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**FINAL REPORT
SRDC PROJECT BS206
A PARTICIPATORY APPROACH TO IMPROVING
FURROW IRRIGATION EFFICIENCY
by
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1.0 ABSTRACT

A combination of low water use efficiencies on a significant proportion of furrow-irrigated farms, and a serious decline in water availability for a majority of farms, gave strong impetus to improving application efficiencies of furrow irrigation, which is practised over 35% of total cane production area in the Bundaberg district. This project, which was based in the Millaquin/Qunaba area, has identified the main operation of contributors to low application efficiencies and methods to alleviate them.

Evaluation of data from three irrigation seasons using the irrigation simulation model SIRMOD provided practical, low-cost solutions to a range of problems encountered. In most cases, ensuring suitable and stable inputs, and refinement of inflow rates and cut-off times raised application efficiencies substantially. Deep infiltration, outflow, and losses associated with end-fill were strongly reduced.

The project demonstrated that monitoring of common operational factors such as inflow, advance rate and cut-off time, provides excellent information for evaluation of irrigation efficiencies. The simulation model SIRMOD proved particularly useful in evaluation of irrigation practices and provided direction for improvement of application efficiencies. Participating growers involved in the monitoring programs were able to form action plans quickly which modified inefficient practices. In many cases, this led to highly significant improvements to application efficiencies and resulted in better use of available water. A survey conducted at the close of the project indicated that improvements to a number of practices associated with application efficiency are underway.

Monitoring and evaluation outcomes were relayed to participating growers through shed meetings, demonstrations and personal contact. Technology transfer to district growers involved similar events and included also field days, workshops, bus tours, displays and presentations. A practical furrow irrigators' handbook was produced for ongoing extension.

2.0 OBJECTIVES

The project objectives were to:

- identify factors and practices contributing to low efficiency of furrow irrigation systems, and areas of low water use efficiencies;
- counteract identified contributors to low efficiency levels using appropriate technology through a grower participatory group approach;
- increase irrigation efficiency of identified problem areas by 20%;
- produce a best practice furrow irrigators' handbook.

Monitoring and evaluation of furrow irrigation practices have identified the major operational factors contributing to low irrigation efficiency in the Bundaberg district. Although activities mainly took place in the Millaquin/Qunaba area, water use efficiency data indicated that the problems identified occurred throughout the district; no defined

areas were identified for specific attention other than those which applied normally due to differences associated with soil types, water sources and cultural practices.

Application of established irrigation technology successfully counteracted a majority of problems encountered. This was conducted through a grower participatory approach. Most group input, however, was relatively passive and modification to practices relied primarily on the enthusiasm of site holders. Changes to irrigation practice occurred, therefore, in an uneven manner. Monitoring data showed that just as many practices proved highly inefficient, individual modifications brought highly significant improvements, in excess of the 20% objective in many instances. Comparison of irrigation practices of growers active in the groups over the duration of the project, indicates that substantial improvements have been achieved. Quantifying overall gains, however, was not possible due to prevailing highly variable water supplies.

Outcomes resulting, accrued from monitoring and modification evaluations were summarised in an irrigators' handbook provides a practical guide to furrow irrigators to address the major factors affecting application efficiencies.

3.0 EXECUTIVE SUMMARY

The Bundaberg Cane Productivity Committee and Millaquin/Qunaba Cane Protection and Productivity Board had each, since the early 1900s, conducted annual monitoring programs of farm water use efficiency as part of a larger program to improve productivity levels under irrigation. The surveys showed a large range of productivity for each megalitre of irrigation. Data showed a wide range of water use and productivity levels as well as highly variable productivity at each level of water application. This was common to each mill area and was not influenced apparently by soil type, water source, variety or other agronomic factors.

Furrow irrigation remained a popular form of irrigation at Bundaberg with approximately 35% of the total cane production area irrigated in this manner. Millaquin/Qunaba area relied on furrow irrigation for over 50% of its production. Many furrow-irrigated farms recorded poor irrigation efficiencies, well below the benchmark of 12.2 tonnes cane/ML. Monitoring data indicated that this was due mainly to inefficient irrigation practices and that two-thirds of farms had potential for improvement of 20%. Additionally, water supplies deteriorated substantially during the 1990s, due to prevailing drought conditions, and irrigation allocation fell to approximately half nominal levels. This made it imperative to maximise productivity from reducing water supplies. Targeting of furrow irrigation was considered an effective way of improving productivity, profitability and sustainability as water resources became even more uncertain.

A participatory extension project was commenced in 1998 to identify factors contributing to low furrow irrigation efficiency, and to actively counteract poor efficiency levels using established irrigation technology. The program was established in the Millaquin/Qunaba area.

Twelve monitoring sites were established on three predominant soil types of district furrow irrigation areas; namely, red ferrosol, red kandosol and yellow dermosol.

Monitoring included all appropriate irrigation inputs; namely, inflow, advance rates, cut-off times, soil moisture, rainfall and evaporation. To commence, grower initiated irrigations were monitored to better understand current practices and their outcomes. Irrigation events were evaluated using the irrigation simulation model SIRMOD, which confirmed poor application efficiencies of most irrigation events.

Four major contributors to poor furrow irrigation efficiency were identified.

- Uneven and inappropriate inflow rates
- Uneven and unsuitable advance rates
- Mismatched cut-off times
- Excessive end-filling

Data showed that each factor substantially influenced application efficiencies, and their effects were cumulative. High inflow variability was common and due primarily to poorly cut cups used with plastic fluming. Use of moulded cups reduced variability greatly. With gated fluming careful adjustments of gates was required to reduce variability.

The combination of inappropriate inflow rates, which led to unsuitable advance rates, and poorly controlled cut-off times, was responsible for low efficiencies of many events. Where excessive end-filling was practised, deep infiltration and/or run-off detracted substantially from efficiency levels.

Modelling with SIRMOD identified many of these problems and also provided direction for remedial modification to irrigation practices. These were introduced progressively using a passive group participatory approach. Modifications were evaluated and feedback supplied to group participants. Targeting of identified contributors in this manner meant that action plans could be formed progressively. The process was reasonably rapid with many improvements being made within a single irrigation season.

Regular technology transfer activities were conducted for participating growers and other district irrigators. These included shed meetings, workshops, demonstrations, field days, bus tours, meetings, displays and presentations. Activities were supported by a modest media program. These activities, together with cooperative activities with the Rural Water Use Efficiency Initiative, provided exposure of project outcomes and recommendations to a majority of furrow irrigators. Additionally, a practical furrow irrigators' handbook was produced for follow-up extension.

Results of an irrigation practices survey conducted at the closure of the project indicated that significant potential exists for improvement to furrow irrigation practices, and that a trend for significant improvement of practices was established.

4.0 BACKGROUND

During the period 1990–1997, rainfall at Bundaberg and associated inland areas reached long-term averages in only two years, and fell as low as 40 and 53% of average levels on two occasions. This resulted in serious depletion of both surface and groundwater

supplies and was reflected by storage levels in Fred Haigh dam, Bundaberg's major water storage. This facility was virtually at full supply level (586,000 ML) at the beginning of 1993 but, despite controlled use of surface water, had reduced to 11% by 1998. At the end of the century, the dam contained only 15%, a precariously low level of storage in an extended dry period. During this period, irrigation application rates had declined by 45% and were equivalent to approximately half nominal allocation on a district basis.

As part of a program to increase productivity from limited water supplies, the Bundaberg Cane Productivity Committee and Millaquin Cane Protection and Productivity Board conducted annual water use efficiency (WUE) evaluations for all district farms where a reliable comparison could be made between water use and cane yields. The studies identified a positive trend in gross WUE from 1993 onward. By 1998, a 24% increase in WUE had been recorded, indicating significantly improved irrigation practices, but efficiency was still well below the established benchmark of 12.2 tonnes cane/ML.

The studies showed also a very wide range of WUE across farms as illustrated by water use/yield relationships depicted in Addendum 1 (1996 Fairymead). Typically, a divergence of yields in the order of 20 to 50 tonnes/ha was demonstrated at every level of water use. These large differences could not be explained by varying levels of rainfall, soil type, varieties, or other agronomic factors. Although general farm management undoubtedly played a significant role in determination of yield, data strongly suggested that irrigation management was a major factor in determining return from water use.

Furrow irrigation remained a popular type of irrigation with approximately 35% of the gross area of canelands at Bundaberg irrigated in this manner. Given the level of furrow irrigation practised and the potential for improved efficiency indicated by the annual WUE surveys, targeting of furrow irrigation was considered an effective way of improving productivity under a restricted water supply.

Monitoring outcomes indicated that an improvement of 2 tonne cane/ML could increase Bundaberg district annual production by 160,000 tonnes, valued in 1997-1998 at \$6.5m gross. Data indicated that two-thirds of furrow-irrigated farms displayed a potential for a WUE improvement of 20%, and for a lesser degree for farms already at relatively high efficiency levels. Additionally, substantial yield benefits could be gained while water supplies remained uncertain, helping to safeguard sustainability of furrow-irrigated farms. The rapidly worsening water availability situation made attention to water efficiency even more urgent.

5.0 METHODOLOGY

The methodology adopted for this group extension program involved a survey x evaluation technique followed by targeted modification of irrigation practices through cooperative group activity. Confirmation of modified practices followed, to establish changes as best practice.

The project was conducted in the Millaquin/Qunaba area using representative soil types and block configurations that reflected furrow irrigation practices in the Bundaberg district.

The program set out firstly to evaluate current furrow irrigation practices, and to identify the main causes of poor irrigation efficiency. Problems were then targeted through adoption of modifications suggested from evaluation of monitoring outcomes.

The process was an evolving one supported in all stages by monitoring of irrigation inputs and evaluation of irrigation events. Modifications to irrigation practice were introduced at the earliest opportunity, although this proved erratic due to disruption to irrigation schedules caused by uncertain water supplies and weather delays.

Efficiency evaluations were largely carried out using the irrigation simulation model SIRMOD (Walker, 1993). Use of this program provided:

- (a) measurement of irrigation efficiency (requirement and application);
- (b) identification of causal practices contributing to low efficiency;
- (c) direction for modifications;
- (d) confirmation of improved practices.

As the process developed, varying irrigation scenarios were encountered. Understanding of these and the appropriate methods for improved WUE were developed through regular interaction with cooperators and group activities.

Technology transfer activities were held regularly with grower groups established around each major monitoring site. Displays and demonstrations were set up and presentations given at district field days, demonstrations, workshops, seminars and meetings. A modest promotional program was conducted in parallel to the monitoring program and involved local publicity and internal media.

Details of the main project components follow.

5.1 Monitoring

The monitoring program was preceded by a desktop study of farm WUE during 1994-1997 of farms in the Millaquin/Qunaba area wholly irrigated by the furrow method. WUE was measured by comparing total water used (effective rain + irrigation applied) with farm yields. This provided a clear picture of the range of farm irrigation efficiencies, and a baseline from which to gauge potential for improvement.

Twelve monitoring sites were established on three predominant soil types, which represented the majority of furrow irrigated farms; namely, red ferrosol, yellow dermosol and red kandosol as described by Donnollan *et al.* (1998). Two farms each in the upper and lower 50% efficiency rank order established in the desktop study were selected in each soil type. Sites were chosen to conform to the physical characteristics of soil texture, situation and slope of district furrow-irrigated areas, and included surface and groundwater supplies. Plant and first ratoon blocks were selected to ensure monitoring could extend over at least two crops.

Regular monitoring was conducted of inflow, flow rates, advance rates, growth and rainfall. Inflow was assessed by bucket-fill techniques and a flowmeter. Advance rates and cut-off times were monitored for each quarter of row length by water-activated stopwatch, and following end-fill events.

Profile soil moisture levels were recorded on one site of each soil type at two to three day intervals surrounding irrigation or rainfall events. Probes were located in 6 to 9 positions at the inflow end, mid-section and outlet ends of monitored fields. Soil moisture measurements were made at 10 cm intervals down the profile to one metre depth; use of a capacitance meter (Diviner 2000) facilitated regular measurements. Tensiometers were installed at the remaining sites at three depths - 0.3 m, 0.6 m and 0.9 m – closely beside the row.

Growth was measured during January-March when peak moisture demand and growth rates could be expected. Stalk elongation was assessed on 10-20 stalks each side of moisture probes by measuring stalk height from ground level to top visible dewlap, at the same intervals as the moisture measurements.

5.2 Evaluation

Irrigation efficiency was evaluated using the irrigation-modelling program SIRMOD. Grower initiated irrigation events were evaluated first to establish application and requirement efficiencies. Options for operational specifications, particularly of inflow and cut-off, were explored with the objective of improving irrigation strategies. Selected modifications were then applied to subsequent irrigations, which were also monitored and evaluated for confirmation. Irrigation application levels were based on readily available water (RAW) levels for Bundaberg soils as defined by Stephens (1962).

6.0 RESULTS AND DISCUSSION

The desktop study of 130 Millaquin/Qunaba farms solely irrigated by the furrow system identified a range of WUE of 5.31 to 15.55 tonnes cane/ML total water across all soil types. Data showed that, within each soil type, approximately the same proportion of farms displayed WUE levels in the highest, and lowest, 30% efficiency bands. This indicated that WUE was related more to irrigation practices than soil type. However, it was recognised that differences in water availability associated with groundwater and surface water supplies, could be a significant component of WUE variability. The lack of significant general influence of soil type on WUE is shown in Table 1.

Table 1
Per cent Millaquin/Qunaba furrow-irrigated farms in the highest and lowest 30% WUE categories according to soil type (1994-1997)

Soil type *	Highest 30% WUE	Lowest 30% WUE
Brown volcanic	8	12.5
Red volcanic	33	25
Red earth	15	10
Yellow earth	18	15
Yellow podsolic	8	10
Gleyed podsolic	18	22.5
Sands	0	5

* Source: Soil survey by C L van Wijk, Agricultural Chemical Laboratory Branch. Compiled by Division of Land Utilization, Queensland Department of Primary Industries, Brisbane.

Early identification of the main contributors to low water use efficiency occurred mainly through monitoring of existing irrigation practices. Ironically, regular rainfall occurred at the commencement of year 1 monitoring and it was necessary, initially, to concentrate efforts on sites where several irrigations were likely. Growth appeared generally aligned to rain rather than to irrigation in the first year, due to most irrigation occurring when soil moisture was adequate, or just prior to rain. See Addendum 2 (a, b and c). The markedly improved rainfall received during the first monitoring period was reflected in the record crop harvested in 1999.

Despite the interruptions experienced in year 1, monitoring of inflow, advance rates, irrigation duration (cut-off) and soil moisture identified several factors that contributed to low irrigation efficiency

- Uneven and inappropriate inflow rates
- Uneven and unsuitable advance rates
- Mismatched cut-off times
- Superfluous end-wetting

Each factor was found to directly influence irrigation efficiency. The factors also displayed a cumulative effect; where poorly suited operational settings were used, inefficiencies quickly multiplied resulting in excessive wetting, deep infiltration and highly inefficient use of limited water allocations. These general outcomes were confirmed repeatedly in years 2 and 3 when weather was generally dry and stable.

