Observations from initial evaluation trials of Bankless Channel Irrigation Systems

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Abstract
Increasing community pressure for efficient water use, competition for water resources and rising production costs mean it is important to optimise all aspects of irrigated production. Bankless channel surface irrigation systems are a relatively new and increasingly popular method of irrigation for broadacre cropping systems. Motivation for the installation of these systems is attributed to labour efficiency gains, improved machinery access and the versatility of the system to irrigate a wide variety of crops. While bankless channel irrigation systems may enhance the performance of many aspects of irrigation production, no water-related design, management or evaluation criteria exist for optimising the irrigation performance of the system.

This paper presents initial observations of an irrigation evaluation aimed at developing a tool to measure and improve the irrigation performance of bankless channel irrigation systems. These initial observations concentrate on the advance and elevation variation within the evaluated system. These observations demonstrate that, under the described flow conditions, water depth appears to have a small influence on the advance of water and that soil and furrow properties have a substantial effect on irrigation advance. This initial field data will be used to develop and/or validate suitable hydraulic simulation models to improve the design and operation of bankless channel irrigation systems.

Introduction
Australian bankless channel systems operate in a similar way to American “drain back level basins” (Dedrick 1989) albeit with larger dimensions and higher flow rates. Australian systems were developed in the 1990's to improve water management and production performance in rice based farming systems. Subsequently, hills or beds and furrows were added to the system enabling the production of row crops within a rice based farming enterprise. These adjustments not only provided cropping alternatives, but also increased operational and labour efficiencies while decreasing occupational health and safety (OHS) risks and, though largely anecdotal, water use efficiency improvements over conventionally siphon fed systems (Grabham and Williams 2005; Hood and Carrigan 2006). Row-crop focussed enterprises recognised the advantages of the system over traditional siphon irrigated methods and the system is now used in a number of areas outside the rice based farming enterprises of southern NSW.

Bankless channel systems consist of a series of terraced bays which, while irrigated separately, are connected by a bankless channel (Figure 1). Each bay is irrigated by backing-up water behind a closed gate in the bankless channel, causing water to spill into the adjacent bay. Once the bay has been sufficiently inundated, the gate in the bankless channel is opened allowing both supply water from the channel and drainage water from the bay to flow into the next bay in the series. This process is repeated until all bays are irrigated. The bankless channel delivers the water to the bay, distributes water across the inlet width of the bay and also acts as a drain for the bay.

