BANKLESS CHANNEL IRRIGATION SYSTEMS: IRRIGATION PERFORMANCE ASSESSMENT

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ABSTRACT

Bankless Channel Irrigation Systems are being used by broadacre irrigators seeking to improve farm efficiencies. Evaluation of the irrigation performance of these systems has been difficult due to the operational nature of these systems. Using novel evaluation methods and tools an evaluation of the irrigation performance of a bankless system was achieved. These evaluations revealed the application efficiency at both the system and bay scale and will assist in the development of an irrigation evaluation technique and simulation model capable of simulating the performance of this system.

INTRODUCTION

Australian bankless channel systems are similar to “drain back level basins” (DBLB) used in the United States (Dedrick 1989). The differentiating feature of bankless systems from DBLB is a positive slope away from the bankless channel (0.01-0.08 %). This feature was introduced to facilitate drainage during irrigations and following rainfall. Bankless systems were first developed in Australia in the 1990's to improve water management and production performance in rice based farming systems. Furrows and beds were subsequently added to the system to enable the production of row crops. These adjustments not only provided alternative cropping options, but also increased operational and labour efficiencies while decreasing occupational safety risks associated with siphon fed systems. Anecdotal evidence also identifies the potential for water use efficiency improvements over siphon fed systems (Grabham and Williams 2005; Hood and Carrigan 2006). This paper outlines the evaluation techniques employed to determine irrigation performance of a bankless system, providing the foundation from which suitable design and management criteria may be developed for bankless systems.

Bankless systems consist of a series of terraced bays (Figure 1) which, while irrigated separately, are connected by a channel constructed below field level—hence, a bankless channel. Each bay is irrigated by holding water behind a closed check-gate in the bankless channel causing water to flow into the adjacent bay and advance up the positive slope. Once irrigated, the check gate in the bankless channel is opened allowing both supply and drainage water from the bay to irrigate the subsequent bay. This process continues until all bays in the series have been irrigated. The bankless channel delivers the water to each bay, distributes water across the inlet width of each bay and acts as a drain for each bay.

