatever the cause, damage was considered by system management and the water users to be a major factor affecting the proper functioning of the irrigation system. In Kaudulla, all respondents reported that some of the physical structures in their area were damaged. Most of the farmers stated that such damage occurred frequently. Respondents also indicated that floods during maha largely contributed to structural damage.

Respondents cited several other causes of structural damage including siltation (Table 77). In addition, tractors and buffalo were reported to damage structures. For instance, tractor owners drive their tractors into irrigation channels to clean the tractors, which damages channel bunds; and buffalo owners allow their animals to feed on the grass growing on channel bunds since land reserved for pasture has been encroached upon.

Some human actions that result in structural damage are deliberate. For instance, cutting channel bunds, drilling holes in bunds, or breaking turnout gates to divert water to fields are examples of deliberate damage.

Table 77. Causes of structural damage as identified by respondents in Kaudulla, 1986 *yala* (n=80).

Cause	Number of Responses*
Buffalo	80
Soil erosion	73
Lack of maintenance	71
Illicit tapping	70
Tractors	66

*Multiple responses were possible.

Lack of proper and regular maintenance also contributes to damage since damaged structures that are not repaired continue to deteriorate. When the efficiency and the capacity of the water distribution network are reduced by damage, some water users may cause further damage to divert water to their fields.

Respondents in Kaudulla were unanimous that damaged structures aggravated water problems in the scheme. Seventy-one respondents (89 percent) felt that the damage reduced the conveyance capacity of the waterways. Some also said that damage caused water waste.

Sixty percent of the respondents said that they reported structural damage to authorities. Respondents also said that damages were reported to agrarian and irrigation officials, particularly when someone deliberately damaged structures. However, when asked whether or not officers took action against offenders, only a few respondents answered affirmatively. Most of them said that officials were unable to do anything about damages. Once again, the majority of the respondents thought that officials were either not interested or were partial. Some respondents pointed out that some offenders were influential individuals and could not be punished.

Respondents in Kaudulla suggested several remedial measures regarding damage to physical structures. They were the following:

* Line canals with concrete.
* Introduce and impose a clear set of rules and regulations to safeguard structures.
* Provide adequate amounts of water to farmers to prevent them from resorting to illicit tapping.
* Prohibit the use of canals for washing tractors.
* Build bridges across canals where needed so that tractors and buffalo can cross without damaging canal bunds.
* Educate farmers on the value of the structures.
* Appoint a special officer in the Irrigation Department to look after irrigation structures.

Encroachments. Encroachment was common in all the major irrigation schemes in Polonnaruwa District. As a result of encroachment, Kaudulla's command area had increased from about 10,500 ac to about 13,300 ac. Because water issues to Stage II can be unreliable during

yala, some of these settlers have moved to reservation areas around Stage I in order to obtain a more predictable water supply. In addition, land reserved for canal bund protection, roads, pastures, and drainage have been cultivated throughout the entire Kaudulla Scheme.

Seventy-eight percent of the farmers interviewed in Kaudulla felt that encroachment constituted a major problem in the area. Most respondents said that encroachers were from the immediate locality, but about 21 percent of the respondents said that encroachers were from outside a particular field channel. Table 78 indicates where farmers felt encroachment had occurred within their field channel.

Table 78. Location of encroachments in Kaudulla as reported by respondents, 1986 yala (n=65).

Location on Field Channel	Number of Responses	Relative Percent
Right along field channel	46	71
Tail	15	23
Head	3	5
Middle	1	2

Fifty-seven farmers interviewed thought that encroachments burdened the irrigation system since more land was included in the command area and the amount of water available to legitimate allotments was reduced. Most of those who thought encroachment was not a burden claimed that drainage water was used to cultivate encroached land. Others felt that encroached areas did not constitute a significant acreage within the scheme. Nearly 50 percent of the respondents (38) said that encroachments led to disputes over water and land rights. In particular, water disputes appeared to take place when encroachers resorted to illicit tapping.

Encroachment also has implications for the operation and maintenance of the irrigation system. As a result of widespread encroachment, land tenure and land use patterns have become more complex over the years. The boundaries of many original allotments have become blurred because new parcels have been added through encroachment. In Kaudulla, 42 percent of the respondents said that they cultivated encroached land. In most cases, this was in addition to original allotments. As a result, farmers need more irrigation water than before. This need has created problems in water sharing at the field channel level.

Highland Cultivation. Highland cultivation using irrigation water was reported by respondents. Farmers whose land was above the irrigation channel use some form of lift irrigation to get water to their fields. Though many farmers used irrigation water for highland cultivation, they generally agreed that it creates a burden for the irrigation system. Nevertheless, in the absence of an alternative

source of water for such cultivation, farmers are likely to continue to extract water from the irrigation system for highland cultivation.

System Maintenance. The maintenance of physical structures was viewed by sample farmers as a major issue in Kaudulla. Yet, while farmers complained that authorities did not attend to maintenance work regularly, local officials said that water users did not routinely clean their field channels.

d. Irrigation Organization, Farmers, and Farmer Organizations

Even though the management of water is centrally organized in Sri Lanka, actual distribution and allocation involves a large number of intermediate-level and local officials and functionaries. It is inevitable that farmers come into contact with these officials, whether directly or indirectly.

Eleven farmers (14 percent) interviewed said that they had met irrigation officials during 1986 yala. Most of these had met with a work supervisor, while one respondent had met with technical assistants. These farmers said they had contacted these officers to discuss shortage of water, rotational issues, and damage to irrigation structures, among other topics. Thirteen respondents (16 percent) reported that they were acquainted with irrigation officers. In some instances, irrigation officers resided in the same neighborhood as farmers. Most of those who reported such social contacts mentioned that the contacts were with the work supervisor.

Those who said that they did not meet with officials during the last yala were asked whether or not they had met with any officials earlier regarding irrigation matters. Twenty-seven respondents (34 percent) answered affirmatively, but over 50 percent of the farmers interviewed had not met with any irrigation officials at all. However, most of the respondents reported meeting with the vel vidane regarding irrigation problems. Thirty-six respondents reported that they knew a vel vidane, and they meet him whenever they are faced with a problem. The vel vidane was reported by respondents to resolve the issues himself or to mediate between officials and water users. Some farmers appeared to find it unnecessary to go to irrigation officers directly, at least concerning some matters.

Thirty-five respondents (43 percent) reported that they felt that irrigation officers performed their duties satisfactorily. Forty-two (53 percent) farmers did not think so, and 3 respondents said that they did not know. Most of those who felt that officials did not perform their duties well said the officials were not concerned about farmers' problems.

In spite of the negative views expressed by the respondents, 79 of them said that irrigation officials were important to irrigation management. Only about 50 percent of the respondents said the same about the vel vidane.

To facilitate irrigation management and farmer participation in major schemes, the project committee system was introduced in 1984 by the Irrigation Management Division of the Ministry of Lands and Land Development (Gunasekera, 1986). A three-tier organizational structure was established which consisted of a project committee at the system level, a project subcommittee at the intermediate level, and a turnout group at the field channel level. These committees were to promote farmer involvement in the management of the irrigation system and to mobilize local resources for local operation and maintenance (O&M).

Under the committee system, farmers were asked to pay an annual O&M fee of Rs. 100/ac to a common O&M fund maintained by the Irrigation Management Division of the Ministry of Lands and Land Development. The initial response of Kaudulla farmers was positive. Over 420,000 rupees were collected for 1984. However, the annual collection has dropped rapidly since then. For instance, the amount paid for 1986 was just over 100,000 rupees.

Respondents gave several reasons for the rapid decline in O&M fee payment. First, farmers complained that O&M work which was supposed to be done using O&M fees was not done as expected. Second, there was no remedial action taken against those who did not pay. Third, many farmers said they were unaware of the newly introduced project committee system and its objectives.

Only 22 respondents (28 percent) in Kaudulla had heard about the project subcommittee in the area. Of these, only 17 farmers (21 percent) knew their representative in the local project subcommittee. Of these respondents, only 6 respondents (8 percent) said that they were satisfied with their representative. Nineteen respondents said that they were dissatisfied since no service has been rendered so far. Only 1 respondent said that he was satisfied with the local project subcommittee.

Though formal farmer organizations at the local level do not exist in Kaudulla, farmers at the field channel level have informal, joint agreements with one another to share water. Eighty-eight percent of the farmers interviewed said that they have such informal agreements. Note that these agreements only relate to sharing water and do not extend to system maintenance, prevention of illicit tapping, or punishment of offenders. The general feeling among water users in Kaudulla appeared to be that a more formal, collective organization consisting of all the water users at the field channel level was required to deal with such issues.

Eighty-eight percent of the farmers interviewed expressed a willingness to become members of such an organization. Encroachers who had no permits for their landholdings and others who were not convinced that a farmer organization could solve their problems reported that they would not want to join such an organization. Some of the respondents expressed the view that the water user association's authority should extend beyond the field channel area.

Examination of farmer expectations revealed considerable confusion regarding the function of project committees. Although water allocation, adjudication of disputes, supplying agricultural inputs, and extension were all cited, these were not expected roles of the project committee or project subcommittee (Table 79).

Table 79. Perceived functions of project committees identified by respondents in Kaudulla, 1986 yala (n=80).

Function	Number of Responses*
Allocate water at field channel level	51
Maintain channels	51
Rehabilitate channels	44
Prevent illicit tapping	42
Resolve conflict	33
Supply inputs	8
Agricultural extension	1

*Multiple responses were possible.

The majority of the sample farmers in Kaudulla felt that all the cultivators should be able to take part in the organization irrespective of whether they were original allottees or not. There was general agreement that leaders should be elected by the members of the farmer organization, yet there was some disagreement about who should have voting rights. Some felt that all the cultivators should be able to vote, while others thought that only the original allottees or descendants should retain voting rights.

Respondents generally agreed that local irrigation officials should also be members of the association. Most of the respondents mentioned the work supervisor when asked which officers should be members, while other respondents mentioned the technical assistant. Sample farmers gave various reasons why these officials should be members. Among them were the following: it would be easier to meet with these officials regarding irrigation matters, it would strengthen the link between higher authorities and farmers, and because these officials are in charge of the irrigation system.

Of those who said that a farmer organization was needed, 88 percent said the vel vidane should be a member of the organization because of his familiarity with the local people, local conditions, and irrigation matters. Most of those who did not think the vel vidane should be a member said that he did not perform his duties. Others said that since farmer leaders would be there, there was no need for the vel vidane's presence.

F. WOMEN IN DEVELOPMENT

1. INTRODUCTION

In Sri Lanka, the national government and international donors such as USAID are increasingly promoting the development and improvement of irrigation systems, large and small alike, as a means for increasing agricultural production. Parallel to this is a greater awareness of the importance of women's roles in agricultural production. Despite the noticeably greater attention given to farm women in recent development projects, understanding of women's roles in irrigated agriculture and their interaction with the irrigation system is minimal.

Therefore, a component relating to women's roles in an irrigated agricultural production system was included as a part of the Diagnostic Analysis Project. The women in development (WID) component sought to gather the following specific information:

1. Women's activities on- and off-farm, agricultural and non-agricultural.

2. Sources of agricultural information for women.

3. Information about home gardening and permanent tree crop production.

4. The income and expenditure patterns and preferences of the household, including the role of women in family resource management.

5. The participation of women in community organizations and informal groups.

The study made an effort to cover many broad topics of interest and was basically exploratory in nature. It was not expected that all questions relating to women's roles in irrigated agriculture would be conclusively answered, but that important and significant areas would be identified. Information from the study was aimed toward providing the Diagnostic Analysis Project with an additional dimension to understanding the complex operation and interaction of the irrigated agricultural system and the farm household.

The funding for the WID component of the Diagnostic Analysis Project was derived from the USAID/Colombo Mission. Initially, only two irrigation schemes (Parakrama Samudra and Giritale) were included for WID studies. However, some additional funding allowed the inclusion of Kaudulla and Minneriya schemes. This additional funding was significantly less than for the initial PSS and Giritale studies. Therefore, the WID studies on Kaudulla and Minneriya were more limited in scope and detail than the PSS and Giritale studies.

2. METHODOLOGY

The Kaudulla Scheme was investigated by the Diagnostic Analysis Project during the 1986 yala. The head, middle, and tail sites on the irrigation system were chosen by the engineering and agronomy components to represent expected hydrological differences. The WID sample was composed of farm households with field allotments from head and tail field channels on the distributary channels named in Table 80.

Table 80. Field sites for the 1986 yala WID study on Kaudulla.

	Stage I	Stage II	Households (Economics)	Households (Sociology)
Head	Tract 1/D1	Tract 1/LB Main	23	23
Middle	Tract 4/D8	Tract 4&5/D1	20	19
Tail	Tract 8/D1	Tract 12/D2A	29	36
Total			72	78

While hydrological locations may exhibit significant social and economic differences, correlation was determined to be less important for the WID component than for disciplines such as engineering. Therefore, only data relating to domestic water were analyzed according to hydrological location.

The actual number of households in Kaudulla were unknown. However, based on the original number of allottees, and adjusted for the second generation, a sample of approximately 2-3 percent of the estimated population was obtained. Efforts were made to include only those households engaged in cultivation during the 1986 yala. However, due to the complexity of land tenure arrangements and restrictions imposed by the hydrological selection of the sample, some households that had leased or mortgaged their fields to others were also surveyed. In addition, some households were cultivating more than one allotment, but were only interviewed about activities and information relating to one holding. Within each household, the selection of the female respondent was based on availability, accessibility, and the subjective opinion of the field investigator as to which female family member could best provide the information requested.

Because of limited funding, assistance from the other discipline components was necessary. The economics component and the sociology component collected various information for the WID study. Due to logistical problems involved in implementing a study of this scope, precise replication and coordination among all of the disciplines was difficult to achieve.

Although 80 households were actually selected for interviews by the WID, economic, and sociology components, only 72 were interviewed by the economics component and 78 by the sociology component. There-

fore, in some cases the size and composition of the WID sample varied, depending on whether the information was collected by the economics or the sociology component. These discrepancies in sample size are noted in the heading of the respective tables.

The economic and sociology field investigators, supervised by the WID coordinator and the WID field leader, administered the WID questionnaires. These investigators were all previously involved in the Parakrama Samudra and Giritale studies, and had worked closely with the WID field investigators. Although all of the economic and sociology investigators were males, their prior experiences with the WID investigators served to sensitize them to issues concerning women and methods and techniques for administering the questionnaire to women. THe WID field leader accompanied the economic and sociology investigators to the field, observed interviews, and assisted in resolving any problems.

The WID questionnaires were based largely on previous workshops and studies conducted in Sri Lanka (1983 Diagnostic Analysis Workshop: System H of the Mahaweli, 1984 Diagnostic Analysis Workshop: Parakrama Samudra System, and Kilkelly, 1986). The actual design, construction, and testing of the questionnaire is detailed in previous reports (Kilkelly, 1986; Nelson et al., 1987a and 1987b). All questionnaires were administered in Sinhala. Because of limited funding, the questionnaire for Kaudulla was considerably reduced from those used in the PSS and Giritale studies. Although most of the questions were restricted to specified responses, a few "open-ended" questions involving discussion were also included.

The questionnaires were administered in a single session by the economic and sociology investigators, during the same survey in which economic or sociology interviews were conducted. In previous studies, investigators noted that male family members tended to intrude on the WID interview. However, investigators in this study reported that they were able to resolve this problem.

Field investigators were issued tabulation forms and coding sheets. Coded data were verified by the WID field supervisor and the WID coordinator. The coded data were entered on a Compaq™ microcomputer for analysis using Microstat™ -- a statistical analysis software program. In addition, some of the open-ended discussion questions found to be incompatible with computer analysis were hand tabulated. Basically, a one-way frequency analysis was used for most variables and the arithmetic mean for other variables. A cross-tabulation of one variable was performed.

3. RESULTS AND DISCUSSION

a. Demographic Information

The family position of Kaudulla women respondents and their marital status is given in Table 81. The status of the woman within the family is an important variable when topics such as work responsibilities and decision-making are examined. As expected, the overwhelm-

ing majority of respondents were married women, with three young unmarried women still living in their parents' homes. Three widows were in the sample: one was the widow of an original male allottee and two were widows unrelated to an allottee (encroacher, tenant, or purchaser). The small number of widows in the WID sample is probably a reflection of the relatively young age of the Kaudulla resettlement scheme.

While a large proportion of women sampled were the wives of original male allottees, an unexpectedly large proportion reported that they were unrelated to the original allotment holder. Those bearing no relationship to the original allottee were related to encroachers, purchasers, or tenants. Although sale, mortgage, or division of the allotment is technically prohibited in the resettlement scheme, in reality a variety of complex tenurial relationships exist.

Table 81. Family position and marital status of Kaudulla respondents, 1986 *yala*.

	Econ (n=72)	Soc (n=78)
	----------%----------	
Familial Relationship		
Wife of allottee	38	46
Widow of allottee	1	1
Daughter of allottee	8	8
Daughter-in-law of allottee	8	8
Female allottee	3	10
Not related to allottee	42	27
Marital Status		
Married	89	90
Unmarried	4	5
Divorced/separated	3	1
Widowed	4	4

The age and educational level of the women interviewed is shown in Table 82. The age of the women ranged from 17 to 55 years with an overall average of 36 years of age. Although the Kaudulla Scheme resettlement began in 1950, a large proportion of the allotments (Stage II) were not settled until as late as 1976. Therefore, the number of elderly women sampled on the Kaudulla Scheme was significantly less than some of the older settlements.

The educational level of the women interviewed ranged from none to a woman with a college degree (B.A.), with an overall average of 7 years of formal schooling. Approximately 38 percent of the sample had received at least 10 years of schooling (GCE), a fairly high level for a rural area. In fact, when only the women classified as unrelated to an original allottee were considered, the average education level was found to be 8 years of schooling. This may be related to the fact that many of these households relocated from more densely populated cities

in the Wet Zone (such as Kandy or Colombo) with the financial ability to either purchase or lease land from the original allottee.

Table 82. Age and education of Kaudulla respondents, 1986 *yala* (n=72).

Age (yrs)	Percent	Education	Percent
< 20	3	None	8
21-30	25	1-5 years	29
31-40	36	6-9 years	25
41-50	25	(GCE)'O'*	32
> 50	11	(GCE'A'**	4
		B.A. (16 years)	1

*GCE'O' = General Certificate of Education - ordinary level (10 years of schooling plus exam)
**GCE'A' = General Certificate of Education - advanced level (12 years of schooling plus exam)

b. Activities of Kaudulla Women

A general description of activities reported by the women interviewed is found in Table 83. Overall, even though women were primarily responsible for the majority of household duties, almost 90 percent were also involved in some form of agricultural work. Five women were engaged in full-time employment outside of the home, which seemed to be relatively high for the predominantly rural setting of the Kaudulla Scheme.

Table 83. Primary activities of Kaudulla respondents, 1986 *yala* (n=72).

Activity	Percent
Mainly housework	6
House/fieldwork	88
House/field/job	1
House/job	5

Although funds were not available to gather detailed information concerning specific activities associated with the various stages of irrigated crop production, some general information about the type of agricultural activities performed by Kaudulla women is reported in Table 84.

Table 84. Agricultural activities of Kaudulla respondents, 1986 yala (n=72).

Activity	Number of Responses*
Home vegetable garden	30
Highland crop	1
Family fields	65
Other's fields	28
No agricultural work	8

*Multiple responses were possible.

Only 11 percent of the women interviewed reported that they performed no agricultural work at all. The majority of women (90 percent) were engaged in agricultural work on their own family fields. In addition to work in their own fields, women also worked in other's fields (15 women), home gardens (18 women), or both (12 women). One woman was primarily engaged in growing a dryland crop of kurrakan (finger millet) on the highland.

The 28 women (39 percent) involved in off-farm, agricultural work reported that this was primarily attam (a form of exchange labor), casual wage labor, or shramadana (volunteer work) as shown in Table 85.

Table 85. Off-farm, agricultural work of Kaudulla respondents, 1986 yala (n=28).

Off-farm work	Number of Responses*	Type of activity	Number of Responses*
Attam	23	Transplanting paddy	27
Wage labor	18	Weeding paddy	20
Shramadana	5	Harvest paddy	14
		Harvest other field crops	1

*Multiple responses were possible.

Almost all of the off-farm, agricultural work was in paddy cultivation. Because the labor intensive activity of paddy transplanting is done solely by women, many households either exchanged labor with neighbors or hired local teams of women. In fact, local female labor is generally insufficient to meet the labor demands during transplanting, and crews of women from outside the area are contracted for this particular activity. Local women usually provide most of the labor for weeding throughout the cultivation season, either by attam or casual wage labor. Harvesting the paddy crop is another labor intensive activity, but both men and women commonly work together. Although harvesting also requires outside hired labor, the crews are composed primarily of men. Shramadana is generally associated with non-agricul-

tural work such as community projects, but five women reported that they had donated their time to assist others with agricultural work.

Besides agricultural work, 21 women (29 percent) reported that they performed off-farm, non-agricultural work (Table 86). This work primarily involved shramadana, wage labor, business, or a job. Those engaged in performing shramadana reported their work as road repair, cleaning irrigation channels, or community work. Although shramadana is technically termed volunteer work, often there is some type of payment, such as canned food, offered by local government agencies. In fact, there is a special "shramadana" program by the Cultural Triangle (UNESCO and the Government of Sri Lanka) in which food goods are given daily to anyone willing to perform supervised, menial labor within the ancient archeological sites in Polonnaruwa. The five women with full-time jobs included one school teacher and four women who owned, managed, or were employed in local neighborhood boutiques (small tea and sundries shops).

Table 86. Off-farm, non-agricultural activities of Kaudulla respondents, 1986 yala (n=21).

	Number of Responses*
Shramadana	13
Road repair	11
Channel maintenance	1
Cultural Triangle	2
Community work	3
Wage labor	3
Road repair	2
Community work	1
Business/job	5
Teacher	1
Boutique	4

*Multiple responses were possible.

c. Home Gardens and Permanent Tree Crops

The highland allotment can be considered an important production unit that contributes toward the support of the farm family. During yala, however, home gardening is limited due to insufficient rainfall and the absence of a water delivery system to the highlands. Even then, 45 percent of the households reported that they maintained home gardens. Information concerning 1986 yala home gardens on Kaudulla is presented in Table 87. Unavailability of water was the most common reason cited for not having a vegetable garden. In addition, some women also mentioned that they had little or no energy to devote to vegetable gardening due to their responsibilities in the family paddy fields.

Table 87. Kaudulla gardening activities, 1986 *yala* (n=72).

	Number of Responses*
Vegetable gardens	
Yes	32 (45)**
No	40 (56)
Why not	
Inadequate water	30
No time/labor	6
Poor soil	3
No seeds available	2
Uneconomical	1
No response	2
Location	
Highland/house	27
Fields/bunds/threshing floor	7
Care	
Females only	6
Females/males	26
Males only	0
Water	
Well/tap	24
Irrigation channel	11
Use	
Home only	27
Home/sale	5
Sale only	0

*Multiple responses were possible.
**() = Percent

Despite the lack of water, most gardens were located on the highland around the house. A few women reported that they also grew vegetables in their fields, usually around the perimeter, on the bunds, or on the vacant threshing floor. These field gardens were then able to receive the benefit of the irrigation water supplied to the paddy crop. While 7 women reported that their gardens were located in the fields, 11 women reported that their gardens were watered from a nearby irrigation channel. In some locations within the Kaudulla Scheme, the highland allotment can be easily irrigated from a nearby channel. The irrigation of these allotments is a sensitive subject since it is illegal to do so. While the farm household may realize definite benefits from irrigating highland allotments, it is incompatible with the design of the irrigation system and undoubtedly affects the delivery of irrigation water to the fields.

These small plots of vegetables were usually consumed at home and only occasionally sold. Consequently, the care of these gardens was

often not considered "agricultural" work, and women often neglected to mention the existence of these gardens. In addition, throughout the study there was difficulty in defining "home gardens." The home garden was usually limited in scope, contained a diverse mix of vegetables, and was used primarily for home consumption. However, women occasionally assumed that the interviewer was only interested in "highland crops," a larger and more homogeneous stand of vegetables than the home garden. Furthermore, the highland crop had economic connotations not associated with the home garden. For these reasons, women may not have indicated that they were growing a few vegetables around the house for the family. Only through successive probing and conversation on the part of the interviewer was information on home gardening obtained. Therefore, the data in Table 87 may underestimate the home gardening of Kaudulla respondents.