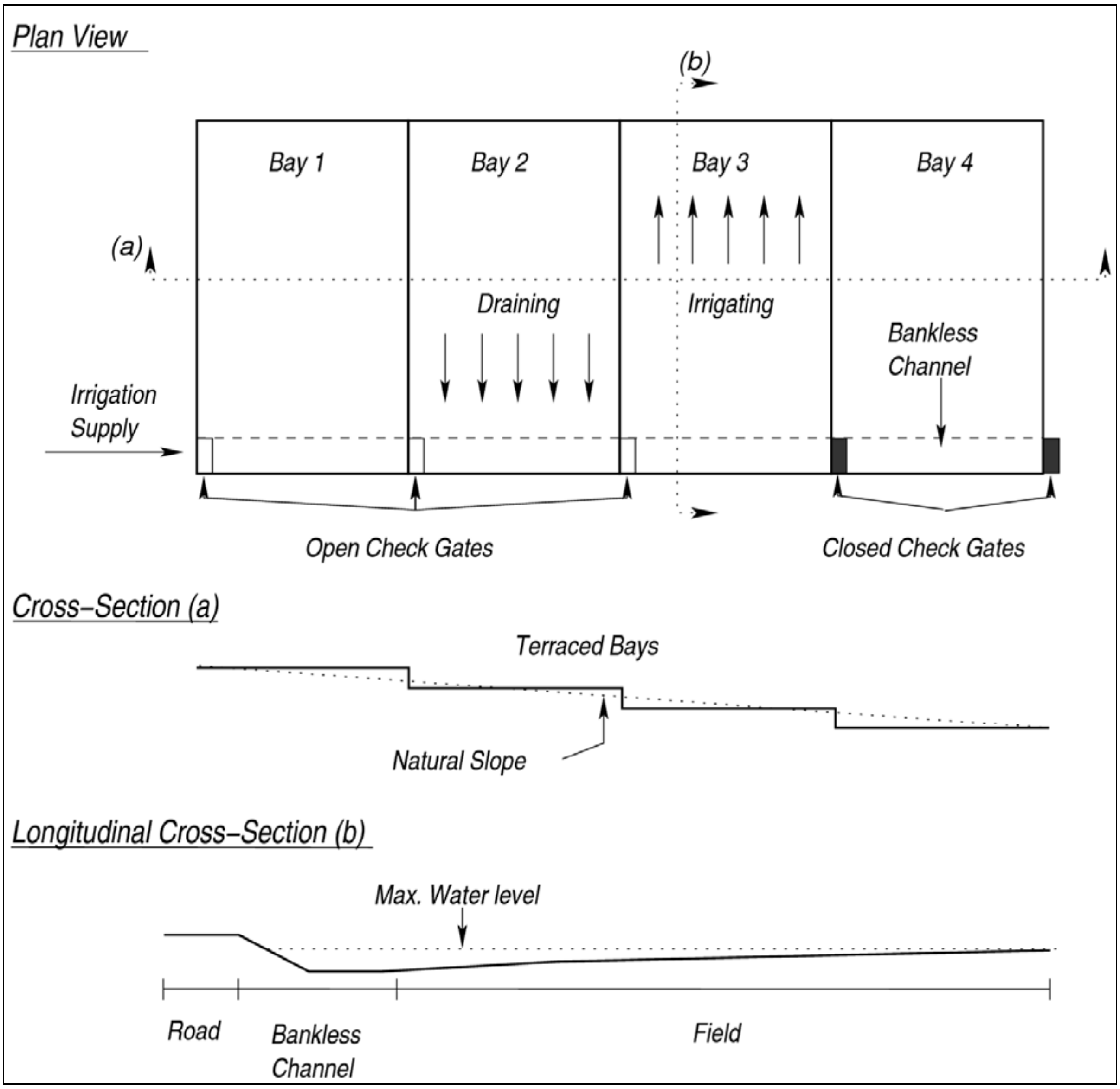

Figure 1: Schematic of bankless channel irrigation system.

Bankless channel irrigation systems, because of their numerous advantages, are increasing in popularity. However, little is known about the hydraulic performance of these systems. Water applied to a single bay of summer crop over a single season has been quantified (Hood and Carrigan 2006), however intra-bay evaluations of application efficiency have not been conducted. Similarly, the influence of inter-bay interactions has yet to be fully investigated. To improve the overall performance of the irrigation system, irrigation application efficiency and hydraulic performance of the system, an improved understanding of the system is required. This will enable the irrigation performance of bankless channel irrigation systems to be optimised. The first step to improving hydraulic performance is to evaluate a system's current performance. Unfortunately, due to the unique mode of operation and atypical features of these systems, existing furrow irrigation evaluation methods (e.g. Raine *et al.* 2005) cannot be applied to bankless channel irrigation systems. Under conventional surface irrigation, where water flows from supply to drain, irrigation advance is largely controlled by soil characteristics. It is hypothesised that irrigation advance on reverse grades associated with bankless channel irrigation systems, are largely controlled by water depth (Figure 2). This paper reports on field and irrigation data obtained from a single bankless channel irrigation event.