Highly significant infiltration occurred past target wetting depths on red ferrosol and red kandosol sites. Infiltration occurred past one metre depth two days post irrigation resulting in application efficiency levels of 41% as shown in Figure 1. A similar problem was demonstrated in podzolic soils as illustrated in Addendum 3.

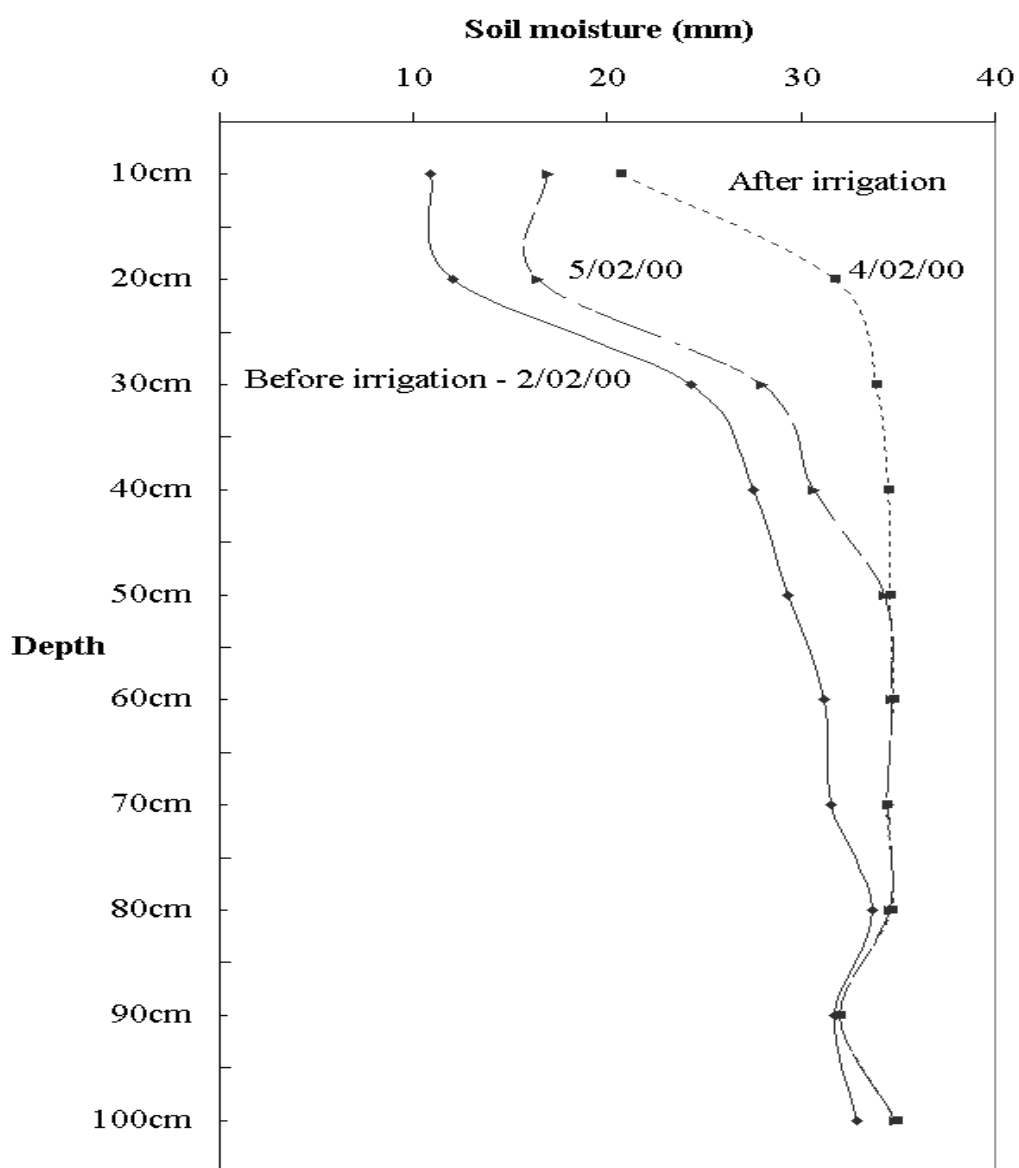


Figure 1 - Deep infiltration was recorded within a short period on all soil types monitored

Details of the major contributors to poor WUE are discussed in the following sections.

6.1 Inflow

High inflow variability was recorded in a majority of blocks monitored for the first time. This was due mainly to rough cutting of cup apertures and irregular settings for gates, as well as few checks of inflow being carried out by irrigators. Realisation of problems, and subsequent adjustments if any, often occurred only when 'slow' or 'fast' rows became obvious.

Tests with cups, which have moulded outlets of predetermined sizes, showed that inflow variability could be reduced by 69%. Table 2 illustrates the significant variability of inflow commonly recorded, and the positive outcomes from using moulded cups, in field trials on five different sites. This easily activated and low-cost improvement became a

firm recommendation for irrigators using plastic fluming. Alternatively, cup apertures should be made using a properly sized hollow punch, and *not* cut by hand.

Table 2
Inflow variability: Hand-cut versus moulded cups

Site	Average inflow litres/sec	Range of deviation to average inflow (%)	
		Hand-cut cups	Moulded cups
1	2.28	-21 to +27	-7 to +9
	2.20		
2	0.59	-32 to +69	-7 to +11
	0.54		
3	1.24	-11 to +5	-3 to +4
	1.54		
4	0.9	-22 to +11	-11 to + 6
	1.46		
5	1.35	-15 to +11	-8 to +4
	1.69		
Average range %		45	14

With gated fluming, pressure changes strongly influenced inflow rates. Increased sensitivity was encountered when adjusting individual gates requiring a cautious adjustment strategy and close monitoring of inflow.

Inappropriate inflow rates were commonly recorded, especially for first and other early irrigations. Typically, low rates were applied to absorptive soil types and conditions, eg plant cane on red ferrosol and red kandosol soils. This resulted in long duration time and excessive infiltration, leading to highly inefficient irrigation and excessive early use of water. A typical example of this outcome is shown by a SIRMOD evaluation in Addendum 4. The latter exacerbated the problem of restricted allocations as crop demand increased under prevailing dry weather conditions. In many instances, approximately one-third to one-half of current allocation was expended on early irrigations.

SIRMOD modelling and confirmation monitoring were used to establish practical inflow settings for the representative soil types and conditions. Table 3 shows a range of settings that provided high irrigation efficiency in monitored events.

Table 3
Inflow rate ranges for major Bundaberg soil types

Soil type	Inflow rate (litres/sec)		
	Early season or freshly cultivated conditions	Mid-season and/or uncultivated, compacted conditions	Late season and/or uncultivated, compacted conditions
Red volcanic	4 – 6	2 - 4	2 - 4
Red forest and sandy soils	3 –5	1 – 3	1 –3
Grey forest, Yellow forest Black earth	2 –4	1 – 2	1 – 1.5

Note - Higher flow rates are recommended for blocks with low slope or long row length

6.2 Advance rates

Advance rates were strongly influenced by inflow rates, soil condition, and furrow shape and size. Advance slowed progressively downfield in many monitored events. Where advance took more than twice the time in the second half of the field than in the first half, excessive infiltration was recorded, particularly in highly absorptive soils. An example of the nature of advance recorded and its effect upon efficiency is given in Addendum 5. Increasing inflow alleviated this problem on each representative soil type.

Furrow shape and size, and soil condition were also demonstrated to affect advance. Accepted standard practices were found to generally apply, ie relatively deep narrow furrows for absorptive soils, shallow wide furrows for soils of low absorption capacity. Furrow shapes encountered are shown by examples in Addendum (6a, b, and c). Rough soil tilth should be avoided especially in absorptive soils with low slope.

Modelling with SIRMOD, however, showed that of all input factors, furrow shape had the least effect on efficiency, making little difference to outcomes of many of the evaluations conducted.

Variable slope caused uneven advance; where slope decreased downfield, advance slowed markedly. However, on red ferrosols, impedance to advance under trash blanketed conditions and the surface compaction normally encountered on this soil type, proved beneficial when slope was reasonably high, eg 0.5 – 0.7%.

6.3 Duration (Cut-off time)

Cut-off time was dependent largely on advance for most irrigation events. Poor efficiencies were recorded due to deep infiltration where cut-off was extended unnecessarily. Delayed cut-off was practised by several growers in the belief that it resulted in proper wetting of the soil profile.

SIRMOD evaluations showed that targeting causal factors such as slow advance due to low inflow rates and/or physical impediments, such as wrongly shaped furrows, would reduce duration time significantly. This resulted in effective wetting to the target depth, little deep drainage or outflow, shorter irrigation time and operation costs, and less total water used.

SIRMOD proved particularly useful for exploring options and potential outcomes from varying combinations of inflow and cut-off times. When significant problems were identified, modifications suggested by SIRMOD were introduced and confirmed by further evaluation of subsequently monitored events.

This targeted approach proved successful on all soil types and significant improvements to application efficiencies were achieved. Examples of successful modifications to inflow and cut-off time are given in Table 4, which shows outcomes on the three representative soil types. The table includes an example (yellow dermosol) where reversion to original settings by the irrigator reduced efficiencies to their original, unacceptable levels.

Table 4
Efficiency levels achieved by progressive targeting on three representative soil types through modifications to inflow rate and cut-off times

Red ferrosol

Cultivated, conventional ratoon

Irrig. No. & Year	Spacing A-alt. row E - every row	Inflow litres/sec	Application target (mm)	Advance (min)	Cut-off (min)	App. effic. %	Water use (ML/ha)
1 1999	A	2.80	40	375	360	56.9	0.67
1 2001	A	4.20	40	125	120	98.9	0.33

Red kandosol

Green cane trash blanket, nil tillage

1 2000	A	2.35	80	Incomplete	565	Na	1.06
3 2000	A	4.10	80	145	490	55.5	1.61
1 2001	A	3.80	80	412	450	63.1	1.37

Yellow dermosol**Cultivated, conventional tillage**

1 2000	E	0.82	50	815	808	45.4	1.10
3 2000	E	0.85	50	835	770	44.4	1.09
4 2000	A	1.70	50	483	480	72.9	0.68
1 2001	E	1.02	50	835	830	34.4	1.41

Matching cut-off with appropriate inflow rate was the most effective method experienced to improve application efficiencies. In most cases, modification could be made at nil or low cost to the irrigator, yet resulted in significant savings in time, operation costs and water.

6.4 Alternate row irrigation

Irrigation of alternate furrows proved to be an effective method of improving efficiency and better utilizing scarce water resources. In some cases, where modifications to conventional systems were not particularly effective, an alternate row strategy improved efficiencies significantly.

The method was most effective when the irrigated area remained the same as for the conventional system, but the number of furrows reduced by half. Although inflow rate was higher, advance rates were faster and more appropriate; when careful attention was paid to cut-off, significant improvement to application efficiency resulted. Water use in each furrow generally increased; however, total water use declined due to the reduction in furrows. Application efficiencies above 75% were generally achieved and applied water better matched requirement, especially for initial irrigations, eg rates of 68 mm, 67 mm and 33 mm were representative of applications achieved.

6.5 Soil structural problems

Evidence of soil structural problems and their influence on soil water was found in each soil type monitored. At red ferrosol and red kandosol sites, a significant reduction in the infiltration rate and storage of water occurred around 30 cm below soil surface. The effect on stored water is graphically illustrated in Figure 2. Data indicated that in some cases application efficiency was improved by reduced infiltration of this nature but scheduling difficulties were apparent where reduced storage capacity was recorded.

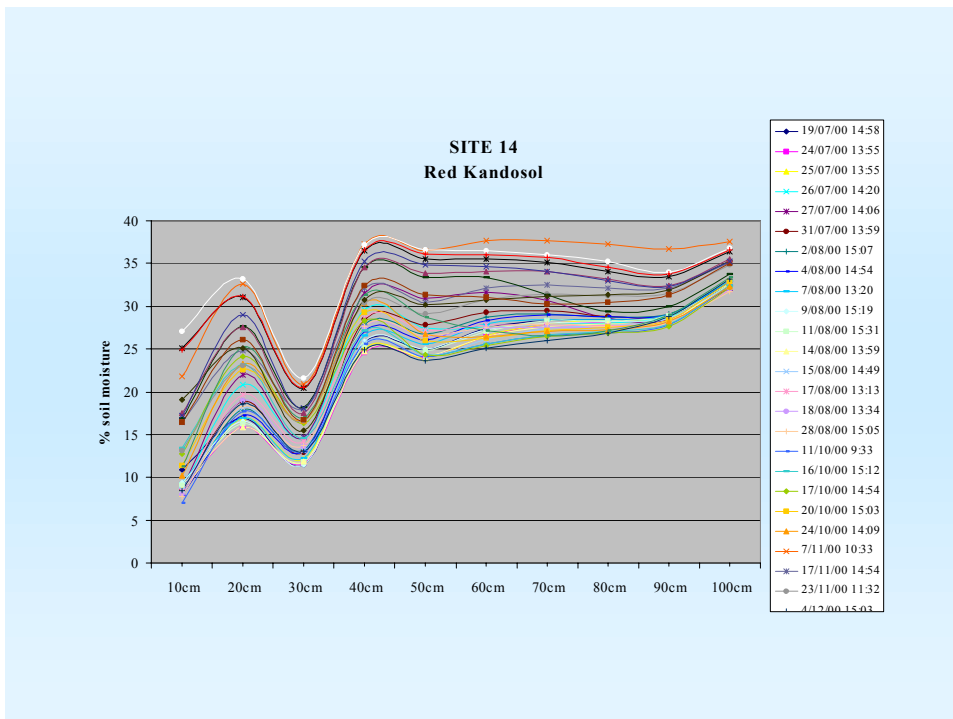
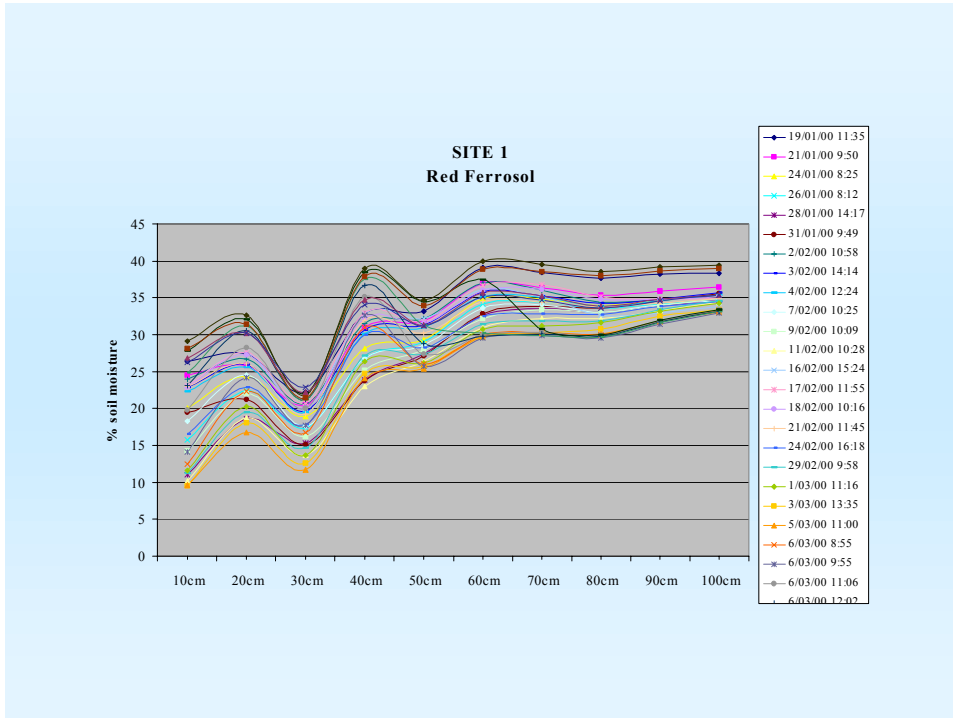


Figure 2 - Illustrating reduced water storage capacity of a red ferrosol and a red kandosol at approximately 30 cm below soil surface

6.6 End-filling

The practice of letting water run for a significant period after it has reached ends of rows to achieve a thorough wetting of row ends was shown to be extremely wasteful. Deep drainage losses were severe and, if rows were not banked, outflow was extreme. The wasteful nature of this practice is depicted in the SIRMOD evaluations in Addendum 7. Similarly, prolonged cut-off while waiting for “slow rows” to reach ends resulted in heavy losses.