Eighty-one percent of the home gardens were tended by both men and women, rather than by one family member exclusively. Since the irrigated paddy crop generally receives priority, labor for the home garden relied on some contribution from all family members. Most (84 percent) of the home gardens were grown for family consumption, with only a few households selling produce from the home garden.

Seventy-five percent of the Kaudulla sample households cultivated permanent trees on the highland or around the house. Compared to the other irrigation systems studied, this was a relatively low percentage. The primary reason cited for not growing permanent trees was that of poor soil (Table 88).

Table 88. Permanent tree crops on Kaudulla, 1986 yala (n=72).

	Number of Responses*
Permanent Tree Crops	
Yes	54 (75)**
No	18 (25)
Why Not	
Poor soil	11
No water	4
No space	3
No response	2
Care	
Females only	0
Females/males	47
Males only	7
Use	
Home only	38
Home/sale	10
Sale only	0
No produce	6

*Multiple responses were possible.
**() = Percent

While the majority of women stated that fruits were used solely for home consumption, almost 20 percent of those women with trees replied that they occasionally sold the produce when cash was required and a surplus of produce (primarily coconuts) existed. However, no regular marketing of produce was identified. A few women noted that although they had planted permanent trees, due to poor growing conditions no produce had been obtained.

Again, because care of the trees comes only after the labor requirements of the irrigated paddy crop are met, all family members contributed to the care of permanent tree crops.

d. Domestic Water

The farm women normally assumed the responsibility for obtaining water for domestic use. While the majority of families were able to obtain domestic water from a shallow hand-dug well on their own highland, a significant number of women reported that they used a neighbor's well or a community well.

Observations suggested that most of the highland wells depended on recharge provided by seepage from the nearest irrigation channel. It may be that some households were not as conveniently located (close to an irrigation channel) as other households, for a reliable source of domestic water.

Approximately 80 percent of the women interviewed reported that they had some difficulty with their wells during yala (Table 89). The most common complaint was low water level, which meant decreased quality of the well water. However, 27 percent of those experiencing well problems indicated that the well actually dried up during the latter part of yala, requiring an alternative source of domestic water.

Table 89. Information about domestic water, as reported by Kaudulla respondents, 1986 yala (n=78).

Domestic Water	Number of Responses	Percent
Source		
Highland well	51	65
Neighbor's well	18	23
Community well	8	10
tank	1	1
Problems		
No	16	20
Yes	62	80
What		
Low water level	30	48*
Occasionally dry	17	27*
Poor water quality	13	21*
Distance	2	3*

*Relative percentage

Households located in the middle and tail regions of the irrigation system experienced more difficulty with wells than households located in the head region (Table 90). This may be due to lower volumes of water, lower flow rates of water in channels, or delayed issues. Towards the end of yala cultivation, irrigation issues are normally reduced to coincide with harvesting activities. During this period wells may be inadequate for supplying domestic water.

Table 90. Distribution of well problems by hydrological location as reported by Kaudulla respondents, 1986 yala (n=78).

Domestic Water	Head (n=23)		Middle (n=19)		Tail (n=36)	
	Freq.	Rel %	Freq.	Rel %	Freq.	Rel %
No problems	7	30	3	16	6	17
Well problems	16	70	16	84	30	83

e. Agricultural Information

Overwhelmingly, women indicated that their main source of agricultural knowledge came from traditional experiences. Most women reported that what they knew of agriculture was gained through their mothers, sisters, or other family members. In fact, "informal" sources of agricultural knowledge (husband, neighbors, and other farmers) surpassed any other sources of agricultural information for women (Table 91).

Table 91. Primary sources of agricultural information for Kaudulla respondents, 1986 yala (n=78).

Source	Number of Responses*
Traditional	69
Husband/son	64
Neighbor/farmer	43
Radio	23
Newspaper	2
Private traders	2
Pamphlets	1
Ag. Extension staff	1
No information obtained	9

*Multiple responses were possible.

Overall, about a third of the sample indicated that they had used the mass media to obtain information about agriculture. Considering the relatively high education level of the Kaudulla women sampled, the

mass media (especially printed material) could be a means of extending agricultural information to women. Only one woman cited the agricultural extension staff of the Agriculture Department as a source of information. This woman indicated that she had attended a farmer training class sponsored by the local Agriculture Department office. Although the agricultural extension staff are charged with providing information about home gardening and tree crop production, there were no reports of extension visits from the women interviewed. Upon further questioning, a number of women reported that they occasionally listened to agricultural radio programs and read information about agriculture in the local newspapers, but did not rely on or seek these as their main source of agricultural information (Table 92). Radio programs such as Sarabumi (sponsored by the Agriculture Department), agricultural quiz shows, and advertisements were specifically cited, as well as newspaper articles.

Table 92. Occasional sources of agricultural information for Kaudulla respondents, 1986 yala (n=78).

Source	Number of Responses*	Percent
Radio programs		
No	49	63
Yes	29	37
What		
Sarabumi	12	
Ag. quiz shows	17	
Newspapers		
No	60	77
Yes	18	23

*Multiple responses were possible.

Information concerning the irrigation schedule, cropping calendar, and other general agricultural information is disseminated at the seasonal kanna (pre-cultivation) meeting. Only one woman reported that she had attended the kanna meeting for 1986 yala. While a relatively high proportion of male family members reported that they attended this meeting, informal observations at a few of the kanna meetings in the Polonnaruwa District indicated that the number of farmers attending kanna meetings was minimal. The magnitude of the survey response was probably the result of a "courtesy response" since, technically, all farmers on the irrigation scheme are supposed to attend kanna meetings.

f. Family Finances

Although the primary source of family income was generally from paddy cultivation, other supplemental sources of income usually existed. Approximately 93 percent of all sampled households identified some form of income in addition to the irrigated crop.

Day-to-day household expenses managed by women were met by cash obtained from a variety of sources (Table 93). The majority of women reported that they obtained cash from their husband, son, or other family member. However, a significant number of women (almost half of the Kaudulla sample) also indicated that a common source of ready cash existed for temporary use from either neighbors or the local boutique. Women reported that when a small amount of cash for daily needs was required, they would borrow from these sources. This practice of borrowing cash may be a result of the overall limitations of the family budget during most of the cultivation season (see economics chapter) or may reflect the unavailability of ready cash to women themselves. However, seventeen women indicated that they alone provided and managed the cash for day-to-day expenses.

Table 93. Sources of cash for day-to-day expenses of Kaudulla households, 1986 yala (n=72).

Source	Number of Responses*
Husband/son/family	32
Woman's own source	17
Borrow from boutique	33
Borrow from neighbors	19
Fruit/vegetables/coconuts	13
Animals/products	3
Sale of subsidiary crops	3
Job/business	7

*Multiple responses were possible.

Fruits, vegetables, livestock, poultry, or animal products were also means of supplementing family income. This type of income was difficult to quantify because most women could not recall or estimate the cash received through these occasional sales. Without some sort of record-keeping system it would be difficult to identify the economic contribution of the highland. Other significant sources of income included earnings from a business (boutique), a job (teacher), and wage or casual labor.

The management of resources (especially cash) within the family is a complex process and not always readily revealed to outsiders. Therefore, a number of questions about general purchases were included. In this manner, the individuals actually conducting the purchase were identified. While this does not account for the actual management of cash, Table 94 may offer insights into the purchasing power of various family members.

Overall, in 43 percent of the sampled households women participated in the purchase of daily items. However, it appeared that the majority of daily purchases were made by male family members. Since some areas of the Kaudulla Scheme are remote from shops or markets and involve travelling some distance outside the neighborhood, male family members probably assumed these responsibilities. Even

though cultural restrictions do not significantly limit movement outside the household, women are generally constrained by time and travel requirements, compared to men who commonly use bicycles and tractor carts.

Table 94. Purchase of day-to-day items by Kaudulla households, 1986 yala (n=72).

Purchaser	Number of Responses	Percent
Males only	40	57
Males/females	24	32
Females only	8	11

In approximately 92 percent of the households, individuals earning cash contributed all of their earnings to the family (Table 95). When women were asked about the management of family cash, the responses indicated that while this was the responsibility of males in the majority of households, management was shared between males and females in a significant number of families (Table 95). In addition, in 19 percent of the Kaudulla households, women reported that they alone managed the family cash.

Table 95. Management of cash resources in Kaudulla households, 1986 yala (n=72).

Individual Earnings	Number of Responses	Cash Management	Number of Responses
Keep all	1 (1)*	Females only	14 (19)
Contribute part	5 (7)	Females/males	28 (39)
Contribute all	66 (92)	Males only	30 (42)

*() = Percent

When women were asked about personal access to cash, 40 percent reported that they have their own source of cash to spend as they wish (Table 96). The most common source cited by women for obtaining personal cash was by their own wage labor earnings. Other sources of personal cash for women included vegetable or fruit sales, operating a small business, sale of animals or animal products, and a job. Two women were also independently cultivating leased-in paddy land.

The majority of family expenses revolved around family subsistence and agricultural input needs. No doubt, these probably compete in households of limited finances, with family subsistence barely preceding agricultural expenses (see economics component). One opportunity to reduce family expenses is through establishing a vegetable garden for home consumption. During yala, the price of vegetables locally is quite high, and most of the women (54 percent) reported that they had to purchase vegetables for family meals (Table 97). Whereas, those

women with gardens were able to use the produce for family meals, only six women reported that their home gardens were sufficient to supply their entire vegetable requirement.

Table 96. Personal cash sources for Kaudulla women, 1986 *yala* (n=72).

	Number of Responses*
Own source of cash	
No	43 (60)**
Yes	29 (40)
What	
Wage labor	18
Vegetable/fruit	6
Business/boutique	6
Animals/products	2
Additional cultivation	2
Job	1

*Multiple responses were possible.
**() = Percent.

Table 97. Vegetable sources for Kaudulla households, 1986 *yala* (n=72).

Source	Number of Responses	Percent
Own garden only	6	8
Garden/purchase	27	38
Purchase only	39	54

When asked what an unexpected, large sum of cash (such as a lottery winning) would be used for, the majority of women responded with new home construction or improvement of the existing home (Table 98). Their second preference was for purchase of agricultural equipment, closely followed by purchasing or leasing in additional lands for cultivation. Surprisingly (based on the overall financially constrained condition of most households, noted by the economics component), a relatively high proportion of responses included educating children, establishing a savings, and even giving cash gifts to relatives, the temple, or community donations.

Table 98. Spending preferences of Kaudulla respondents, 1986 *yala* (n=72).

Use of Lottery Winnings	Number of Responses	Percent
House construction/repair	22	31
Agricultural equipment	11	15
Purchase/lease in land	10	14
Child's education	9	13
Gift to relatives/temple/community	8	11
Savings	6	8
Business investment	4	6
Car/motorcycle	1	1
Loan/mortgage repayment	1	1

g. Society Membership

When women were asked about their membership in local organizations, 45 percent reported that they were members of some society (Table 99). The most popular society appeared to be the Rural Development Society (RDS). This was followed by both formal and informal temple societies, and Sarvodaya (a voluntary service group). Although membership in the RDS is not restricted to men, a special chapter of the RDS for women, the Kantha Samithi does exist. On other irrigation schemes studied, women generally preferred membership in Kantha Samithi rather than the RDS, but this apparently was not the case on the Kaudulla Scheme. A few other women cited membership in the local cooperative, the Death Donation Society (where dues are paid to a fund for the funerals of contributing members), and the Young Farmers Club.

Table 99. Participation of Kaudulla respondents in local societies, 1986 *yala* (n=78).

Society	Number of Responses*
Not a member	43 (55)**
Member	35 (45)
Which	
Rural Development Society	18
Temple	12
Sarvodaya	11
Kantha Samithi	4
Death Donation	2
Cooperative	1
Young Farmers Club	1

*Multiple responses were possible.
**() = Percent

4. CONCLUSIONS

Due to the more recent settlement of the Kaudulla Scheme, few women over 50 years of age were included in the sample, which also resulted in having fewer widows in the sample than in other schemes studied. A large percentage of the women interviewed reported that they were unrelated to an original allottee, but rather they were related to encroachers, tenants, and purchasers of land in the scheme.

An overall average of seven years of schooling among the women represented a fairly high level of education for a rural area and may be the result of the large proportion of women from cities outside the area.

While most women were usually responsible for household duties, 90 percent were also involved in some form of agricultural work. Women were primarily engaged in work on their own family fields, but 38 percent of the respondents reported off-farm, agricultural work such as attam, wage labor, and shramadana. Off-farm, agricultural work mainly involved activitie in paddy cultivation, such as transplanting, weeding, and harvesting.

In addition, almost one-third of the Kaudulla women interviewed reported that they also performed off-farm, non-agricultural work. This work involved shramadana, wage labor, operation of a business, or a job. The relatively high level of off-farm employment of women in non-agricultural activities may reflect the lower economic status of Kaudulla households compared to other schemes studied.

Forty-five percent of the Kaudulla households interviewed maintained a home garden during 1986 yala. While all gardens were used for home consumption (with five households selling some produce from the garden) only six of the gardens were sufficient to provide the entire vegetable requirement for family meals. Generally, both men and women cared for the garden. Some gardens on the highland were illegally watered by tapping water from nearby irrigation channels.

Seventy-five percent of the households were cultivating permanent tree crops on the highland or around the house. This was a relatively low percentage compared to other schemes studied. The primary reason cited for not growing tree crops was that of poor soil. Trees were usually cared for by both men and women. Although the majority of produce was consumed at home, occasional surplus (primarily coconuts) was sold.

While the majority of households obtained domestic water from shallow, hand-dug wells on the highland, 35 percent of the households interviewed reported their domestic water source as a neighbor's well, a community well, or the tank (reservoir). Approximately 80 percent of the women reported some well-water problems during yala. Twenty-seven percent of those reporting problems indicated that the well dried up during the latter part of yala. Households located in the middle and

tail regions of the scheme reported more well-water problems than households from the head region.

The main source of agricultural information for women was through traditional experiences or "informal" sources such as the husband, son, neighbors, or other farmers. About a third of the women indicated that they had obtained agricultural information through the mass media (newspapers, radio, and pamphlets). Only one woman cited contact with the KVS (agricultural extension agent) as a source of information.

Day-to-day household expenses were met from a variety of sources. A significant number (almost half of the sample) reported that cash was often borrowed from neighbors or the local boutique. This method of obtaining cash for daily needs may indicate the limitations of the family budget during most of the cultivation season. Seventeen women (24 percent) reported that they provided and managed the cash themselves for daily expenses.

Although in many households the management of cash was considered a responsibility of male family members, in an almost equal number of households both men and women shared the management of family finances.

Forty percent of the women interviewed reported that they had their own sources of personal cash, including wage labor (which was most commonly cited); the sale of vegetables, fruits, animals, and animal products; operating small businesses; and holding a job.

House construction or improvement was most often cited by Kaudulla respondents when asked about spending preferences. This was followed by agricultural equipment purchase and the purchase or leasing-in of additional land for cultivation. Surprisingly (based on the overall financial conditions of Kaudulla households), educating children, establishing a savings, and giving cash gifts were also mentioned.

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V. APPENDICES

APPENDIX A

RICE EVAPOTRANSPIRATION IN POLONNARUWA DISTRICT, SRI LANKA, 1986 YALA

(Estimated using method by Jensen and Haise, 1980)

Julian Date	Mean Temp. (C)	Solar Radiation (langleys)	ETo (mm/day)	Kc	ET (mm/day)
151	30.6	561	8.45	1.15	9.72
152	30.6	529	7.97	1.15	9.17
153	31.1	579	8.87	1.15	10.20
154	30.6	535	8.06	1.15	9.27
155	30.0	485	7.19	1.15	8.27
156	30.6	475	7.16	1.15	8.23
157	31.1	519	7.95	1.15	9.14
158	31.1	463	7.09	1.15	8.15
159	31.1	481	7.36	1.15	8.47
160	30.0	330	4.89	1.15	5.63
161	30.0	440	6.53	1.15	7.50
162	31.1	467	7.15	1.15	8.22
163	31.1	531	8.13	1.15	9.35
164	30.6	529	7.97	1.15	9.17
165	30.0	491	7.28	1.15	8.37
166	30.0	381	5.65	1.15	6.50
167	28.9	300	4.30	1.15	4.95
168	28.9	494	7.09	1.15	8.15
169	28.9	577	8.28	1.15	9.52
170	28.3	503	7.10	1.15	8.16
171	28.9	516	7.40	1.15	8.51
172	28.3	489	6.90	1.15	7.93
173	28.9	554	7.95	1.15	9.14
174	28.9	556	7.98	1.15	9.17
175	28.3	496	7.00	1.15	8.05
176	28.9	477	6.84	1.15	7.87
177	28.3	483	6.81	1.15	7.84
178	28.3	476	6.72	1.15	7.72
179	28.9	514	7.38	1.15	8.48
180	27.8	513	7.18	1.15	8.26
181	28.3	502	7.08	1.15	8.14
182	28.9	558	8.01	1.15	9.21
183	28.9	538	7.72	1.15	8.88
184	28.9	556	7.98	1.15	9.17
185	28.3	501	7.07	1.15	8.13
186	28.3	625	8.82	1.15	10.14
187	28.9	521	7.48	1.15	8.60
188	28.3	464	6.55	1.15	7.53
189	27.8	440	6.10	1.15	7.02
190	28.9	557	7.99	1.15	9.19
191	28.3	553	7.80	1.15	8.97
192	28.9	529	7.59	1.15	8.73
193	27.2	462	6.30	1.15	7.24
194	27.8	506	7.02	1.15	8.07
195	27.2	350	4.77	1.15	5.48
196	27.2	317	4.32	1.15	4.97

Appendix A (continued)

Julian Date	Mean Temp. (C)	Solar Radiation (langleys)	ETo (mm/day)	Kc	ET (mm/day)
197	27.9	502	6.96	1.10	7.66
198	28.3	522	7.36	1.10	8.10
199	27.8	512	7.10	1.10	7.81
200	27.8	534	7.40	1.10	8.15
201	28.9	562	8.06	1.10	8.87
202	27.8	560	7.77	1.10	8.54
203	27.8	508	7.04	1.10	7.75
204	27.8	557	7.72	1.10	8.50
205	28.3	575	8.11	1.10	8.92
206	28.3	551	7.77	1.10	8.55
207	28.9	570	8.18	1.10	9.00
208	28.3	572	8.07	1.10	8.88
209	28.3	532	7.51	1.10	8.26
210	28.3	567	8.00	1.10	8.80
211	27.2	502	6.84	1.10	7.52
212	26.1	240	3.15	1.10	3.47
213	27.2	579	7.89	1.10	8.68
214	27.8	517	7.17	1.10	7.89
215	27.8	418	5.80	1.10	6.38
216	27.2	374	5.10	1.10	5.61
217	27.2	415	5.65	1.10	6.22
218	27.8	505	7.00	1.10	7.70
219	26.7	448	6.00	1.10	6.60
220	26.7	388	5.19	1.10	5.71
221	26.1	350	4.60	1.10	5.06
222	27.2	448	6.10	1.10	6.71
223	27.2	471	6.42	1.10	7.06
224	27.8	503	6.97	1.10	7.67
225	27.2	522	7.11	1.10	7.82
226	27.8	524	7.27	1.10	7.99
227	28.9	578	8.29	1.10	9.12
228	28.9	541	7.76	1.00	7.76
229	27.8	572	7.93	1.00	7.93
230	28.3	557	7.86	1.00	7.86
231	28.9	564	8.09	1.00	8.09
232	28.9	584	8.38	1.00	8.38
233	29.4	580	8.46	1.00	8.46
234	28.3	496	7.00	1.00	7.00
235	28.3	546	7.70	1.00	7.70
236	27.8	503	6.97	1.00	6.97
237	27.8	600	8.32	1.00	8.32
238	27.8	568	7.88	1.00	7.88
239	27.8	409	5.66	1.00	5.66
240	28.3	576	8.13	1.00	8.13
241	28.3	566	7.98	1.00	7.98
242	27.8	552	7.65	1.00	7.65
243	28.3	534	7.53	1.00	7.53
244	27.8	545	7.56	1.00	7.56

Appendix A (continued)

Julian Date	Mean Temp. (C)	Solar Radiation (langleys)	ETo (mm/day)	Kc	ET (mm/day)
245	28.3	535	7.55	1.00	7.55
246	28.9	541	7.76	1.00	7.76
247	28.3	572	8.07	1.00	8.07
248	28.3	472	6.66	1.00	6.66
249	27.8	367	5.09	1.00	5.09
250	28.3	507	7.15	1.00	7.15
251	28.3	498	7.03	1.00	7.03
252	28.3	499	7.04	1.00	7.04
253	28.3	521	7.35	1.00	7.35
254	28.9	540	7.75	1.00	7.75
255	28.9	557	7.99	1.00	7.99
256	28.9	504	7.23	1.00	7.23
257	27.2	409	5.57	1.00	5.57
258	27.2	368	5.01	1.00	5.01
259	26.7	412	5.51	1.00	5.51
260	27.8	434	6.02	1.00	6.02
261	27.8	461	6.39	1.00	6.39
262	28.3	575	8.11	1.00	8.11
263	26.9	576	8.26	1.00	8.26
264	28.3	450	6.35	1.00	6.35
265	28.3	530	7.48	1.00	7.48
266	28.9	546	7.83	1.00	7.83
267	28.3	508	7.17	1.00	7.17
268	28.3	470	6.63	1.00	6.63
269	28.9	478	6.86	1.00	6.86
270	30.0	583	8.35	1.00	8.35
271	29.4	567	8.27	1.00	8.27

APPENDIX B

AVERAGE DAILY AND WEEKLY SUPPLY RATES

Table 1. Average daily and weekly supply rates for Stage I of Kaudulla Scheme (mm/day), 1986 *yala*.

Location	Area (acres)	Distance (ft)	Daily Supply Rates Average (mm/day)	Daily Supply Rates Std. Dev. (mm/day)	Daily Supply Rates C.V.	Weekly Supply Rates Average (mm/day)	Weekly Supply Rates Std. Dev. (mm/day)	Weekly Supply Rates C.V.
Sluice	5375	0	14.421	5.723	0.397	14.456	4.447	0.308
RB Main canal	4942	350	10.294	3.684	0.358	10.325	2.516	0.244
1 B Tract 1	433	300	18.121	14.872	0.821	18.029	5.178	0.287
FC (B) Tract 1	15	4520	34.959	16.537	0.473	34.882	8.593	0.246
RB1 Tract 1	1058	10350	12.112	4.872	0.402	12.321	3.716	0.302
D1 No. 2 Tract 1	1760	10350	6.329	2.771	0.438	6.228	2.186	0.351
D2 Tract 2	187	10830	13.596	14.234	1.047	13.567	6.101	0.450
D3 All Tract 2	21	17740	6.255	8.722	1.394	7.062	4.158	0.589
D4 Tract 3	74	18270	11.080	8.078	0.729	11.025	3.196	0.290
D5 Tract 3	150	19740	10.313	10.220	0.991	10.184	3.955	0.388
D5A Tract 3	45	20140	1.782	2.615	1.467	1.925	0.983	0.539
D6 Tract 3	12	21170	6.073	8.825	1.453	6.347	3.963	0.624
D7 Tract 3	20	22720	24.901	10.800	0.434	25.550	6.730	0.263
D8 Main Channel	2266	29900	16.180	5.986	0.370	16.284	4.221	0.259
D1 Tract 6	293	37140	14.447	9.044	0.626	14.613	3.342	0.229
FC 17 Tract 6	52	38780	6.395	6.845	1.070	6.660	2.578	0.387
FC1 Tract 7	18	39800	7.264	6.306	0.868	7.173	4.677	0.652
D1 Brch. Ch.	1434	40640	11.616	4.659	0.401	11.566	2.987	0.258
D1 Tract 8	657	40640	10.759	4.296	0.399	10.845	2.675	0.247
D3 Tract 7	837	40640	11.569	5.571	0.482	11.670	3.600	0.308
		Average	12.423	7.733	0.751	12.531	3.990	0.361
		Std. Dev.	7.164	3.883	0.376	7.160	1.670	0.122
		C.V.	0.577	0.502	0.515	0.571	0.419	0.368

Table 2. Average daily and weekly supply rates for Stage II of Kaudulla Scheme (mm/day), 1986 *yala*.

