FINAL REPORT

PROJECT NUMBER : CSR - 35

PROJECT TITLE : An Assessment of Surge Irrigation in the Burdekin.

Furrow irrigation is the natural choice for sugarcane. It is relatively cheap to operate and generally not capital intensive, However in operation furrow irrigation has distinct limitations. It is generally inefficient in its use of water with 50% utilisation being a typical figure (Stewart 1988). With pumping costs being greater than $2 per tonne cane and QWRC water charges being $32 per megalitre for farms on channel supply, there is a need to increase efficiency in order to save money,conserve water resources and guard against rising water-tables and salinity.

With furrow irrigation the furrow is both the source and the sink of irrigation water. The advance of the water down a dry furrow is typically much slower than the recession of water in a wet furrow except for short or flat furrows which are blocked. Inevitably the upper reaches of the furrow receive more water than lower down. To ensure adequate watering of the lower reaches irrigation water is often allowed to run off to waste for some considerable time.

Surge irrigation is the application of irrigation water in pulses rater than continuously. If the off-phase is sufficiently long for the surface soil to dewater, it has been found (see Walker and Skogerboe, 1987) that when irrigation water is reapplied it rapidly advances over the previously wetted section such that less water is required to complete the advance phase of the irrigation. A more rapid advance gives a more uniform distribution of water. Because the irrigation on-time is only a portion of clock time (typically half) it allows better control of run off because irrigators have more time to interact with it.

OBJECTIVES :

The objectives for this project varied a little during its progress. Overall the objectives were:

(i) Determine whether tracking the wetting front advance is an appropriate method of assessing the performance of surge irrigation.

(ii) To compare the performance of surge irrigation and continuous irrigation by measuring the advance rate of the wetting front, inflow/outflow rates and the changes in soil moisture content.

(iii) To measure the performance of surge irrigation in replicated tests on individual furrows to determine the effects of soil texture, slope, inflow rate, furrow length, water quality, cycling time and cut-back.

(iv) To develop a set of recommendations for surge irrigation of sugarcane for various conditions.

(v) To determine the effects of surge irrigation on yields and water-use efficiency.

Meeting of Objectives :

The objectives were met but the outcomes were not necessarily as predicted or expected.

(i) Wetting front advance : Tracking the wetting front advance of a furrow irrigation is a definitive observation except in severely cracked clays. The use of Elliott's two-point method (Elliott and Walker 1982) to define the soil infiltration equation was reasonable for continuous irrigation and for the first surge of a surge irrigation.

With surge irrigation the advance/time curve is not continuous and is not as useful as it is with continuous irrigation. It is necessary to apply a separate analysis to each advance. Curves for the various surges should have similarities. Variances highlight chances in soils, slopes etc.

(ii) The most effective procedure for comparing surge and continuous irrigation is to compare the volumes of water supplied to complete the surface advance. This criterion is applied in most places (see Turral et al 1992 for example).

In the numerous tests done for this project responses to surge irrigation were achieved, but not always. The responses were generally no more than 19% and most times much less. Maximum responses were only found in plant cane at the first or sometimes the second irrigation. For one block with a sand lens through the middle, surge irrigation sometimes required more water to complete the irrigation than continuous irrigation, especially at low inflow rates.

(iii) The measurement of performance under various conditions showed some subtle responses to cycling times and inflow rates. Modelling needs to be done to extract the most from these nuances. The field data collected in this project should provide sufficient information for the validation of model studies.

(iv) A detailed modelling process was not part of this exercise. A number of possible recommendations remain undiscovered. However, a number of things can be said about surge:

a) There is a high probability of saving 20 - 30% irrigation water at the first irrigation after planting.

b) At later irrigations water savings are less likely.

c) By having a knowledge of the infiltration properties of a soil (say in the form of a modified kostiakov equation) it is possible to predict the likelihood of success or otherwise of practical surge irrigation in sugarcane, especially in consolidated soils.

d) Surge has real potential for controlling run off losses even when surge does not reduce the water requirement. Because water is on for only half the time, it is much easier to schedule personnel interaction and thus minimise run off. This feature makes it easier to schedule out-times for operator convenience.

(v) Surge irrigation was found to have no effect on cane yields, even where there were some water saving which indicated an increase in water-use efficiency in these cases.

