

Water savings in broader-check irrigated pastures with fully automated fast flow irrigation technology

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Abstract

Water consumption in the irrigation sector has a perception of being a high water consumer, these perceptions are not wrong. Currently it represents 53% of total water consumption in Victoria (ABS, 2010). This body of work continues on what many others have achieved in understanding the efficiency of the practice of fast-flow irrigation (Gillies *et al.*, 2010; Smith *et al.*, 2009). Through few trials were conducted during the two month trial period due to a wetter-than-average summer, application efficiencies of over 99% were obtained for all trials. Comparatively such efficiencies for slow-flow irrigation have been shown to range between 46-86% (Smith *et al.*, 2009). It is universally acknowledged by many in the irrigation industry that fast-flow irrigation has the ability to reduce water consumption in the sector at a modest cost. It is this cost that is usually in the form of increased labor and technology requirements, thus a balanced approach to aiming to reduce water consumption and management of the associated costs is important to the success of any productivity improvement program.

Key words: irrigation, water, efficiency, Victoria, Australia

1. Introduction

The issue surrounding irrigation and its water consumption in Australia appears to be one of the major environmental and economic issues facing the agricultural sector this decade. Water consumption in the sector while reducing still comprises 53% of total water consumption in Victoria (ABS, 2010). The recent release of the Murray Darling Basin Authority's (MDBA) draft guidelines on the future of the Murray-Darling Basin (MDB) has only highlighted the need for attention in this area. Flood irrigation in Australia is part of our agricultural history and while it has served our economy well, the recent drought has highlighted the need for further improvement in this method of irrigation, and the need for a new paradigm. This project short studied into border check irrigation (BCI) aims to establish the most cost-effective method of improving the practice without the need to substantially upgrade existing infrastructure.

The practise of irrigating crops by BCI remains contentious, however studies have shown that efficiencies can substantially be gained by utilising higher flow rates though careful attention to cut-off times was critical to realising these gains (Gillies *et al.*, 2010; Smith *et al.*, 2009). Despite this, and other research into improving efficiency of this type of irrigation, it remains common practice to set the cut-off time when the advanced water front reaches two-thirds of the total length of the irrigation bay (Dassanayake *et al.*, 2009). It is this generic, 'rule-of-thumb' approach to irrigation that often results in major inefficiencies and excessive runoff. Furthermore, approaching irrigation in this manner can not only cost agriculturists in additional water costs, which could otherwise be traded as permits, and does nothing to lift productivity.

Although some deficiencies have been identified, surface irrigation has been shown to have its advantages in particular its low cost and low energy requirements (Khatri and Smith, 2006). Consequently this presents a significant dilemma for the industry as it is widely seen as any further increases to productivity in terms of water consumption per hectare of irrigated land, will likely result in higher labour and technology costs for irrigators (Smith *et al.*, 2009). However, there number of ways of improving the efficiency of BCI; automated operation based on real time sensor networks (Dassanayake *et. al.* 2008) and fast flow technology (Gill *et.al.* 2009). There are number of large scale field research are currently being conducted in Northern Victoria investigating how automation and fast flow water delivery method improve the irrigation efficiency and the economic water productivity.

Main objective of this short project was to understand and monitor advance wetting fronts under high flow water delivery regimes and use this data for generating a model to simulate the advance wetting fronts that could be used in real time automation of BCI.

However, the progress of the planned activities was seriously hampered by persistent unusual wet weather prevailed throughout the summer (irrigation season). Total rainfall from September 2010 to end of March 2011 was nearly 600mm compared to the historical mean annual of rainfall of 560mm. Therefore, we could monitor only three irrigation events during the period, which restricted the work significantly.

deemed to be a wet day). In addition the mean minimum and maximum temperatures were 9.15°C and 21.5°C respectively

3. Methods

Advanced front modelling aims to assess the effectiveness of fast-flow irrigation on efficiency, that is maximising infiltration and minimising unnecessary runoff. Under each irrigation event an array of Odyssey Capacitance Sensors will measure water depth over time as indicated in Figure 3.1.