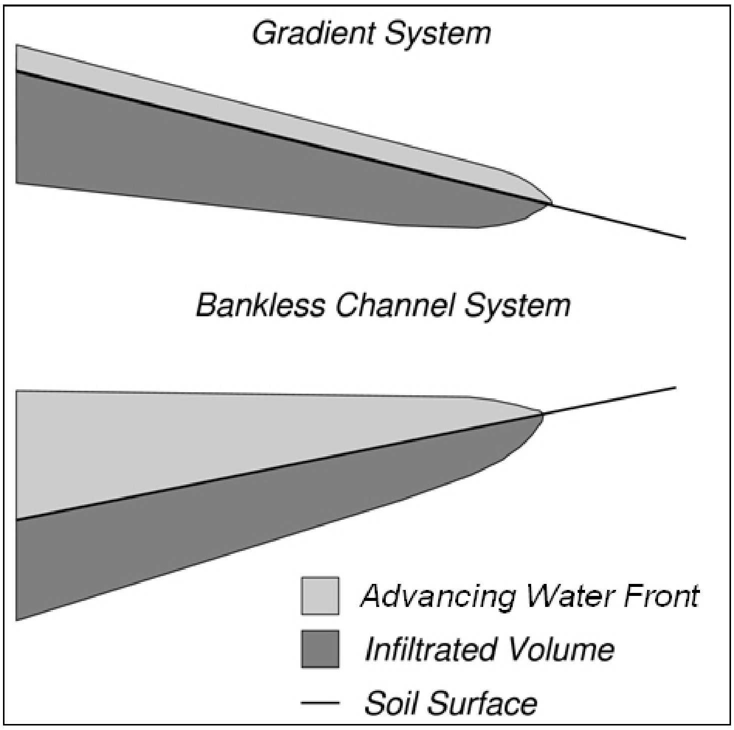

Figure 2: Varying water depths in advancing irrigation front in both gradient and bankless systems.

Methods

A number of potential fields were surveyed using a Geonics EM38 sensor to identify fields with relatively homogeneous spatial conductivity. The electromagnetic field of the sensor is sensitive to soil texture, salinity and moisture content (Sudduth *et al.* 2001) providing a rapid method of identifying spatial homogeneity. Based on the EM38 results and the regular physical dimensions of the bays, three adjacent bays were selected for further evaluation. Physical dimensions of these bays are outlined in Table 1 and depicted in Figure 6. Delivery structures to this field included a 500 mm supply pipe and a 685 mm pipe connecting each of the bays.

Table 1: Bay physical dimensions

Bay Number	Bay Width (m)	Bay Length (m)	Area (ha)	Design Slope
1	72	366	2.6	-1:8000
2	162	366	5.9	-1:8000
3	162	366	5.9	-1:8000

To reduce sampling effort while capturing all furrow variations (ie wheel and non-wheel rows) in a timely manner, every fifth furrow (1,6,11…) was selected as a sampling furrow. An RTK Global Positioning System (RTK GPS) receiver was used to collect elevation data at 20 metre intervals in the base of these measurement furrows, giving a sampling grid of 20 metres by 10 metres. This sampling grid provided an insight into elevation variation within and between bays.

Irrigation advance data was collected during an irrigation event in Bay 2. Inflow to the bay progressively decreased from 53 ML/d to the field supply flow rate of 18 ML/d during the irrigation event as the preceding bay drained (Figure 3). Assuming uniform distribution into the 85 furrows in the bay, the average furrow inflow rate was 7.3 L/s. Advance times within the measurement furrows were collected at approximately 15 minute intervals by walking to the advance front in each of the measurement furrows and recording the position of the wetting front with a differential Global Positioning System (dGPS). Advance measurements were collected for the duration of the advance phase.