SIRMOD evaluation and monitoring of recession time showed that very little or no end filling was necessary with a majority of irrigations. *Essentially, the most efficient results occurred when rows were shut down on reaching the end of the field.*

Additionally, it was found that where high inflow rates were applied to absorptive soils, cut-off prior to water reaching the end of rows was most efficient.

Given these findings and allowing that all rows will not reach the end of the field simultaneously, it was recommended that:

- (a) all row ends be blocked;
- (b) “fast rows” should be shut down individually when water reaches the end;
- (c) full shut down should occur when water has reached the end of most rows irrigated on the shift.

6.7 Growth

Growth measurements were monitored at the same time and frequency as soil moisture during the January-March 1999 and 2000 'boom growth' periods. Crop response to irrigation and rainfall varied widely and, on occasions, seemed more influenced by light, temperature and wind conditions than by soil moisture. Table 5 shows that while response to improved soil moisture was rapid in some cases, it took at least seven days to reach peak growth rates in a majority of instances monitored.

Furthermore, run-down to half growth rate was reasonably fast – four days or less in 60% of cases – despite evidence of steady moisture extraction. Average response time to peak growth rate was 6.5 days, and run-down to half growth rate 4-7 days. Examples of growth rate relationships to soil moisture recorded in 2000 are provided in Addendum (8a, b and c).

The range of irrigation cycles indicated by growth rates varied widely also, and pointed to the importance of using some form of monitoring. Additionally, it highlighted the need to establish plant growth/evaporation relationships during stable representative weather where scheduling is based on pan evaporation.

Table 5
Response time to peak growth rate and run-down to half growth rate
following irrigation or rainfall – 2000 season

Site	Peak growth rate cm/day	Date	Days to reach peak growth	Run-down days peak to half growth rate	Indicated irrigation cycle (days)
1	2.25	24 January	6	4	10
	1.75	24 February	8	8	16
2	3.0	9 February	12	3	15
	2.5	25 February	4	6	10(Non-irri.)
	3.75	25 February	9	4	13 “
3	2.0	31 January	8	2	10 GCTB “
	2.25	23 February	8	5	13
	2.0	1 March	2	11	13(Non-irri.)
	2.0	31 January	8	3	11
	2.0	6 March	7	7	14
4	1.25	31 January	8	3	11
	2.75	1 March	5	2	7
5	2.25	24 January	4	3	7
	2.00	31 January	4	3	7
	2.25	24 February	3	7	10
6	2.75	9 February	6	2	8
	2.25	23 February	8	7	15
Aver.			6.5	4.7	11.2

6.8 Evaluation of tensiometers

Recognition of practical and financial constraints for irrigators to adopt reasonably expensive soil monitoring devices, led to comparisons between a Diviner 2000 capacitance meter and tensiometers, valued at approximately one-twentieth of the former. Tensiometers of three sizes – 30 cm, 60 cm, 90 cm – were placed near Diviner probes at the same row setting, and read at the same time.

Results correlated well, excellent on two sites ($r^2 = 0.89$) and fair on two others ($r^2 = 0.38$) where known infiltration problems were encountered. As illustrated in Figure 3, responses were good at 30 cm and 60 cm depths, but little reaction was recorded at 90 cm. Regression analyses of three additional comparisons are included in Addendum (9a, b and c).

The tests showed that, properly sited, tensiometers were suitable low-cost tools for assessing soil moisture and establishing irrigation schedules. The 30 cm and 60 cm tensiometers positioned as a set in a representative portion of a field provided a good practical option for this purpose.

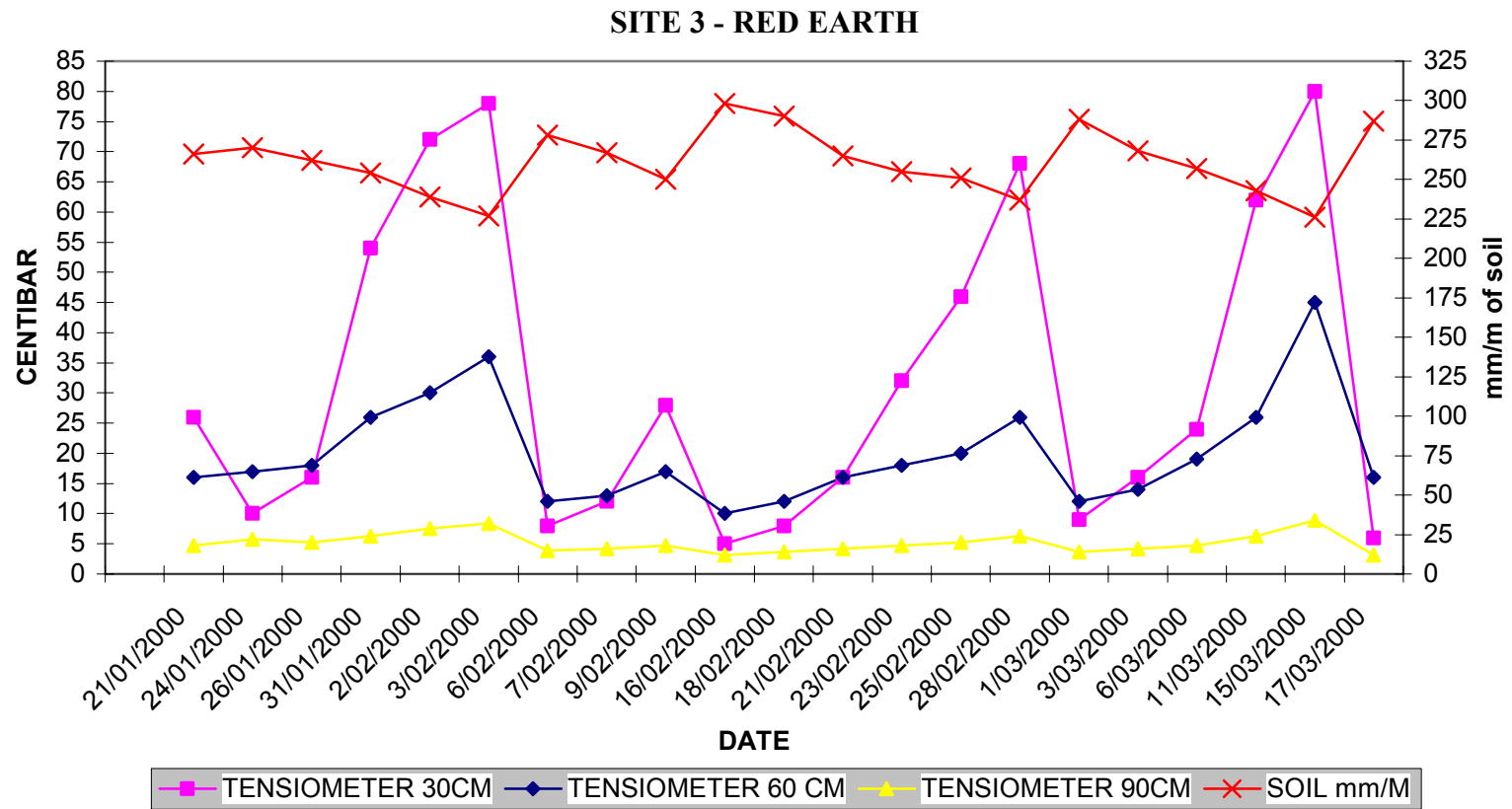


Figure 3 – Tensiometer readings (centibars) at 30 cm, 60 cm and 90 cm compared to soil moisture (mm/m) measured by Deviner 2000

6.9 Technology Transfer

Technology transfer primarily involved a grower participatory component centred around a monitoring program, which led to action planning. This was supported by demonstration and general extension of project outcomes to district growers.

Four grower participatory groups were established around the major monitoring sites. These were based on existing cell groups to achieve maximum commonality of irrigation factors (eg soil type, water source). Close liaison was maintained with site holders. As contributors to low efficiencies were progressively identified and modifications introduced to alleviate them, outcomes were quickly fed back to group members, mainly at a personal level. This process evolved at a pace determined mainly by the cooperators and their irrigation frequency. It was rapid in some cases, more measured in others.

Additionally, outcomes were discussed at a series of group shed meetings, which involved also other growers from the group localities. Eleven meetings were conducted in this manner and involved 70 growers. Collaboration with the State Rural Water Use Efficiency Initiative developed during the latter half of the program and involved a further nine shed meetings in the greater Bundaberg area. These involved 90 additional growers. Two district meetings designed to heighten awareness of efficiency issues and the means to achieve improved efficiencies (which attracted 170 growers) were also addressed on the outcomes of the project.

The program was supported by demonstrations and displays at several local field days including AgroTrend, BSES and Alloway field days. Live demonstrations of SIRMOD evaluations were given on several occasions including field days and workshops. Displays were also set up at industry functions such as the Annual Awards Presentations. Demonstration of monitoring activities were given on three bus tours.

A limited promotions campaign involved a number of small articles published in the local paper and a specialist magazine *Water Review*. Three short talks were given on rural radio and articles were included in industry newsletters. A feature article was printed in the *Sugarcane* magazine. A paper describing the project's outcomes was presented at ASSCT conference, 2001.

6.10 Action planning

As monitoring and evaluation activities identified contributors to low efficiencies, action plans were developed progressively to correct these. Changes were introduced very quickly in several instances allowing evaluation of modifications within the same irrigation season, and establishment of best practice for the future. This was best demonstrated on red ferrosol and red kandosol sites where SIRMOD dramatically illustrated that rapid drain-through and excessive end-fill were occurring. More suitable combinations of inflow rates and cut-off times achieved excellent, and early, improvement of application efficiency in these cases.

However, changes to physical layouts and cultural practices were more slowly introduced partly due to lack of opportunity and economic considerations. Grower practices also tended to revert when work-loads increased and less attention was given to irrigation.

Despite this, practices related to several factors affecting irrigation efficiency were modified and generally improved within the participatory groups.

6.11 Irrigation survey

Results of a grower practices survey conducted in 2001 amongst growers with reasonable exposure to project activities, have indicated increased awareness of factors contributing to poor irrigation efficiencies and changes to practices that reduce them. Comparisons with anecdotal data and expected norms point to positive trends in a number of practices that were demonstrated to effect efficiency. These are illustrated in Table 6, which shows also considerable potential for improvement in some factors. Full survey results are included in the Addenda.

Table 6
Grower irrigation practices in 2001

Factor	Practice	% growers conforming
Furrow shape	Broad based furrows	52
	Vee shaped furrows	48
Rows irrigated	Every row	51
	Alternate rows	49
Blocked ends	Ends banked	61
Type of cups	Hand-cut	79
	Moulded	21
Number of rows watered in a single shift	1st irrigation	21
	Plant cane	29
	Later irrigation	19
	GCTB	33
Inflow adjustment	Adjustments made:	74
	At quarter row length	18
	At half row length	6
	At three-quarter row length	29
	Shutdown*	47
Shut down fast rows	Shut down fast rows when water reaches ends	84
End-fill	Extend cut-off after water reaches ends	23
Tailwater	Tailwater return	34

* Adjustments often made on next shift

7.0 ASSESSMENT OF IMPACT

The major impact expected from the outcomes of this project relates to more efficient early season irrigation when over-watering appears to be relatively common and, at times, extreme. Efficient early irrigations will mean more water available later in the season when demand is greater. Additionally, growers could be expected to commence watering earlier than currently if concerns of running out of allocation too early are alleviated. A general improvement to irrigation efficiency would be expected to have a positive impact on yield overall.

The restrictions currently applying to water supplies at Bundaberg have caused a significant reduction in gross production and have a far greater impact than any other water related factor. However, data suggest that a 20% increase in efficiency could be expected on at least half the area furrow irrigated, equivalent to increased annual production of 70,000 tonnes. This could be achieved at minimal direct cost.

Additionally, problems related to deep drainage and farm run-off, such as accession of nitrates and pesticides to groundwater, would be reduced.

8.0 RECOMMENDATIONS

A major outcome of this project has been the demonstration of the importance of monitoring as a prerequisite to selection of operational settings. However, few growers use any form of monitoring system. Commercial monitoring services are available but, due to scale, these are basic and would probably not capture sufficient data for effective improvement to application efficiencies, particularly at block level. It is recommended that stronger promotion should be given by all organisations with an interest in irrigation to adopting monitoring as an integral part of irrigation practice. This will involve, at least initially, stronger extension of methodology and instruments as well as back-up evaluation services. The latter could be provided by existing extension agencies and agribusiness and will apply just as strongly to other methods of irrigation.

Investigation of soil structural problems and relationships to irrigation efficiency bear further study.

9.0 PUBLICATIONS

A paper describing the outcomes of the project was published in the Proceedings of the Australian Society of Sugar Cane Technologists, Mackay, 2001. A feature article based on the paper was printed in the *Sugarcane* magazine.

Linedale, A I, Haines, M G and Collins, J C (2001). Factors contributing to low application efficiency of furrow irrigation in the Bundaberg district. Proc. Aust. Soc. Sugar Cane Technol. 23:122-127.

Linedale, Tony, Haines, Maurie and Collins, Julian. Better furrow efficiencies from low cost changes. Australian Sugarcane 5 (4):3-5

Several small articles were published in local papers and newsletters during the course of the project, and short interviews given on local radio.

10.0 REFERENCES

Donnollan, T E, Wilson, P R, Zund, P R and Irvine, S A (1998). Soils and irrigated land suitability of the Bundaberg area, South East Queensland. DNR Land Resources Bull., DNRQ980142.

Stephens, C G (1962). A manual of Australian soils, Third edition. CSIRO, Melbourne.

Walker, W R (1993). SIRMOD. Irrigation simulation software. Univ. of Utah, Logan, Utah.