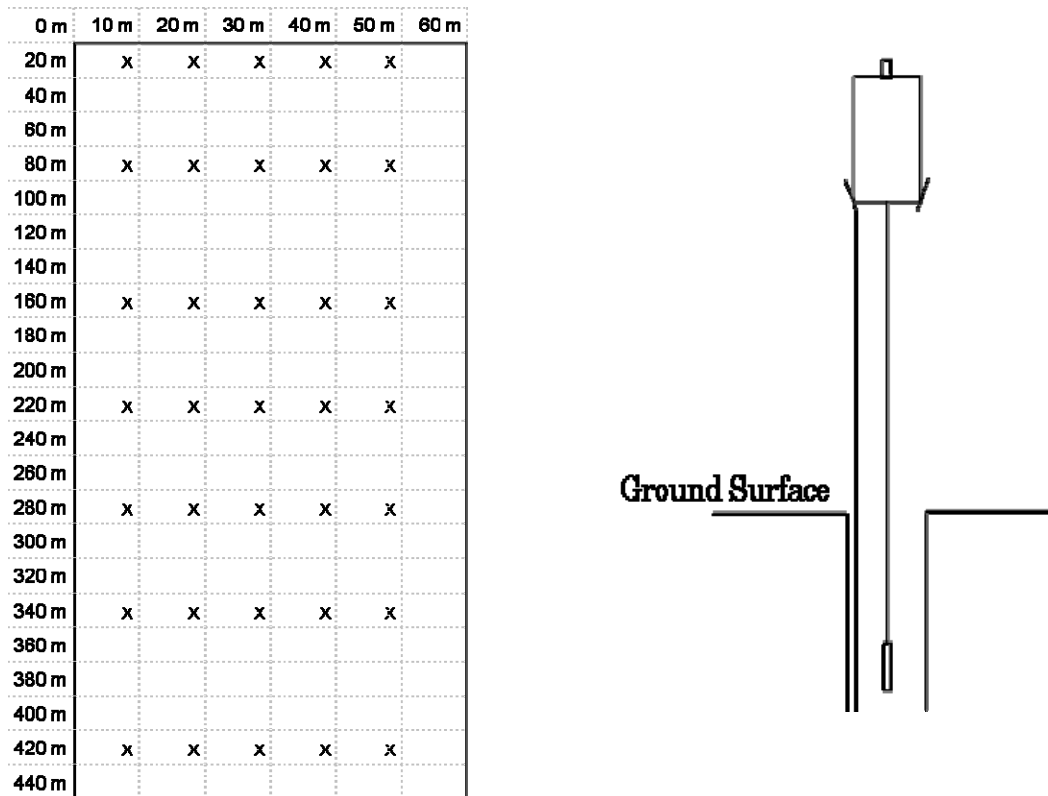


Figure 3.1: (a – LEFT) Geometry of field and Location of Odyssey sensors
(b – RIGHT) Schematic of Odyssey sensor in soil.

Data associated with each trial will be downloaded and the key points of baseline, peak, and recession.