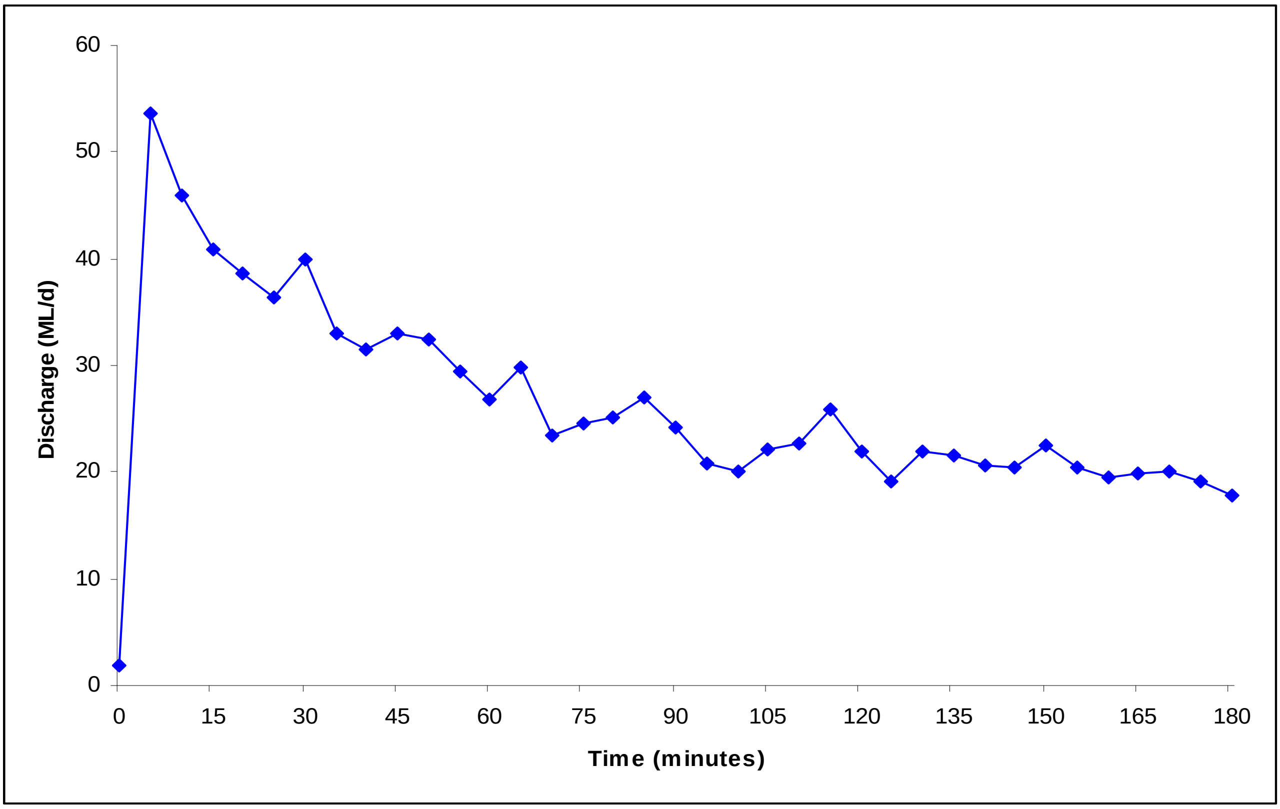

Figure 3: Discharge into Bay 2 during the advance phase of an irrigation.

Results and Discussion

The elevation survey (Figure 4) shows a general trend of increasing elevation from left to right in line with the reverse grade slope, albeit with some degree of variability, particularly in Bay 2. As expected, a significant difference in elevation existed between the bankless channel end and the far end of each bay (where n = 18, $F_{18,\ 247}$ = 42.622, P < 0.05). There was no significant difference in the furrow elevation measured using the RTK GPS within any of the bays (where n = 13, $F_{13,\ 252}$ = 0.311 P > 0.05). Therefore, if furrow elevation (and hence, water depth) has a large influence on water advance, the advance front should be relatively uniform as it moves up the bay. Figure 5 illustrates the advance front during the irrigation event with the elapsed time displayed adjacent to each line. The figure shows the advance front is far from uniform.

The EM38 electromagnetic survey (Figure 6) of Bay 2 revealed a mean EC_a of 45 with a CV = 13%; this is classified as having a low variability (Wilding 1985). Low variability suggests that the non-uniform irrigation advance is unlikely to be attributed to an underlying variation in soil salinity or properties within the bay. However, when the advance within individual furrows is examined, wheel track furrows appear to advance more quickly than non-wheel track furrows (Figure 7). This implies that the variability in the wetting advance may be attributable to differences in the soil or furrow characteristics associated with traffic.

The assumption that uniform flow distribution into the furrows occurs is founded on the lack of any significant measured difference in elevation between the furrows. However, this assumption may be inappropriate. Hydraulic conditions in the bankless supply channel and microtopographical changes may influence the distribution of water encouraging preferential flow to some furrows. Furthermore, while irrigation advance was non-uniform for the measured irrigation event, the influence of flow rate into the bay has not been examined. Variation in, and the magnitude of, the flow rate into the bay may influence both the uniformity and rate of advance. A falling inflow rate may result in decreased uniformity, while increasing the flow rate into the bay may accelerate the advance and place a greater importance on water depth than upon soil characteristics.