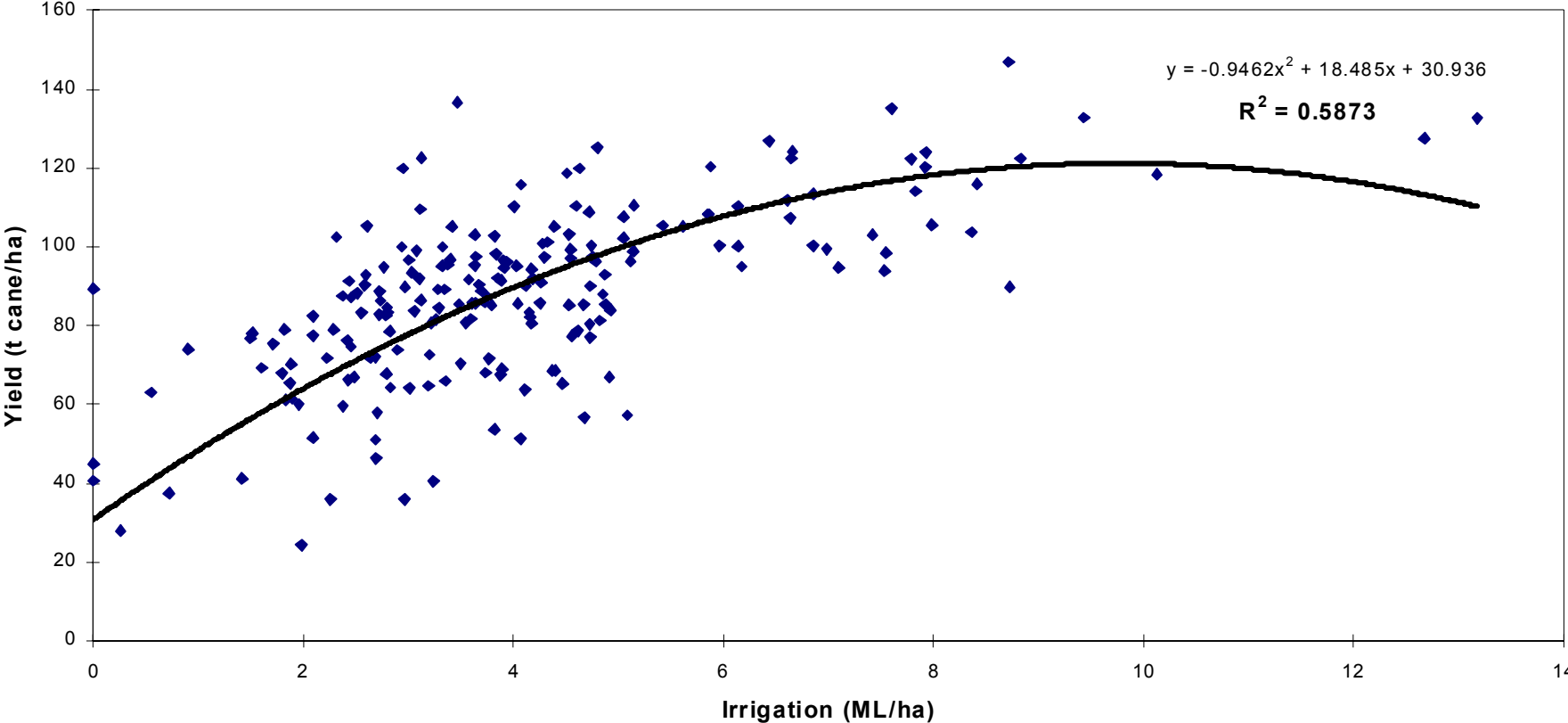
11.0 ACKNOWLEDGEMENTS

The assistance, patience and general cooperation received from the various site holders, on whose properties detailed monitoring was conducted, is gratefully acknowledged.

Special acknowledgement is made of co-workers Maurie Haines (Millaquin/Qunaba CPPB) and Julian Collins (BSES) for their active contributions to the project. Maurie Haines was responsible for the majority of monitoring and evaluation activities and deserves special recognition for these.

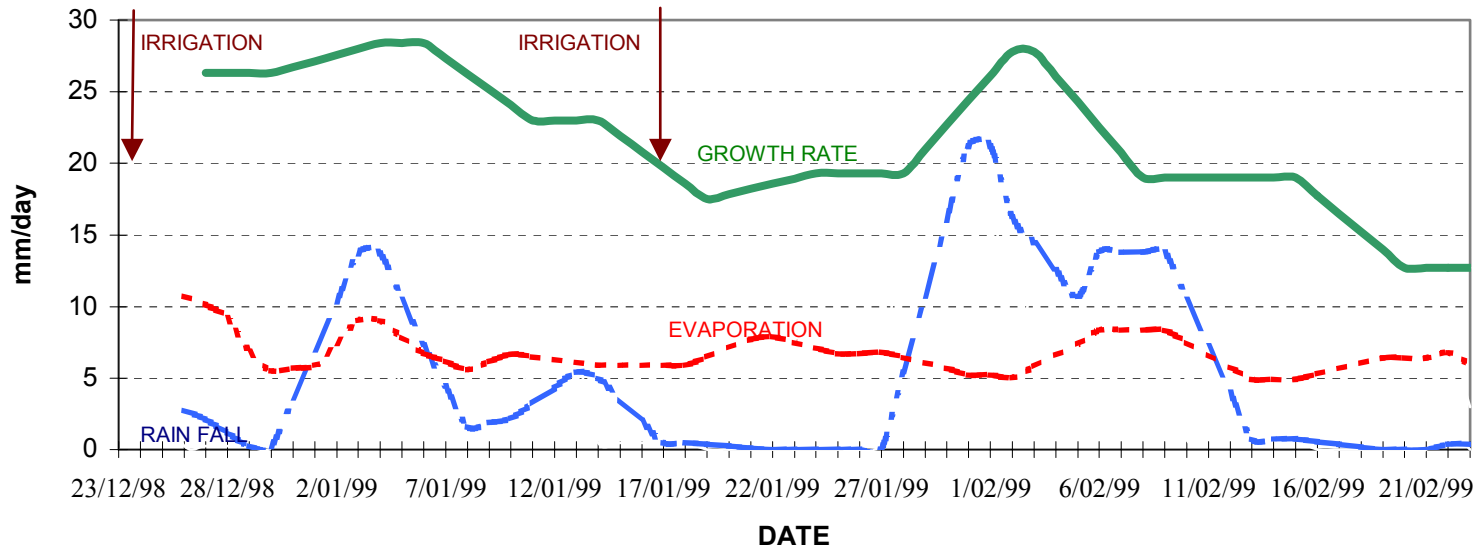
12.0 ADDENDUM 1

Yield and Water Use - Fairymead



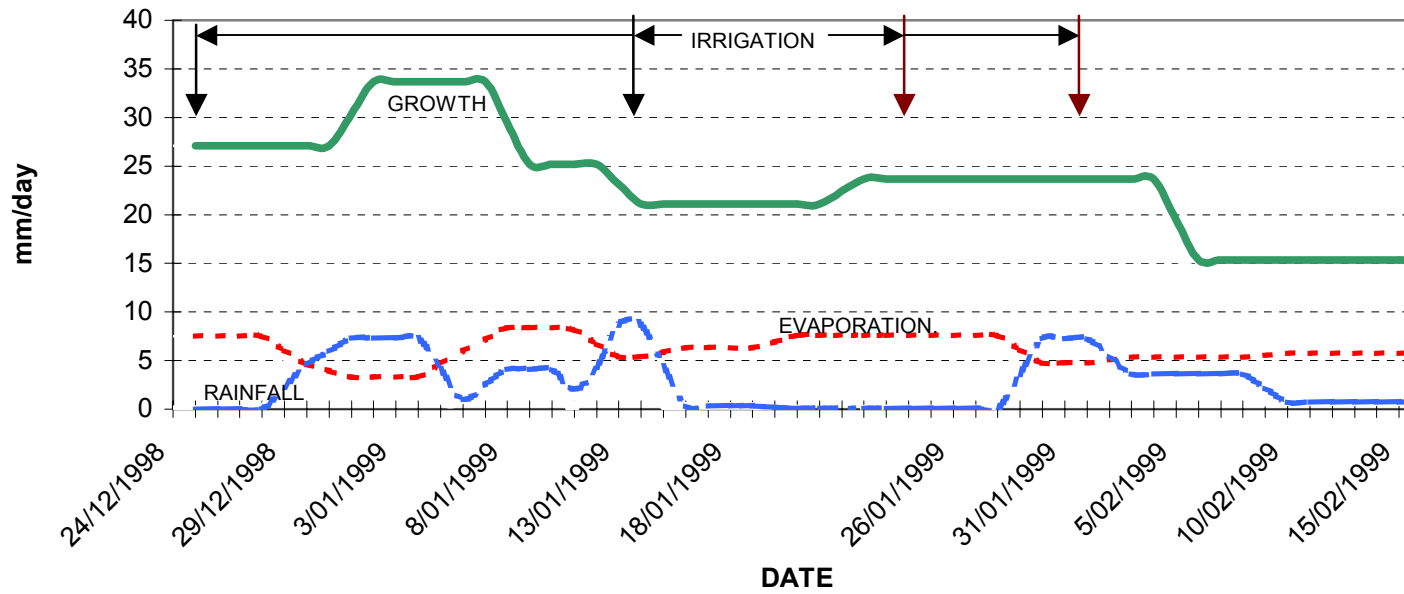
13.0 ADDENDUM 2

RED FERROSOL



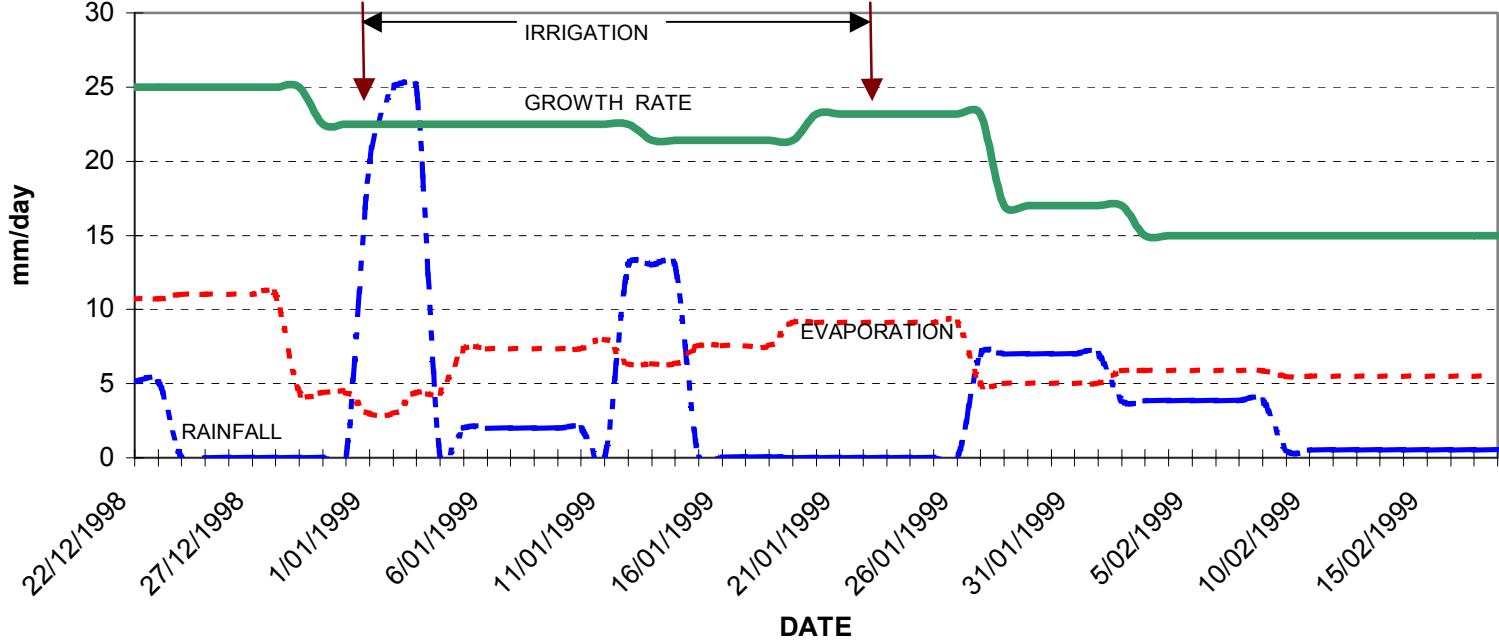
(a) Comparison of growth rate, rainfall, irrigation and evaporation - 1999 season

RED KANDOSOL



(b) Comparison of growth rate, rainfall, irrigation and evaporation – 1999 season

YELLOW DERMOSOL

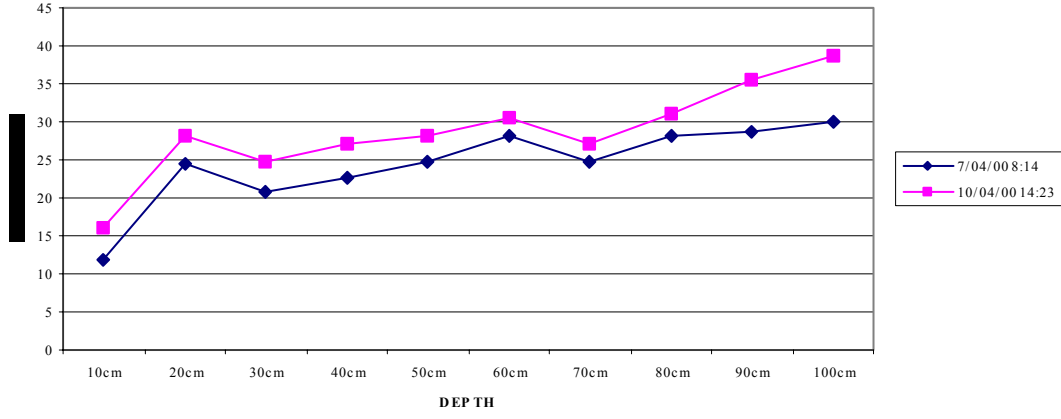


(c) Comparison of growth rate, rainfall, irrigation and evaporation – 1999 season