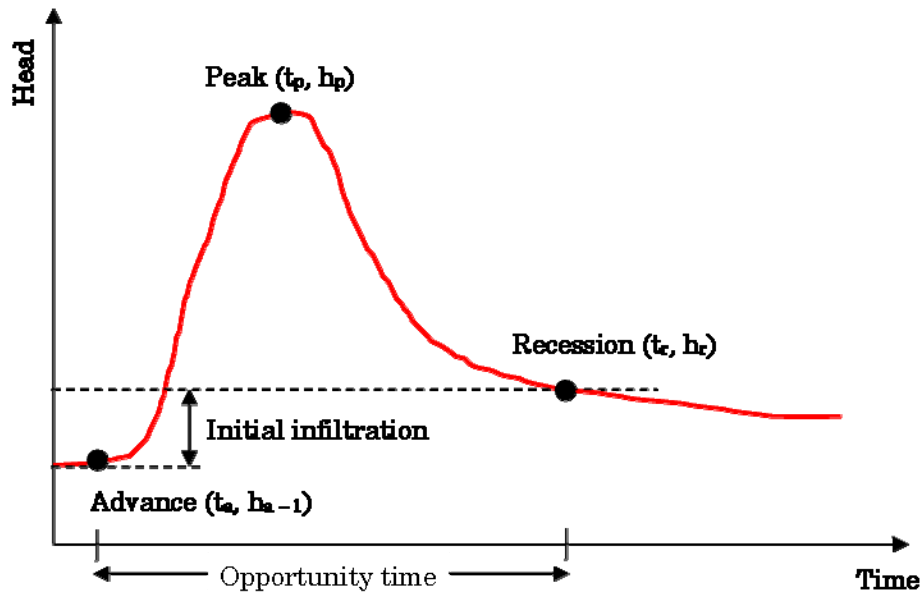


Figure 3.2: Features of hydrographs used to establish essential parameters.

Note: t_a – advanced front start time; h_{a-1} – baseline head; t_p – peak time
 h_p – head of peak; t_r – recession time; h_r – head of recession

Data across each row will be averaged and run the software package WinSRFR will be utilised to determine average depth of infiltration, opportunity time, and application efficiency.

Cumulative infiltration can similarly be assessed using a linear model called the Kinematic Wave Model (Austin and Prendergast, 1997) presents Equation 1 as follows:

$$Z = Z_{cr} + i_f t_{op} \quad (\text{Equation 1})$$

Where Z_{cr} : initial infiltration (depth of water rapidly infiltrating into cracks); i_f : final infiltration rate and t_{op} : opportunity time.

While it is important to recognise that the linear model ($r^2 = 0.99$) of cumulative infiltration is not perfect, rather a more accurate model is the Kostiakov model ($r^2 = 1.00$) (Austin and Prendergast, 1997) however the added complexity does not achieve a significant improvement in accuracy when compared to the simplicity and ease of the linear model.

In addition to measuring infiltration variable t will also be determined, that is, a measurement of the time taken to travel a specific distance (x), this is specified in Equation 2 (Austin and Prendergast, 1997):

$$t = \frac{m y_0}{i_f} \left[1 - \left(1 - \frac{i_f x}{q_0} \right)^{\frac{1}{m}} \right] - \frac{Z_{cr}}{i_f} \ln \left(1 - \frac{i_f x}{q_0} \right) \quad (\text{Equation 2})$$

Where x : flow travel distance; q_0 : inflow rate; m : empirically fitted constant ($m = 5/3$) and y_0 : flow depth when $x = 0$.

4. Results

As a result of a particularly wet year in northern Victoria three trials of advanced front monitoring were conducted, which was significantly less than originally anticipated.

Table 4.1: Details of trials.

Trial Number	Time Step (minute)	Inflow Rate (kL/minute)	Duration (minute)	Total Volume (kL)	Infiltrated Volume (kL)	Runoff (kL)	Application Efficiency (E_a)
1	5	100.69	205	2064.15	2061	3.55	99.85 %
2	1	100.69	205	2064.19	2045	9.32	99.07 %
3	1	104.17	200	2083.34	2074	8.86	99.55 %

Some issues with the data were clearly present especially in trials 2 and 3 (**Table 4.2:** Infiltration data and advanced front travel times.), however there did appear to be a fairly consistent trend of initial infiltration (Z_{cr}), followed by a peak and gradual infiltration into the soil (recession)

Table 4.2: Infiltration data and advanced front travel times.