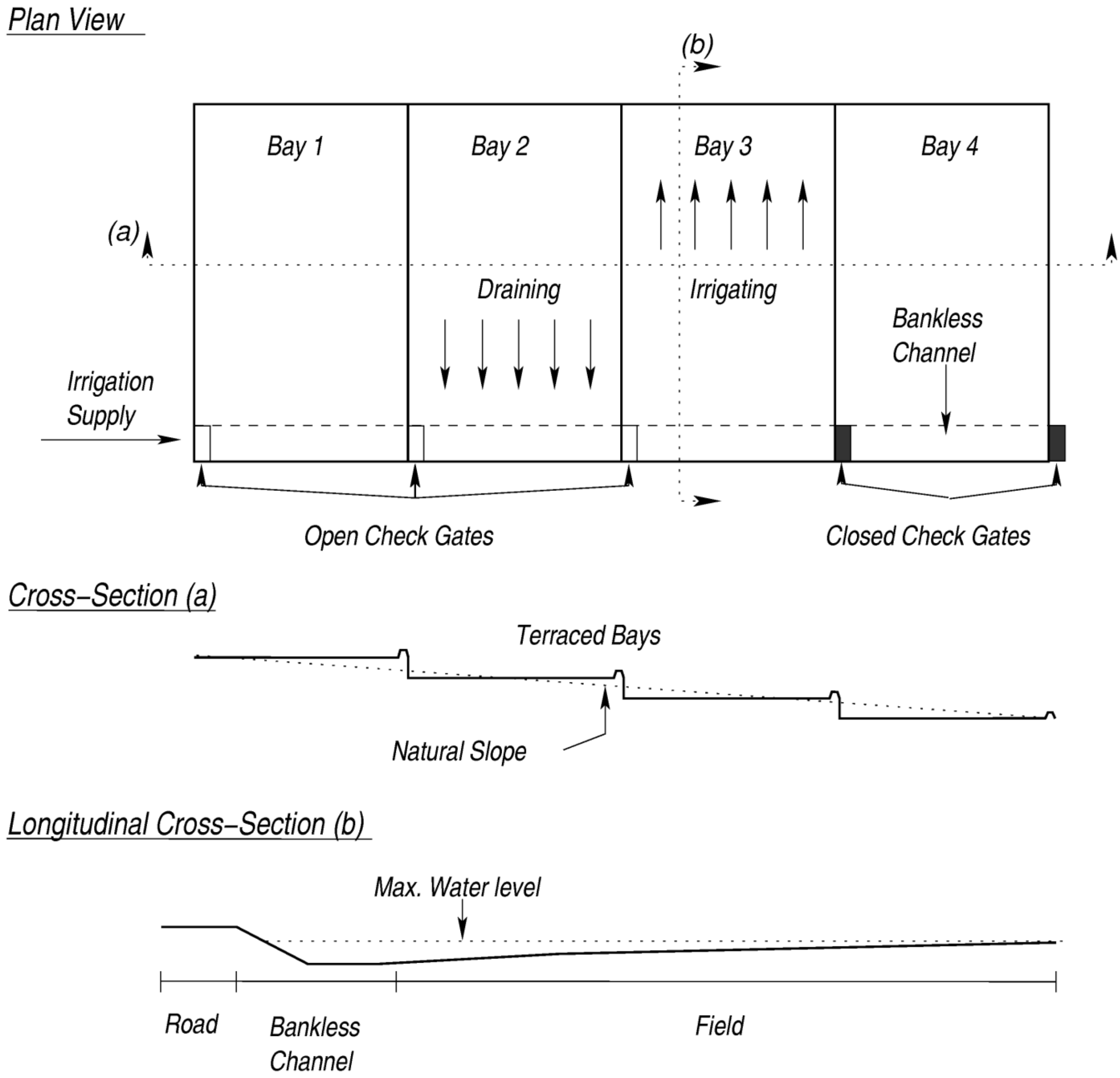

Figure 1: Schematic of bankless channel irrigation system.

The popularity of bankless systems is increasing as irrigators strive to improve the economic returns from their system. Ensuring irrigation performance compliments the desirable aspects of the system is important. Through gaining an understanding of the irrigation performance of bankless systems, optimisation methods can be developed which will improve the management and design of both existing and new systems. The first step towards optimisation is evaluating a system's current performance. One measure of irrigation performance is field application efficiency (E_a). E_a is defined as the ratio of crop water use to water delivered to the irrigation field (IAA 1998). To date, evaluation of bankless system irrigation performance has focussed on the comparative performance of the system with other irrigation methods (e.g. Hood and Carrigan 2006). Evaluations to determine E_a have not been conducted. A reason for this is the complexity introduced by the physical and operational features of the system such as a positive grade and the interaction of flow between bays. However, several evaluation methods for similar systems such as DBLB and level basins are available (Dedrick 1983; 1984; 1989; Dedrick and Clemmens 1988; Martin and Eusuff 2000; Merriam and Keller 1978). While these methods have not been applied to bankless systems, they may be applicable for the measurement of bay and furrow discharge, advance and recession times, soil moisture content and cumulative infiltrated volume. This paper outlines the methods used to evaluate a bankless system and reports the seasonal E_a of the system at both the system and bay scale and identifies factors contributing to application variability at the furrow scale.

MATERIALS AND METHODS

Irrigation evaluations were conducted in a field near Whitton in the Murrumbidgee Irrigation Area (MIA) of New South Wales (-34.586 lat. 146.181 long.). Evaluations were conducted over the summer cropping season in 2008/09. Dimensions and features of the field are detailed in Figure 2.