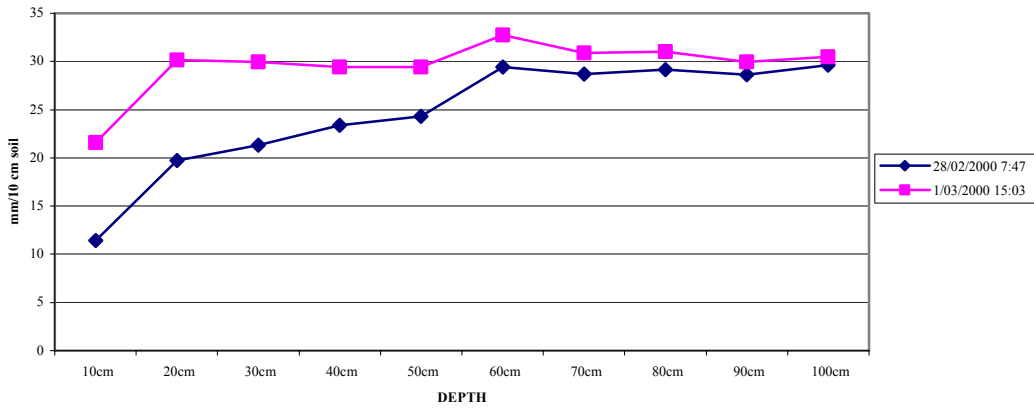
14.0 ADDENDUM 3

Pre- and post- irrigation soil moisture - Site 4 – Yellow Podzol

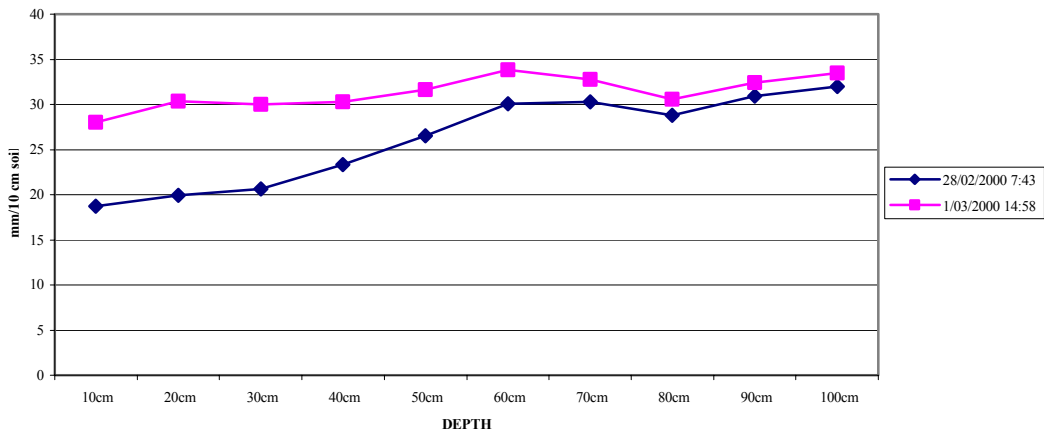
START OF FURROW



MID FURROW



END OF FURROW

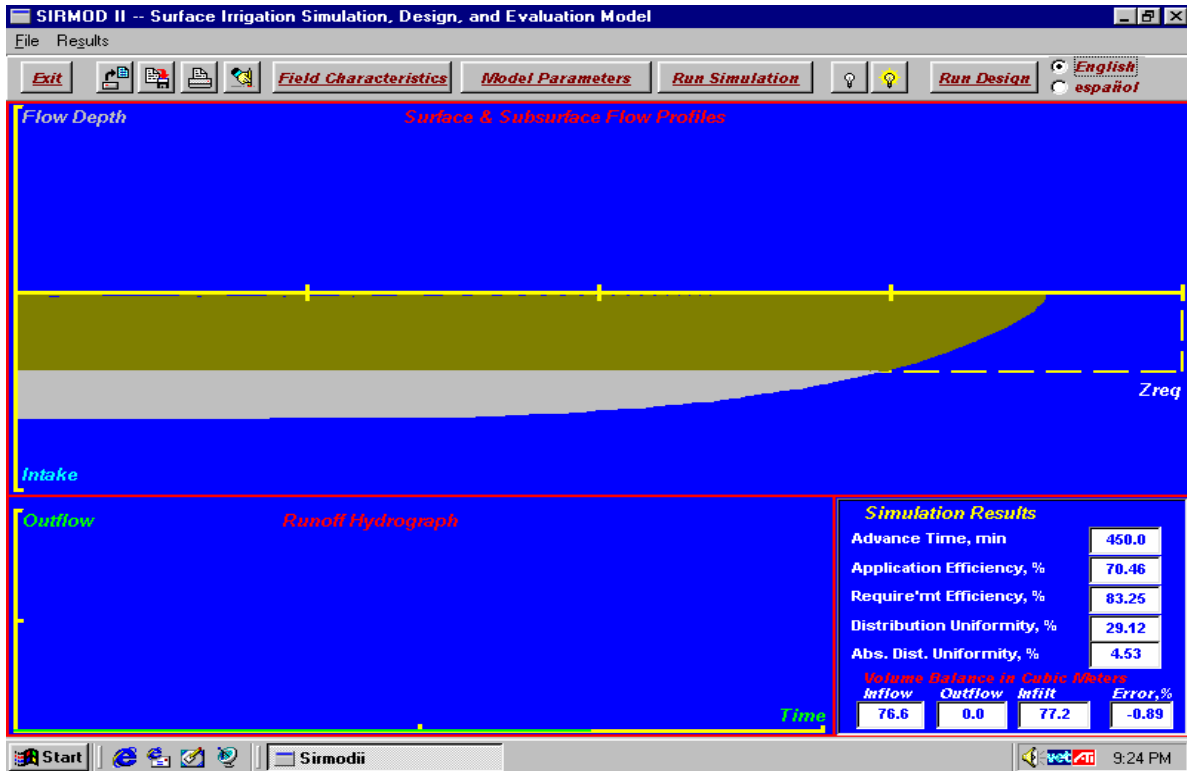


15.0 ADDENDUM 4

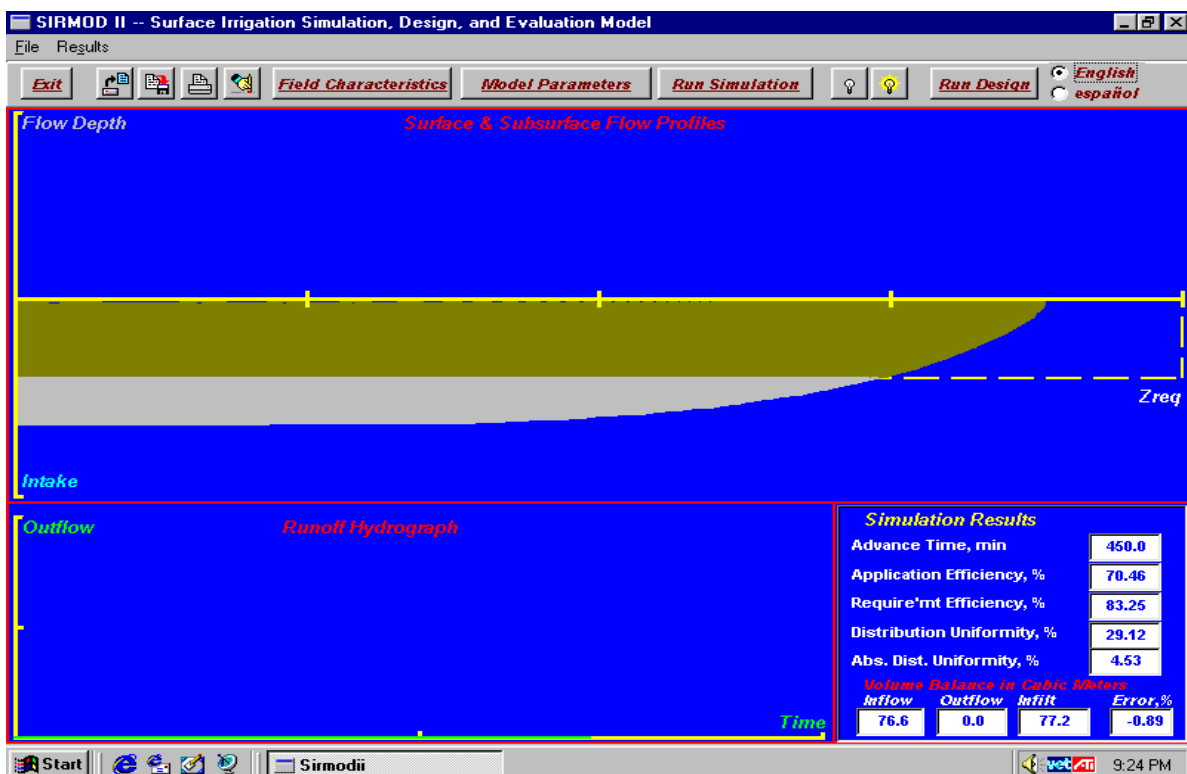
Deep infiltration resulting from low inflow and long duration

SITE : 3 RED EARTH

28/02/00

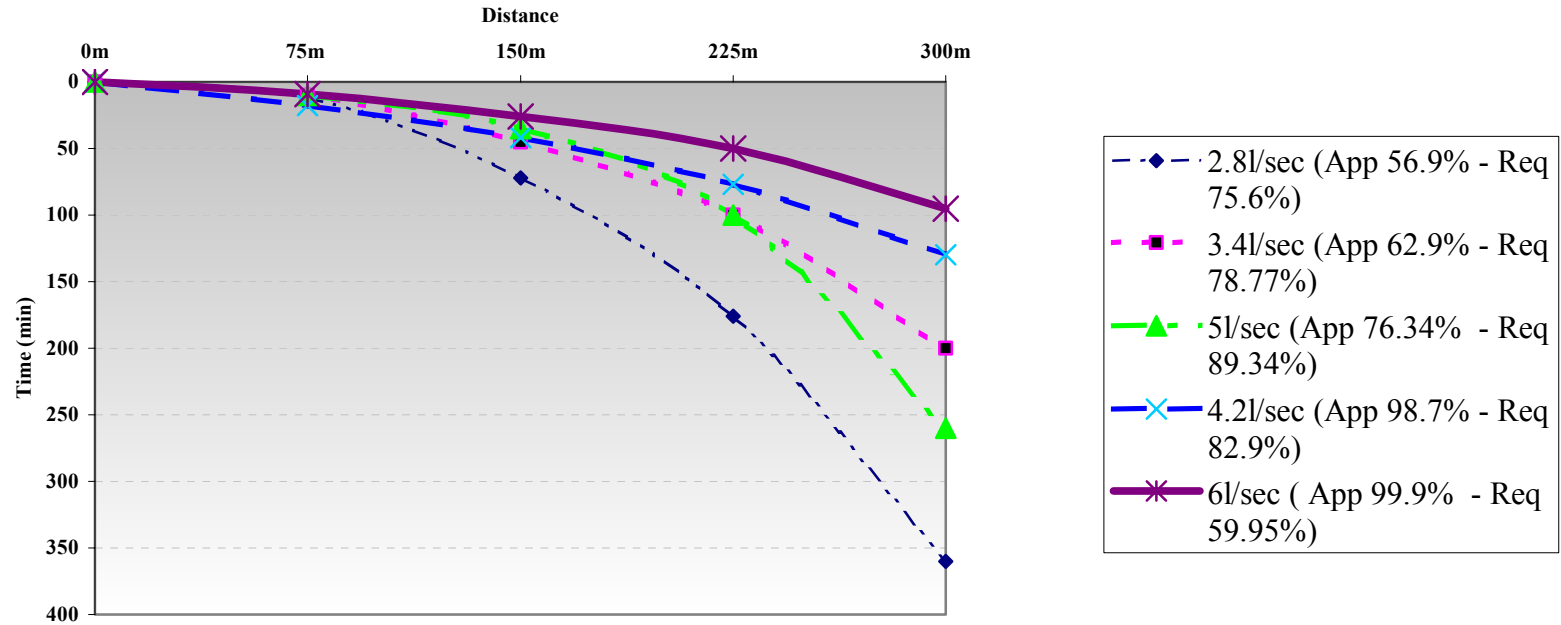


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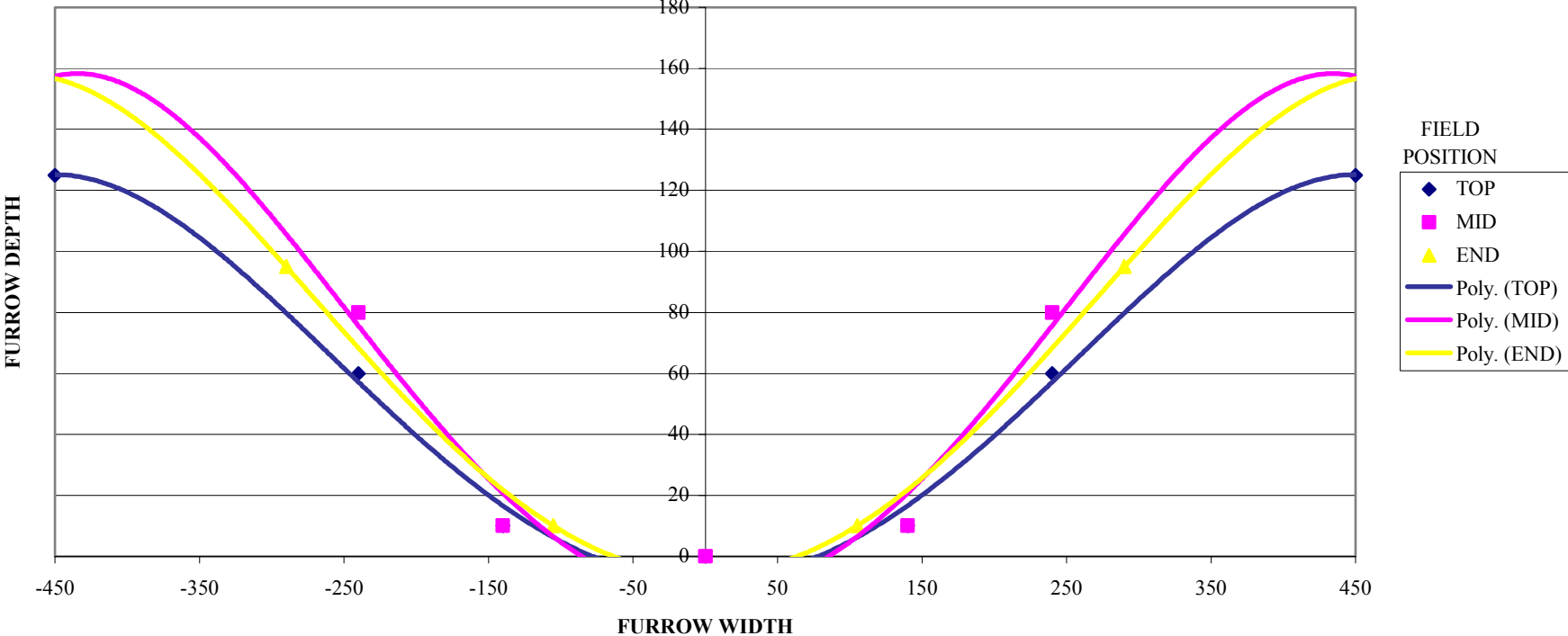