Location	Area (acres)	Distance (ft)	Daily Supply Rates Average (mm/day)	Daily Supply Rates Std. Dev. (mm/day)	Daily Supply Rates C.V.	Weekly Supply Rates Average (mm/day)	Weekly Supply Rates Std. Dev. (mm/day)	Weekly Supply Rates C.V.
Sluice	5317	0	8.455	7.574	0.896	8.548	2.540	0.297
FC1 Tract 1	33	5400	20.990	20.055	0.955	21.220	4.837	0.228
FC2 Tract 1	81	9380	20.837	52.338	2.512	21.066	18.877	0.896
FC5 Tract 1	90	10210	10.296	10.058	0.977	10.409	2.659	0.255
FC7 Tract 1	60	11440	18.461	17.480	0.947	18.664	4.362	0.234
D1 Tract 2	300	15130	13.798	13.832	1.002	13.950	4.210	0.302
D2 Tract 2	178	17750	12.964	12.619	0.973	13.132	3.717	0.283
D1 tract 3	219	21820	17.214	17.105	0.994	17.437	5.240	0.300
D1 Tract 4	664	24010	15.833	15.230	0.962	16.007	3.069	0.192
FC8 Tract 5	138	26460	1.904	2.589	1.360	2.068	1.072	0.518
FC9 Tract 3	85	27150	1.082	1.329	1.228	1.136	0.586	0.516
FC13 Tract 3	12	27020	8.640	11.607	1.343	9.074	5.428	0.598
FC16 Tract 6	40	26370	5.023	12.649	2.518	4.869	7.139	1.466
FC17 Tract 6	10	26420	5.236	7.927	1.514	5.577	2.778	0.498
FC18 Tract 6	59	27060	9.268	12.384	1.336	9.731	4.843	0.498
FC19 Tract 6	7	27120	13.066	19.287	1.476	14.648	9.636	0.658
FC22 Tract 6	30	27910	8.580	9.674	1.128	8.878	3.356	0.378
D2 Tract 6	471	28350	6.051	7.054	1.166	6.315	2.659	0.421
D1 Tract 7	129	31420	15.043	15.089	1.003	15.361	2.721	0.177
D2 Tract 7	172	34600	15.175	17.289	1.139	16.278	7.214	0.443
FC 26	25	35490	13.857	14.954	1.079	13.995	5.511	0.394
D3 Tract 8	72	36050	12.505	13.537	1.083	13.177	4.777	0.362
FC 24	25	37050	21.107	24.512	1.161	23.207	10.460	0.451
Branch Channel 1 A	955	39550	7.934	8.265	1.042	8.104	1.572	0.194
D1 Tract 12	124	40300	15.691	14.620	0.932	16.524	5.632	0.341
D1 Branch Channel	654	40350	12.915	11.816	0.915	13.586	4.304	0.317
D2 Branch Channel	198	41850	11.515	11.231	0.975	12.052	3.856	0.320
FC7 Tract 12	18	42760	10.115	10.147	1.003	10.328	2.947	0.285
FC7 D2 Tract 12	438	42760	11.210	10.801	0.964	11.344	2.773	0.244
D2A Tract 12	203	43340	7.679	7.685	1.001	8.006	2.258	0.282
D2A D2 Tract 12	235	43340	14.522	13.198	0.909	15.161	4.349	0.287
D3 Tract 12	53	43540	4.920	5.095	1.036	4.984	1.970	0.395
D4 Tract 12	118	45330	8.580	8.776	1.023	8.692	2.640	0.327
D5 Tract 12	27	46400	8.027	22.743	2.833	8.131	8.349	1.027
FC1 Tract 4	55	28740	17.930	17.723	0.988	18.968	6.013	0.317
FC 10A Tract 4	12	34000	36.822	41.264	1.121	37.874	2.396	0.063
FC8 Tract 4	23	33590	5.615	5.708	1.017	5.776	0.759	0.131
Average			12.131	14.196	1.203	12.548	4.533	0.403
Std. Dev.			6.535	9.392	0.459	6.772	3.294	0.258
C.V.			0.539	0.662	0.374	0.540	0.724	0.642

APPENDIX C

REGRESSION ANALYSIS OF KAUDULLA SCHEME

Table 1. Regression analysis of Stage I, Kaudulla, 1986 yala.

Weekly Average Supply vs Distance

Regression Output:

Constant	15.486
Std Err of Y Est	7.249
R Squared	0.077
No. of Observations	20.000
Degrees of Freedom	18.000
X Coefficient(s)	-0.000
Std Err of Coef.	0.000

Regression Model:

Weekly Average Supply =
(X Coeff.) * Distance + Constant

This is a linear model only

Daily Coeff. Variation vs Distance

Regression Output:

Constant	0.716
Std Err of Y Est	0.237
R Squared	0.001
No. of Observations	20.000
Degrees of Freedom	18.000
X Coefficient(s)	0.000
Std Err of Coef.	0.000

Regression Model:

Daily Coeff. Variation =
(X Coeff.) * Distance + Constant

This is a linear model only

Weekly Coeff. Variation vs Distance

Regression Output:

Constant	0.343
Std Err of Y Est	0.140
R Squared	0.009
No. of Observations	20.000
Degrees of Freedom	18.000
X Coefficient(s)	0.000
Std Err of Coef.	0.000

Regression Model:

Weekly Coeff. Variation =
(X Coeff.) * Distance + Constant

This is a linear model only

Weekly Std. Dev. of Supply vs Distance

Regression Output:

Constant	4.735
Std Err of Y Est	1.079
R Squared	0.091
No. of Observations	20.000
Degrees of Freedom	18.000
X Coefficient(s)	-0.000
Std Err of Coef.	0.000

Regression Model:

Weekly Standard Dev. of Supply
(X Coeff.) * Distance + Constant

This is a linear model only

Table 2. Regression analysis of Stage II, Kaudulla, 1986 *yala*.

Weekly Average Supply vs Distance

Regression Output:

Constant	14.828
Std Err of Y Est	6.900
R Squared	0.018
No. of Observations	37.000
Degrees of Freedom	35.000
X Coefficient(s)	-0.000
Std Err of Coef.	0.000

Regression Model:

Weekly Average Supply =
(X Coeff.) * Distance + Constant

This is a linear model only

Daily Coeff. Variation vs Distance

Regression Output:

Constant	1.231
Std Err of Y Est	3.462
R Squared	0.001
No. of Observations	37.000
Degrees of Freedom	35.000
X Coefficient(s)	-0.000
Std Err of Coef.	0.000

Regression Model:

Daily Coeff. Variation =
(X Coeff.) * Distance + Constant

This is a linear model only

Weekly Coeff. Variation vs Distance

Regression Output:

Constant	0.418
Std Err of Y Est	0.268
R Squared	0.001
No. of Observations	37.000
Degrees of Freedom	35.000
X Coefficient(s)	-0.000
Std Err of Coef.	0.000

Regression Model:

Weekly Coeff. Variation =
(X Coeff.) * Distance + Constant

This is a linear model only

Weekly Std. Dev. of Supply vs Distance

Regression Output:

Constant	5.929
Std Err of Y Est	3.227
R Squared	0.029
No. of Observations	37.000
Degrees of Freedom	35.000
X Coefficient(s)	-0.000
Std Err of Coef.	0.000

Regression Model:

Weekly Standard Dev. of Supply
(X Coeff.) * Distance + Constant

This is a linear model only

APPENDIX D

WATER DELIVERY MEASUREMENT SITES FOR KAUDULLA SCHEME, 1986 YALA

Site Number	Fluae Numbers	Site Location	Command Area (acre Rice	Other
1	1	Head of field channel FC3,canal D-1 Tract 1,Stage I	11.94	-
2	2	Allotment 310,field channel FC3,canal D-1,Tract 1, Stage I	3.21	-
3	3	Allotment 309,field channel FC3,canal D-1,Tract 1,Stage I	2.66	-
4	4	Head of field channel FC9,canal D-1,Tract 1,Stage I	12.15	1.83
5	5	Head of field channel FC10A,canal D-1,Tract 1,Stage I	7.8	-
6	6	Head of field channel FC37,canal D-1,Tract 1,Stage I	16.38	-
7	7	Head of field channel FC38,canal D-1,Tract 1,Stage I	24.65	-
8	8	Allotment 55,field channel FC38,canal D-1,Tract 1,Stage I	2.7	-
9	9	Allotment 54,field channel FC38,canal D-1,Tract 1,Stage I	3.06	-
10	10	Head of field channel FC36,canal D-1,Tract 1,Stage I	7.75	0.18
11	11	Allotment 28,field channel FC36,canal D-1,Tract 1,Stage I	3.99	0.18
12	16	Head of field channel LB1,canal D-8,Tract 4,Stage I	7.29	-
13	(17+19)	Allotment 149,field channel LB1,canal D-8,Tract 4,Stage I	2.06	-
14	18	Allotment 722,field channel LB1,canal D-8,Tract 4,Stage I	2.82	-
15	20	Head of field channel LB3,canal D-8,Tract 4,Stage I	9.94	-
16	21	Head of field channel LB5,canal D-8,Tract 4,Stage I	9.57	-
17	22	Allotment 711,field channel LB5,canal D-8,Tract 4,Stage I	2.9	-
18	23	Allotment 712,field channel LB5,canal D-8,Tract 4,Stage I	3.64	-
19	25	Head of field channel LB7,canal D-8,Tract 4,Stage I	5.88	-
20	26	Head of field channel FC1,canal D-1,Tract 8,Stage I	27.98	-
21	27	Allotment 1627,field channel FC1,canal D-1,Tract 8,Stage I	2.16	-
22	(29A+29B)	Allotment 1633,field channel FC1,canal D-1,Tract 8,Stage I	2.05	-
23	30	Head of field channel FC10,canal D-1,Tract 8,Stage I	18.38	2.18
24	31	Head of field channel FC11,canal D-1,Tract 8,Stage I	11.93	-
25	35	Head of field channel FC16,canal D-1,Tract 8,Stage I	20.89	-
26	36	Allotment 1638,field channel FC16,canal D-1,Tract 8,Stage I	2.61	-
27	37	Allotment 1639,field channel FC16,canal D-1,Tract 8,Stage I	1.91	-
28	42	Allotment 7,field channel FC1,canal LB Main,Tract 1,Stage II	1.43	-
29	43	Allotment 9,field channel FC1,canal LB Main,Tract 1,Stage II	3.03	-
30	44	Head of field channel FC3,canal LB Main,Tract 1,Stage II	8.54	-
31	45	Allotment 21,field channel FC3,canal LB Main,Tract 1,Stage II	1.92	-
32	46	Allotment 22,field channel FC3,canal LB Main,Tract 1,Stage II	2.15	-
33	47	Head of field channel FC4,canal LB Main,Tract 1,Stage II	2.01	1.09
34	(48A+48B)	Head of field channel FC7,canal LB Main,Tract 1,Stage II	61.18	2.39
35	49	Allotment 103,field channel FC7,canal LB Main,Tract 1,Stage II	4.91	-
36	50	Allotment 105,field channel FC7,canal LB Main,Tract 1,Stage II	2.98	-
37	56	Head of field channel FC2,canal D-1,Tract 4,Stage II	9.23	1.47
38	57	Allotment 11,field channel FC2,canal D-1,Tract 4,Stage II	2.2	0.32
39	58	Allotment 8,field channel FC2,canal D-1,Tract 4,Stage II	1.19	0.28
40	59	Head of field channel FC1,canal D-1,Tract 4,Stage II	9.28	2.15
41	60	Head of field channel FC9,canal D-1,Tract 4,Stage II	11.07	1.07
42	61	Allotment 431,field channel FC9,canal D-1,Tract 4,Stage II	1.65	0.38
43	(62-63)	Allotment 426,field channel FC9,canal D-1,Tract 4,Stage II	1.45	0.55
44	64	Head of field channel FC21,canal D-1,Tract 4,Stage II	9.73	1.37
45	65	Head of field channel FC17,canal D-1,Tract 4,Stage II	7.49	0.65
46	66	Allotment 403,field channel FC17,canal D-1,Tract 4,Stage II	2.02	-
47	67	Allotment 401,field channel FC17,canal D-1,Tract 4,Stage II	1.52	0.28
48	68	Head of field channel FC23,canal D-1,Track 4,Stage II	14.52	0.8
49	71	Head of field channel FC22,canal D-2A,Track 12,Stage II	19.61	3.63
50	72	Allotment 171,field channel FC22,canal D-2A,Track 12,Stage II	2.07	0.18
51	73	Allotment 175,field channel FC22,canal D-2A,Track 12,Stage II	2.39	-
52	74	Head of field channel FC26,canal D-2A,Track 12,Stage II	28.7	-
53	75	Head of field channel FC27,canal D-2A,Track 12,Stage II	11.91	-
54	76	Allotment 232,field channel FC27,canal D-2A,Track 12,Stage II	2.8	-
55	77	Allotment 230,field channel FC27,canal D-2A,Track 12,Stage II	2.45	-
56	78	Head of field channel FC25,canal D-2A,Track 12,Stage II	18.54	-
57	79	Allotment 205,field channel FC25,canal D-2A,Track 12,Stage II	1.19	-
58	80	Allotment 207,field channel FC25,canal D-2A,Track 12,Stage II	2.66	-

APPENDIX E

RAINFALL MEASURED BY IRRIGATION DEPARTMENT AT FIVE STATIONS

Table 1. Rainfall recorded at Ambagaswewa Station, Kaudulla Scheme, 1986 *yala*.

Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)
	108	0.0		156	0.0		204	0.0
	109	0.0		157	0.0		205	0.0
	110	0.0		158	0.0		206	0.0
	111	0.0		159	0.0		207	0.0
	112	0.0		160	0.0		208	0.0
	113	0.0		161	0.0		209	0.0
	114	0.0		162	0.0		210	0.0
	115	0.0		163	0.0		211	0.0
	116	0.0		164	0.0		212	0.0
April 27	117	0.5		165	0.0	August 1	213	15.0
April 28	118	62.0		166	0.0		214	0.0
April 29	119	5.5		167	0.0		215	0.0
April 30	120	27.0		168	0.0		216	0.0
	121	0.0		169	0.0		217	0.0
May 2	122	38.0		170	0.0		218	0.0
	123.	0.0		171	0.0		219	0.0
May 4	124	5.0		172	0.0		220	0.0
May 5	125	10.5		173	0.0		221	0.0
	126	0.0		174	0.0		222	0.0
	127	[illegible]		175	0.0		223	0.0
	128	[illegible]		176	0.0		224	0.0
	129	0.0		177	0.0		225	0.0
	130	0.0		178	0.0		226	0.0
	131	0.0		179	0.0		227	0.0
	132	0.0		180	0.0		228	0.0
	133	0.0		181	0.0		229	0.0
	134	0.0		182	0.0		230	0.0
	135	0.0		183	0.0		231	0.0
	136	0.0		184	0.0		232	0.0
	137	0.0		185	0.0		233	0.0
	138	0.0		186	0.0		234	0.0
	139	0.0		187	0.0		235	0.0
	140	0.0		188	0.0		236	0.0
	141	0.0		189	0.0		237	0.0
	142	0.0		190	0.0		238	0.0
	143	0.0		191	0.0		239	0.0
	144	0.0		192	0.0		240	0.0
	145	0.0		193	0.0		241	0.0
	146	0.0		194	0.0		242	0.0
	147	0.0		195	0.0		243	0.0
	148	0.0		196	0.0			
	149	0.0		197	0.0			
	150	0.0		198	0.0			
	151	0.0		199	0.0			
	152	0.0		200	0.0			
	153	0.0		201	0.0			
	154	0.0		202	0.0			
	155	0.0		203	0.0			

Table 2. Rainfall recorded at Diyasenapura Station, Kaudulla Scheme, 1986 *yala*.

Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)
	108	0.0		156	0.0		204	0.0
April 19	109	25.0		157	0.0		205	0.0
	110	0.0		158	0.0		206	0.0
	111	0.0		159	0.0		207	0.0
	112	0.0		160	0.0		208	0.0
April 23	113	1.0		161	0.0		209	0.0
	114	0.0		162	0.0		210	0.0
April 25	115	1.0		163	0.0		211	0.0
April 26	116	2.0		164	0.0	July 31	212	7.0
April 27	117	1.0		165	0.0	August 1	213	11.5
April 28	118	5.0		166	0.0		214	0.0
April 29	119	11.0		167	0.0		215	0.0
April 30	120	1.0		168	0.0		216	0.0
	121	0.0		169	0.0		217	0.0
May 2	122	11.1		170	0.0		218	0.0
	123	0.0		171	0.0		219	0.0
May 4	124	2.0		172	0.0		220	0.0
May 5	125	5.0		173	0.0	August 9	221	1.0
	126	0.0		174	0.0		222	0.0
	127	0.0		175	0.0		223	0.0
	128	0.0		176	0.0		224	0.0
	129	0.0		177	0.0		225	0.0
	130	0.0		178	0.0		226	0.0
	131	0.0		179	0.0		227	0.0
	132	0.0		180	0.0		228	0.0
	133	0.0		181	0.0		229	0.0
	134	0.0		182	0.0		230	0.0
	135	0.0		183	0.0		231	0.0
	136	0.0		184	0.0		232	0.0
	137	0.0		185	0.0		233	0.0
	138	0.0		186	0.0		234	0.0
	139	0.0		187	0.0		235	0.0
	140	0.0		188	0.0		236	0.0
	141	0.0		189	0.0		237	0.0
	142	0.0		190	0.0		238	0.0
	143	0.0		191	0.0		239	0.0
	144	0.0	July 11	192	2.0		240	0.0
	145	0.0		193	0.0		241	0.0
	146	0.0		194	0.0		242	0.0
	147	0.0		195	0.0		243	0.0
	148	0.0		196	0.0			
	149	0.0		197	0.0			
	150	0.0		198	0.0			
	151	0.0		199	0.0			
June 1	152	42.0		200	0.0			
June 2	153	15.1		201	0.0			
	154	0.0		202	0.0			
	155	0.0		203	0.0			

Table 3. Rainfall recorded at Fourth Mile Camp Station, Kaudulla Scheme, 1986 *yala*.

Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)
	108	0.0		156	0.0		204	0.0
April 19	109	32.0		157	0.0		205	0.0
	110	0.0		158	0.0		206	0.0
	111	0.0		159	0.0		207	0.0
	112	0.0		160	0.0		208	0.0
	113	0.0		161	0.0		209	0.0
	114	0.0		162	0.0		210	0.0
April 25	115	66.4		163	0.0		211	0.0
	116	0.0		164	0.0	July 31	212	5.2
	117	0.0		165	0.0		213	0.0
April 28	118	78.0		166	0.0		214	0.0
	119	0.0		167	0.0		215	0.0
April 30	120	12.0		168	0.0		216	0.0
	121	0.0		169	0.0		217	0.0
May 2	122	18.2		170	0.0		218	0.0
	123	0.0		171	0.0		219	0.0
May 4	124	2.1		172	0.0		220	0.0
May 5	125	1.3		173	0.0		221	0.0
	126	0.0		174	0.0		222	0.0
	127	0.0		175	0.0		223	0.0
	128	0.0		176	0.0		224	0.0
	129	0.0		177	0.0		225	0.0
	130	0.0		178	0.0		226	0.0
	131	0.0		179	0.0		227	0.0
	132	0.0		180	0.0		228	0.0
	133	0.0		181	0.0		229	0.0
	134	0.0		182	0.0		230	0.0
	135	0.0		183	0.0		231	0.0
	136	0.0		184	0.0		232	0.0
	137	0.0		185	0.0		233	0.0
	138	0.0		186	0.0		234	0.0
	139	0.0		187	0.0	August 23	235	9.5
	140	0.0		188	0.0		236	0.0
	141	0.0		189	0.0		237	0.0
	142	0.0		190	0.0		238	0.0
	143	0.0	July 10	191	38.1		239	0.0
	144	0.0		192	0.0		240	0.0
	145	0.0		193	0.0		241	0.0
	146	0.0		194	0.0		242	0.0
	147	0.0		195	0.0		243	0.0
	148	0.0		196	0.0			
	149	0.0		197	0.0			
	150	0.0		198	0.0			
	151	0.0		199	0.0			
June 1	152	58.6		200	0.0			
	153	0.0		201	0.0			
	154	0.0		202	0.0			
	155	0.0		203	0.0			

Table 4. Rainfall recorded at Headworks Station, Kaudulla Scheme, 1986 *yala*.

Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)
April 18	108	0.6		156	0.0		204	0.0
April 19	109	15.0		157	0.0		205	0.0
	110	0.0		158	0.0		206	0.0
	111	0.0		159	0.0		207	0.0
	112	0.0		160	0.0		208	0.0
	113	0.0		161	0.0		209	0.0
	114	0.0		162	0.0		210	0.0
April 25	115	11.5		163	0.0		211	0.0
April 26	116	5.5		164	0.0	July 31	212	8.2
	117	0.0		165	0.0	August 1	213	3.1
April 28	118	11.0		166	0.0		214	0.0
April 29	119	7.6		167	0.0		215	0.0
April 30	120	0.3		168	0.0		216	0.0
	121	0.0		169	0.0		217	0.0
May 2	122	27.2		170	0.0		218	0.0
	123	0.0		171	0.0		219	0.0
May 4	124	17.2		172	0.0		220	0.0
May 5	125	1.6		173	0.0	August 9	221	0.0
	126	0.0		174	0.0		222	0.0
	127	0.0		175	0.0		223	0.0
	128	0.0		176	0.0		224	0.0
	129	0.0		177	0.0		225	0.0
	130	0.0		178	0.0		226	0.0
	131	0.0		179	0.0		227	0.0
	132	0.0		180	0.0		228	0.0
	133	0.0		181	0.0		229	0.0
	134	0.0		182	0.0		230	0.0
	135	0.0		183	0.0		231	0.0
	136	0.0		184	0.0		232	0.0
	137	0.0		185	0.0		233	0.0
	138	0.0		186	0.0		234	0.0
	139	0.0		187	0.0		235	0.0
	140	0.0		188	0.0	August 24	236	12.5
	141	0.0		189	0.0	August 25	237	6.3
	142	0.0		190	0.0		238	0.0
	143	0.0	July 10	191	79.0		239	0.0
	144	0.0		192	0.0		240	0.0
	145	0.0		193	0.0		241	0.0
	146	0.0		194	0.0		242	0.0
	147	0.0		195	0.0		243	0.0
	148	0.0		196	0.0			
	149	0.0		197	0.0			
May 30	150	35.6		198	0.0			
	151	0.0		199	0.0			
June 1	152	54.2		200	0.0			
June 2	153	10.1		201	0.0			
	154	0.0		202	0.0			
	155	0.0		203	0.0			

Table 5. Rainfall recorded at Low Level Sluice Station, Kaudulla Scheme, 1986 *yala*.

Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)	Date	Julian Day	Rainfall (mm)
	108	0.0		156	0.0		204	0.0
	109	0.0		157	0.0		205	0.0
	110	0.0		158	0.0		206	0.0
	111	0.0		159	0.0		207	0.0
	112	0.0		160	0.0		208	0.0
	113	0.0		161	0.0		209	0.0
	114	0.0		162	0.0		210	0.0
	115	0.0		163	0.0		211	0.0
	116	0.0		164	0.0		212	0.0
	117	0.0		165	0.0	August 1	213	1.5
	118	0.0		166	0.0		214	0.0
	119	0.0		167	0.0		215	0.0
	120	0.0		168	0.0		216	0.0
	121	0.0		169	0.0		217	0.0
May 2	122	12.1		170	0.0		218	0.0
	123	1.0		171	0.0		219	0.0
May 4	124	7.5		172	0.0		220	0.0
May 5	125	1.6		173	0.0	August 9	221	3.0
	126	0.0		174	0.0		222	0.0
	127	0.0		175	0.0		223	0.0
	128	0.0		176	0.0		224	0.0
	129	0.0		177	0.0		225	0.0
	130	0.0		178	0.0		226	0.0
	131	0.0		179	0.0		227	0.0
	132	0.0		180	0.0		228	0.0
	133	0.0		181	0.0		229	0.0
	134	0.0		182	0.0		230	0.0
	135	0.0		183	0.0		231	0.0
	136	0.0		184	0.0		232	0.0
	137	0.0		185	0.0		233	0.0
	138	0.0		186	0.0		234	0.0
	139	0.0		187	0.0	August 23	235	2.5
	140	0.0		188	0.0		236	0.0
	141	0.0		189	0.0		237	0.0
	142	0.0		190	0.0		238	0.0
	143	0.0	July 10	191	9.5		239	0.0
	144	0.0		192	0.0		240	0.0
	145	0.0		193	0.0		241	0.0
	146	0.0		194	0.0		242	0.0
	147	0.0		195	0.0		243	0.0
	148	0.0		196	0.0			
	149	0.0		197	0.0			
May 30	150	10.5		198	0.0			
	151	0.0		199	0.0			
June 1	152	36.0		200	0.0			
June 2	153	14.2		201	0.0			
	154	0.0		202	0.0			
	155	0.0		203	0.0			

APPENDIX F

SOIL PROFILE DESCRIPTIONS, SOIL LEGEND, AND ENGINEERING AND SOIL SURVEY MAPS OF SELECTED FIELDS IN KAUDULLA SCHEME, 1986 YALA

Soil Profile Description of Reddish-Brown Earth, Well-Drained Soil

Study Site: Kaudulla, Stage II, tract 5, field channel 2, I.M.D. Pit 1; 6/11/86; S.V. Siriwardena. Site was a gently undulating, well-drained home garden with 2-3 percent slope.