RESEARCH RESULTS

1. Use of Volume Advance Ratio (var) for comparing surge and continuous irrigation performance.

VAR is defined as the average depth of water applied in surge flow divided by that applied in continuous flow for a similar field set up. It is the normal criterion of comparison used since the inception of surge irrigation in 1979 (Turrel 1992).

Where it has been shown that yields are not affected by surging this ratio can be used as a sole criterion for success.

2. Kostiakov - Lewis infiltration equations:

The most widely used infiltration equation in modern irrigation analysis is the empirical Kostiakov - Lewis equation in its modified form. The equation is:

$$I = kt^a + Ct$$

Where I = cumulative infiltration (mm)
t = opportunity time
k, a, C = empirical factors

C is in fact the measured long term or basal infiltration rate (units are usually mm/hr).

For furrows the wetted perimeter influences the rate of infiltration. This equation does not specifically allow for this. Generally variations in the wetted perimeter affect only the k factor.

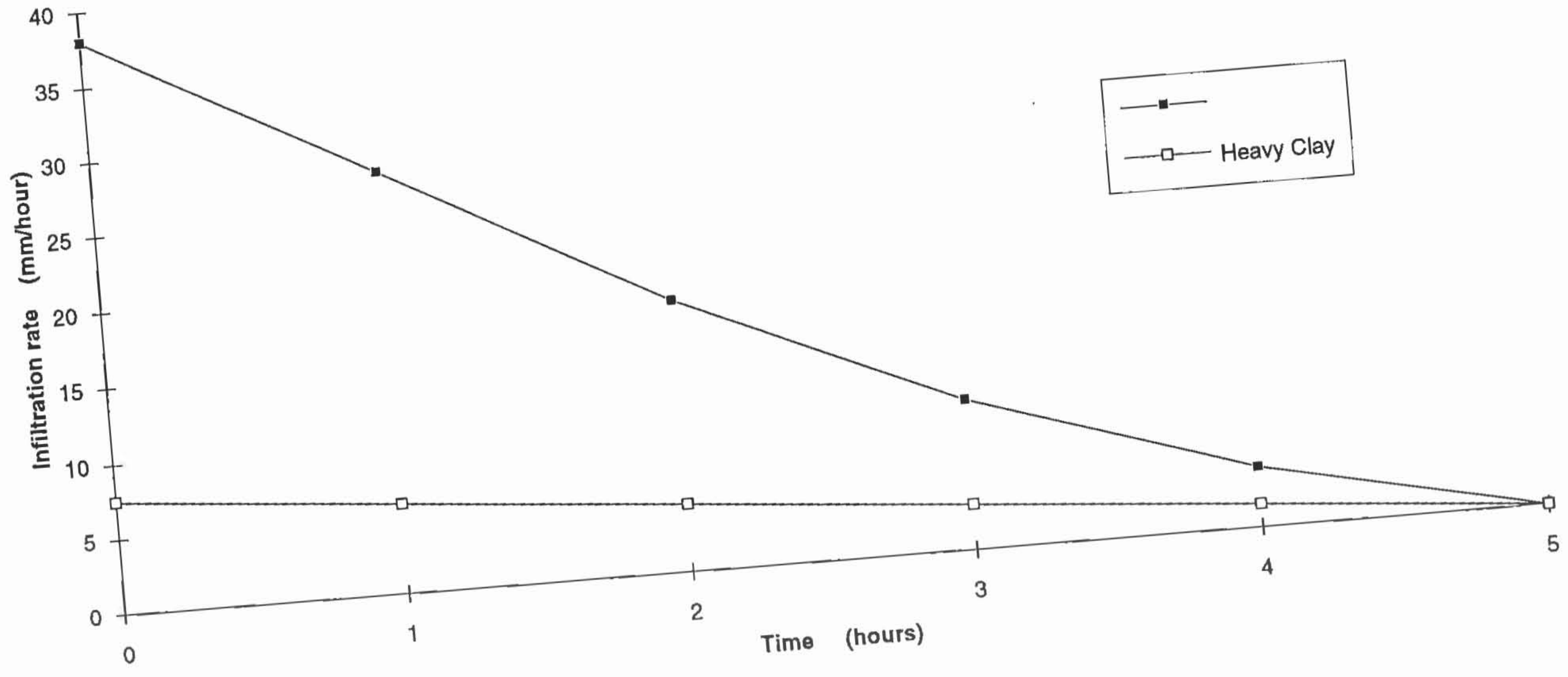
This equation is an integration of the infiltration rate/time curve of which Figure 1 (see appendix 1) is a schematic. The curves shown is the figure represent two different soils. Number 1 soil is a typical loam which has a basal infiltration capacity of 8 -10 mm/hour (around 200 mm/day) and reaches this condition after some five hours of infiltration opportunity time. Soils like this usually respond to surge irrigation. Number 2 soil depicts a heavy clay which has a low basal infiltration rate (1 - 2 mm/hr) and reaches this condition rapidly. These type of soils do not respond to surge irrigation.