16.0 ADDENDUM 5

ADVANCE & EFFICIENCY RELATIONSHIPS
RED FERROSOL

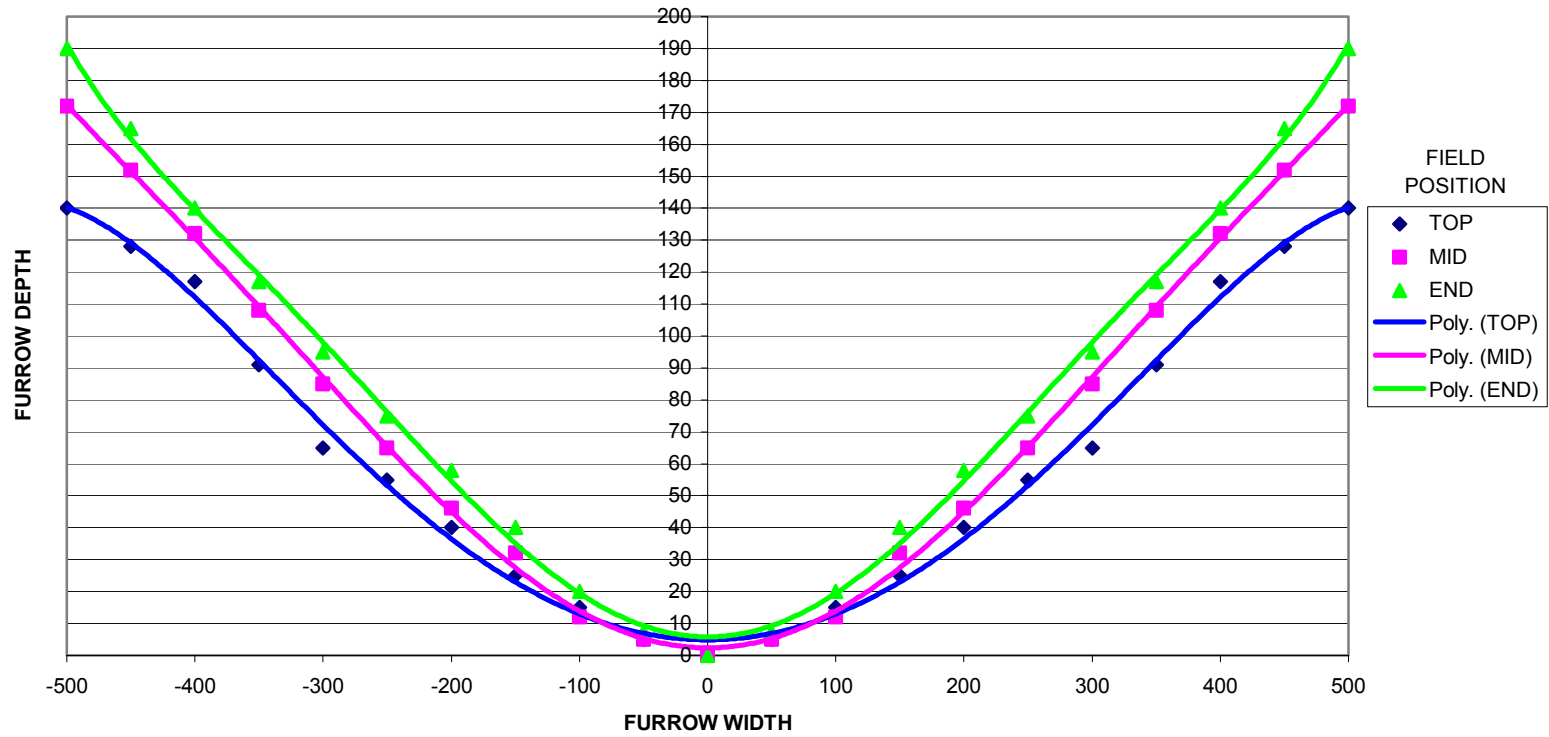


RED FERROSOL



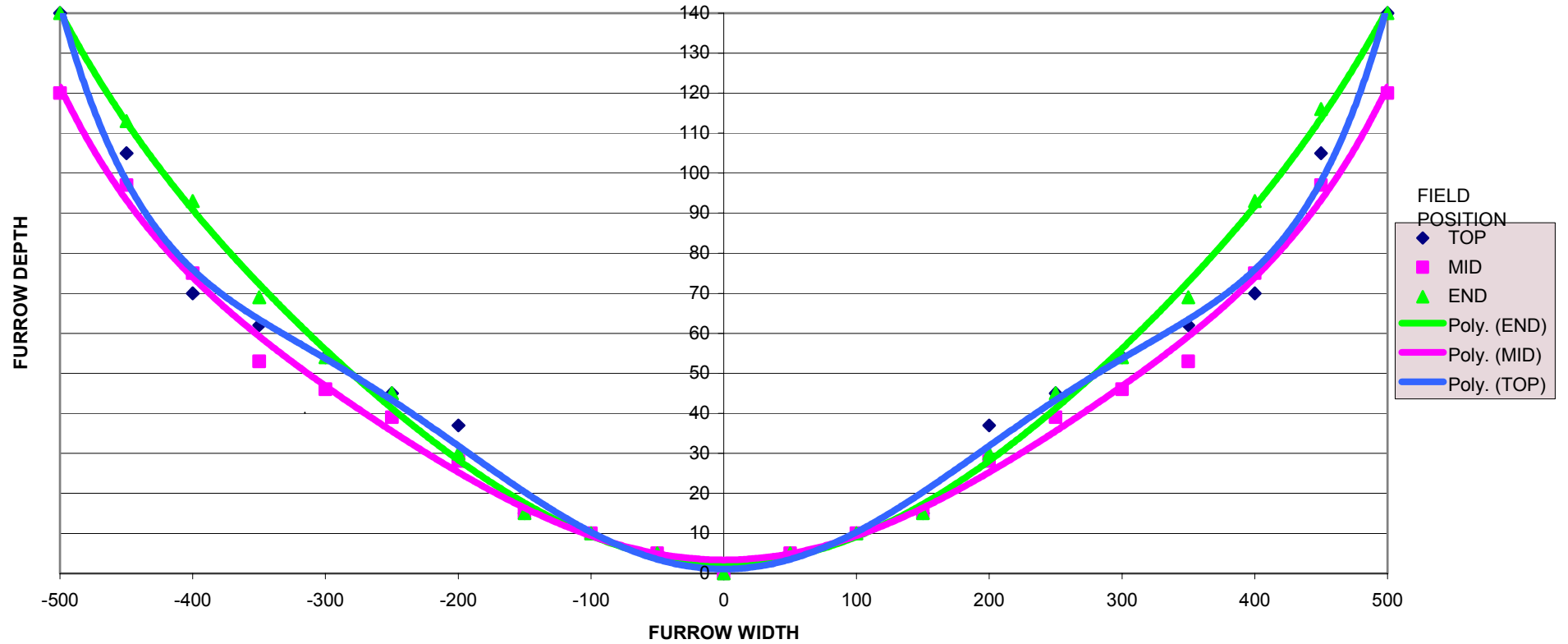
(a) Furrow shape – Red Ferrosol

RED KANDOSOL



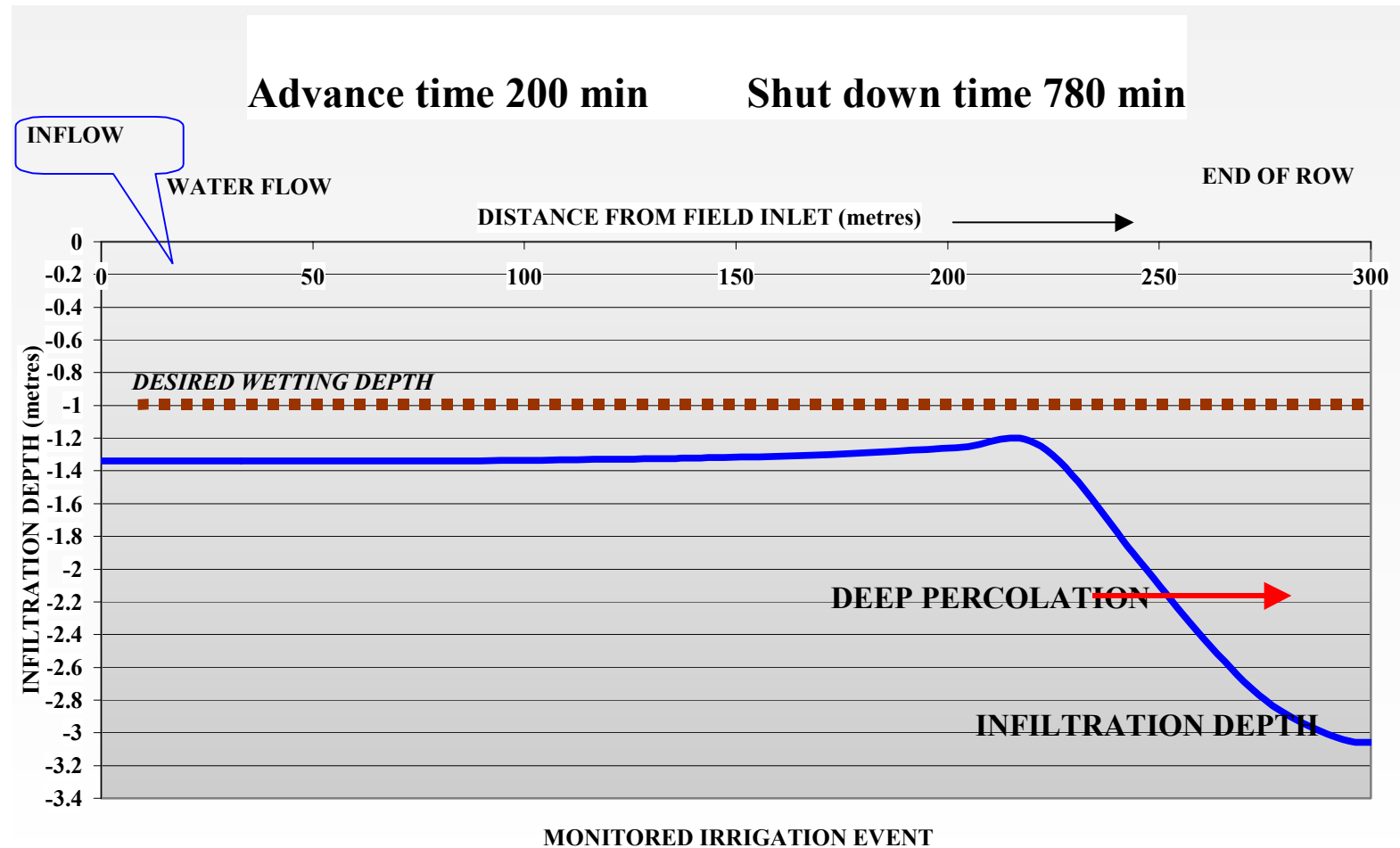
(b) Furrow shape – Red Kandosol

YELLOW DERMOSOL



(c) Furrow shape -Yellow Dermosol

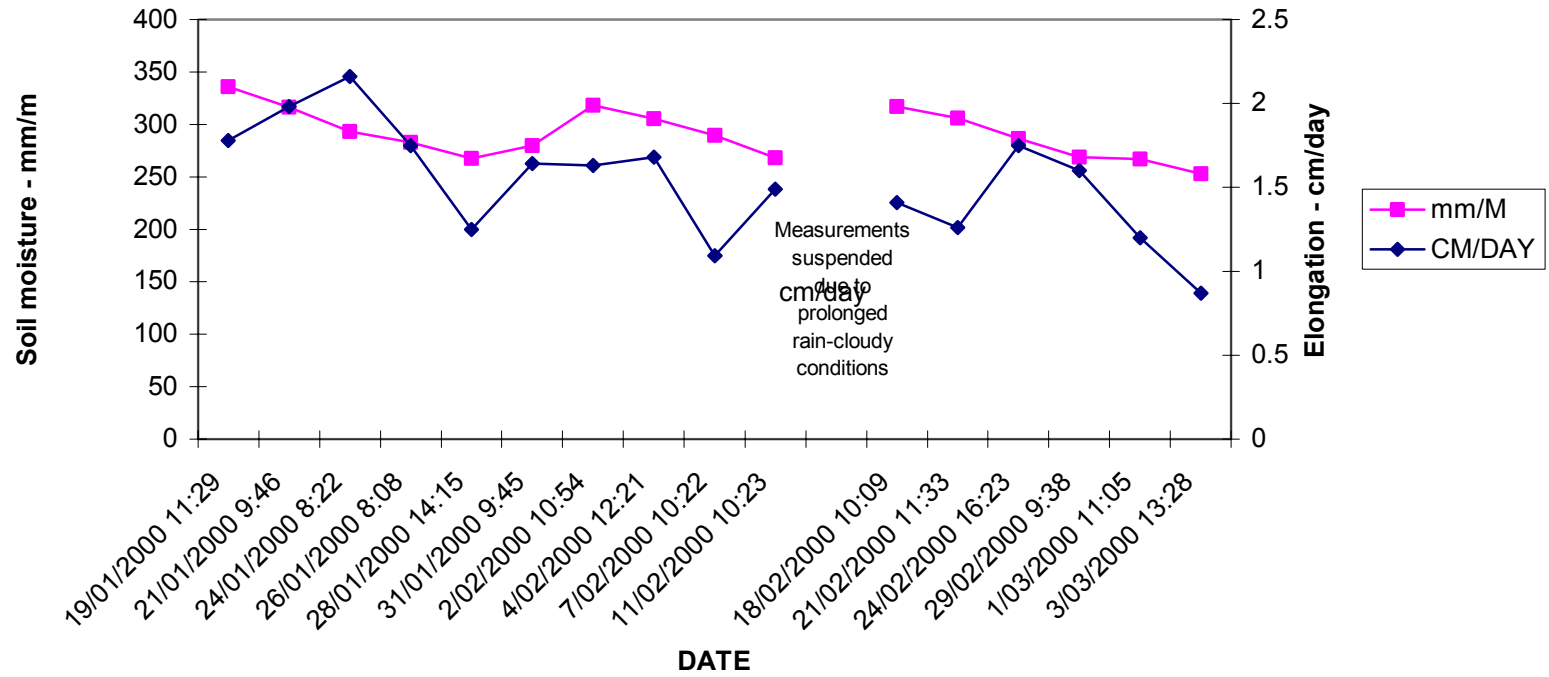
18.0 ADDENDUM 7



End- filling causes excessive infiltration loss

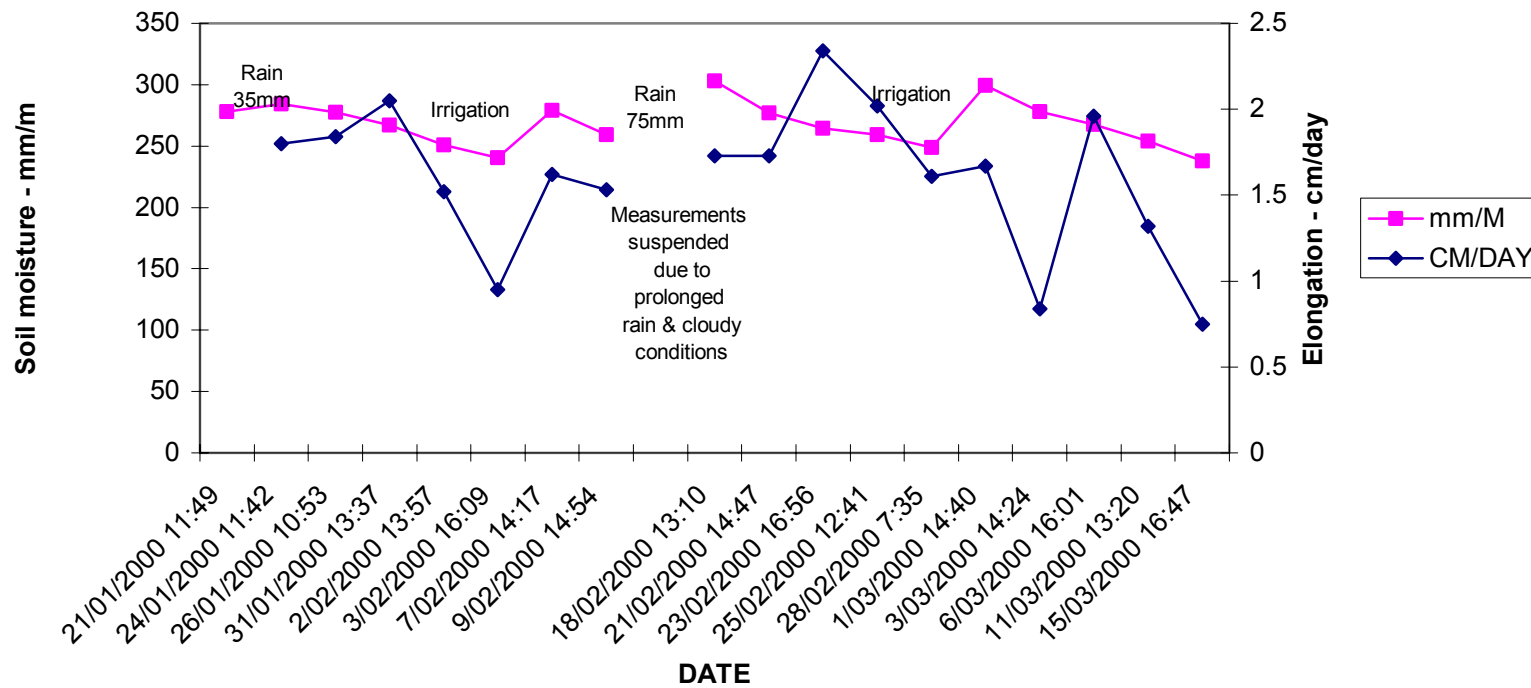
19.0 ADDENDUM 8

**SITE 1: RED FERROSOL (GCTB)
SOIL MOISTURE & STALK ELONGATION**



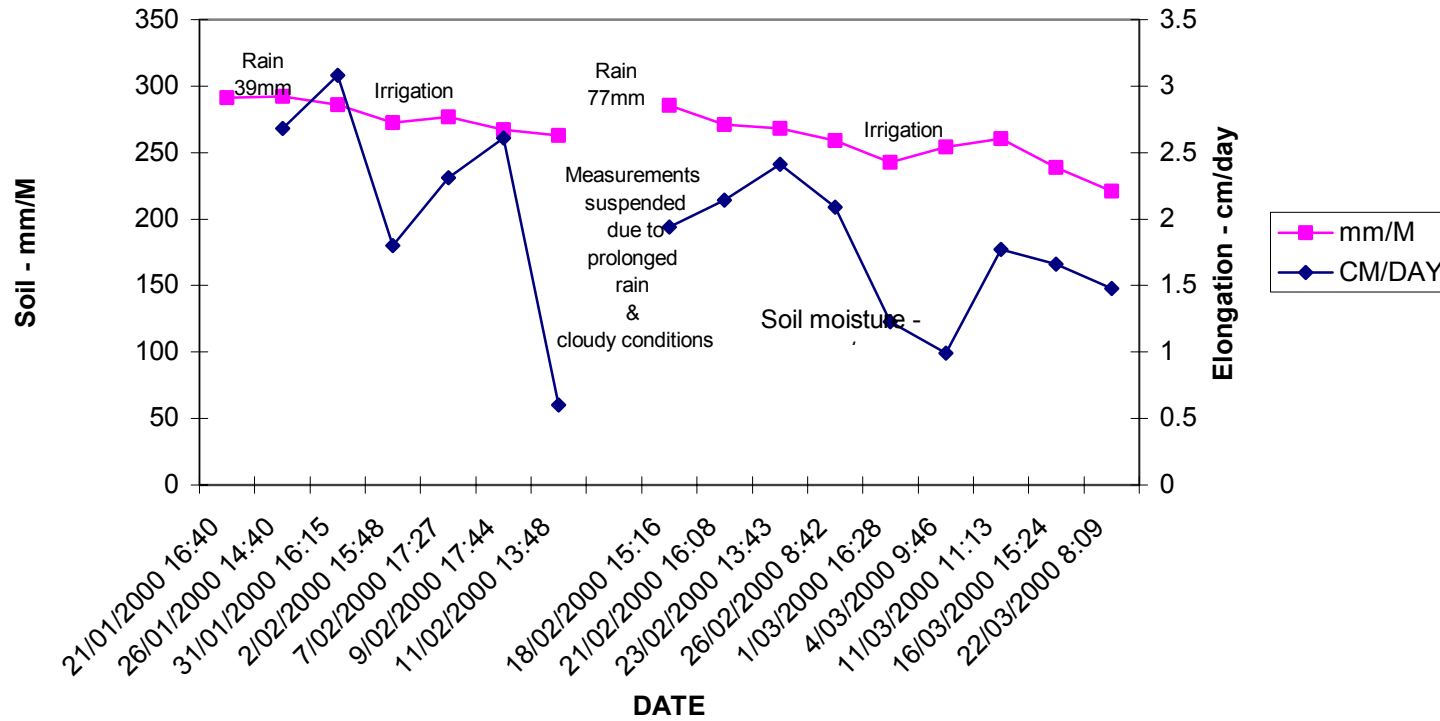
(a) Site 1 – Red Ferrosol

**SITE 3: RED KANDOSOL (GCTB)
SOIL MOISTURE & STALK ELONGATION**



(b) Site 3 – Red Kandosol

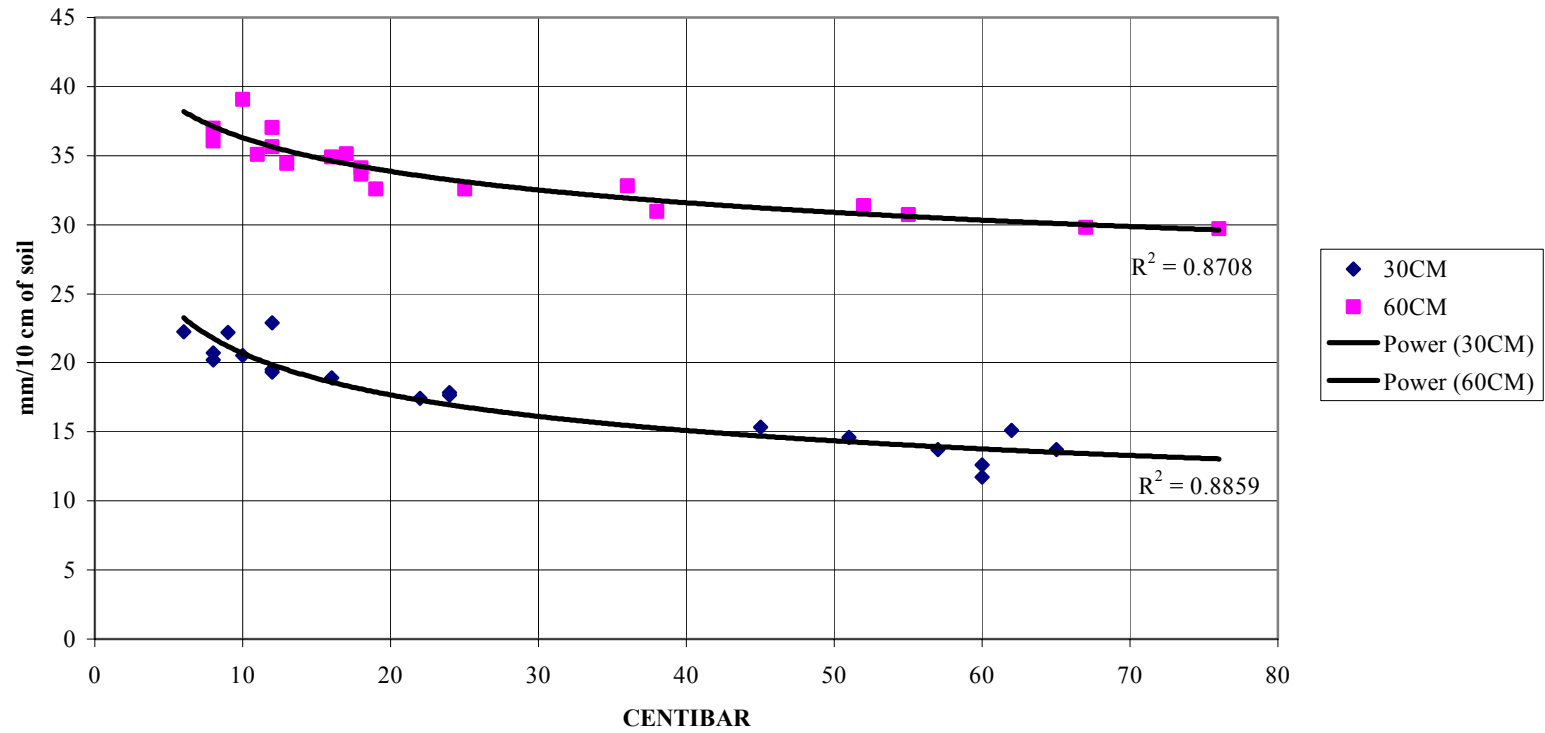
**SITE: 6 YELLOW DERMOSOL
SOIL MOISTURE & STALK ELONGATION**