Soil Profile:

Ap 0-10 cm. Dark brown (7.5YR 4/4); moist, light sandy clay loam; weak, subangular, blocky; very slightly plastic wet, friable moist; few fine quartz gravel, few manganese stains; common fine and few medium tubular inped pores; common fine and few medium roots; clear, smooth change.

B1 10-40 cm. Strong brown (7.5YR 5/6); moist, sandy clay loam; weak, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; few fine quartz gravel, few manganese stains; common fine, few medium tubular inped pores; common fine and few medium roots; few fine mica and feldspar; very thin patchy clay skins; clear, smooth change.

B2t1 40-55 cm. Reddish-brown (5YR 4/4); moist, gravely sandy clay loam; structureless massive; slightly sticky and non-plastic wet, friable moist; common fine and few medium quartz gravel (30-40 percent); occasional quartz pebbles; few manganese concretions; few fine tubular inped pores; common fine and few medium roots; common fine mica and feldspar; thin patchy clay skins; gradual, smooth change.

B2t2 55-100 cm. Reddish-brown (2.5YR 4/4); moist, gravely sandy clay loam; structureless massive; slightly sticky and non-plastic wet, friable moist; common fine and few medium quartz gravel (about 30-40 percent); occasional quartz pebbles; few manganese concretions; few fine tubular inped pores; common fine and few medium roots; common fine mica and feldspar; thin patchy clay skins; clear, smooth change.

B3 100-120 cm. Red (2.5YR 4/8); moist, sandy clay loam; weak, medium, subangular, blocky; slightly sticky and plastic wet, few fine quartz gravel; few manganese concretions; few fine tubular inped pores; common fine and few medium roots; common fine feldspar and mica; clear, smooth change.

C 120-130 cm. Decomposing parent material mixed with many fine mica and feldspar.

130+ cm. Bedrock.

Soil Profile Description of Reddish-Brown Earth, Imperfectly Drained Soil

Study Site: Giritale, Purana Ela, Pit 3; 21/10/85; S.V. Siriwardena. Site was nearly level with 0-0.5 percent slope, tobacco.

Soil Profile:

Ap 0-30 cm. Dark greyish-brown (10YR 4/2); moist, sandy clay loam; weak, medium, subangular, blocky; slightly sticky and slightly plastic; wet, friable, moist faint mottles; common fine and few medium roots; common fine and a few medium tubular inped pores; few manganese concretions, few quartz gravel; faunal activity; clear, smooth boundary.

B1 30-75 cm. Dark brown (10YR 4/3); moist, sandy clay loam; moderate, medium, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common, medium distinct, yellowish-red (5YR 4/6) mottles; common fine and few medium roots; few fine tubular inped pores; many manganese concretions; few fine quartz gravel; occasional quartz pebbles; common fine feldspar; faunal activity; clear, smooth change.

B2 75-120 cm. Greyish-brown (10YR 5/2); moist, sandy clay loam; moderate, medium, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common, medium distinct, strong brown (7.5YR 5/6) mottles; common fine and occasional medium roots; common manganese concretions (10-20 percent); fine and medium quartz gravel; occasional quartz pebbles; common iron stone gravel; common fine feldspar; faunal activity; clear, smooth change.

B3 120-175 cm. Dark grey (5YR 4/1); moist clay; structureless massive; very sticky and plastic wet, firm moist; common, medium distinct, yellowish-brown (10YR 5/6) mottles; common manganese concretions, fine quartz gravel; thin patchy cutans; gleyed horizon; few carbonate concretions.

Soil Profile Description of
Low Humic Gley, Poorly Drained Soil

Study Site: Giritale, Purana Ela, Pit 2; 21/10/85; S.V. Siriwardena. Site was nearly level, 0-0.5 percent slope, paddy.

Soil Profile:

Ap 0-20 cm. Very dark greyish-brown (2.5Y 3/2); moist sandy clay loam; weak, medium, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common fine and few medium tubular inped pores; faint mottles; few fine quartz gravel; faunal activity; clear, smooth change.

B1 20-24 cm. Dark greyish-brown (2.5Y 4/2); moist, sandy clay; moderate, subangular, blocky; slightly sticky and slightly plastic wet, friable moist; common fine roots; common fine and few medium tubular inped pores; common, fine, distinct, strong brown (7.5YR 5/6) mottles; few fine quartz gravel; few manganese concretions; faunal activity; clear, smooth change.

B21t 40-70 cm. Olive grey (5Y 4/2); moist, sandy clay; medium, subangular, blocky; sticky and plastic wet, friable moist; few fine roots; common fine tubular inped pores; common, medium distinct, yellowish (10YR 5/8); few fine quartz; common manganese concretions and nodules; faunal activity; gradual, smooth change.

B22t 70-100 cm. Dark grey (5Y 4/1); moist, sandy clay; moderate, medium, subangular blocky; sticky and plastic wet, friable moist; few fine roots; few fine tubular inped pores; common fine distinct yellowish-brown (10YR 5/6) mottles; few manganese concretions; fine quartz gravel; few carbonate concretions; faunal activity; thin patchy cutans; gradual, smooth change.

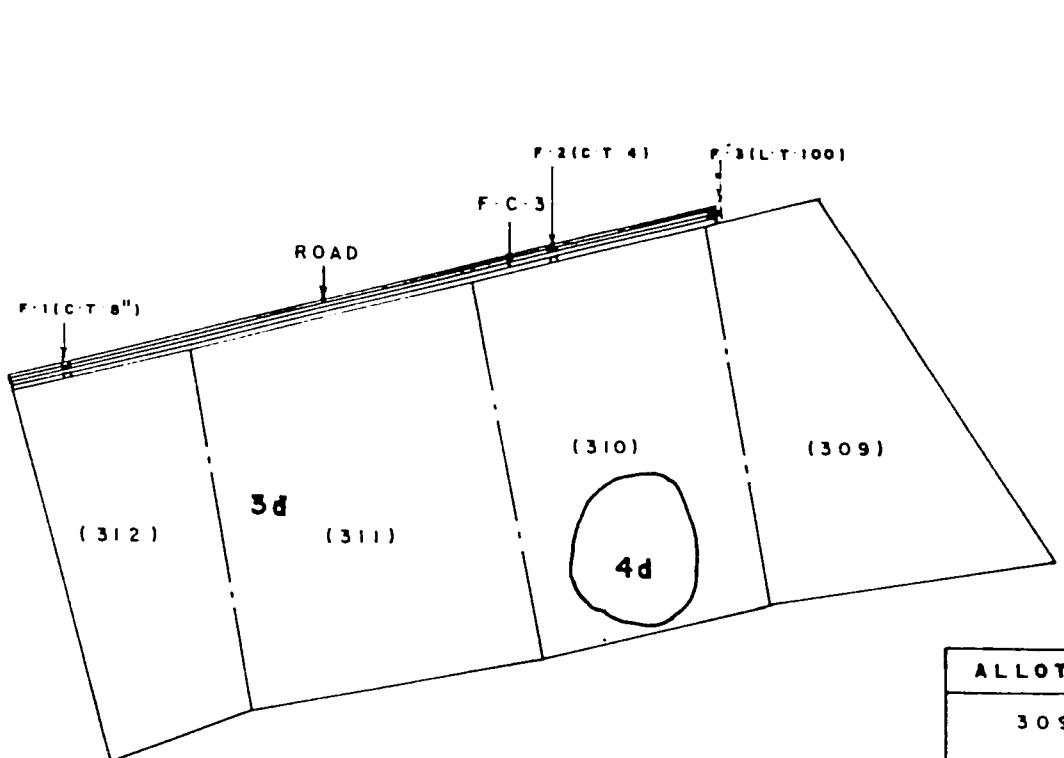
B3 100-150 cm. Grey (5Y 5/1); moist clay; structureless massive; very sticky and very plastic wet, firm moist; few, fine, distinct, strong brown (7.5Y 5/6) mottles; common carbonate concretions; slicken sides; gleyed horizon.

Legend for Engineering and Soil Survey Maps

Physiographic Unit Major	Subunit	Soil Description
Undulating plain	Crest and convex upper slope	1. Reddish-brown earth; well-drained soil. Shallow to deep, brown to dark brown sandy loam to sandy clay loam surface soil with red to dark reddish-brown sandy clay loam to sandy clay subsoil containing quartz (dominant) and feldsphatic gravel and fine mica underlain by reddish or yellowish decomposing material.
	Convex upper slope	2. Reddish-brown earth; moderately well-drained soil. Description same as above.
	Mid-slope to concave lower slope	3. Reddish-brown earth; imperfectly drained soil. Moderately shallow to deep, brown to dark brown sandy loam to sandy clay loam surface soil with yellowish-red to dark yellowish-brown sandy clay loam to sandy clay; mottled subsoil occasionally with quartz and feldsphatic gravel.
Valley bottom of undulating plain	Concave lower slope and depression	4. Low humic gley; poorly drained soil. Deep, brown to gray sandy loam to sandy clay loam surface soil with grayish or bluish sandy clay loam to clay; gleyed subsoil containing carbonate concretion occasionally.
	Depression	5. Low humic gley; very poorly drained soil. Deep, grayish or bluish sandy clay loam to clay; gleyed soil.
Alluvial plain	Depression and flat	6. Alluvial, poorly drained soil. Deep, dark grayish-brown to gray sandy clay loam to clay; gleyed soil.

Mapping Units	
< 60 cm	s (shallow)
60 - 90 cm	ms (moderately shallow)
90 - 120 cm	md (moderately deep)
> 120 cm	d (deep)
	g (gravel layer)

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



N

LEGEND

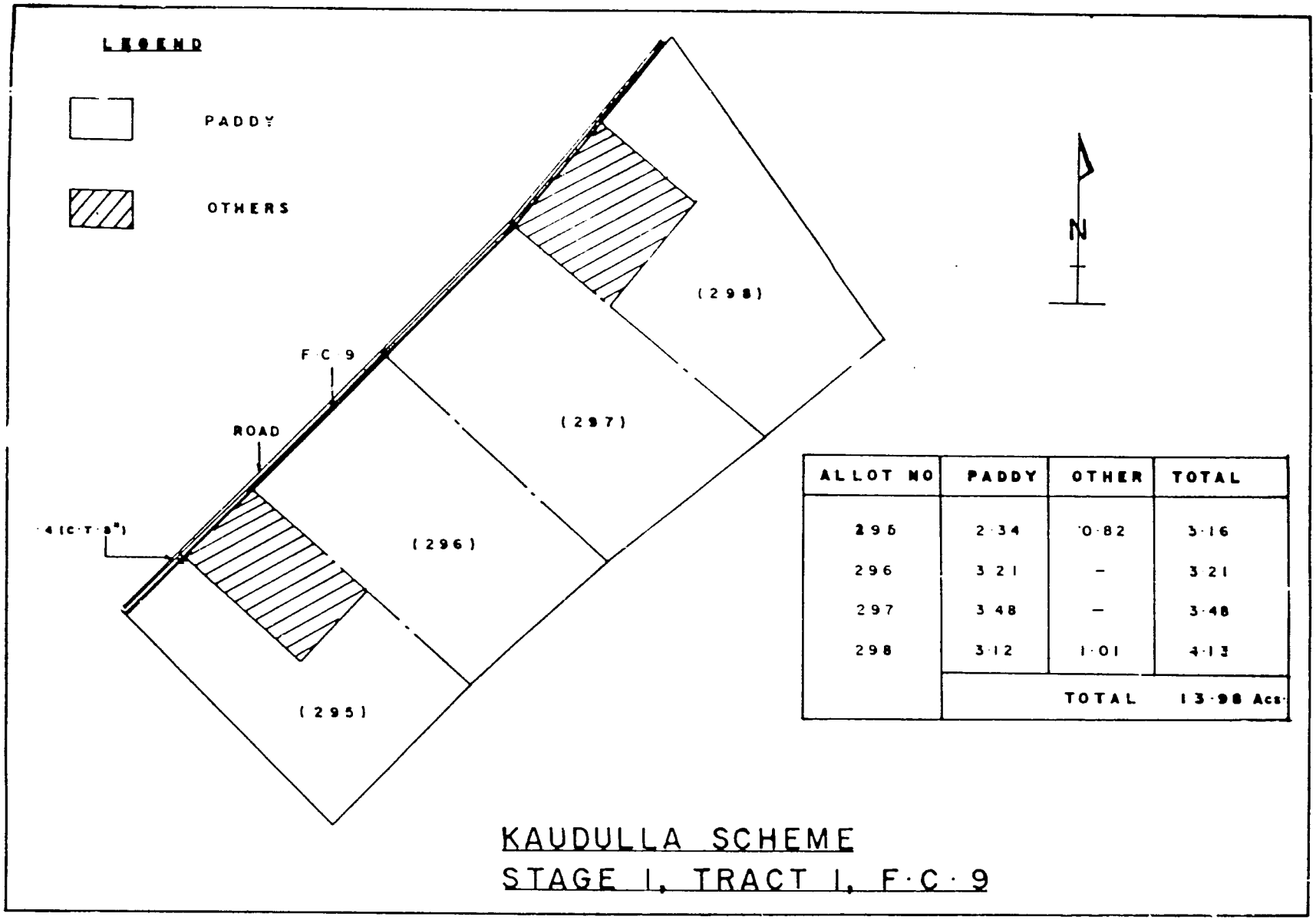
PADDY

ALLOT NO	PADDY	TOTAL
309	2·66	2·66
310	3·21	3·21
311	3·92	3·92
312	2·15	2·15
		11·94 Acs.

KAUDULLA SCHEME

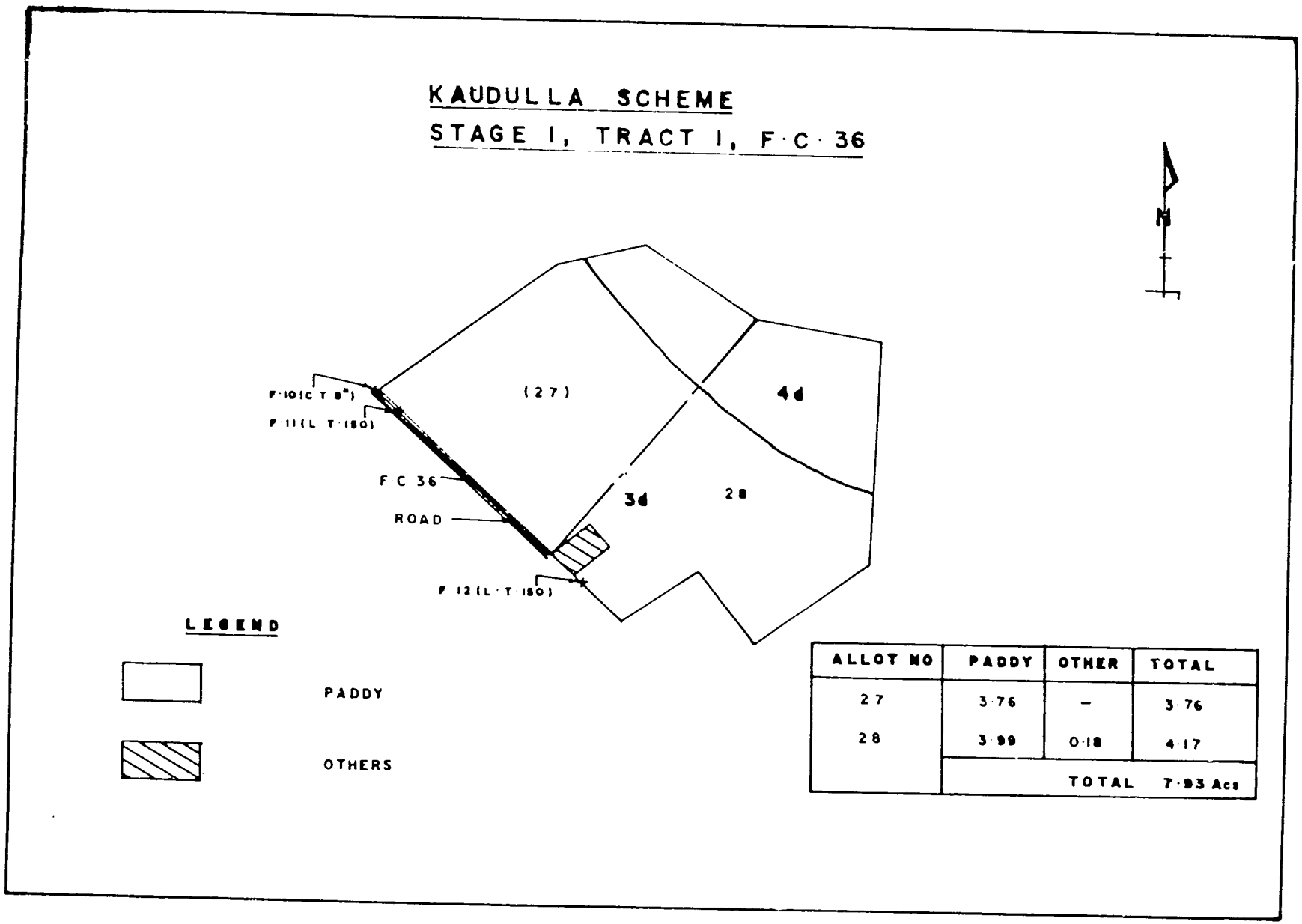
STAGE I, TRACT I, F·C·3

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



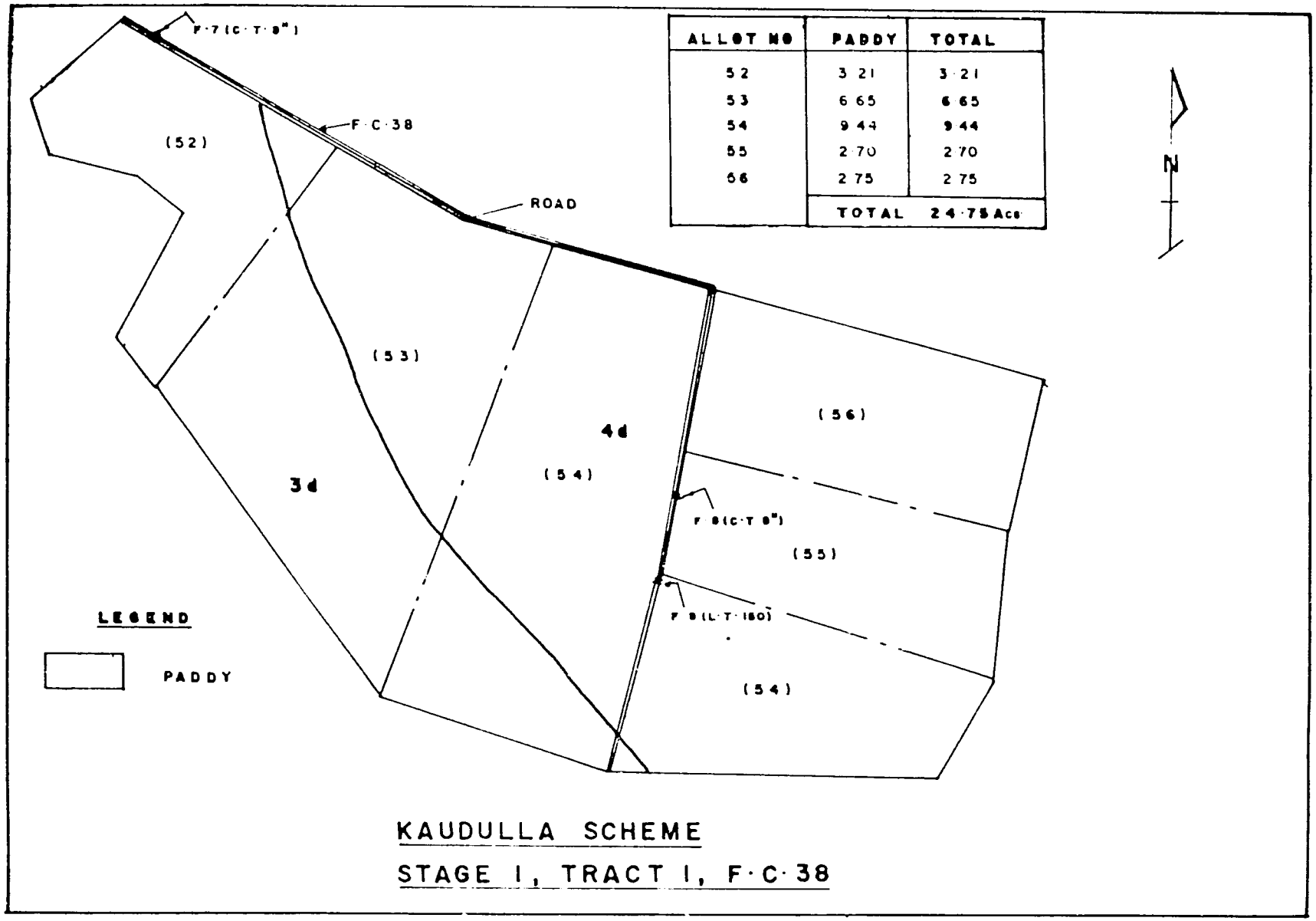
ALLOT NO	PADDY	OTHER	TOTAL
295	2·34	0·82	3·16
296	3·21	–	3·21
297	3·48	–	3·48
298	3·12	1·01	4·13
		TOTAL	13·98 Acs.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



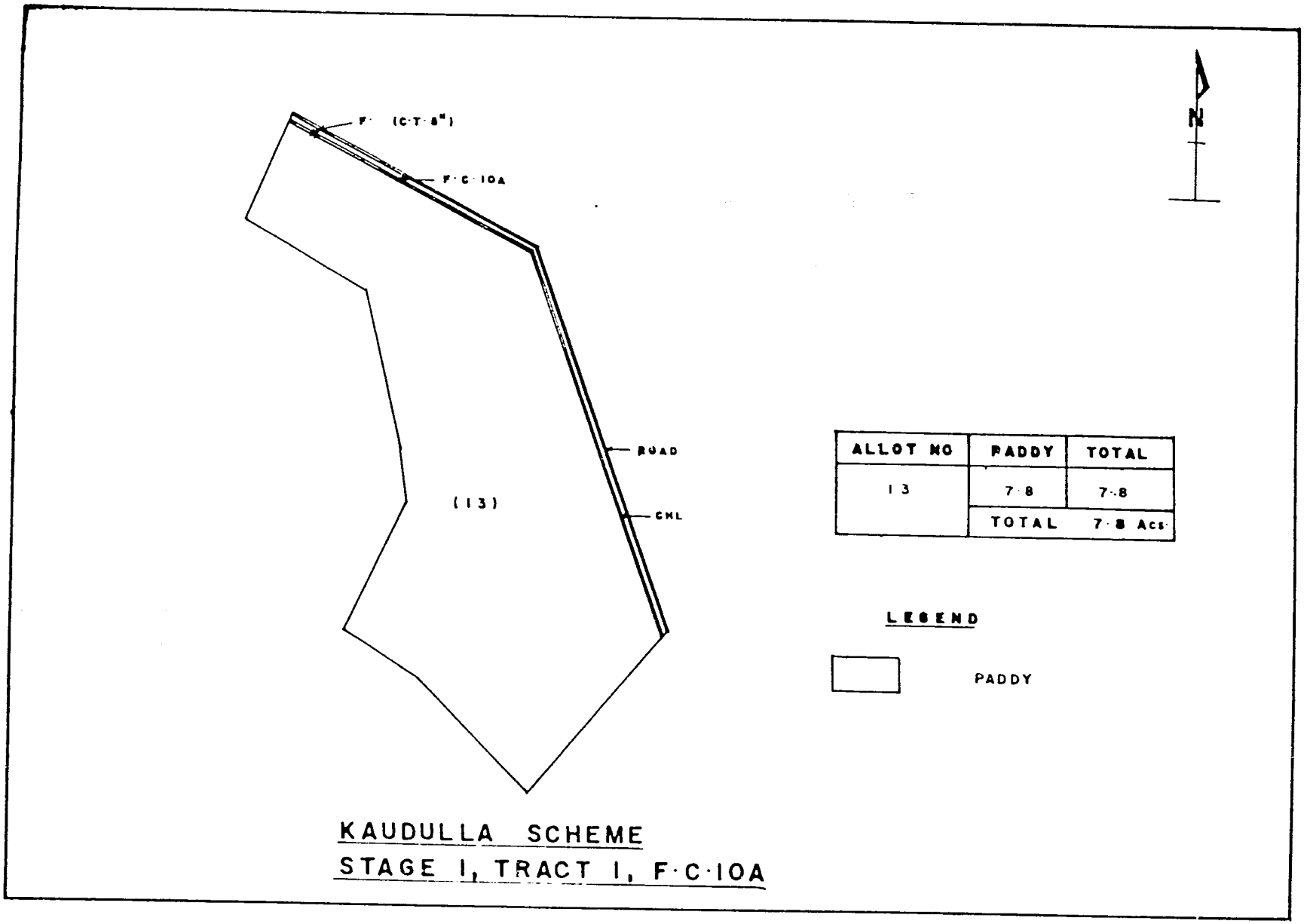
ALLOT NO	PADDY	OTHER	TOTAL
27	3·76	–	3·76
28	3·99	0·18	4·17
		TOTAL	7·93 Acs

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.