	Trial 1					Trial 2					Trial 3				
	Z_{cr} (mm)	if (mm/min)	top (min)	Z (mm)	t (min)	Z_{cr} (mm)	if (mm/min)	top (min)	Z (mm)	t (min)	Z_{cr} (mm)	if (mm/min)	top (min)	Z (mm)	t (min)
20	40.0	1.00	239	279.3	7.0	30.3	0.6	312	205.2	8.2	22.7	0.7	235	179.5	7.3
80	54.3	0.52	150	132.3	15.2	65.7	0.3	194	122.6	17.6	57.2	0.2	215	105.9	19.0
160	58.8	0.24	218	109.9	30.7	20.0	0.2	241	70.4	32.8	34.2	0.1	267	59.3	41.0
220	84.4	0.14	190	110.3	45.7	60.0	0.2	209	120.8	36.3	66.8	0.2	221	100.7	40.0
280	67.8	0.14	180	93.4	52.1	61.8	0.1	325	81.3	68.9	55.8	0.2	198	87.5	45.5
340	68.5	0.15	198	97.8	57.5	0	0.1	425	25.5	*	39.8	0.1	252	63.7	63.6
420	72.5	0.12	183	93.9	71.9	52.7	0.2	209	98.5	51.8	56.7	0.1	399	91.8	74.3
<i>Mean</i>	<i>63.8</i>	<i>0.33</i>	<i>194.0</i>	<i>131.0</i>		<i>41.5</i>	<i>0.24</i>	<i>273.6</i>	<i>103.5</i>		<i>47.6</i>	<i>0.23</i>	<i>255.3</i>	<i>98.3</i>	

Note: * indicates an undefined number returned due to a $Z_{cr} = 0$ at trial 2, $x = 340$ m.

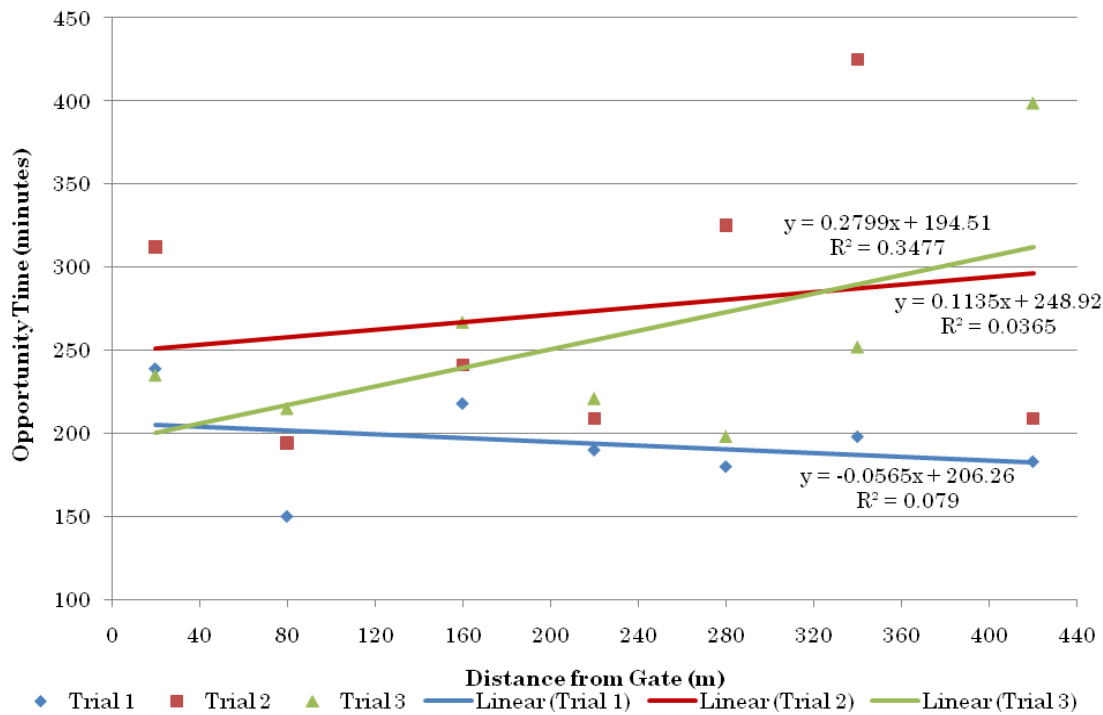


Figure 4.1: Change in opportunity time as the water front reaches the end of the field.