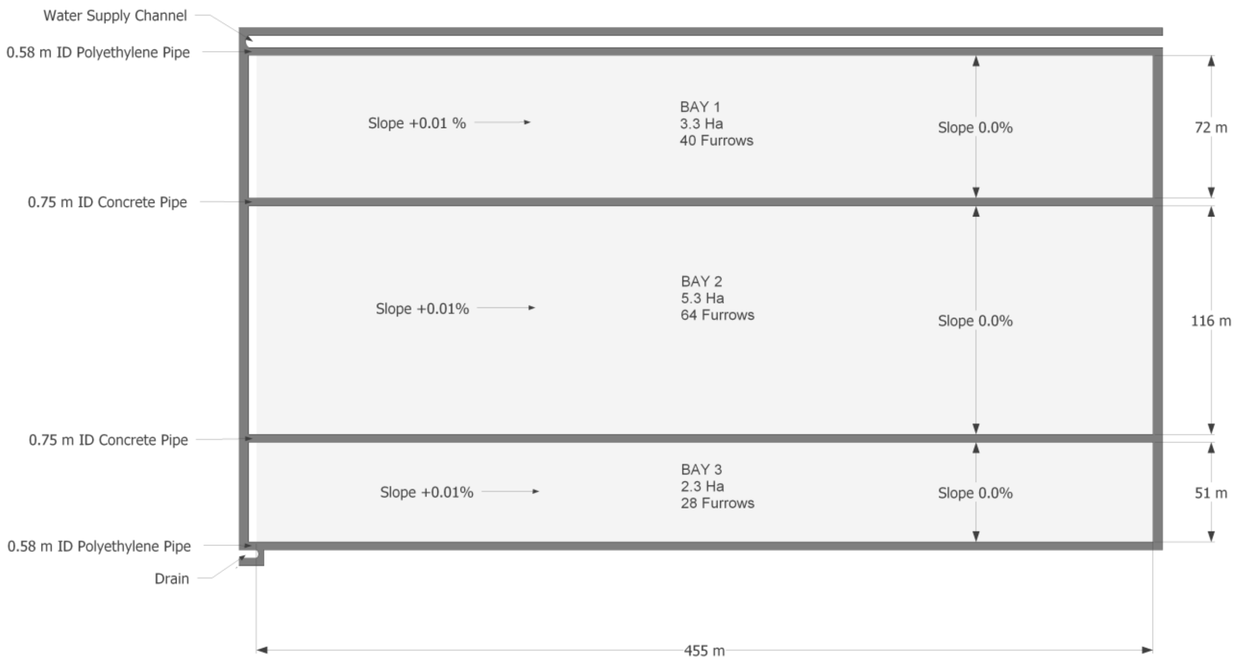

Figure 2: Dimensions, bay area and key features of the field selected for evaluation. Irrigation water is supplied to the field via the supply channel above Bay 1. Pipes connect the supply channel to the bankless channel which distributes the water across the inlet width of the field. A 0.15m step exists between bays, such that bay 3 is lower than bay 2 which is in turn lower than bay 1.

Soil in the field is composed exclusively of Gogilderie Clay; a deep uniform cracking-clay, persisting to the surface and is associated with the Dallas Clay Plain Landscape (Hornbuckle et al. 2008; van Dijk 1961). The soil was laser-levelled prior to the irrigation season, resulting in the disturbance and subsequent redistribution of the topsoil. An electromagnetic survey of the field was conducted using a sled mounted Geonics EM38 (Geonics Limited nd) operating in the vertical dipole. This survey confirmed soil conductivity variation to be low (Wilding 1985) suggesting a relatively uniform soil texture across the field.

Irrigation water is delivered to the field from surface and groundwater sources at approximately 15 ML/d.

Discharge into and out of each bay was measured using dopler flow meters mounted in all pipes across the system. Sensor heads were installed 1m upstream of each pipe outlet on the lower sidewall of the pipe to avoid inference from silt accumulation in the base of the pipe (Measuring and Control Equipment Pty Ltd 2002). Depth, velocity and calculated discharge were integrated for 5 seconds every minute and logged.

One furrow in each bay was selected based on its relative elevation. Furrows with an elevation close to the median elevation for each bay were selected. In all cases these furrows were wheel track furrows. Furrow discharge was calculated from discharge velocity and flow cross-sectional area measurements 8 metres downstream of the furrow entrance. Discharge velocity was recorded using a SonTek FlowTracker (SonTek/YSI 2008) while cross sectional area was determined from water depth measurements in known cross-sections. Measurements were collected every second for 15 seconds at approximately 30 minute intervals from the furrow centreline at a depth of 0.6 the water depth as prescribed by standard collection methods for shallow flows (Rantz 1982). The volume applied to each furrow is a function of the positive discharge less the drainage component and was divided by the area of the furrow to determine application per square metre.