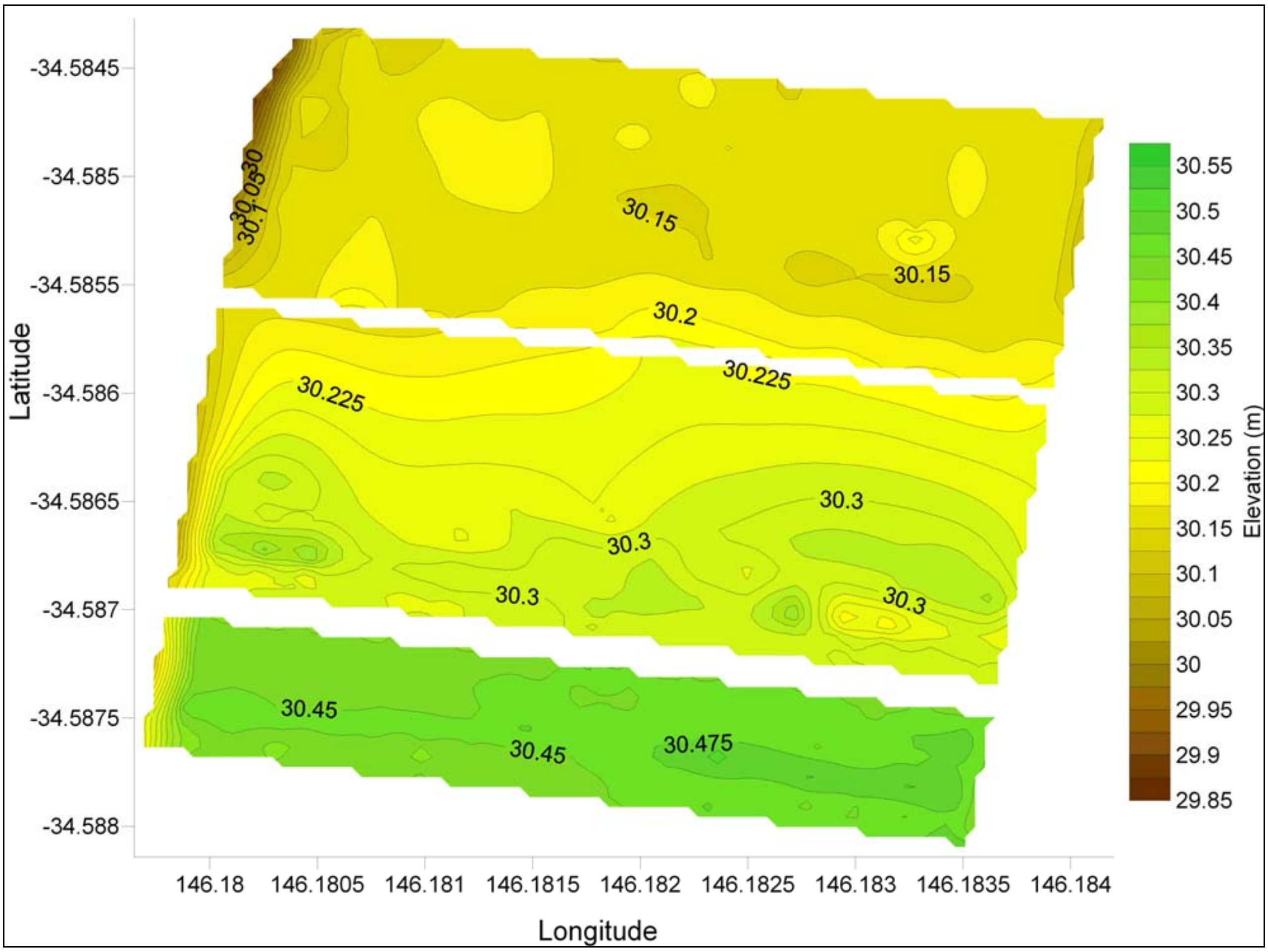

Figure 4: Elevation of furrow bases in selected bays.