5. Discussion

Improving the water use efficiency in the agricultural sector has for some time been seen as a priority to both lift productivity in the sector and assist in securing water supplies for the state of Victoria and indeed Australia. It is for this reason there has been much discussion regarding whether flood irrigation which is seen by some to be a highly inefficient way of delivering water to crops. As previously described there has been a substantial body of research conducted into the practise of high flow or fast irrigation to reduce the level of runoff, deep percolation resulting in nutrient leaching beyond the plant root zone (Sharma and Singh, 2009).

It has been reported that the level of application efficiency (E_a = volume added to root-zone/volume applied) varies substantially (range = 46-86%, mean = 69%) (Smith *et al.*, 2009) under typical (slow-flow) conditions. Comparably, results obtained in my limited study (Table 4.1) indicate that the implementation of fast-flow irrigation techniques can yield significantly greater application efficiencies of over 99%. While, the author acknowledges that the study undertaken in this case was somewhat limited and short and examines only one field site if similar results in the future indicate similar results the future is promising for fast flow irrigation. It is important to recognise that the issue of surface irrigation is not merely an issue in Australia but exists overseas also. For example, in the developing country of Pakistan similar problems exist with a mere 34% of irrigation water actually adding to crop value the remainder is lost through inefficiencies and overflow (Mahmood *et al.*, 2003). In such a developing country with a growing and expanding economy it is important to maximise their productivity to limit the possibility of people going hungry as a result of insufficient production rather than lack of access.

Data presented in Table 4.2 appear to be consistent with logical explanation; it appears that while trial 1 was not the initial irrigation even for the maize harvest, introduction of odyssey sensors has had an impact during trials 2 and 3. This was best illustrated with the initial trial having a significantly greater initial infiltration value (Z_{cr}) than others. The effect of testing was also demonstrated in the effect of final infiltration with a 43% difference between the initial test and subsequent tests.

Determination of travel time did appear to generally be consistent despite an unexpected result in trial 2. The initial and final trial resulted in a travel time with a mean of 73.1 minutes which is essentially the value I had anticipated for trial 2. However comparatively the trials did not provide a good match for cumulative infiltration which this is not at all surprising as this would have depended significantly more on soil moisture deficit (Equation 1) than the travel time of the advancing and receding fronts (Equation 2).

The change in the opportunity time over the distance of the field can be idealistically represented in Figure 5.1. While the results from my research does not indicate that such a relationship exists (Figure 4.1) the rationale remains strong. Research suggests that initially the opportunity time is greater (closer to the inlet gate) due to water having to spread across the width of the field illustrated in Figure 5.2 (left) (Bishop *et al.*, 1967; Criddle *et al.*, 1956; Sharma and Singh, 2009). It is for this reason why we would expect that opportunity time is greater initially then slowly declines over time.