Crop water use was calculated from reference evapotranspiration (ET_o) weather data. Daily measures of the modified Penman-Monteith calculated ET_o data from Griffith, NSW (Meyer 1999; Meyer et al. 1999) and the associated local crop factor for cotton were used to determine crop evapotranspiration (ET_c).

RESULTS AND DISCUSSION

The seasonal Ea across the three bays was 93%. ETc for the field evaluated and water inputs to the system are shown for the full irrigation season (Figure 3).

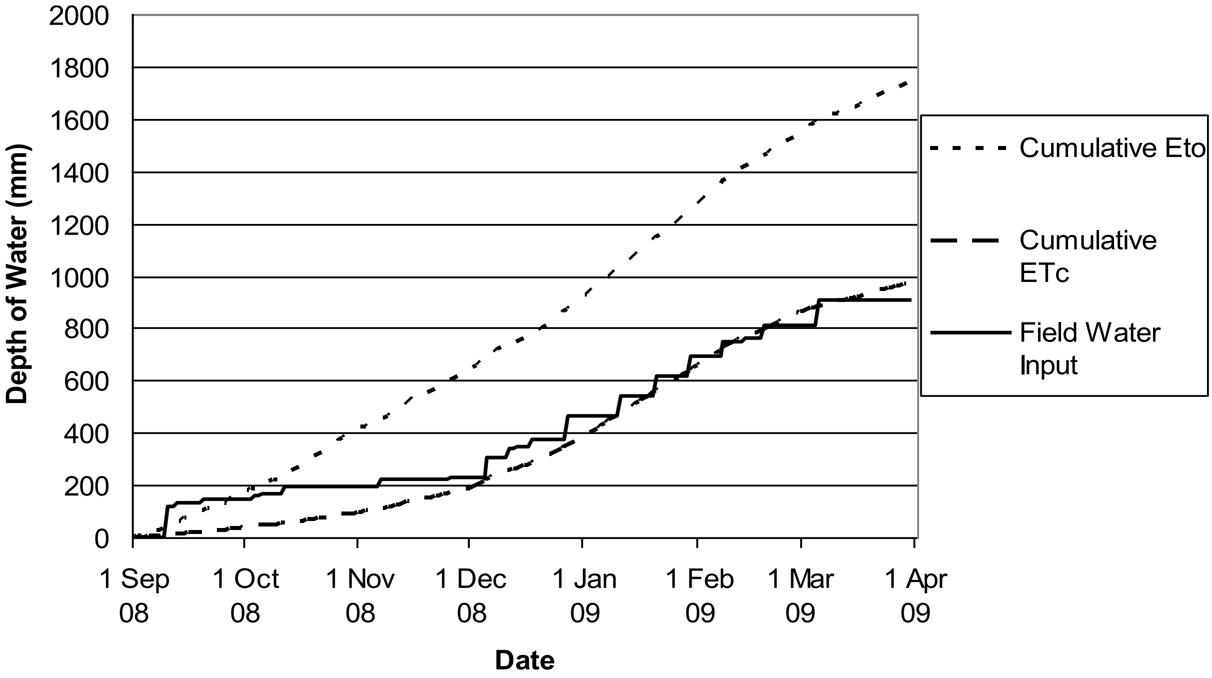

Figure 3: Cumulative ETo, ETc and water inputs for the evaluated field.

The results show that crop water demand was met by water input at the field scale for the duration of the season. This finding is consistent with previous evaluation assessments of bankless systems (Hood and Carrigan 2006) in suggesting that, at the field scale, crop performance should be similar to other row-crop irrigation systems. In siphon-fed row-crop irrigation systems, the degree to which field scale E_a represents irrigation performance is subject to the variation in physical parameters across the field and the degree of consistency in irrigation management. Consequently, in uniform fields with consistent physical conditions and irrigation management, E_a consistency at various scales should be high. In bankless systems, maintaining irrigation management consistency is inherently difficult due to inconsistent discharge to each bay. Consequently, to understand the irrigation performance of bankless systems, the irrigation performance of individual bays is important.