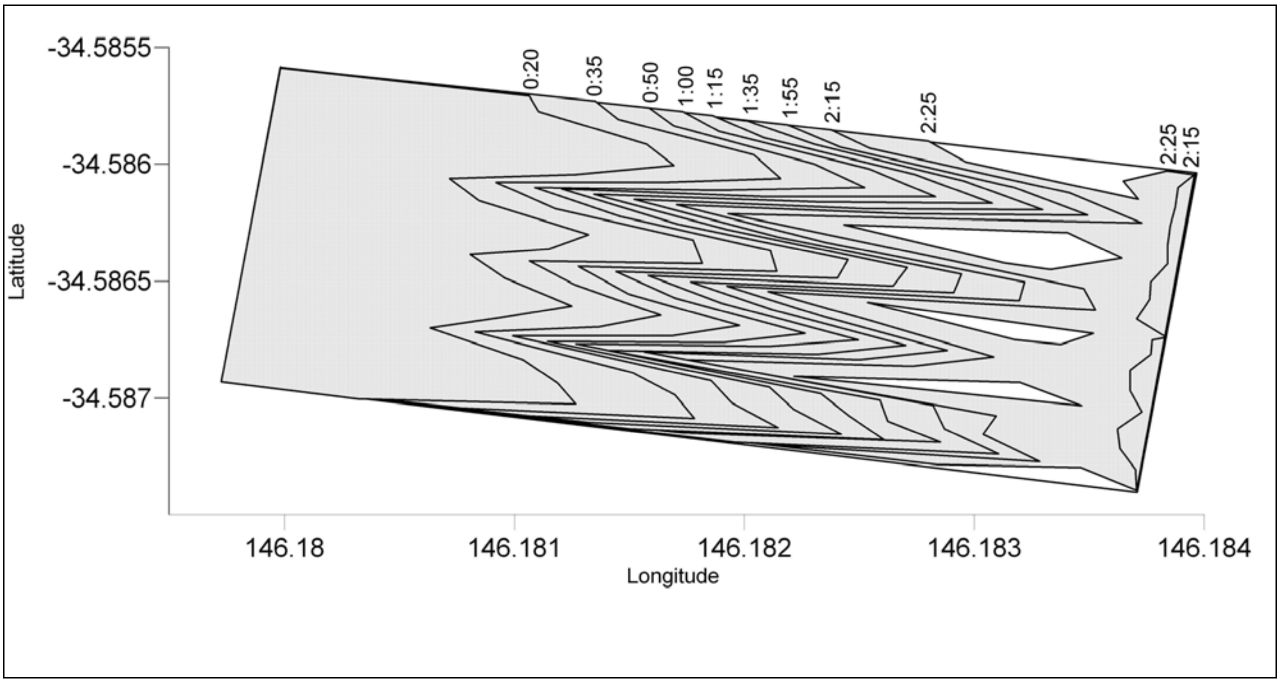

Figure 5: Irrigation advance in Bay 2.