Table 1 Kostiakov - Lewis Equations

Field	Equation	Comment
4	$I = 0.014t^{0.31} + 0.00006t$	
10	$I = 0.033t^{0.24} + 0.00034t$	Surge Worse
25	$I = 0.098t^{0.1} + 0.00007t$	
39	$I = 0.086t^{0.1} + 0.000084t$	Surge ineffective
48 i)	$I = 0.026t^{0.02} + 0.000158t$	Surge effective
ii)	$I = 0.08t^{0.1} + 0.00002t$	Surge ineffective
94	$I = 0.03t^{0.5} + 0.0001t$	Surge effective

Note: For field numbers, refer to seals at CSR Kalamia Estate, Ayr.

Figure 1 Typical Infiltration/Time curves



APPENDIX 1

The Kostiakov - Lewis equations for the various soils tested in this project were determined from irrigation advance/time curves for continuous irrigation using the two point method (Elliott and Walker 1992) or the curve matching technique (Elliott, Walker and Skogerboe (1983).

Equations from some of the fields used for experimental work are shown in Table 1. Comments as to the effectiveness of surge irrigation are included.

3. Comparison of Continuous and Surge Irrigations:

During the course of this work more than 30 irrigations were performed comparing surge and continuous irrigation. It needs to be noted that the surge cycle time and cycle ratio can affect its success. The cycle ratio is usually half on and half off, although there is evidence to suggest that a cycle of 1/3 on 2/3 off is better (Malano 1992). The equipment needed to provide this sort of ratio is a lot more complicated and expensive. Hump Lerys (1989) gives recommendations of 4 - 6 cycles per irrigation run. Modelling would be needed for optimisation. In general 4 - 6 cycles were used in most of the tests reported here.

In these studies some tests were done monitoring individual furrows, others monitoring banks of furrows and some on whole irrigation blocks. The virtues and weaknesses of these different methods are discussed below under the heading - Problems and Difficulties.

The following tables gives a selection of the results. Each table is self contained with comments about the results contained in foot-notes.

Table 2 Young plant cane in a sandy soil (individual furrow analysis).

Flow Regime	Flow Rate (l/sec)	Cycle Time	Depth Water (mm)
Continuous	2.71		105
Continuous	1.81		97
Surge	1.91	90 minutes	63
Surge	1.51	90 minutes	79
Continuous	1.31		115

NOTE: Depth of water is the average depth of water applied (volume/furrow length x furrow width) to complete the advance.

COMMENT: The surge irrigation significantly reduced the water requirement. The volume advances ratio was only 0.64.

Table 3 <u>Whole irrigation block data for 1988/89</u>

Field	Soil Texture	Date	Continuous (mm)	Surge (mm)
48	clay	Aug 88	169	140
		Oct 88	132	140
		Nov 88	150	155
5 (green)	clay loam	Nov 88	237	161
		Feb 89	148	131
5 (burnt)	clay loam	Nov 88	317	296
		Feb 89	216	147

NOTES: Water depths (mm) refer the depth required to complete the advance only.

COMMENTS: In the heavy clay soil (F48) there was a response to surge after a heavy cultivation - VAR = 0.83. However, at hill up and beyond the soil was apparently consolidated and there were no more responses to surge.