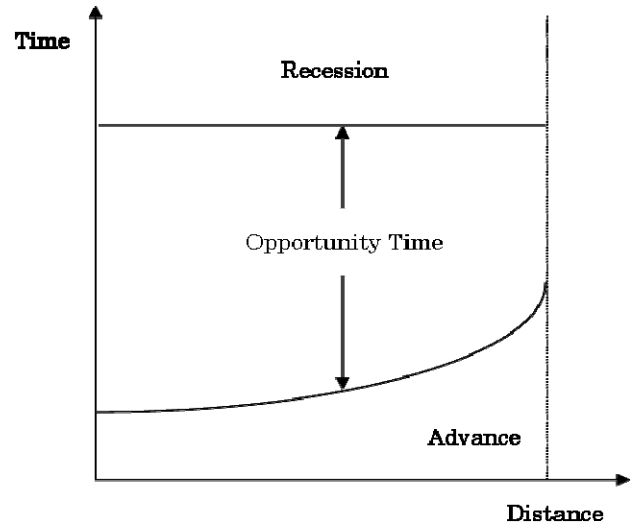
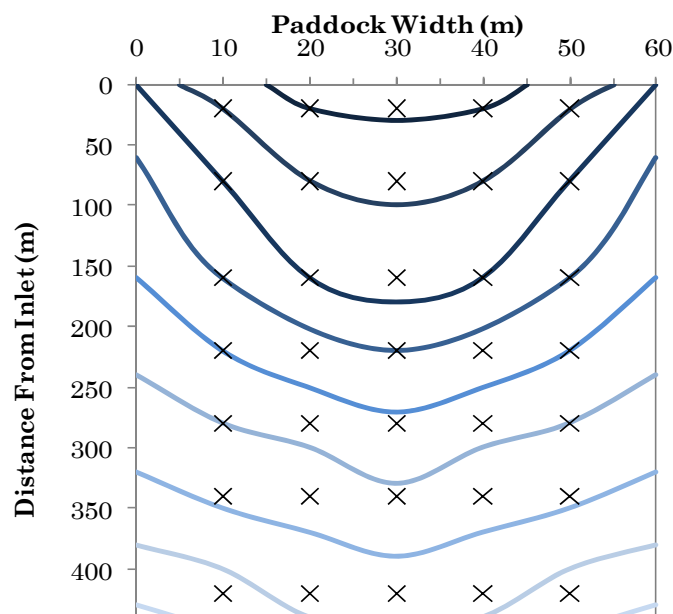


Figure 5.1: Idealised opportunity time changes. **Source:** Sharma and Singh (2009).

Figure 5.2: progression of advancing water front over time.



6. Conclusion and recommendations

Consumption of water in the agricultural sector will always be an issue of concern as long as we have a finite water supply in Australia and around the world. It is for this reason why irrigators should never become complacent when using water for their industry, inefficiencies will never be tolerated as they used to particularly in an age where a more even balance between irrigation and environment is pursued by governments around the world. This balance often results in back-lash from irrigators most recently seen in regional Australia (Cooper and Herbert, 2010; Jopson, 2010). Debate of this type of debate highlights the complexity of the situation in reducing water consumption in the sector with any additional cuts in water to be made through gains in efficiencies and improved technology. While such advancements are generally welcomed by all parties it is expected such improvements will come at a cost. Costs of this nature are generally in the form of increased labor and upgrading technology (Smith *et al.*, 2009) that will be the ultimate test for the industry and governments.

The implementation of fast-flow irrigation systems have been demonstrated to have benefits with improved efficiency, productivity and lower water consumption. This can result in greater profit through additional cropping, or alternatively the selling of water licences to an eager government. However, while increases in flow has notable improvements in application efficiency (North and Griffin, 2008; Gillies *et al.*, 2010; Smith *et al.*, 2009) this is usually the result of a degree of compromise between requirement efficiency (the level that the irrigation meet the soil moisture deficit in the root zone; $E_s = \text{Volume Stored In Rootzone/Soil Moisture Deficit}$) and the uniformity of the irrigation (Smith *et al.*, 2009). In addition to these trade-offs, the major disincentive is the requirement to automate irrigation practices which has implications to the labor force (reduced jobs), as well as increased technological costs and whether the two are equivalent is a matter for further debate and analysis (Smith *et al.*, 2009).

Research into the effect of fast-flow irrigation has shown to have various advantages however the implementation of such systems requires careful management. The author recommends any future research be conducted to test the effect of fast flow systems be conducted over a greater period with greater number of trials to assist in addressing variability.

Finally this short project provided me an excellent opportunity to get first hand experience on agricultural water management, most importantly to interact with people in ground. This also exposed me to 'state of the art' automated irrigation infrastructure at Dookie College.

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