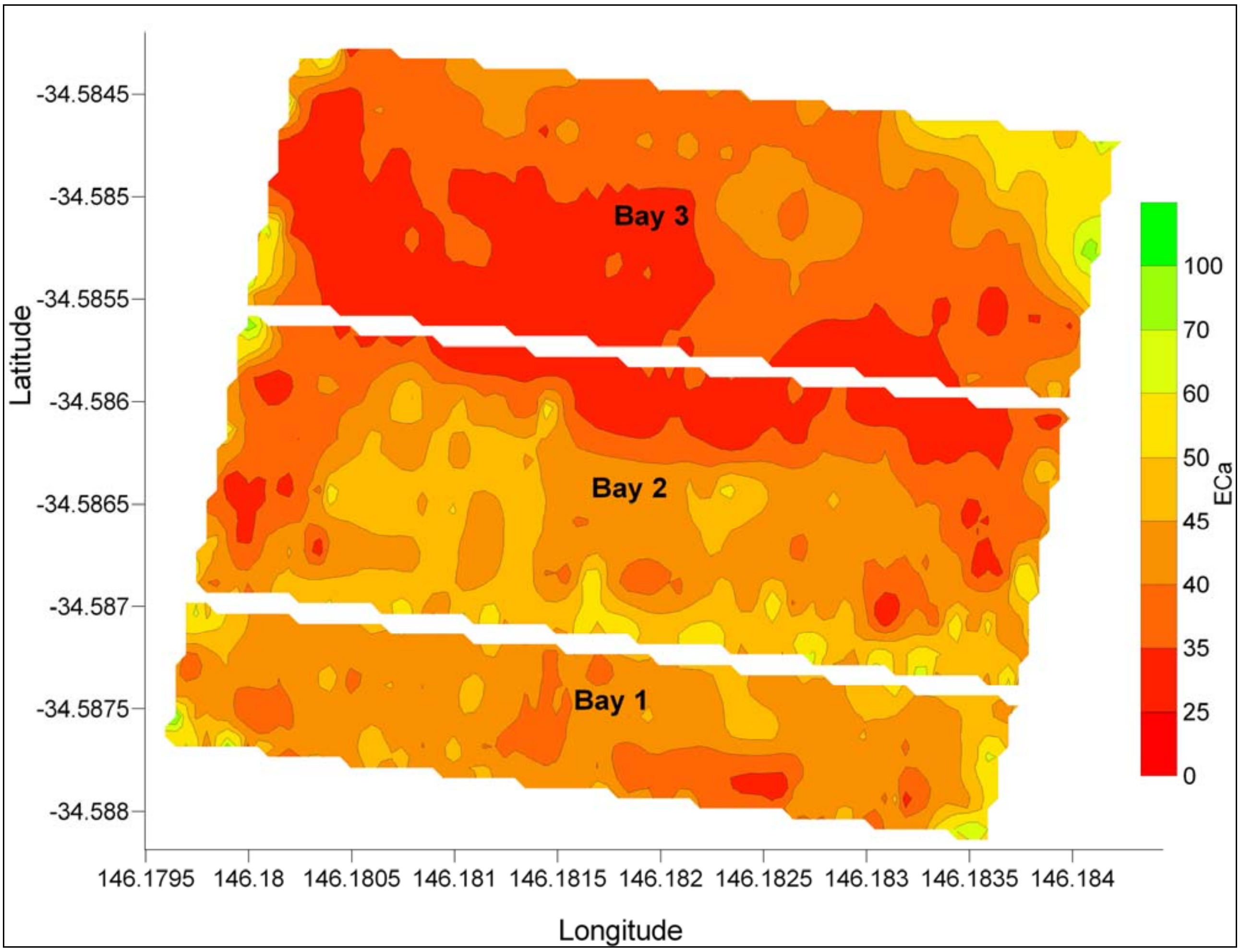

Figure 6: Map showing conductivity (EC_a) contours for bays selected for evaluation.