In the loamy soil (F5) there was a good response after cultivation (Nov'88) with a VAR = 0.68 and the response was maintained, but a lesser extent into February 1989 (VAR = 0.89). In green cane there was a small response at ratooning but a large response (VAR = 0.68) in February. An explanation of this is not clear. One would expect green cane to respond less to surge than burnt cane. Turral <u>et al</u> (1992) have reported a good response to surge on irrigated pastures which may have some analogy with green cane. They also report a better response on clays than sands which goes against most other data. Surge irrigation is still somewhat unpredictable.

Table 4 Small plot data 1989/90

Field	Soil Texture	Date	Contin (mm)	Surge (mm)
25	Sand/sandy loam	Dec 89	161	175
		Jan 90	146	210
		Feb 90	377	214
48	Clay	Sep 89	125	137
		Nov 89	168	154
		Jan 90	137	149
		Feb 90	122	90
		Mar 90	51	46
94 green	Clay loam	Oct 89	96	68
		Jan 90	159	125
		Feb 90	141	132

COMMENTS: F25 has a sand ridge through the middle of the block. This led to unpredictable irrigation performance.

F48 as in the whole block study (see Table 3) showed no response to surge either.

F94 with green cane gave an average VAR of 0.82 and a continuous response to surge over the season. This is similar to F5.

Table 5 <u>Small plot data 1991/92</u>

Field	Soil Texture	Date	Contin (mm)	Surge (mm)
11	Sandy	June 91	477	402
10	Clay	Apr 91	107	161
39	Clay	Nov 91	131	132
		Apr 92	105	106
82	Clay	June 92 (plant)	203	151
		Aug 92	113	169

COMMENTS: In the sandy soil for F11 surge irrigation was effective even though the soil was consolidated (VAR = 0.84). However, a large quantity of water was needed to complete the irrigation even with surge. This particular field needs sprinkler or trickle irrigation.

In F10 and F82 surge was not only ineffective in a consolidated soil condition, it required more water (VAR of about 1.50). Walton and Smith (1992) have reported increases in infiltration rate for short periods following the re-introduction of water after an off phase. In some cases this increased permeability may be maintained.

In F82 the watering of the just planted cane showed a positive response to surge (VAR = 0.74). This response was consistent in all my work. However, the next irrigation gave a negative responsive to surge.

In F39 there was no response to surge. Surge was not tested at the first irrigation, but was for all subsequent ones.

4 Water distribution

A more rapid advance of the wetting front should give a more uniform water distribution. Measurements of soil moisture content were made at a number of sites and at various positions down the furrow. Some data from Field 94 are shown in Table 6. In this field, there was a consistent response to surge irrigation. However, the measurements of soil moisture are quite erratic and no conclusions can be drawn regarding uniformity in application.

Table 6 An example of water distribution down the furrow after irrigating (neutron moisture meter data)

F94 green cane
length 500 m

Date	Surge/ Contin	Soil Moisture increment following irrigation					
		0	1/4	2/4	3/4	4/4	Aver
16/10/89	Surge	80	76	67	75	53	70
	Contin	92	66	69	34	41	60
06/12/89	Surge	14	30	3	51	79	35
	Contin	9	43	25	50	93	45
08/01/90	Surge	73	114	18	107	98	82
	Contin	22	114	88	94	94	82
01/03/90	Surge	44	52	94	73	72	67
	Contin	21	47	30	45	80	45

COMMENTS: These data are fairly erratic and no conclusion can be drawn as to whether there is a better distribution of irrigation water under surge.

5 CANE YIELDS

There was no consistent evidence that surge irrigation influenced yields, at least to the levels of precision available in these trials . Table 7 lists some yield data from the various blocks where surge and continuous irrigation were employed over the whole growing season.

Table 7 Yield Data

Year	Field	Area	Crop	Yield	
				Cont	Surge
1989	48	whole	burnt	154	142
1990	48	plots	burnt	122	115
	94	plots	green	121	124
	25	plots	burnt	111	111
1992	39	plots	burnt	71	71

NOTES:

Yield is expressed as tonnes cane/ha

COMMENTS:

It seems that yields are independent of the method of irrigation. The yield differences in F48 in 1989 were due to other factors.

CONCLUSIONS:

Surge irrigation of sugarcane has some prospect of success. It is possible to make some broad prediction regarding its effectiveness from a knowledge of soil infiltration properties. It is most effective just after planting, even in heavy soils.