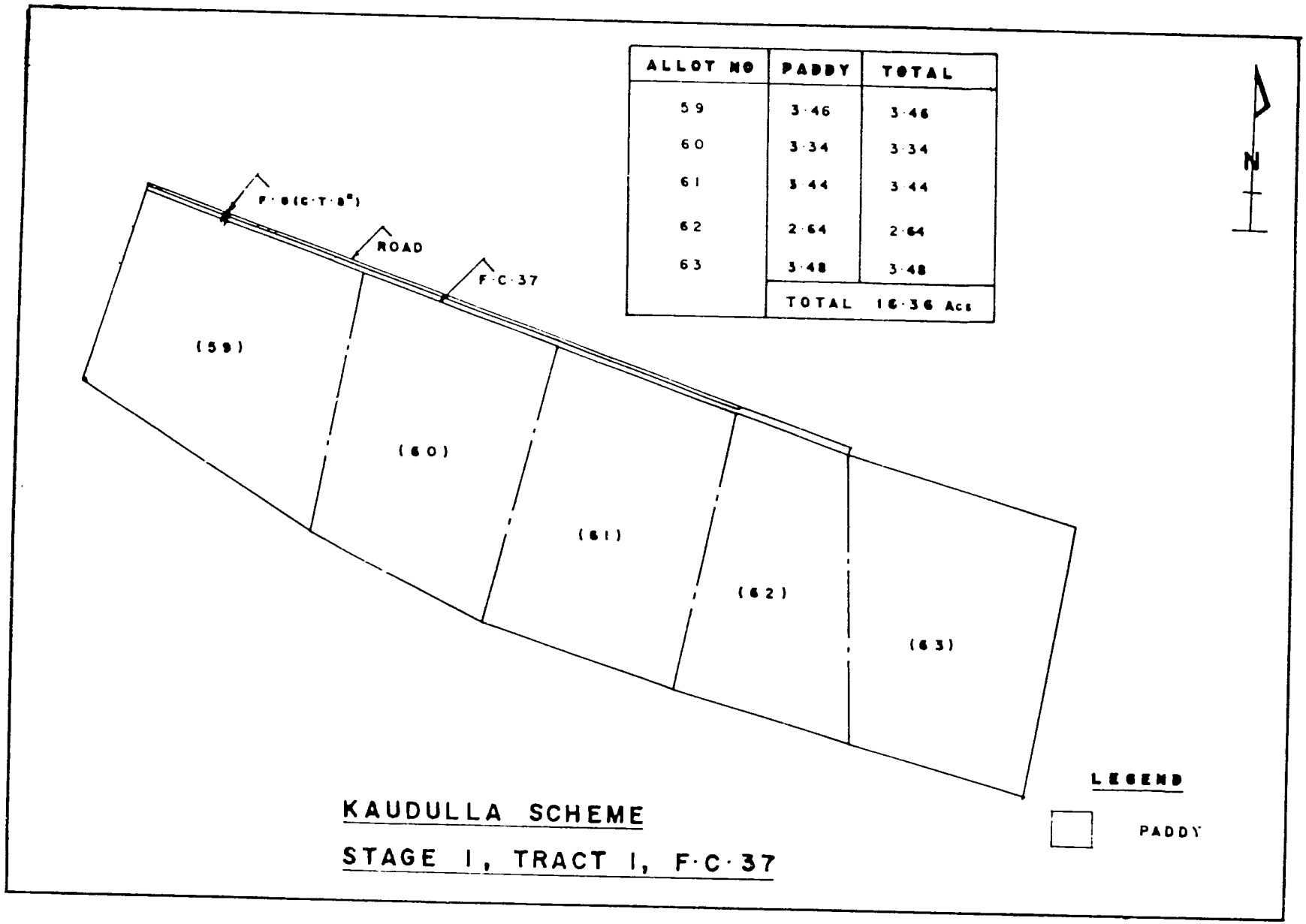


ALLOT NO	PADDY	TOTAL
52	3·21	3·21
53	6·65	6·65
54	9·44	9·44
55	2·70	2·70
56	2·75	2·75
	TOTAL	24·75 Acs

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 vala.

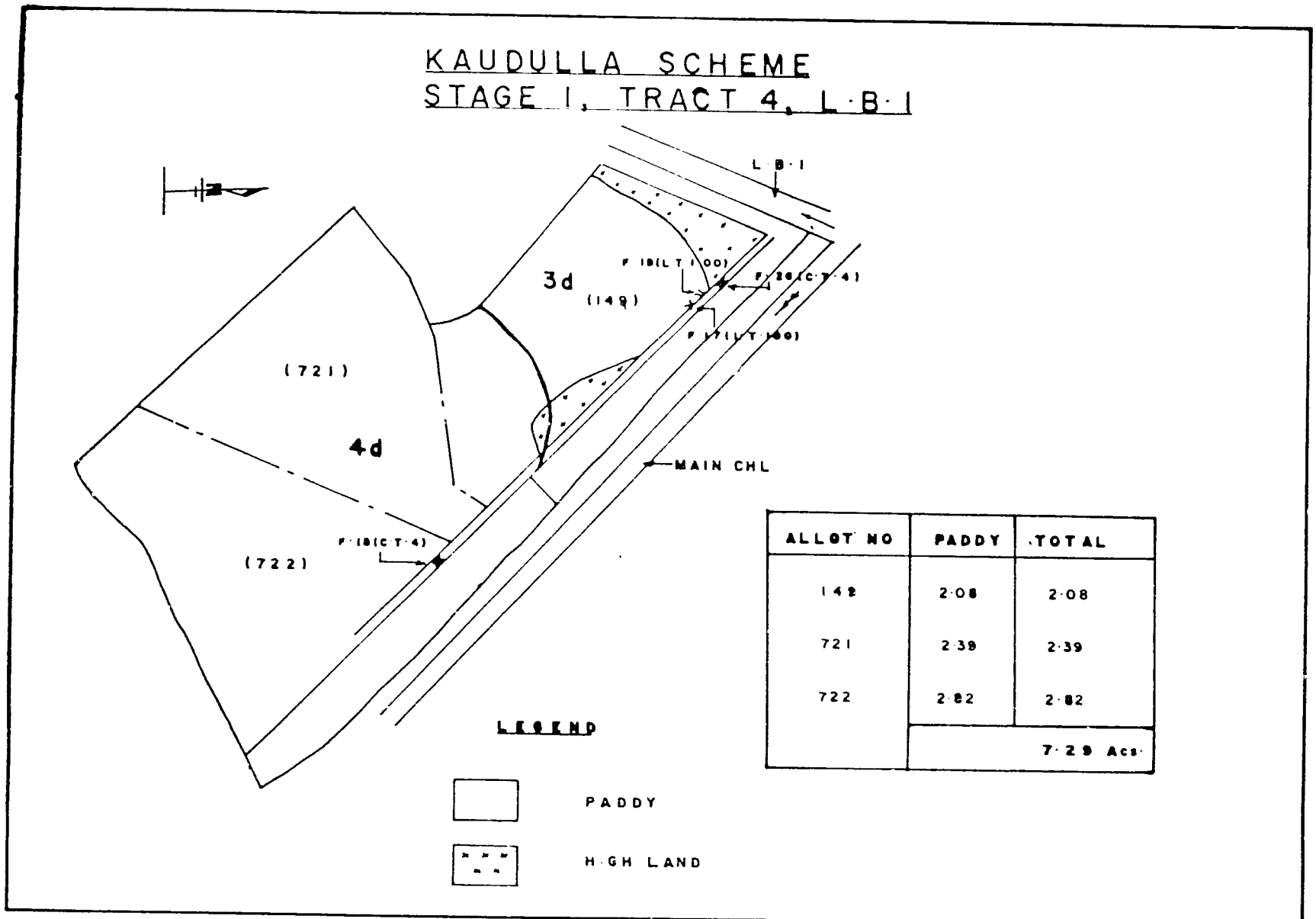


Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



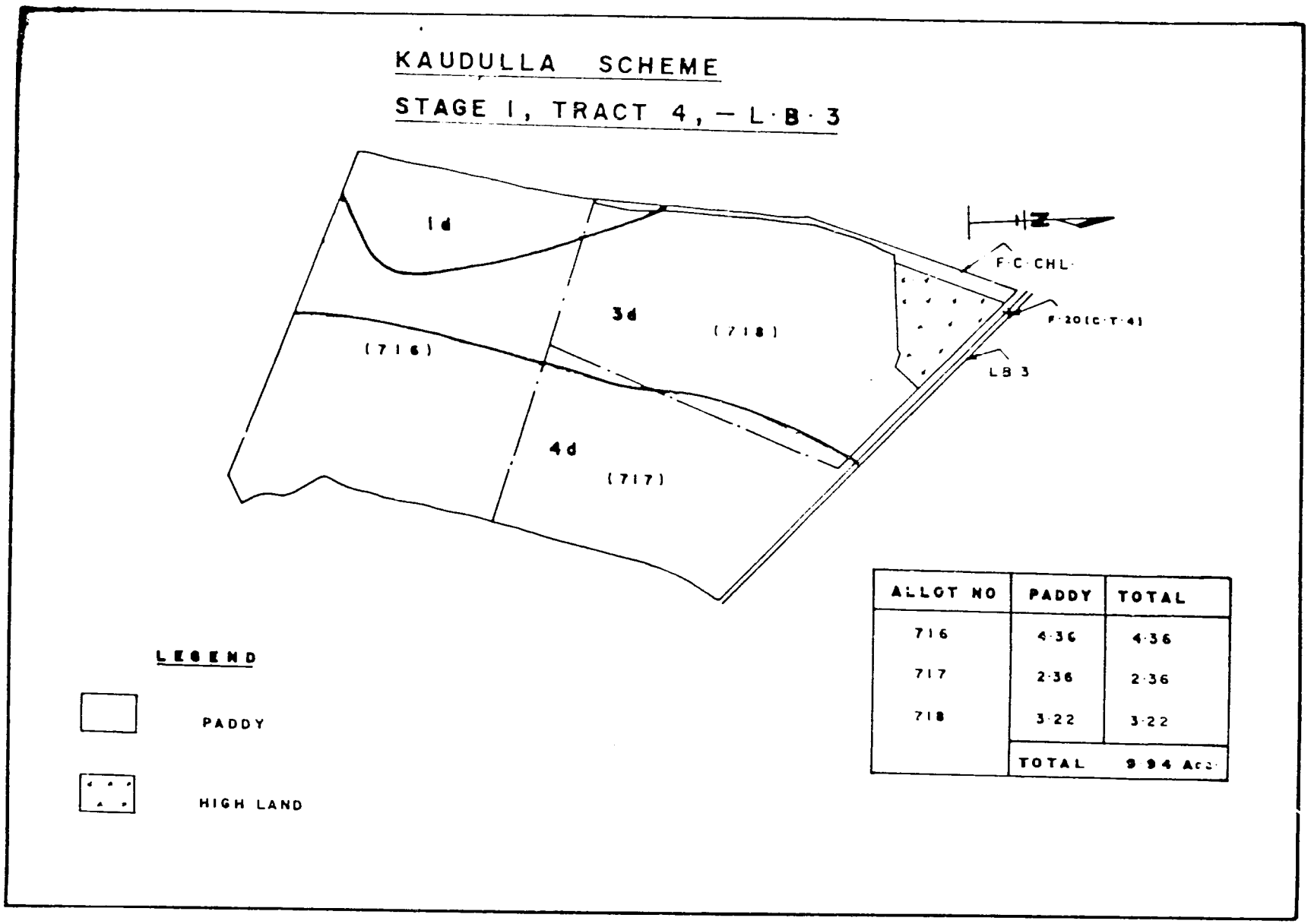
ALLOT NO	PADDY	TOTAL
59	3·46	3·46
60	3·34	3·34
61	3·44	3·44
62	2·64	2·64
63	3·48	3·48
	TOTAL	16·36 Acs

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 vala.



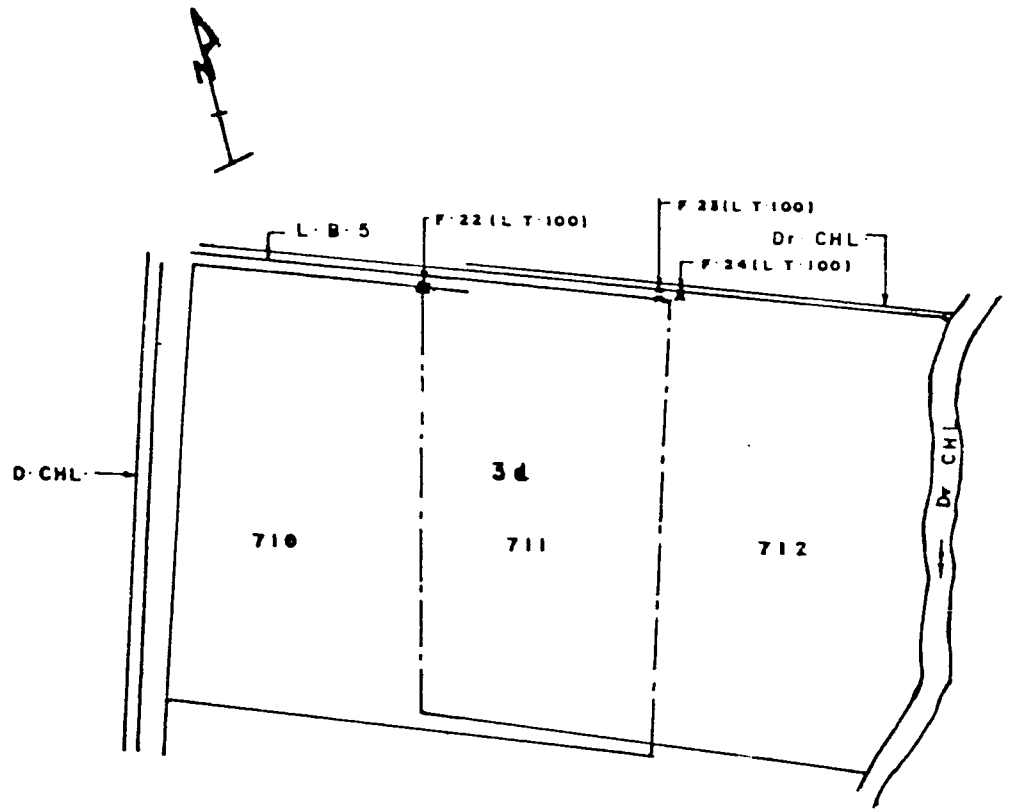
ALLOT NO	PADDY	TOTAL
149	2·08	2·08
721	2·39	2·39
722	2·82	2·82
		7·29 Acs.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	TOTAL
716	4·36	4·36
717	2·36	2·36
718	3·22	3·22
	TOTAL	9·94 Acs.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO.	PADDY	TOTAL
710	3·03	3·03
711	2·90	2·90
712	3·64	3·64
	TOTAL	9·57 Acs

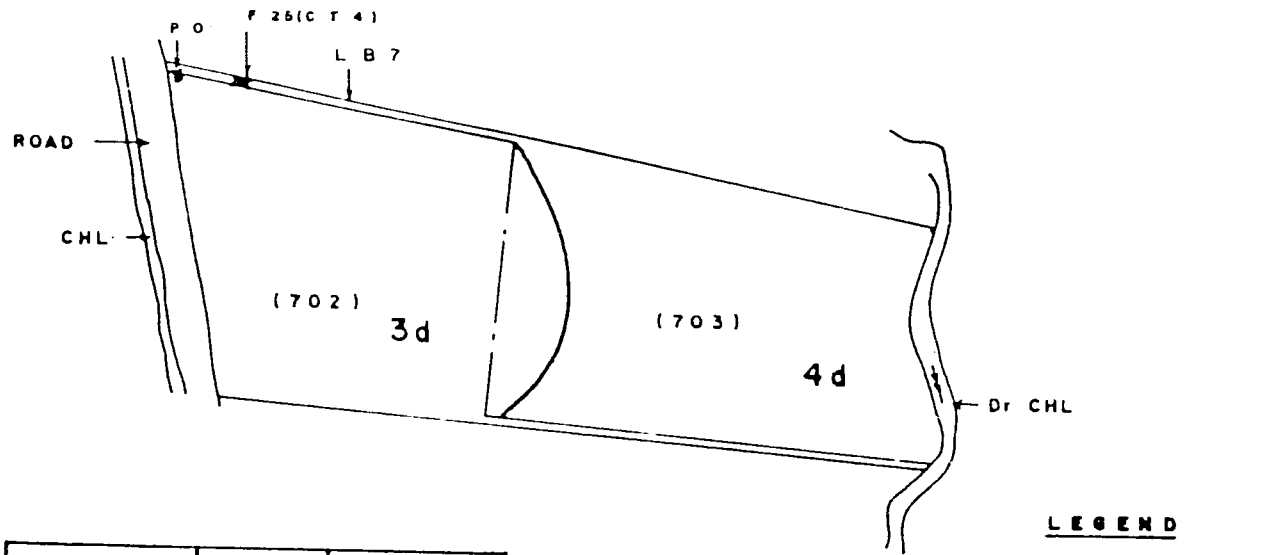
LEGEND

PADDY

KAUDULLA SCHEME

STAGE I, TRACT 4, L·B·5

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	TOTAL
702	2·73	2 73
703	3 15	3 15
	TOTAL	5·18 Acs·

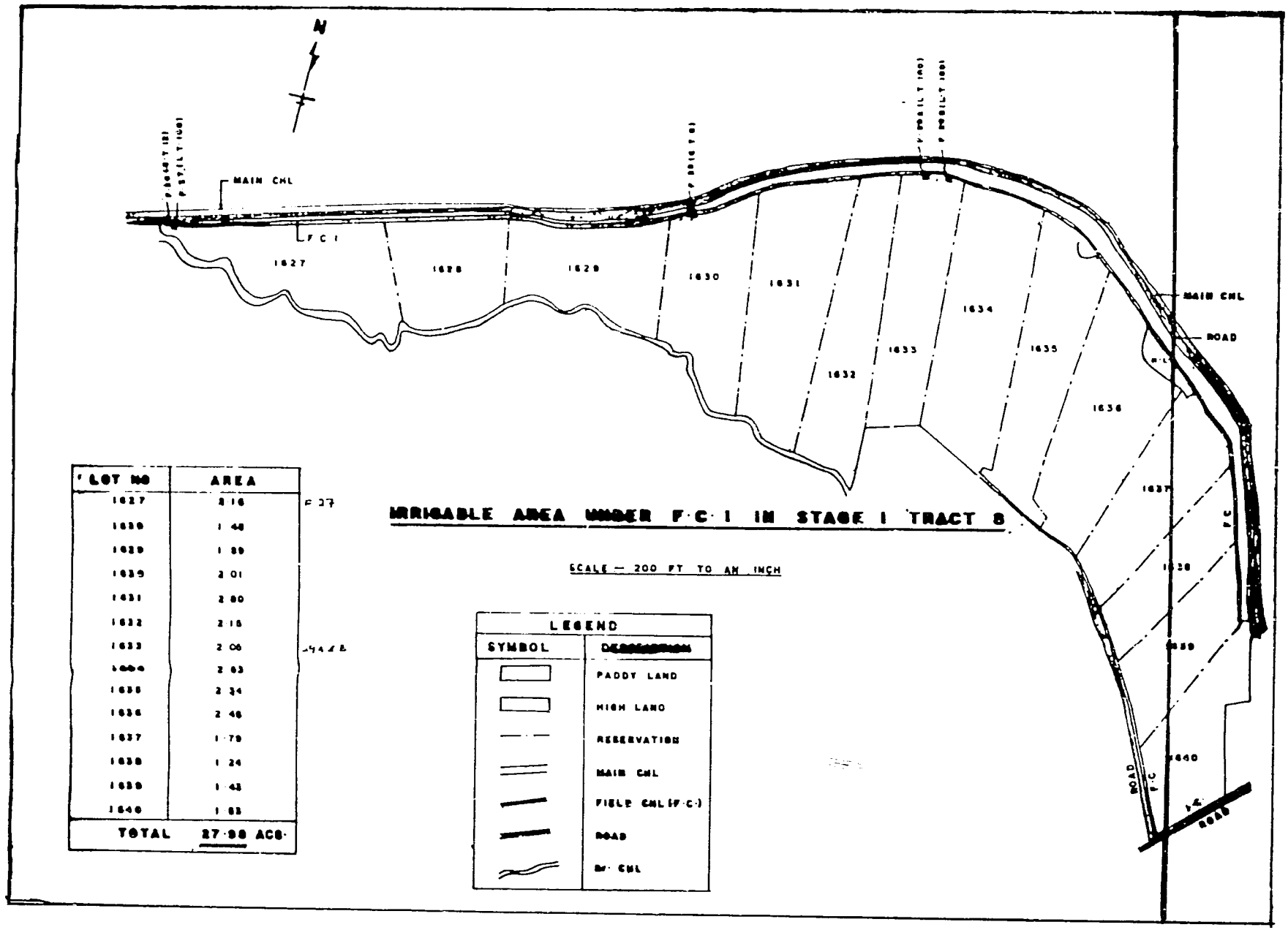
LEGEND

PADDY

KAUDULLA SCHEME

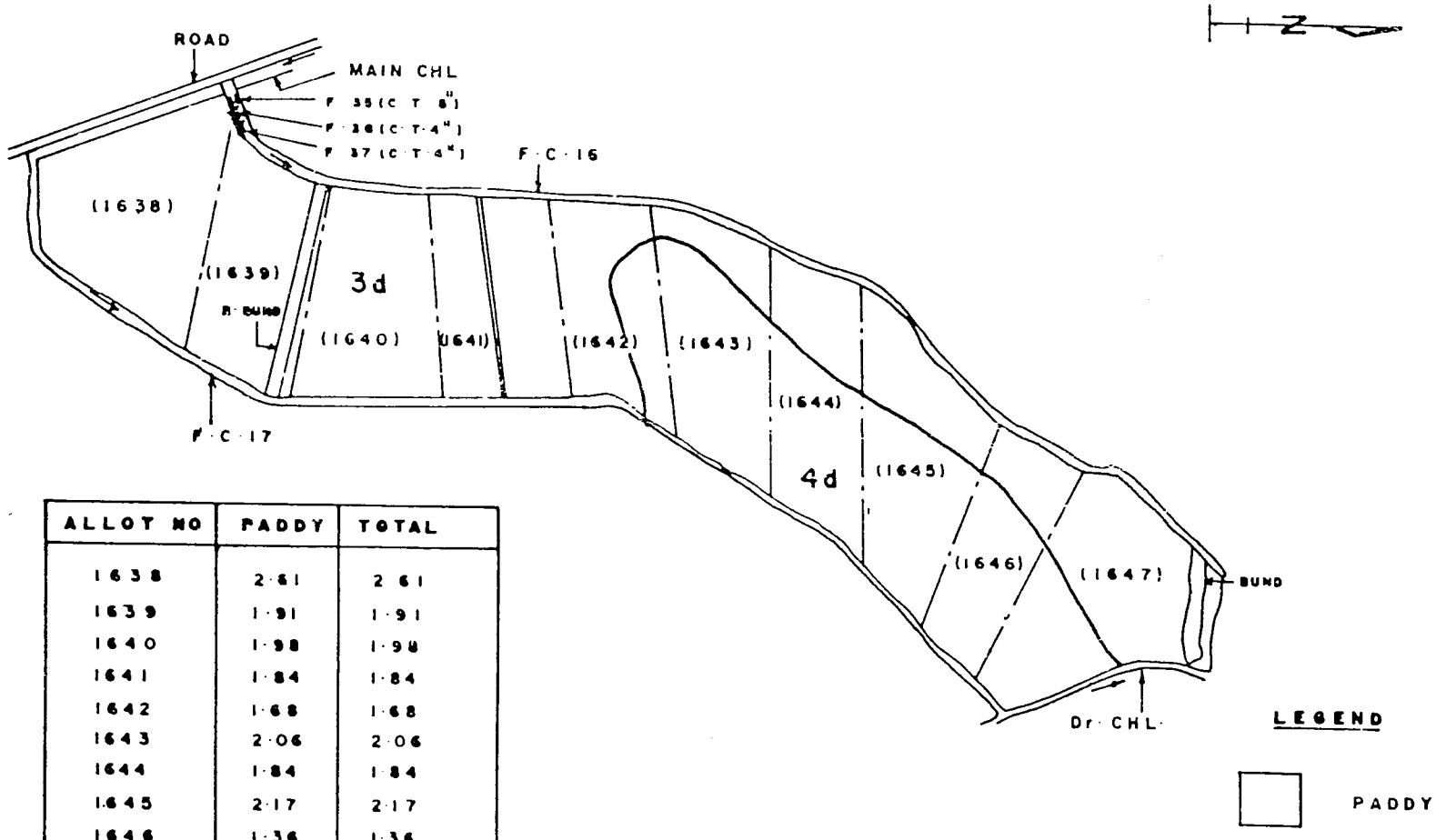
STAGE I, TRACT 4, L·B·7

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



LOT NO	AREA
1627	2·16
1628	1·48
1629	1·89
1630	2·01
1631	2·80
1632	2·15
1633	2·06
1634	2·63
1635	2·34
1636	2·46
1637	1·79
1638	1·24
1639	1·43
1640	1·83
TOTAL	27·98 ACS·