(c) Site 6 – Yellow dermosol

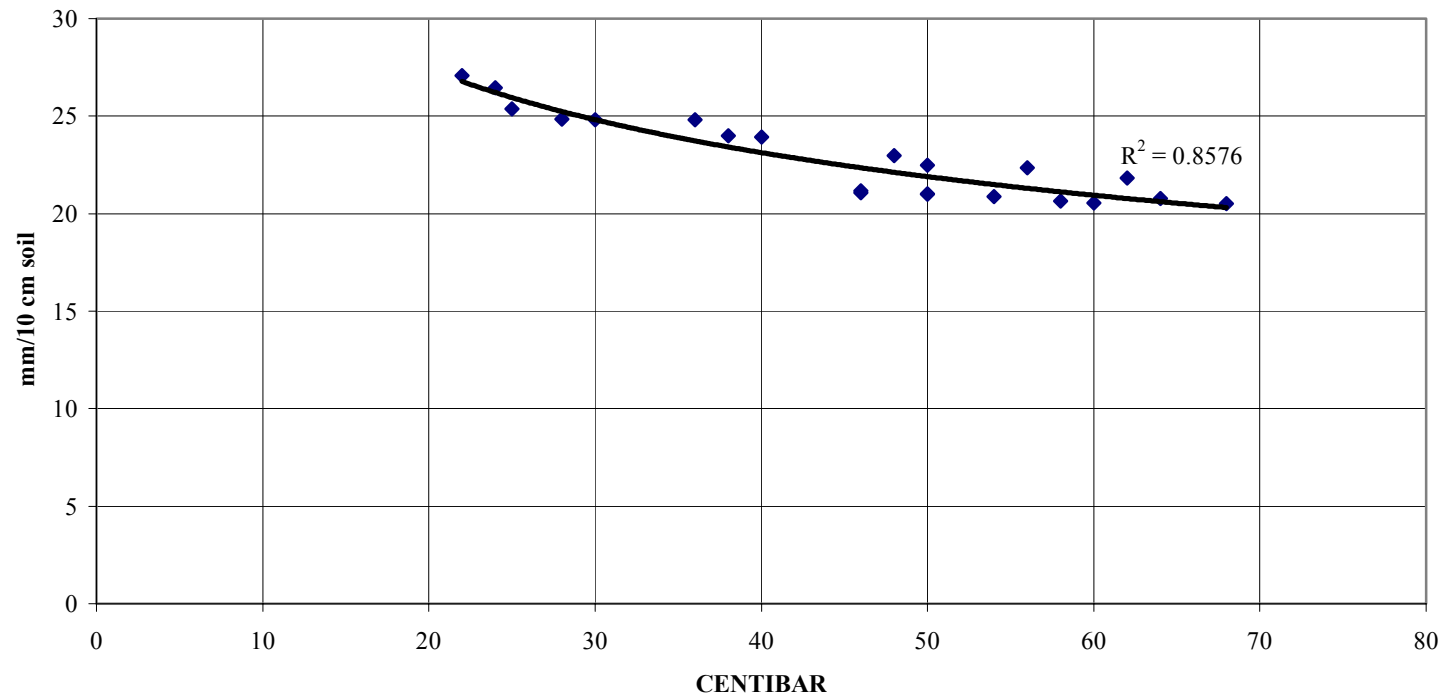
20.0 ADDENDUM 9

RELATIONSHIP OF TENSIMETERS TO DEVINER 2000 SOIL MOISTURE
Site 1 Red Ferrosol



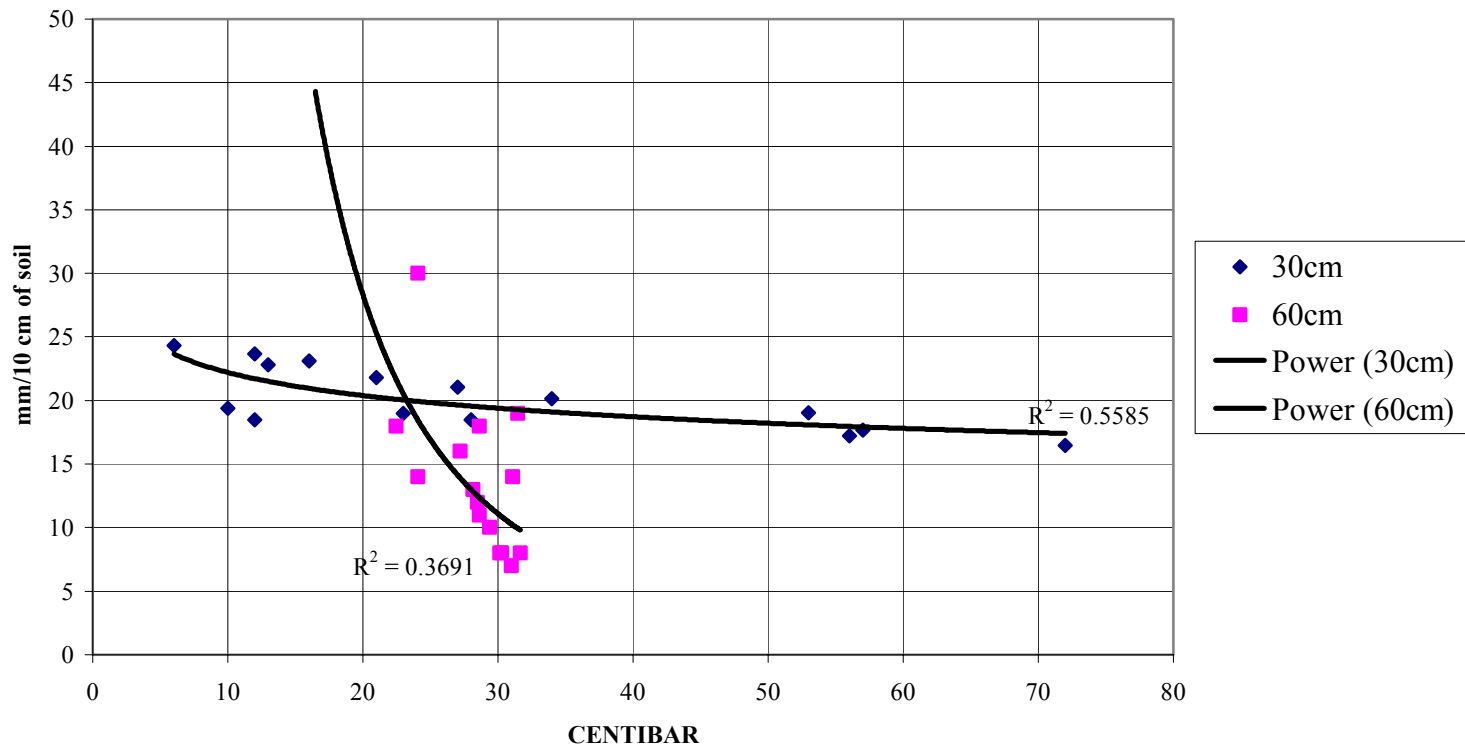
(a) Site 1 – Red Ferrosol

**RELATIONSHIP OF TENSIO METER (90 cm) TO DEVINER 2000 SOIL MOISTURE
SITE 5 RED EARTH**



(b) Site 5 – Red Earth

RELATIONSHIP OF TENSIMETERS (30 cm & 60 cm) TO DEVINER 2000 SOIL MOISTURE
Site 6 Yellow Podzolic



(c) Site 6 – Yellow Podzolic

FURROW IRRIGATORS' HANDBOOK

Bundaberg District

About this handbook

The nature of furrow irrigation means that the natural characteristics of soils, and our cultivation practices, have a direct and strong influence on its efficiency. If the operational settings do not suit the soil characteristics and condition, an uneven and probably wasteful irrigation will result.