Cultivation hilling up and continuously irrigating without relieving compaction consolidate the soil giving the mechanisms which make surge effective little opportunity to operate. Under these conditions surge is more likely to be an effective management tool to minimise run off rather than reducing the water requirement to complete the advance.

In green cane there was a consistent response throughout the growing season in two different fields. Although it is difficult to postulate a mechanism for why this should be so it is consistent with the recent findings of a consistent response to surge in irrigated pasture (Turral et al 1992)

PROBLEMS AND DIFFICULTIES:

When tracking the performance of individual furrows it was always difficult to ensure there was no side-ways movement of water either below ground (through cracks) or above ground through breaches in the furrows. Water flowing over the top was a serious problem in the test sites with green cane.

Where batches of furrows were monitored together rather than individual furrows, the problems of cross-flow are not so important. However, all furrows perform differently, so the end of advance is not clearly defined.

The determination of the soil infiltration function from wetting front advance data is difficult. There is no satisfactory calculation package available at present.

On the practical usage of surge irrigation in sugarcane, the following problems mitigate against its wide adoption:

(i) The automatic valves necessary to make it practical cost $2000 - $3000.

(ii) It is generally necessary to run an extra row of lay-flat to feed the surge valve. Due to space limitations, this can often be impractical.

(iii) Water savings are often not apparent especially post-cultivation phase.

(iv) It can be difficult to synchronise the surges and the end of the irrigation. If the out-time occurs, a quarter of the way through a surge on-cycle, any water saved in completing the advance could be lost in run off.

(v) There is a need for a physically based equation to describe infiltration rather than the empirical Kostiakov - Lewis equation. This will enhance our ability to predict where surge will and will not work.

FUTURE:

Surge irrigation would appear to have a limited future on heavy soils. However, it could be a most useful tool on the lighter country of Mackay, Proserpine and the Herbert Valley. In these districts, pressure irrigation is the normal method, when irrigation is used. Surge irrigation permits flood irrigation to be used where it normally could not be. Regrettably it is still unpredictable as to whether it will or will not work.

Future work for surge in sugarcane research need a high degree of modelling, using data generated in this project for calibration. New strategies in the field technique may then be devised. Further field testing could follow.

PUBLICATIONS:

Findings from this research project have been published in the following forums:

(i) Stewart, R.L. (1991). Irrigation advances: Mathematical modelling and surge irrigation. Poster Paper in Proc Aust. Soc. for Sugar Cane Technology. 13 p332.

(ii) Stewart, R.L. (1991). Surge irrigations in sugarcane. A seminar given to CSIRO Davies Laboratory Townsville, August 11, 1991.

(iii) Stewart, R.L. (1992). Surge irrigation in sugarcane. Poster Paper in Proc Inter Soc. for Sugar Cane Technology 2.1.

Technical papers are in preparation for publication in 1993 and 1994.

BIBLIOGRAPHY:

Elliott, R. H. and Walker, W. R. (1982). Field evaluation of furrow infiltration and advance functions. Trans ASAE. p396-400.

Elliott, R. H., Walker, W.R. and Skogerboe, G. V. (1983). Infiltration parameters from furrow irrigation advance data. Trans ASAE p1726-1731.

Humpherys, A. S. (1989). Surge irrigation. Two management. ICID Bulletin 38 (2) p49-61.

Malano, H. M. (1992). Innovations in surface irrigation. Proc Nat. Irrigation Conv. (Irrigation Association Australia), Melbourne May 1992 p171-189.

Stewart, R. L. (1988). The water-use efficiency of a Burdekin sugarcane crop. Proc ASSCT 10 p131-137.

Turral, H. N., Malano H. M. and McMahon, T. A. (1992). The evaluation of surge flow in border irrigation. Conf. in engineering in agriculture. (I.E.A.) Albury N.S.W. 4-7 October 1992. p137-141.

Walker W. R. and Skogerboe, G. V. (1987). Surface irrigation. Prentice - Hall.

Walton, R. S. and Smith, R. J. (1992). Modelling infiltration under surge irrigation. Conf. in engineering in agriculture (I.E.A.) Albury N.S.W. 4-7 October 1992 p 133-136.