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



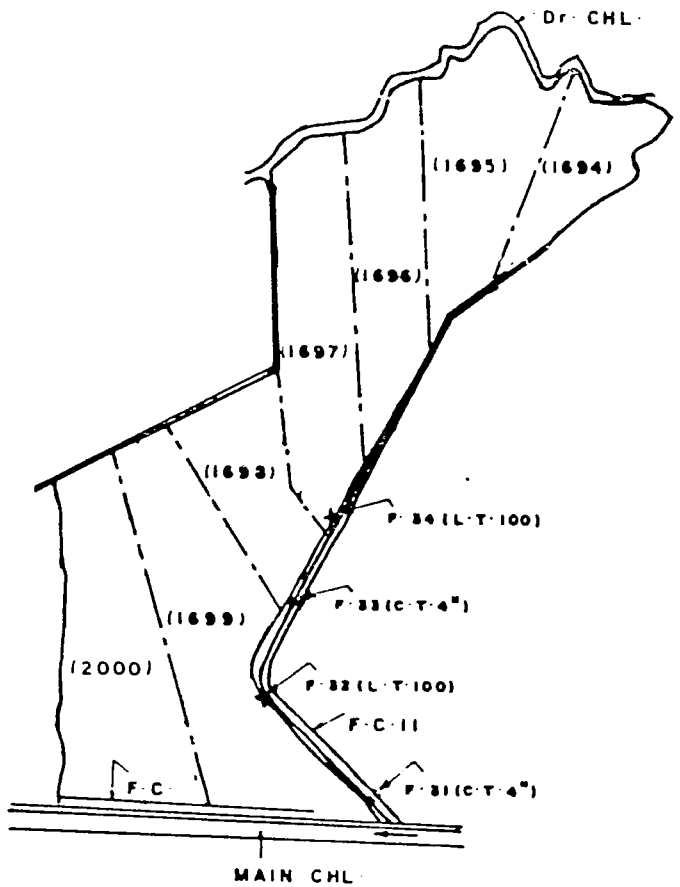
ALLOT NO	PADDY	TOTAL
1638	2·61	2·61
1639	1·91	1·91
1640	1·98	1·98
1641	1·84	1·84
1642	1·68	1·68
1643	2·06	2·06
1644	1·84	1·84
1645	2·17	2·17
1646	1·36	1·36
1647	3·44	3·44
	TOTAL	20·89 Acs

KAUDULLA SCHEME

STAGE I, TRACT 8, F·C·16

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 *yala*.

KAUDULLA SCHEME
STAGE I, TRACT 8, F·C·11

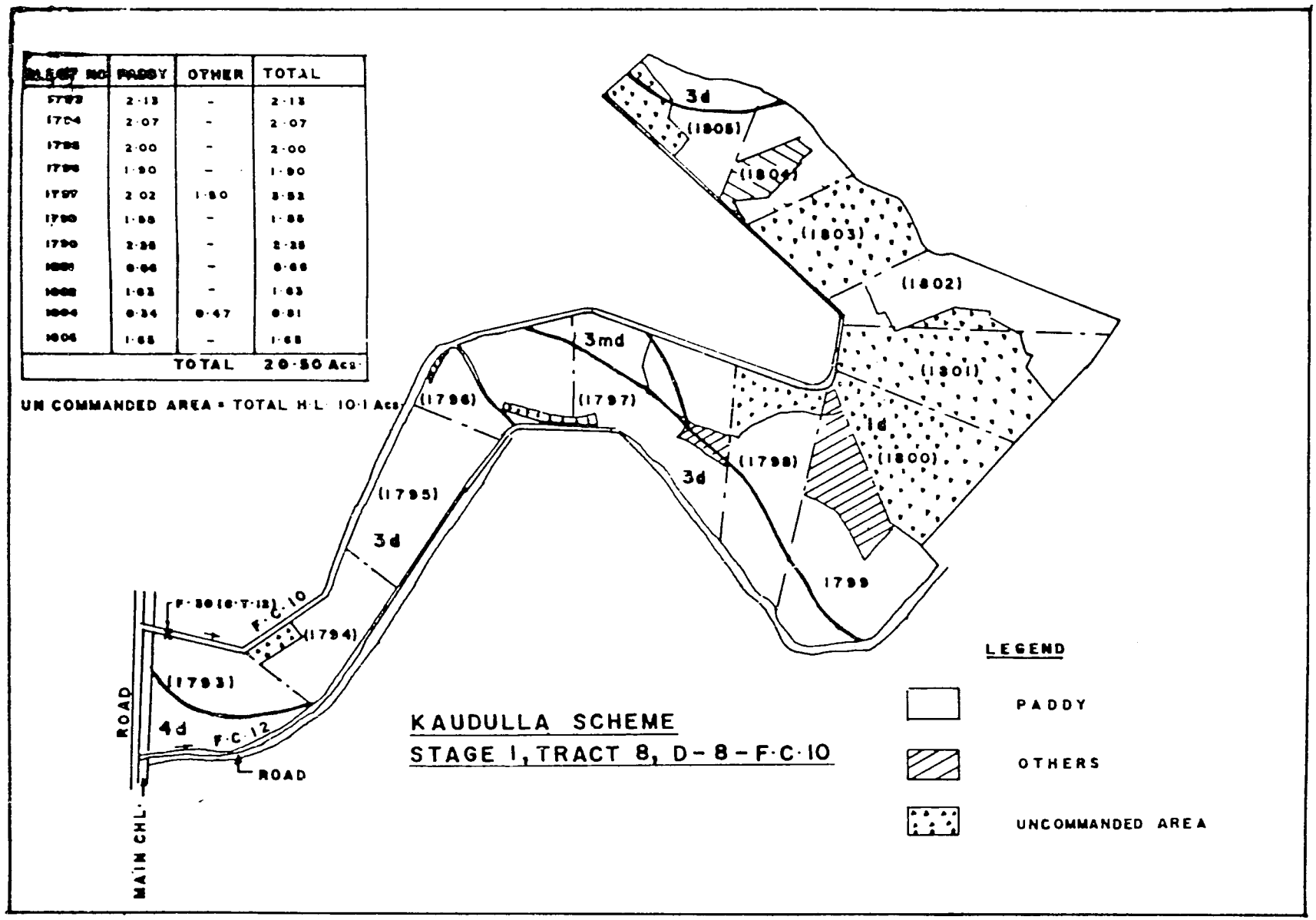


ALLOT NO	PADDY	TOTAL
1694	0·92	0·92
1695	1·94	1·94
1696	1·43	1·43
1697	1·92	1·92
1698	1·16	1·16
1699	2·41	2·41
2000	2·15	2·15
	TOTAL	11·93 Acs·

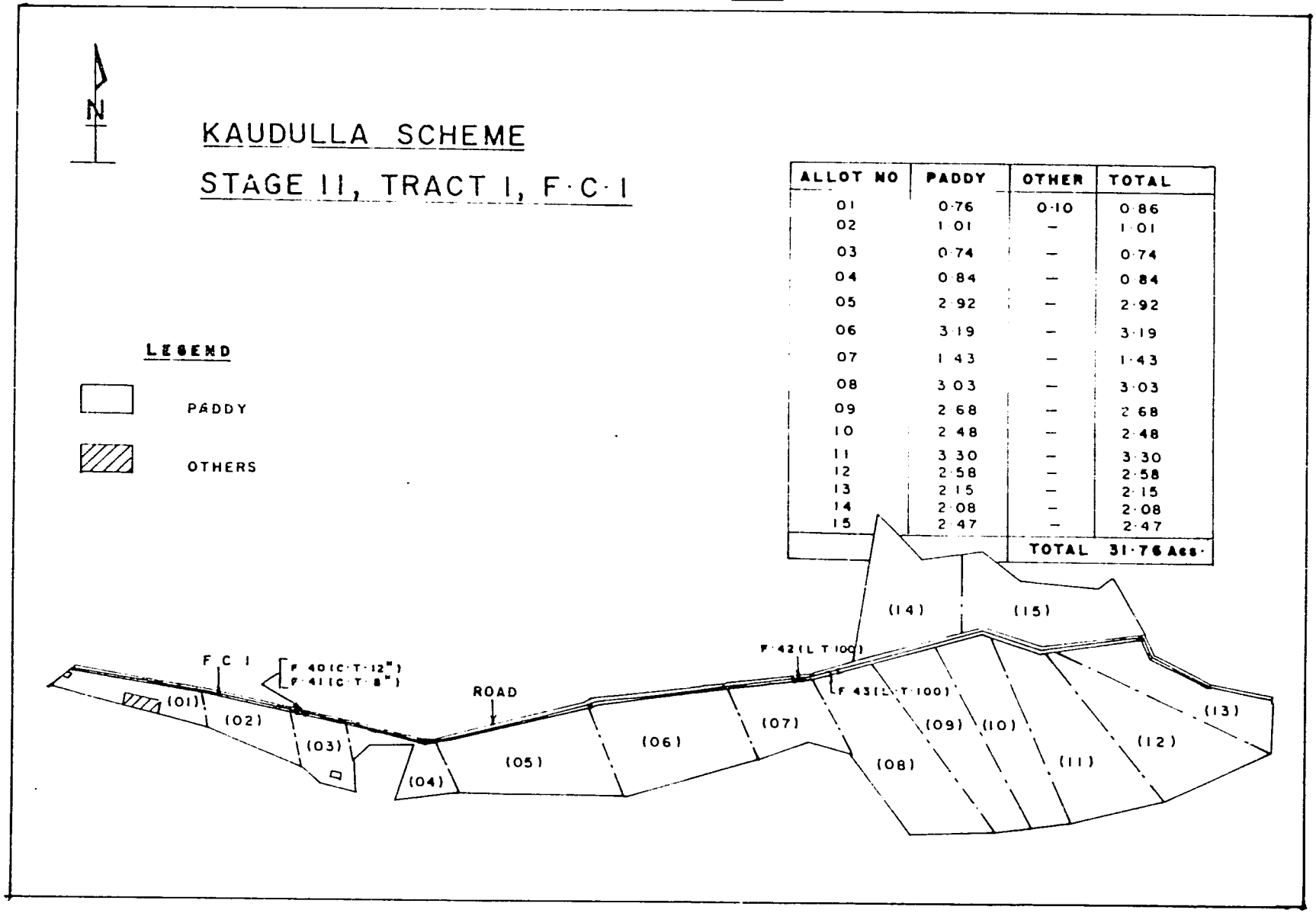
LEGEND

PADDY

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.

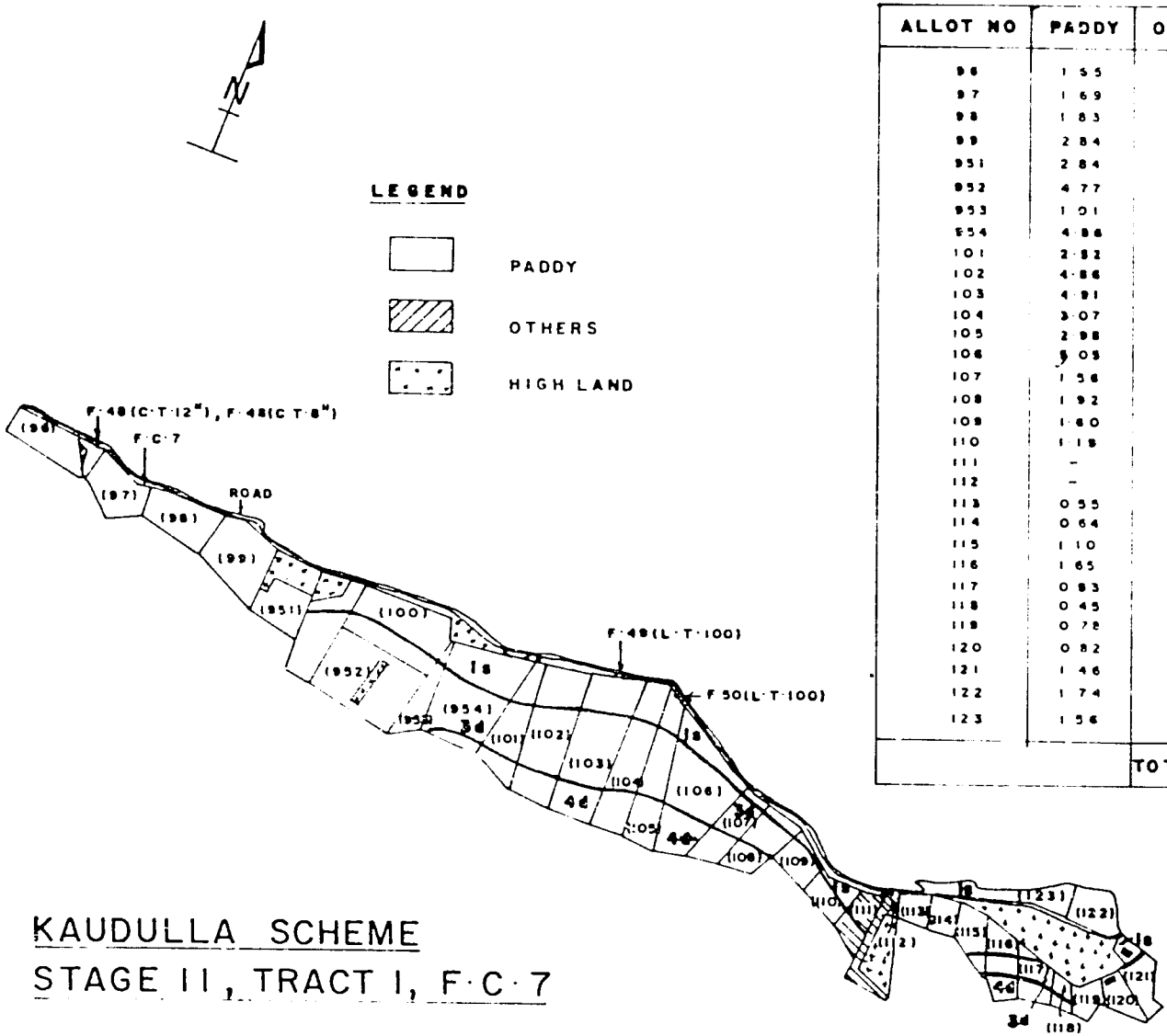


Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



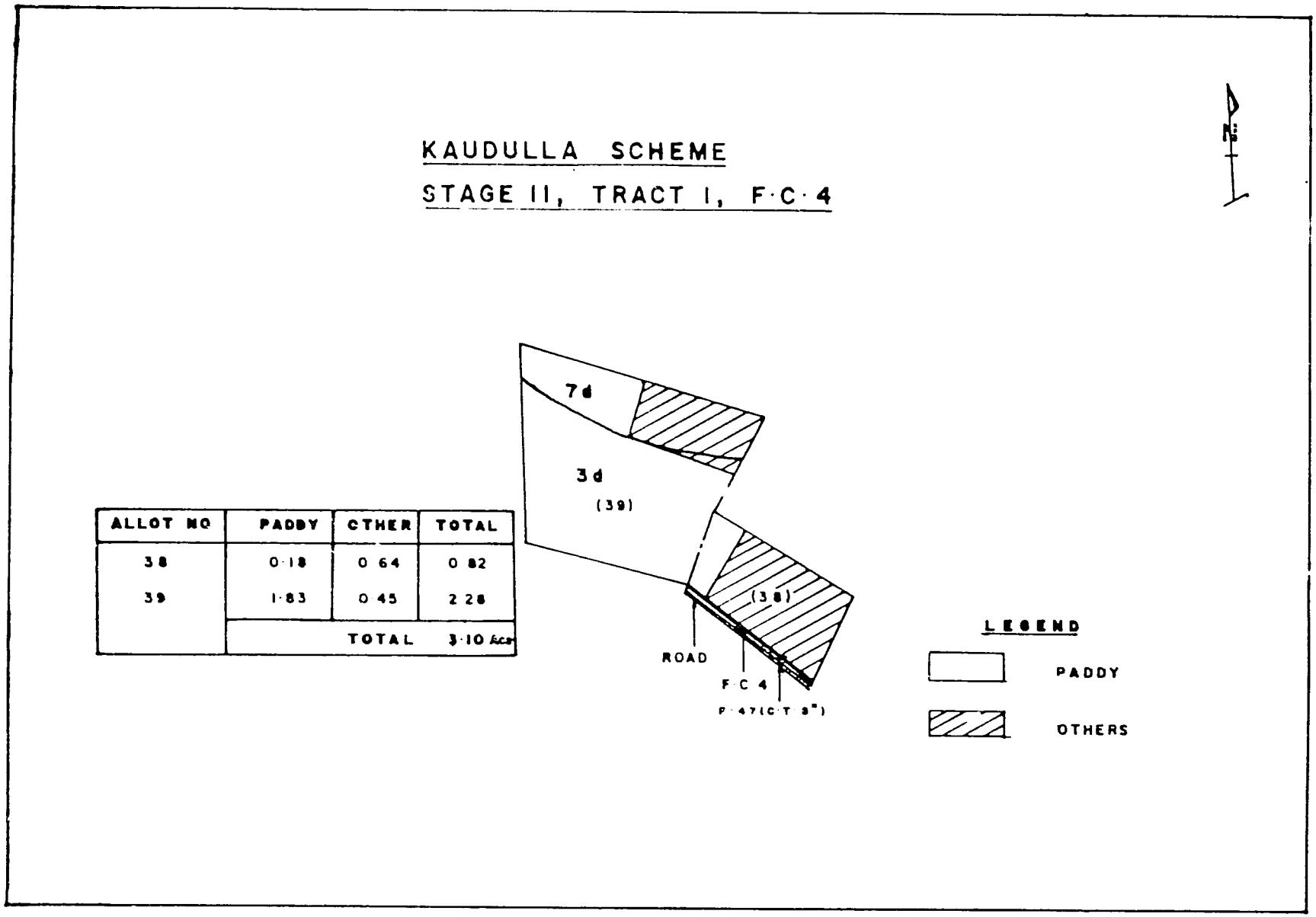
ALLOT NO	PADDY	OTHER	TOTAL
01	0·76	0·10	0·86
02	1·01	–	1·01
03	0·74	–	0·74
04	0·84	–	0·84
05	2·92	–	2·92
06	3·19	–	3·19
07	1·43	–	1·43
08	3·03	–	3·03
09	2·68	–	2·68
10	2·48	–	2·48
11	3·30	–	3·30
12	2·58	–	2·58
13	2·15	–	2·15
14	2·08	–	2·08
15	2·47	–	2·47
		TOTAL	31·76 Acs.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



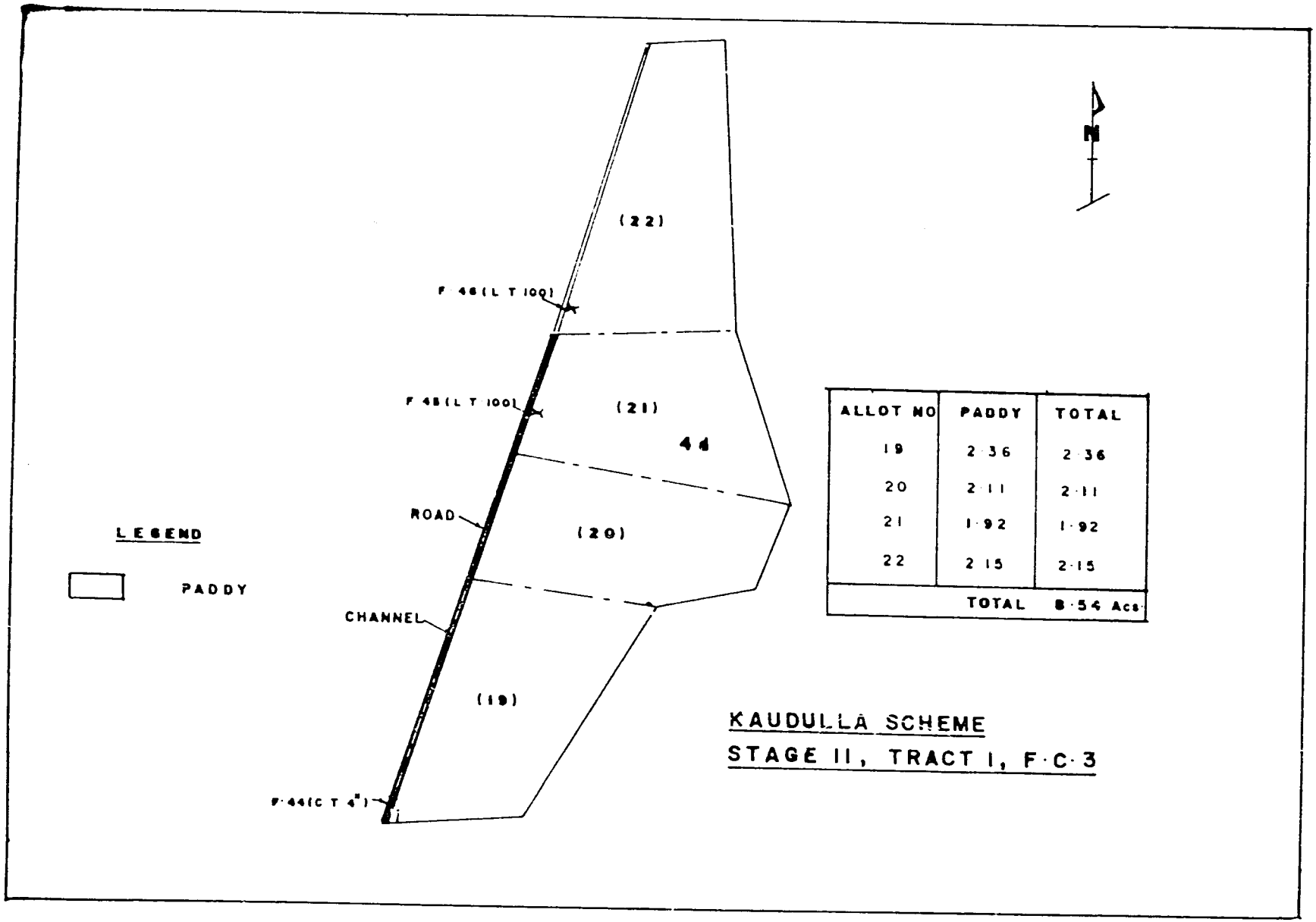
ALLOT NO	PADDY	OTHERS	TOTAL
96	1·55	0·1	1·75
97	1·69	–	1·69
98	1·83	–	1·83
99	2·84	–	2·84
951	2·84	–	2·84
952	4·77	–	4·77
953	1·01	–	1·01
954	4·86	–	4·86
101	2·52	–	2·52
102	4·86	–	4·86
103	4·91	–	4·91
104	3·07	–	3·07
105	2·98	–	2·98
106	3·05	–	3·05
107	1·56	–	1·56
108	1·92	–	1·92
109	1·60	–	1·60
110	1·19	–	1·19
111	–	1·33	1·33
112	–	1·05	1·05
113	0·55	–	0·55
114	0·64	–	0·64
115	1·10	–	1·10
116	1·65	–	1·65
117	0·93	–	0·93
118	0·45	–	0·45
119	0·78	–	0·78
120	0·82	–	0·82
121	1·46	–	1·46
122	1·74	–	1·74
123	1·56	–	1·56
		TOTAL	65·31 Acs.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 vala.