This handbook sets out, in a practical way, how to manage the main aspects of furrow irrigation to ensure that the operational settings best suit the block conditions. Each of the major operational settings is considered, as are their effects on each other.

The guide also gives practical, low-cost ways to counteract problems, which lead to poor irrigation efficiency. By improving application efficiency, crop requirements are better met, and water available for irrigation is made that much more effective overall. This is particularly important under restricted water conditions.



Information contained in this handbook was derived from an SRDC irrigation monitoring project (BS206) conducted by BSES and Millaquin/Qunaba Cane Protection and Productivity Board, 1998 – 2001.

HOW MUCH WATER DOES YOUR SOIL HOLD?

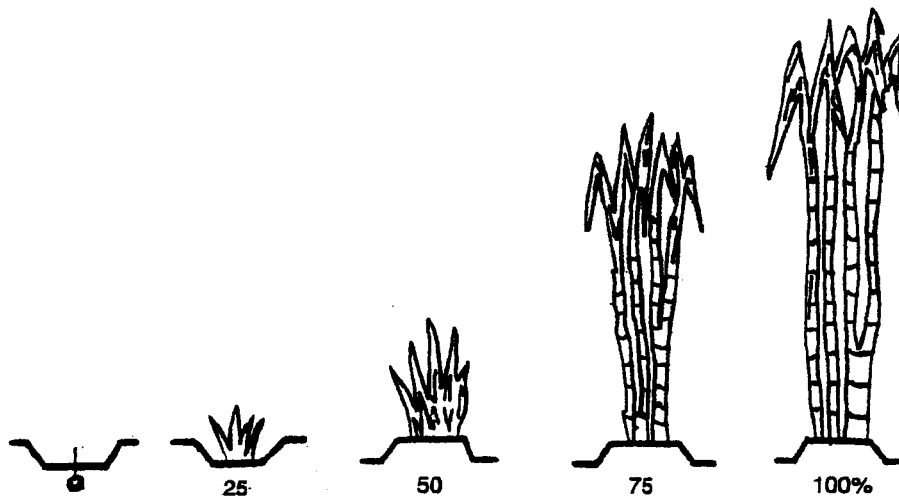
Bundaberg soil's have highly varying natural characteristics that affect furrow irrigation efficiency. The most important of these is how much water the soil can hold.

If the amount of irrigation applied exceeds this level, run-off and/or deep drainage will occur. Scarce water supplies can be wasted in this way, thus lessening the number of irrigations possible with limited water supplies.

One measure of a soils irrigation capacity is called Readily Available Soil Water (RASW). The table below shows the level of RASW for each common soil type in the Bundaberg district. **These levels represent the safe upper limit for the total amount of water applied in any single irrigation.**

Crop water requirements increase as growth takes place. Young crops require only low amounts of irrigation. For first irrigations (especially in loose soil conditions encountered in young plant cane and cultivated ratoons), apply half to two-thirds of the RASW value only as shown in the table. This will result in an adequate “starter” irrigation with virtually no waste, while maintaining the same irrigation cycle.

Readily available soil water and irrigation amounts for Bundaberg soils



Ground Cover

Soil type	RASW value (mm)	Early irrigation (mm) 50% ground cover	Mid-crop irrigation (mm) 75% ground cover	Later irrigation (mm) 100% ground cover
Grey forest	50	30	35	50
Yellow forest	60	35	45	60
Red forest	80	50	55	80
Red volcanic	80	50	55	80
Alluvial	60-80	35-50	45-55	60-80
Black earth	40-60	25-35	30-40	40-60
Sand	40	25	30	40

OPERATIONAL EFFICIENCY FACTORS

Extensive monitoring of furrow irrigation practices in the Bundaberg district has identified five important operational factors, which affect application efficiency.

These are:

- Inflow variability
- Inflow rate
- Advance rate
- Duration of irrigation
- Cut-off time

The five efficiency factors are closely related: if one is not suited to the conditions, it is likely to adversely affect the others eg highly variable inflow causes uneven advance rates, which results in some rows reaching the outlet end of a block well before the others. If the irrigation is extended to allow the “slow” rows to reach the end, heavy end-fill, or out-flow, is likely to occur in the “fast” rows.

It is important that the operational settings for the five factors are appropriate to achieve the desired amount of irrigation for the conditions prevailing in the block.

Correct settings can be achieved in the following ways.

Inflow variability

A major cause of variable inflow is unevenly cut cups. To remedy this, use only **moulded** cups, or cups cleanly punched with a properly sized hollow punch. Avoid hand-cut cups. Where gated fluming is in use, variations in pressure strongly influence inflow variability; minor adjustment to one or more gates alters the flow of the remainder.

Moulded cups come in different sizes, eg Chino cups - small (22 mm), medium (30 mm) and large (40 mm). Generally, cups with the larger holes are suitable for early irrigations (say 1st and 2nd), followed by the medium size during the middle irrigations, and the small size for later waterings. They are also useful when inflow rates need adjustment to match prevailing soil conditions, pressure differentials, and varying row lengths.

With gated fluming, **gate size** should be matched to inflow requirements: 38 mm (1.5 inch) gates are best for flow rates up to 3 L/sec, and 57 mm (2.25 inch) gates are best for flow rates up to 6 L/sec.

How to check

Check inflow at each cup or gate once delivery lines are full. Ensure that (a) the rate is appropriate, and (b) variability is no greater than + or – 7% from average. If inflow

reduces noticeably the further cups are away from the pump, reduce the number of outlets until inflow is more even.

Adjust inflow rates to suit soil type and condition as follows:

- Relatively **high** for absorptive, cultivated conditions and for early irrigations;
- Relatively **low** for fast setting, uncultivated and/or compacted conditions and for late irrigations;
- Decrease inflow rates as the irrigation season progresses.

A guide to suitable inflow rates for a range of usual conditions is shown in the table:

Soil type	Inflow rate (litres/sec)		
	Early season or freshly cultivated conditions	Mid-season and/or uncultivated or compacted conditions	Late season and/or uncultivated or compacted conditions
Red volcanic	4-6	2-4	2-4
Red forest and sandy soils	3-5	1-3	1-3
Grey forest, yellow forest, black earth	2-4	1-2	1-1.5

Advance

The rate at which water advances down a furrow is strongly influenced by:

- Inflow rate
- Size and shape of the furrow
- Slope
- Soil condition

A slow, uneven advance can lead to deep infiltration and high end-fill or run-off. Manage advance rates by adjusting inflow rates and ensuring correct furrow shape and size for the soil type and conditions.

Match the furrow shape and size with the absorptive capacity of the soil:

- Use **narrow V-shaped furrows for highly absorptive soils** such as red volcanics, red forest soils, and sandy soils;
- Use **wide, shallow furrows for soils with low absorption** characteristics such as grey forest soils, yellow forest soils, and black earths.

Tips

Time the advance on the first run in each block.

- If the time taken to advance in the second half of the block is *more than twice* that for the first half, *increase* inflow rate.
- If the time taken for the second half is *less than twice* taken for the first half, *decrease* the inflow rate.

Duration of irrigation and cut-off

The time taken for a single irrigation determines the total amount of water applied. This should be long enough to ensure an even wetting to the target depth, but not exceeding the water holding capacity of the soil. High inflow rates reduce irrigation time and generally result in application of *less* water. Heavy infiltration losses and/or run-off, and extreme wetting of the outflow end of fields occur when irrigation duration is too long.

- Ensure inflow rates, and advance rates, result in a suitable duration time for the soil type and its condition (see previous notes).
- Match inflow rate, row shape and size, and duration with the rate of advance and cut-off to achieve a total application not exceeding the RASW.
- Check that the advance is relatively even and there is no necessity to wait long periods for “slow rows” to come through.
- Bank row ends.
- Cut off flow in individual rows once water reaches the end.
- Where high inflows are applied to highly absorptive soils, consider cut-off *before water reaches the ends*.
- *Do not practise end-filling*.

Monitoring

Knowing how much water goes on, and where it ends up, are good practical indicators of irrigation efficiency. Relating water applied to growth of cane gives the irrigator the information needed to judge how much, and how often, water is needed. Monitoring of these factors can be achieved at low cost using a number of simple methods.

Total water use is easily monitored by recording water meter readings before and after irrigation takes place. Details of how to read various meters are on the back cover of this handbook.

Soil moisture levels can be monitored by use of **tensiometers** placed in, or near, cane rows. Using 30 cm and 60 cm tensiometers in pairs will provide a graphic picture of changes in soil moisture, and signal when irrigation is required.

Moisture probes such as Diviner 2000 and Enviroscan can provide rapid, accurate assessment of moisture down the soil profile and show rate of water use. Similar instruments are available at lower cost but are probably not as reliable as the two exemplified.

Comparing **growth measurements** to soil moisture levels, or those of a water evaporation pan, will also signal when irrigation is needed.

These techniques not only help select start-up times after rain, scheduling and other management considerations but also help prevent losses from over-wetting. As a result, scarce water supplies can be better used. The result is improved income for total water applied through an increase in marginal returns after core production expenses (fertilizer, cultivation, pesticides, etc) have been met.

A monitoring audit and establishment service is provided by Sugar Services. To find out how to set up a low-cost monitoring program on your farm phone 41 325200 for further information.

Tailwater and run-off

When it occurs, tailwater should be harvested and stored in small tailwater structures or on-farm water storages. These also trap run-off from rainfall thus providing additional water for irrigation. Run-off in the Bundaberg area approximates 0.7-1.0 ML/ha/year, worthy of saving where opportunity allows.

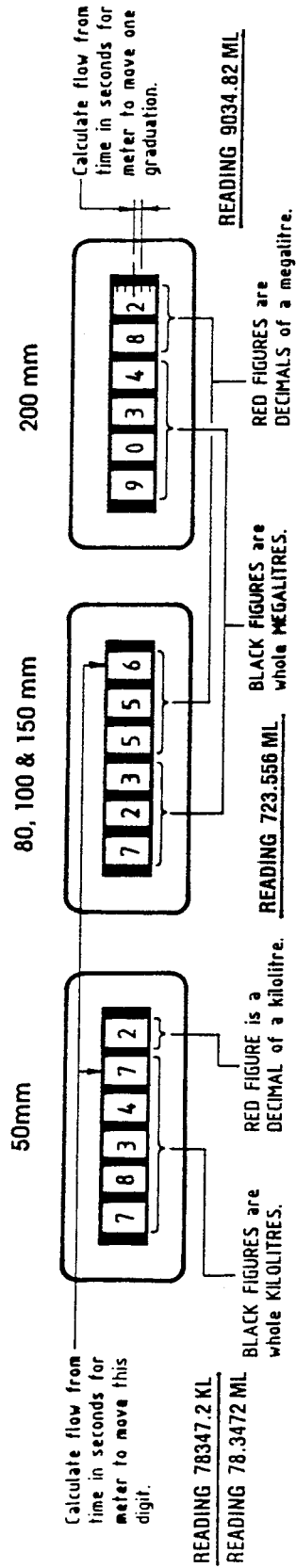
CHECK LIST

- Check that inflow from individual outlets does not vary by more than 7% from the average inflow.
- Adjust inflow rate to suit soil type and condition:
 - relatively fast for absorptive soils and/or cultivated conditions
 - relatively slow for fast setting soils, uncultivated or compacted conditions.
- Take particular care with first irrigations – use relatively high inflow and short duration.
- Use narrow furrows for highly absorptive soils, wide furrows for soils with low absorption.
- Decrease inflow rates with successive irrigations.
- Monitor advance times on the first run in each block:
 - increase inflow if time elapsed in the second half of the advance is more than twice that of the first half
 - decrease inflow if time elapsed is less than twice that for the first half.
- Adjust cut-off to ensure a controlled recession or end-fill. (This may mean cutting off before water reaches the end).
- Avoid long end-fills. Cut off “fast” rows once water reaches the end.
- Block ends.
- Where trash blanketing, form furrows and hill up rows adequately in plant cane to help maintain suitable row profiles in ratoons.
- Irrigate *alternate rows* in ratoons and past out-of-hand stage in plant cane, except where soils have poor lateral wetting characteristics.
- Adjust inflow to suit trash blanketing conditions.
- Try surge techniques where relatively long rows (>400 m) and low grades exist.

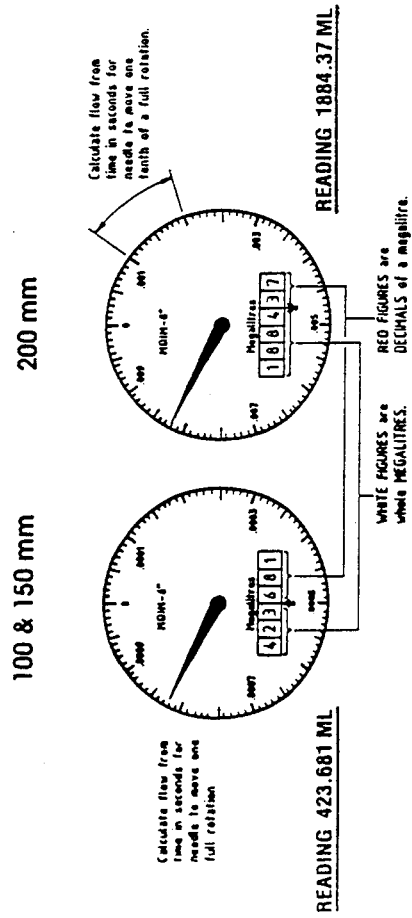
<p>For further information on how to check your irrigation operation settings, or for other advice on irrigation, call SUGAR SERVICES on 41 325200.</p>
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HOW TO READ YOUR METER & CALCULATE FLOW RATE

DAVIES SHEPHARD METERS



BADGER METERS



RMC METERS