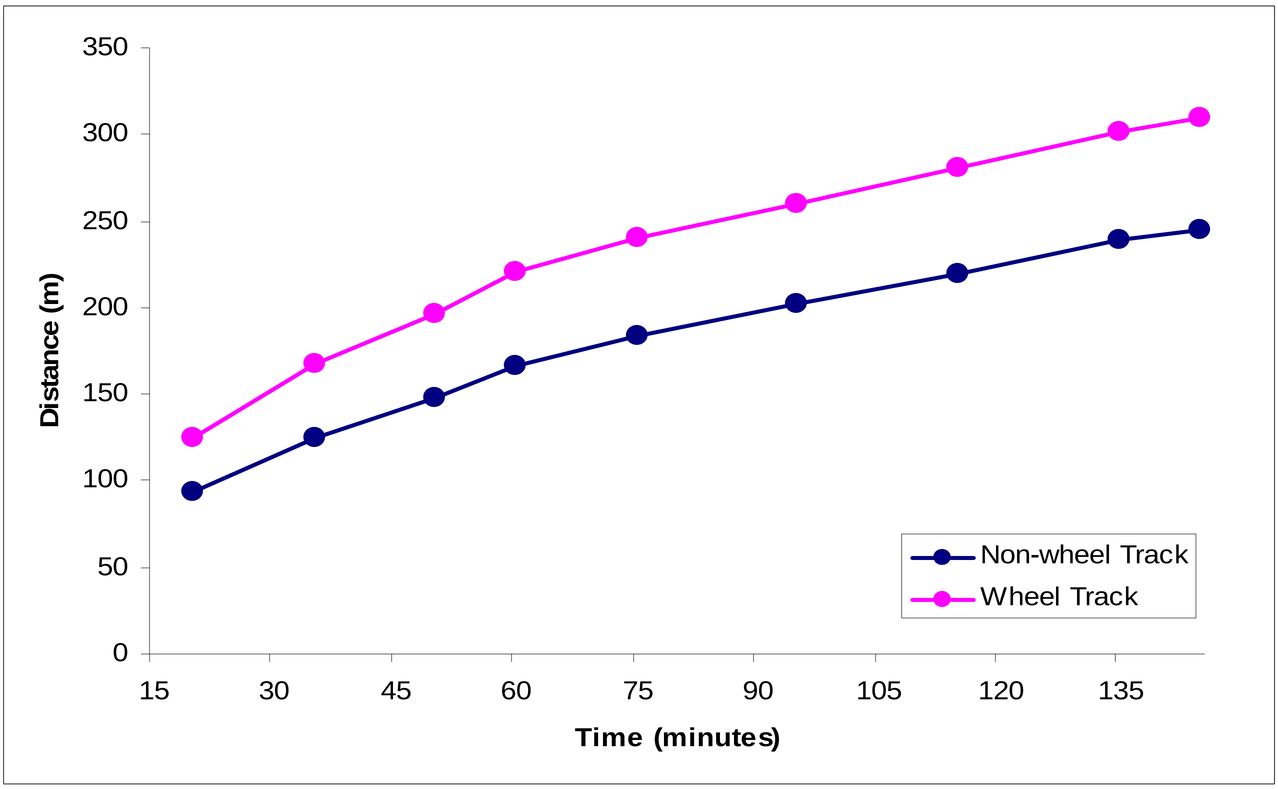

Figure 7: Averaged wheel and non-wheel track advance rates for Bay 2.

Conclusion and Future Directions

Differences in furrow traffic appears to be a primary factor influencing the uniformity of irrigation advance in bankless channel irrigation systems. Conversely, water depth within the bay may not influence advance to the degree expected. However, these observations are limited in context to the irrigation event monitored. A greater number of events under a variety of flow conditions will be completed to substantiate these observations. Furthermore, the influence of microtopography will be examined as a potential cause of non-uniform advance.

While a diminishing flow rate into the bay may affect advance rates, the possibility of non-uniform distribution of flow into furrows will also be examined. Measurement of furrow flow rates will confirm or refute the assumption of uniform flow distribution from the bankless channel into the furrows. These measurements will be conducted as part of the determination of a valid evaluation method.

Understanding the impact of furrow and soil characteristics on irrigation advance rates may prove helpful in establishing an evaluation technique. Advance data is less problematic to collect than depth data and, if a reliable relationship between advance and infiltrated volume can be established, advance data may provide a useful tool for evaluating bankless channel irrigation systems. Further work exploring the interaction of water depth and advance is required to develop a relationship between these two parameters.

While irrigation advance measurements may prove useful as part of an irrigation evaluation tool, measurements of water depth variations across bankless channel irrigation systems are needed to model the hydraulic parameters of the system. Measuring flow rates into, out of and between bays and assessing crop, furrow and soil variability will also be required to conduct simulation modelling of bankless channel systems. A simulation model will enable improved water management to be incorporated into new designs and provide an optimisation tool for improved management and modification of existing layouts. Improved understanding of the factors influencing irrigation advance will form the basis of an evaluation method, which in turn is essential for the validation of hydraulic simulation models. Ongoing research into bankless channel systems is expected to provide tools to improve the irrigation performance of these systems. Such outcomes should compliment the advantageous aspects of this system leading to improved productivity and water management in the irrigation industry.

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