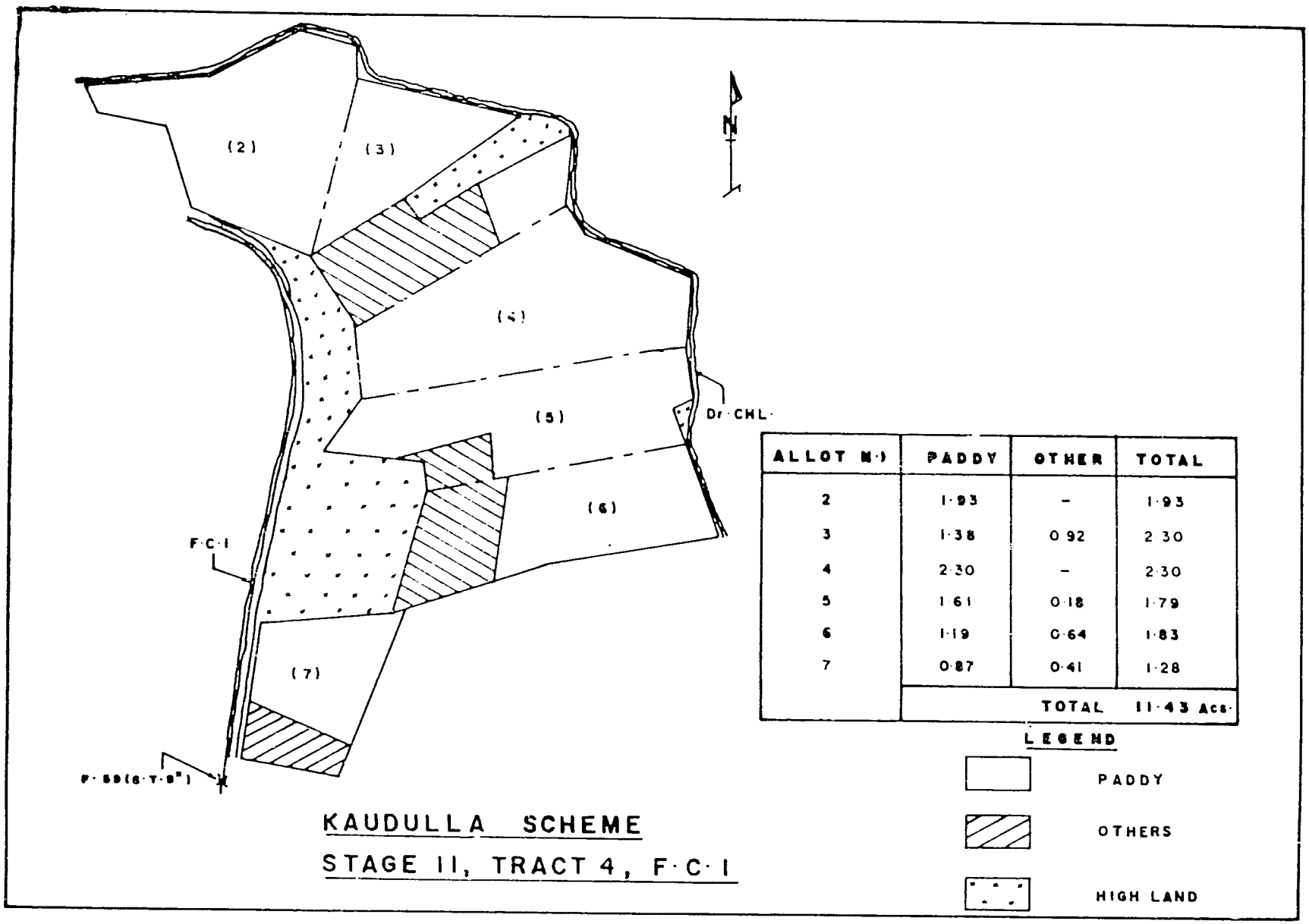
ALLOT NO	PADDY	OTHER	TOTAL
38	0·18	0 64	0 82
39	1·83	0 45	2 28
		TOTAL	3·10 Acs

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



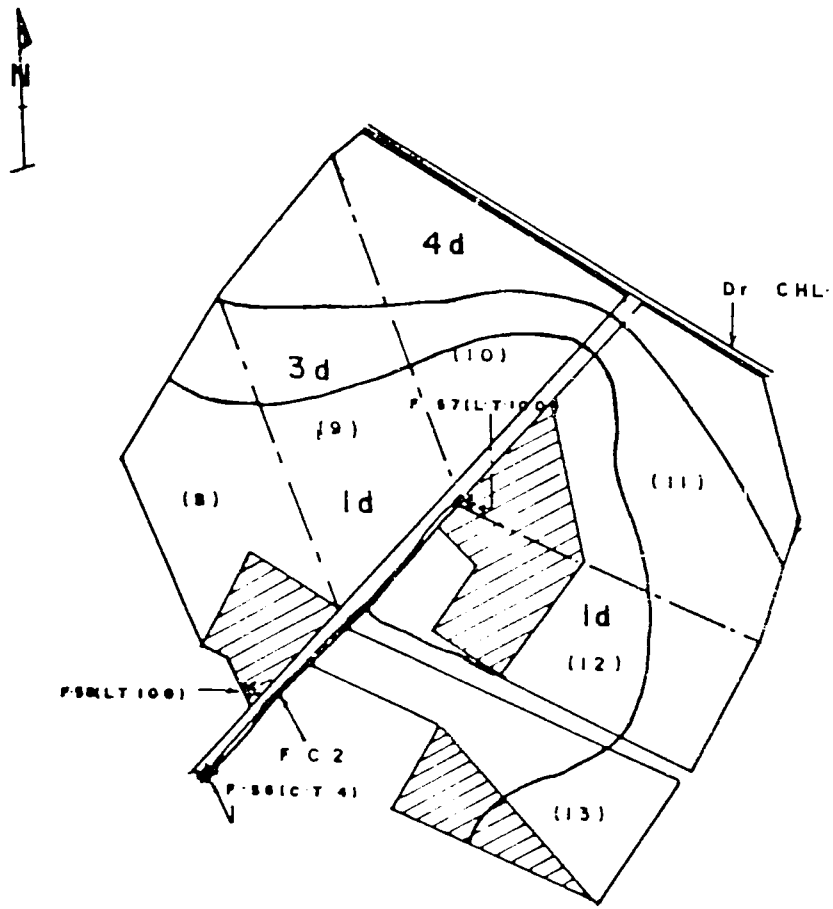
ALLOT NO	PADDY	TOTAL
19	2·36	2·36
20	2·11	2·11
21	1·92	1·92
22	2·15	2·15
	TOTAL	8·54 Acs

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	OTHER	TOTAL
2	1·93	–	1·93
3	1·38	0·92	2·30
4	2·30	–	2·30
5	1·61	0·18	1·79
6	1·19	0·64	1·83
7	0·87	0·41	1·28
		TOTAL	11·43 Acs·

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	OTHER	TOTAL
8	1·19	0·28	1·47
9	1 84	–	1·84
10	1 84	–	1·84
11	2·20	0·32	2·52
12	1·15	0·46	1·48
13	1·01	0·41	1·42
	TOTAL 10·57 Acs		

LEGEND

PADDY

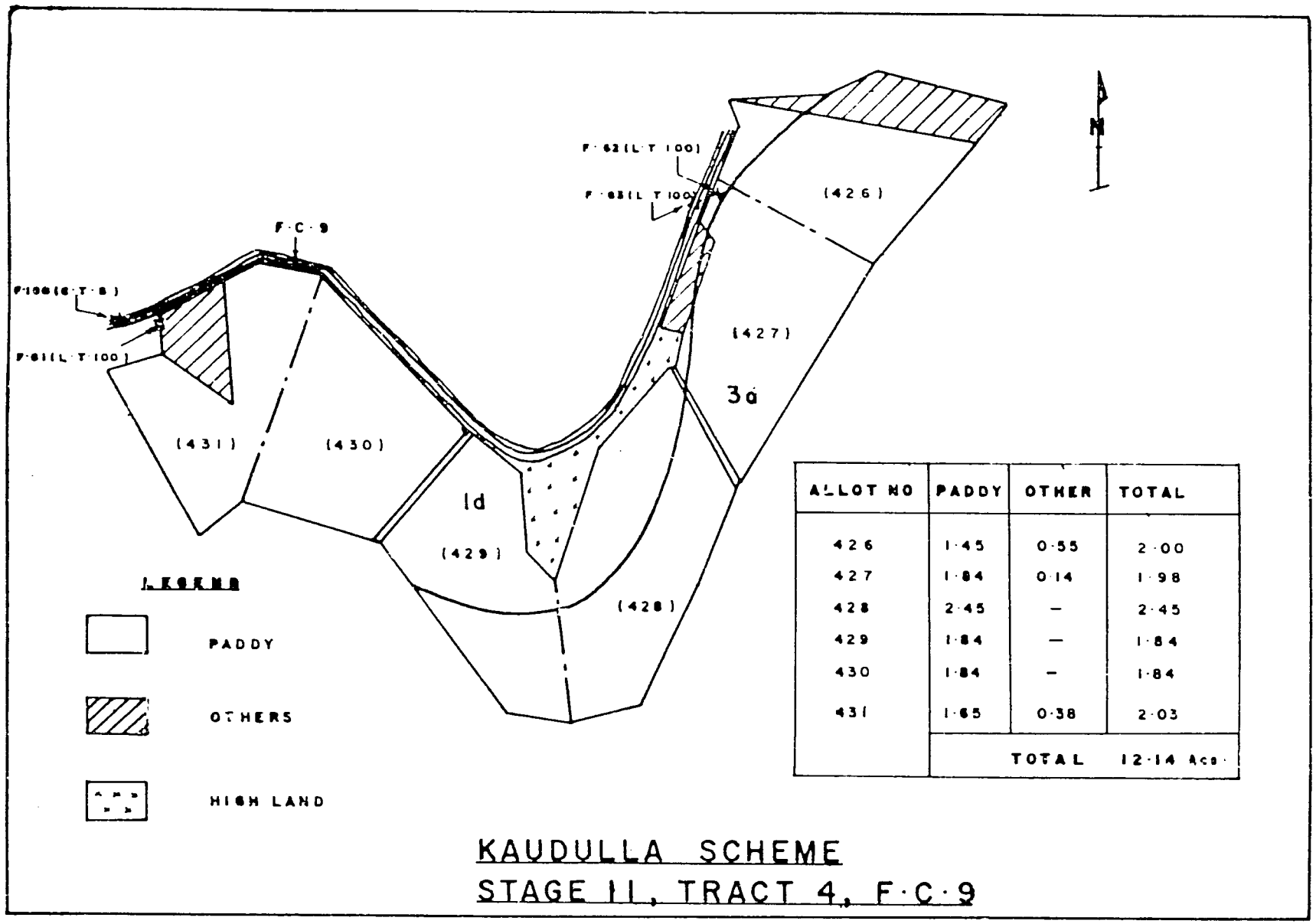
OTHERS

HIGH LAND

KAUDULLA SCHEME

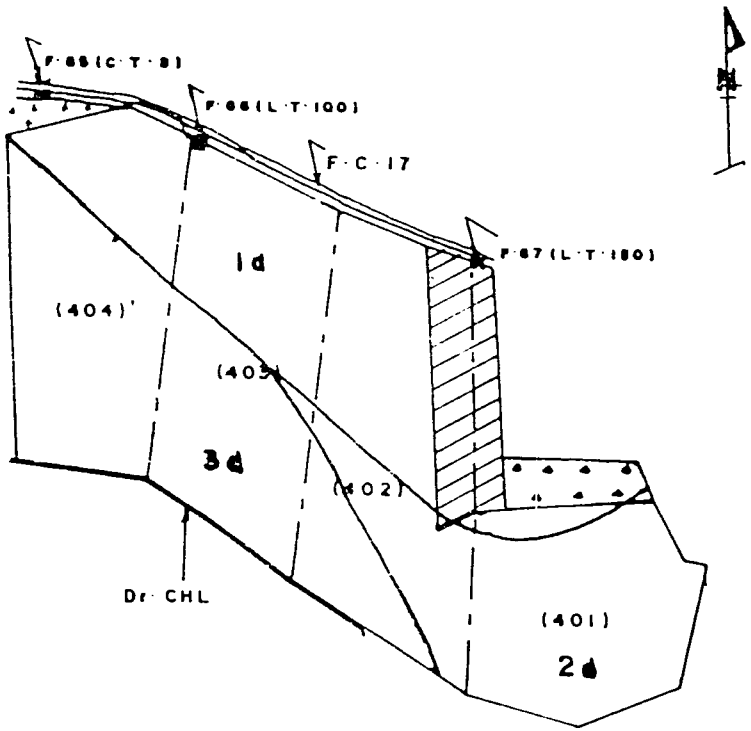
STAGE II, TRACT 4, F·C·2

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 vala.



ALLOT NO	PADDY	OTHER	TOTAL
426	1·45	0·55	2·00
427	1·84	0·14	1·98
428	2·45	–	2·45
429	1·84	–	1·84
430	1·84	–	1·84
431	1·65	0·38	2·03
	TOTAL		12·14 Acs.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	OTHER	TOTAL
401	1·52	0·21	1·80
402	1·93	0·37	2·30
403	2·02	-	2·02
404	2·02	-	2·02
		TOTAL	8·14 Acs.

LEGEND

PADDY

OTHERS

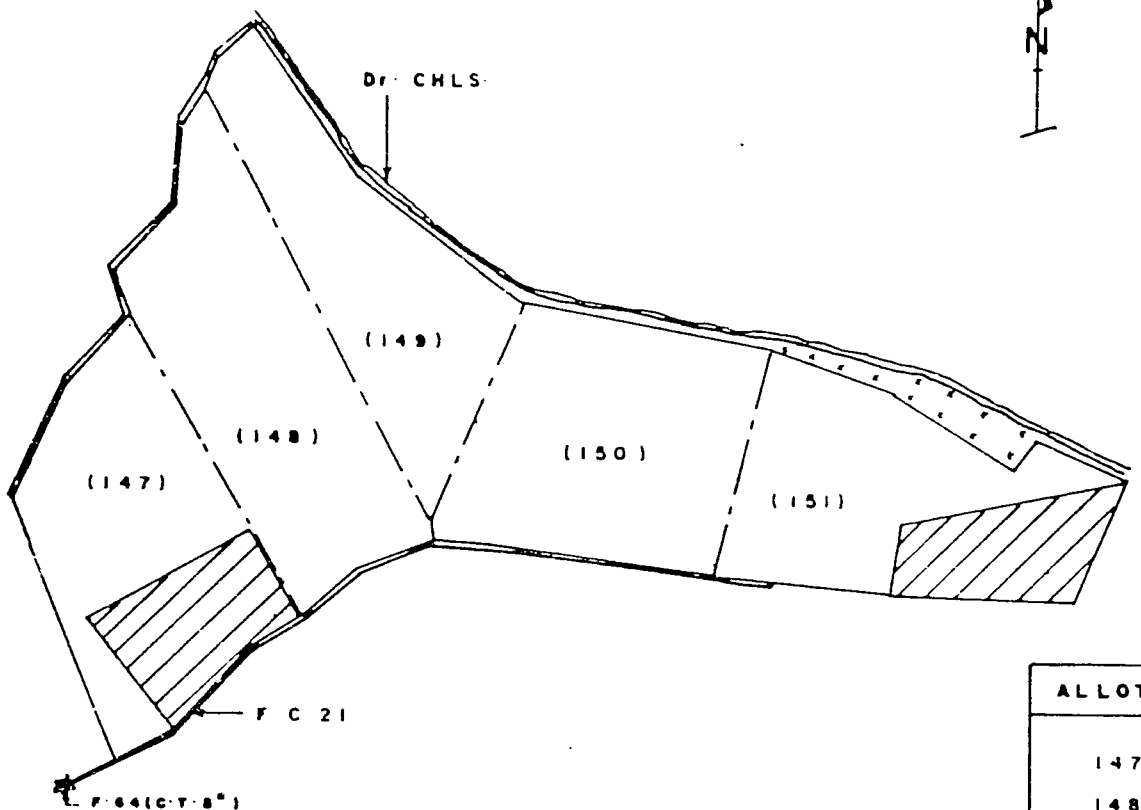
HIGH LAND

UNCOMMANDED AREA

KAUDULLA SCHEME

STAGE II, TRACT 4, F·C·17

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



LEGEND

PADDY

OTHERS

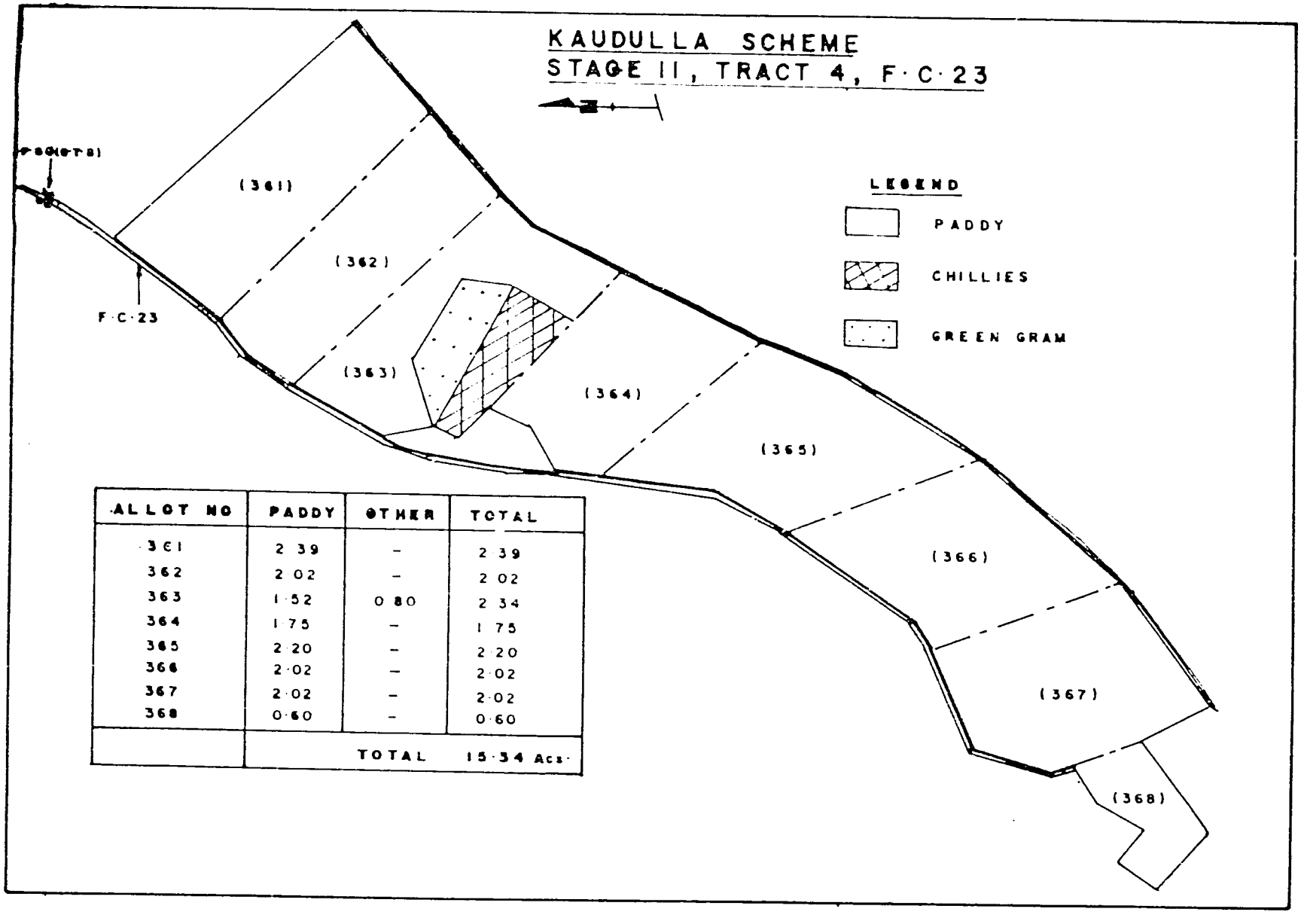
HIGH LAND

ALLOT NO	PADDY	OTHER	TOTAL
147	1.65	0.73	2.38
148	2.39	-	2.39
149	1.84	-	1.84
150	2.20	-	2.20
151	1.65	0.64	2.29
	TOTAL		11.10 Acs.

KAUDULLA SCHEME

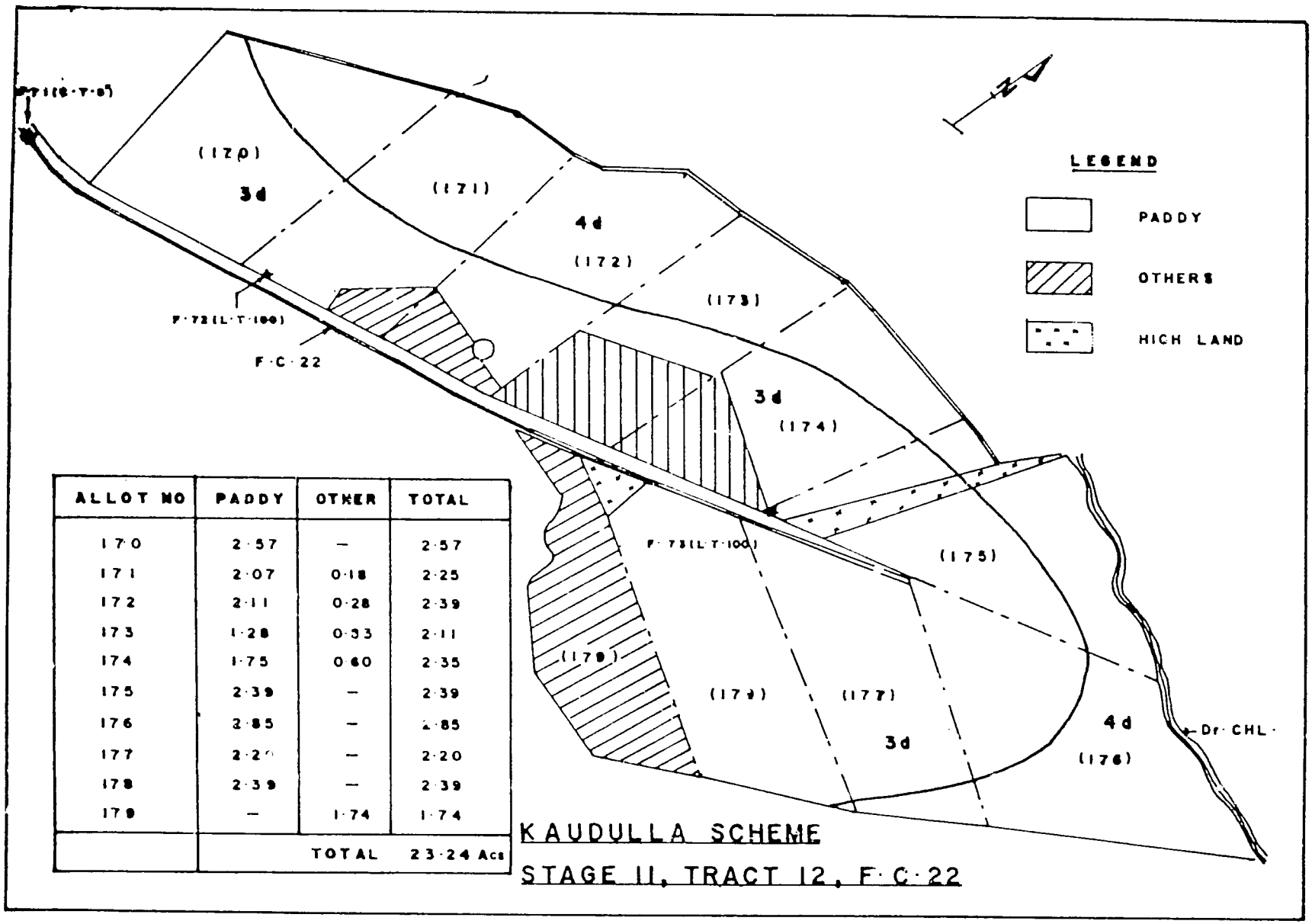
STAGE II, TRACT 4, F.C.21

Engineering and Soil Survey Map, Kaudulla Scheme, 1936 vala.



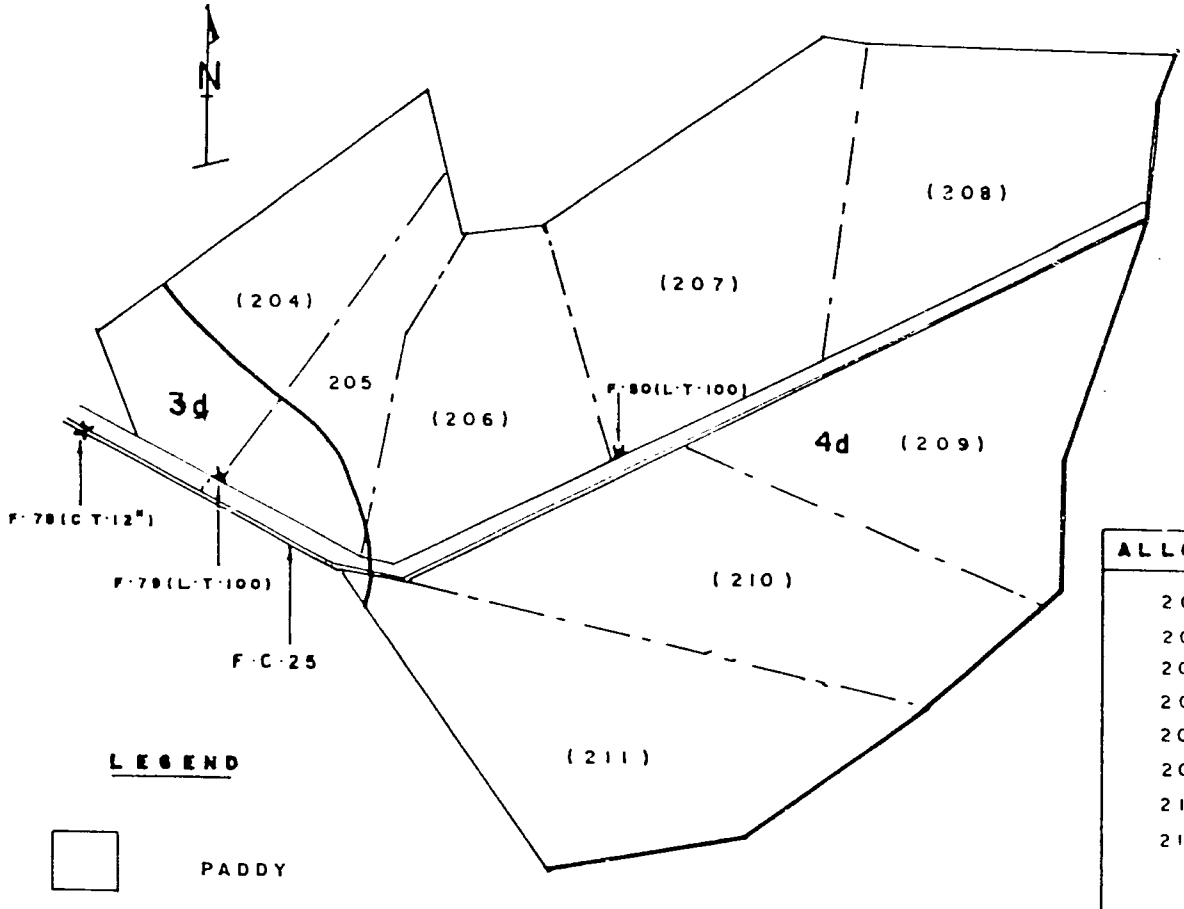
ALLOT NO	PADDY	OTHER	TOTAL
361	2 39	–	2 39
362	2 02	–	2 02
363	1·52	0 80	2 34
364	1 75	–	1 75
365	2 20	–	2 20
366	2·02	–	2·02
367	2·02	–	2·02
368	0·60	–	0·60
		TOTAL	15·34 Acs·

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	OTHER	TOTAL
170	2·57	—	2·57
171	2·07	0·18	2·25
172	2·11	0·28	2·39
173	1·28	0·33	2·11
174	1·75	0·60	2·35
175	2·39	—	2·39
176	2·85	—	2·85
177	2·20	—	2·20
178	2·39	—	2·39
179	—	1·74	1·74
		TOTAL	23·24 Acs

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.

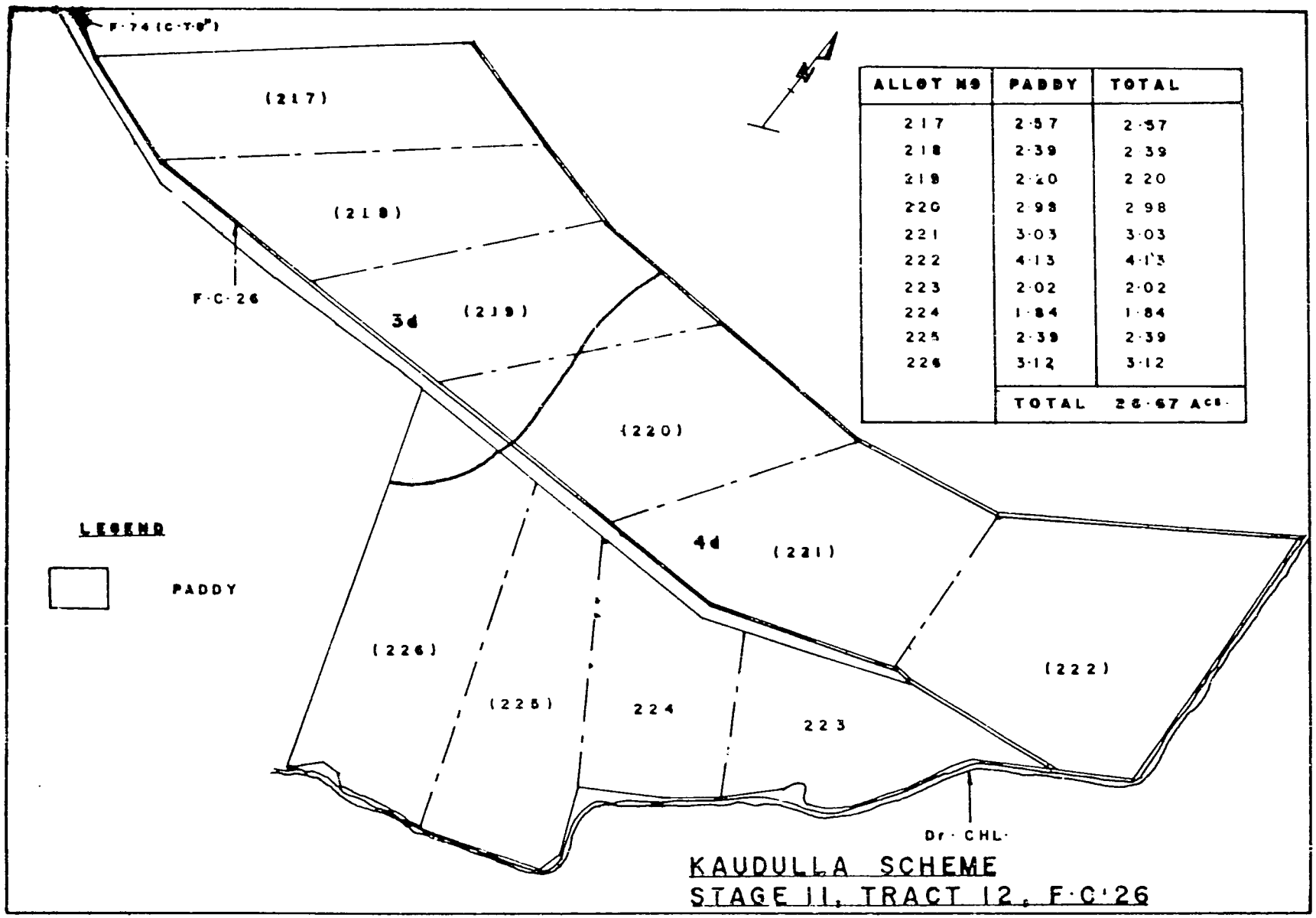


ALLOT NO	PADDY	TOTAL
204	1·93	1·93
205	1·19	1·19
206	1·88	1·88
207	2·66	2·66
208	2·48	2·48
209	2·62	2·62
210	2·80	2·80
211	2·98	2·98
	TOTAL	18·54 Acs.

KAUDULLA SCHEME

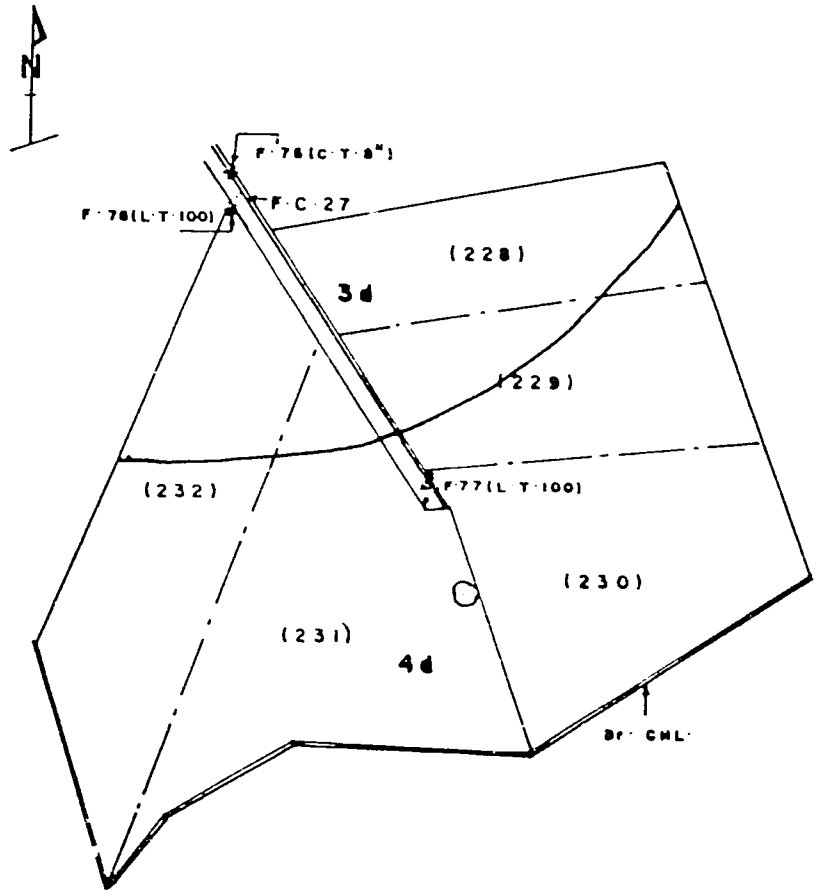
STAGE II, TRACT 12, F·C·25

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	TOTAL
217	2·57	2·57
218	2·39	2·39
219	2·20	2·20
220	2·98	2·98
221	3·03	3·03
222	4·13	4·13
223	2·02	2·02
224	1·84	1·84
225	2·39	2·39
226	3·12	3·12
	TOTAL	26·67 ACS.

Engineering and Soil Survey Map, Kaudulla Scheme, 1986 yala.



ALLOT NO	PADDY	TOTAL
228	1·52	1·52
229	2·07	2·07
230	2·45	2·45
231	3·07	3·07
232	2·80	2·80
	TOTAL	11·91 Acs·

LEGEND

PADDY

KAUDULLA SCHEME

STAGE II, TRACT 12, F·C·27

APPENDIX G

VARIETAL IDENTIFICATION, PLANTING METHOD, SAMPLE YIELDS (CORRECTED FOR SEED MOISTURE CONTENT), GRAIN YIELDS, AND STANDARD DEVIATION FOR THE KAUDULLA STUDY AREA (1986 YALA)

FC Loc. & Allot. No	Short vs Long	TP vs BC	Sample Grain Weight (g/m2) 1	2	3	4	5	Yield bu/ac	STD bu/ac
Stage I, Tract I									
309	1	2	390.16	396.00	290.40	489.60	426.50	73.3	13.2
310a	1	1	450.90	561.40	424.90	351.30	550.90	86.1	16.3
310b	1	2	705.60	532.15	570.70	447.90	459.30	100.0	19.2
311a	1	2							
311b	2	2							
311c	1	2	285.05	511.00	253.10	457.05	540.90	75.3	24.3
312	2	2	634.00	604.40	608.00	593.70	651.10	113.8	4.3
53	1	1	297.50	508.50	407.70	680.20	446.10	86.1	26.0
54	1	1	586.30	531.80	562.30	569.85	739.50	110.1	15.0
180	12	2	494.00	512.70	575.90	492.80	568.40	97.3	7.4
55	1	2							
56	1	12	426.00	447.70	429.10	643.30	549.60	51.9	17.5
57	1	2	172.40	199.00	325.80	352.30	291.30	49.0	14.4
27	1	12	222.00	366.65	379.70	351.00	285.00	59.4	12.4
28a	1	2	324.05	320.70	64.10	240.60	352.20	47.9	21.5
28b	1	2							
29	1	2	239.10	453.80	262.80	316.70	667.00	73.2	30.3
30	1	2	398.10	502.70	522.50	202.70	338.20	74.1	23.4
31a	1	2	684.50	450.30	662.50	579.30	391.05	101.9	23.3
31b	1	1	430.80	529.30	474.30	517.20	616.70	100.0	12.9
31c	1	1	473.30	474.90	629.10	387.80	329.20	54.4	20.8
32	1	2	692.10	432.90	590.60	669.60	664.00	112.2	19.5
33	12	2	464.30	515.10	405.00	475.60	417.90	83.9	3.2
52	1	2	600.20	542.40	711.00	378.30	477.20	99.7	23.1
Stage I, Tract 4									
670	2	2	204.10	359.20	318.50	331.05	328.10	56.7	11.0
671	12	2	371.90	440.00	355.40	291.80	468.10	70.9	12.9
672	12	12	347.60	404.90	344.00	279.10	224.70	58.9	12.8
702	12	2	13.20	176.10	153.20	267.70	154.70	28.2	16.8
703a	2	2	199.90	363.10	331.00	320.00	329.20	55.9	11.6
703b	1	2							
149	1	2	290.70	437.60	469.30	403.95	453.60	75.6	13.2
721a	1	1							
721b	1	1	75.10	75.20	89.90	36.50	64.10	12.5	3.7
722	12	1	332.20	309.40	64.70	221.10	252.40	43.4	19.4
710	12	12							
711	12	12	660.20	580.80	548.10	432.80	374.10	95.5	21.2
712	12	12	481.95	274.85	529.10	523.75	487.00	84.5	19.4

Appendix G (continued)

FC Loc. & Allot. No	Short vs Long	TP vs BC	Sample Grain Weight (g/m2) 1	2	3	4	5	Yield bu/ac	STD bu/ac
Stage I, Tract 8									
1627a	1	2	311	385	269	302	314	59.1	7.8
1627b	1	1	548	420	458	555	316	84.9	18.2
1628	1	2	485	515	242	249	235	63.5	26.2
1629	1	2							
1630a	1	2	174	165	306	381	378	51.7	19.5
1630b	1	2							
1630c	1	2							
1631	1	2							
1632	12	2							
1633	1	2	337	269	487	349	315	64.6	15.1
1634	1	2	128	385	383	146	372	52.0	24.5
1635	1	2							
1636	12	2							
1637	1	2							
1638	1	2							
1639a	1	2							
1639b	1	2	255	275	234	130	178	39.4	10.9
1640	1	2	448	491	281	117	541	69.2	32.1
1694	1	2	725	405	524	468	604	100.3	22.9
1695a	1	2	589	382	109	508	485	76.3	34.3
1695b	1	2							
1696	1	2	427	259	360	393	304	64.2	12.4
1697	1	21	319	282	381	405	586	72.6	21.7
1698	1	2	365	404	275	369	301	63.1	9.7
1699	1	2	197	200	214	315	168	40.3	10.4
1738	1	2	310	242	151	244	202	42.3	10.9
1739	1	2							
1740	1	2							
1741a	1	2							
1741b	1	2							
1742	2	1							
1743	1	2							
1744	12	2	597	556	590	500	544	102.6	7.2
1745a	1	2							
1745b	1	2							
1746	1	2	585	493	386	621	465	93.9	17.3
1747	1	2	396	191	180	210	259	45.5	16.3
Stage II, Tract 1									
1	2	1	207	153	426	381	231	51.5	21.7
2	1	1	255	172	560	334	258	58.2	27.5
3	1	1	289	387	318	282	494	65.2	16.3
4	1	1	283	503	180	276	226	54.0	22.9
5a	2	1	289	337	303	423	329	61.8	9.6
5b	2	1							
6	1	2	216	172	344	388	517	60.2	25.4

Appendix G (continued)

FC Loc. & Allot. No	Short vs Long	TP vs BC	Sample Grain Weight (g/m2) 1	2	3	4	5	Yield bu/ac	STD bu/ac
7	1	1	474	322	238	300	364	62.5	16.2
8	12	12	315	404	327	393	327	65.0	7.7
9	12	2	367	372	474	98	342	60.8	25.7
10	1	2	471	426	483	577	620	94.9	14.8
11	1	2	585	252	489	223	327	70.5	27.5
12	1	2	625	74	491	15	39	45.9	52.8
13	1	2	474	277	309	510	117	62.1	29.3
14		12	412	310	345	280	499	67.9	16.1
15		2	341	403	275	410	402	67.4	10.7
19	2	1	799	695	486	383	440	103.2	32.7
20	2	2	187	350	296	525	424	65.6	23.5
21	12	2	421	531	289	438	372	75.5	16.4
22	1	2	529	290	470	441	546	83.8	18.7
39	1	2	436	284	289	314	242	57.5	13.5
Stage II, Tract 4 & 5									
8	1	2	585	423	686	293	519	92.2	27.8
9a	1	2							
9b	1	2	535	462	431	383	490	84.7	10.6
10a	1	2							
10b	1	2							
10c	1	1	279	192	320	424	226	53.0	16.6
11	1	2	618	583	577	509	493	102.3	9.7
12	1	2	596	565	632	389	627	103.4	18.5
13	1	2	496	601	290	330	353	76.1	23.9
401	1	2	159	159	101	125	188	26.9	6.2
402	1	2	550	439	484	366	249	80.5	15.3
403a	1	2							
403b	1	2	459	276	298	391	292	63.1	14.5
404a	1	2	504	507	554	440	162	79.7	28.9
404b	1	2	621	324	376	491	361	80.0	22.3
404c	1	2	489	594	392	315	352	78.8	20.8
405a	2	2	328	230	330	169	196	46.1	13.8
405b	1	2							
426a	1	2	459	131	344	488	319	64.1	26.0
426b	1	2	163	309	113	149	67	29.5	16.7
427a	2	2							
427b	1	2	543	201	590	412	378	78.2	28.2
428	1	2							
429	1	2	432	488	453	505	457	85.9	5.4
430	1	12	556	467	448	458	310	82.4	16.2
431a	1	2							
431b	1	2	515	449	394	359	436	79.2	10.8
432	2	2	442	310	321	312	172	57.3	17.6
433	1	1	248	333	313	283	271	53.3	6.2
			360	296	251	231	343	54.5	10.3

Appendix G (continued)

FC Loc. & Allot. No	Short vs Long	TP vs BC	Sample Grain Weight (g/m2) 1	2	3	4	5	Yield bu/ac	STD bu/ac
Stage II, Tract 12									
169	1	2	595	414	425	405	293	78.4	20.0
170	1	2	364	465	555	566	313	83.2	20.8
171	1	2							
172	12	2	594	322	209	191	486	66.3	32.3
173	1	2							
174	1	2							
175a	1	2	416	546	529	536	742	101.9	21.6
175b	1	2	253	357	262	379	239	54.9	11.9
176	1	2	541	468	421	514	528	91.0	9.1
177	1	12	138	292	241	224	320	44.7	13.0
178	1	1							
204	1	2	309	384	361	291	173	55.8	15.1
205	1	2	298	180	159	167	273	39.6	12.0
206	1	2							
207a	1	2							
207b	1	2	68	143	156	125	87	21.3	6.9
208	1	2	215	166	142	378	218	41.2	17.0
209	1	1	516	414	274	331	334	69.7	17.3
210	2	1							
211	1	2	423	419	344	334	372	69.7	7.6
212	1	2	429	93	279	297	226	48.8	22.4
213	2	1	25	74	87	137	141	17.0	8.8
227a	1	2							
227b	1	1	252	201	206	534	348	56.7	25.6
229	1	1							
229a	1	2							
229b	1	1	405	499	462	457	391	81.5	8.2
230	1	1	295	262	372	414	408	64.4	12.6
231	1	2	369	295	98	379	296	52.9	20.8
232	1	12	66	518	300	274	274	52.7	29.5
233a	1	2	500	325	525	589	684	96.6	24.4
233b	1	2							
233c	1	2	315	468	367	372	514	74.9	15.0

APPENDIX H

LIST OF FIELD INVESTIGATORS INVOLVED IN THE 1986 DIAGNOSTIC ANALYSIS OF KAUDULLA SCHEME

Agronomy	
Field Supervisor:	R.K.P.A. Wickramasooriya
Field Investigators:	Tissa Jayasinghe Charitha Eragoda K.G. Sugathapala D.A. Kuruppu P.M. Asoke Silva B.M.V.S. Basnayake Kulavansa Bandaranaynke
Economics	W.M. Jenadassa W.M. Pemasiri G.H. Gunatilaka S.H. Mervyn
Sociology	R.R.M.J. Rathnasiri H.M. Dhanapala
Women In Development	Field investigators from economics and sociology (above)
On-Farm Engineering	
Field Supervisor:	M.S.R.K. Marasingha
Field Channel Surveys and Site Supervisors:	A.M.W. Attanayaka B. Jayasooriya H.M.R. Herath
Flume Readers:	Kelum Mallawaarachi Palitha Weragoda Ranjith Dharmawardana Valentine Wickramasingha A.G. Amarapala Sunil Shantha Bandara
Main System Engineering	Technical assistants' names not provided.

APPENDIX I

GLOSSARY

1. ABBREVIATIONS

ac	acre
bu	bushel
cfs	cubic feet per second; cusec
cm	centimeter
CV	coefficient of variation
ET	evapotranspiration
ET_o	reference evapotranspiration
FAO	Food and Agriculture Organization
FC	field channel
ft	feet
GCE	General Certificate of Education
ha	hectare
hr	hour
HYV	high yielding variety
IMD	Irrigation Management Division
in	inch
ISM	Irrigation Systems Management Project
K	potassium
kg	kilogram
km	kilometer
KVS	agricultural field extension officer

LB	left bank of a channel
LHG	low humic gley; soil classification
L/s	liters per second
lb	pound
mb	millibar
MLLD	Ministry of Lands and Land Development
mm	millimeter
m, m^3	meter, cubic meter
N	nitrogen
NA	not applicable
O&M	operation and maintenance
P	phosphorus
PSS	Parakrama Samudra Scheme
RB	right bank of a channel
RBE	red-brown earth; soil classification
RDS	Rural Development Society
Rs.	rupees
RWS	relative water supply
TDM	top dressing mixture
TM	trademark
USAID	United States Agency for International Development
V1	mixture of fertilizer
WID	women in development
WMS	Water Management Synthesis Project
WUE	water use efficiency

2. TERMS

ande	a form of sharecropping, with payment in cash or crop and which can be extended indefinitely
attam	exchange labor
boutique	small neighborhood tea shop with sundries for sale
D-channel	distributary channel
ela niyojitha	field channel representative
Kachcheri	District government agent's office
kanna	precultivation
Kantha Samithi	women's division of the Rural Development Society
kulla	tool used for winnowing
kurrakan	finger millet
liyadda	small, bunded portion of a field
maha	wet season; mid-October to late March
poru ela	small, shallow furrows formed by hand to assist water distribution and draining in a broadcast field
purana	old or traditional; refers to villages or residents of an area before resettlement
Sarabumi	a government sponsored agricultural radio program
Sarvodaya	private, voluntary group that sponsors self-help projects
shramadana	voluntary community work
vel vidane	government-appointed farmer representative responsible for D-channel operation; usually a farmer
wee porunduwa	a form of sharecropping, with payment in crop, lasting for one season
yala	dry season; mid-April to late September