Seasonal E_a at the bay scale varies. Although E_a across all bays was 93%, the E_a for each of the bays was 77, 87 and 109% for bays 1, 2 and 3 respectively. Due to the inter-bay application variability, ET_c for bays 1 and 2 was not met by irrigation while 9% more water was applied to field 3 than was required by the crop. The impact of this variability can be seen in Figure 4 with bays 1 and 2 falling below calculated ET_c while bay 3 receives water in excess of requirement. The results show a best case scenario as data collection methods prior to the 6th December could not differentiate water application between bays. Consequently, an average application value is attributed to each of the bays. If variability in irrigation application between the bays early in the season reflects the variability observed later in the season, then reported irrigation performance of bays 1 and 2 would be greater than reality, while the reported excessive application to bay 3 would be lower than reality.

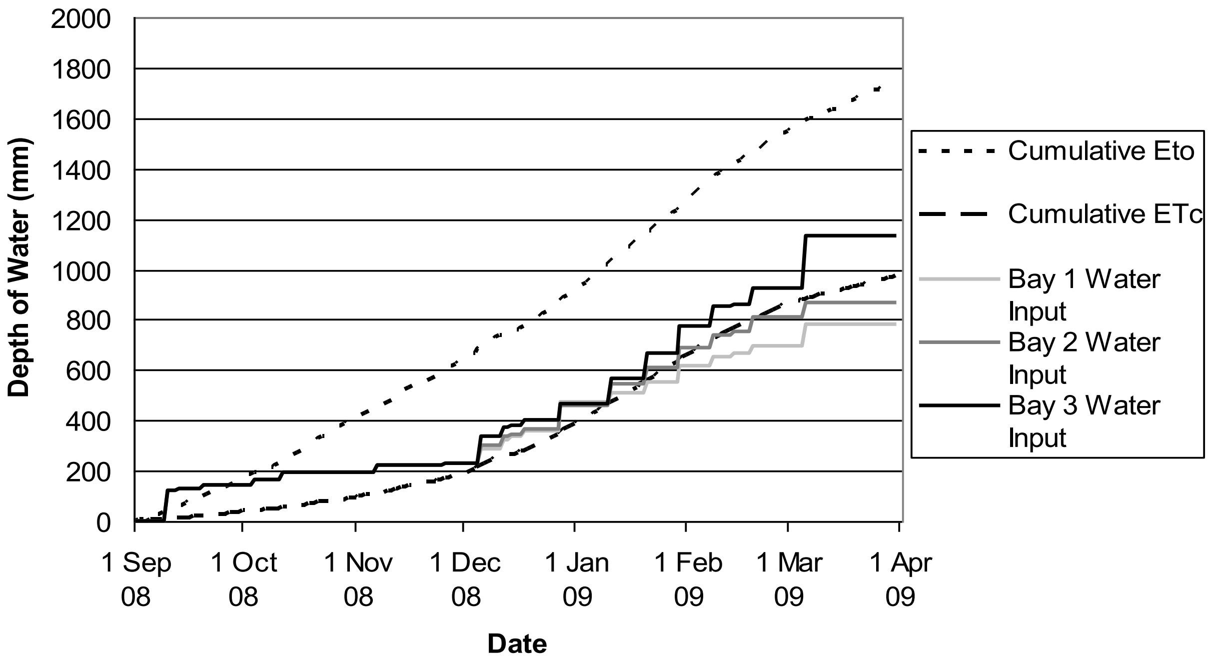

Figure 4: ET demand and irrigations applied. Irrigation application data to the 6-Dec-2009 is estimated due to data collection limitations and is assumed to be consistent across all bays.

Due to the propensity for errors in the calculation of E_a at the furrow scale, only applied volumes for furrows are reported. The difference between average bay application and average furrow application for four irrigation events is represented in Figure 5. The discrepancy between furrow and bay application values indicates considerable variability exists between furrow discharges across each bay. Unlike siphon fed systems, where water is delivered at a constant rate and constrained to a particular furrow, furrows in bankless systems are subject to preferential and variable discharge due to relative furrow elevation and a variable discharge into each bay. The extent of this variability is shown in Figure 6 which shows the discharge in every third furrow across a 40 furrow bay.

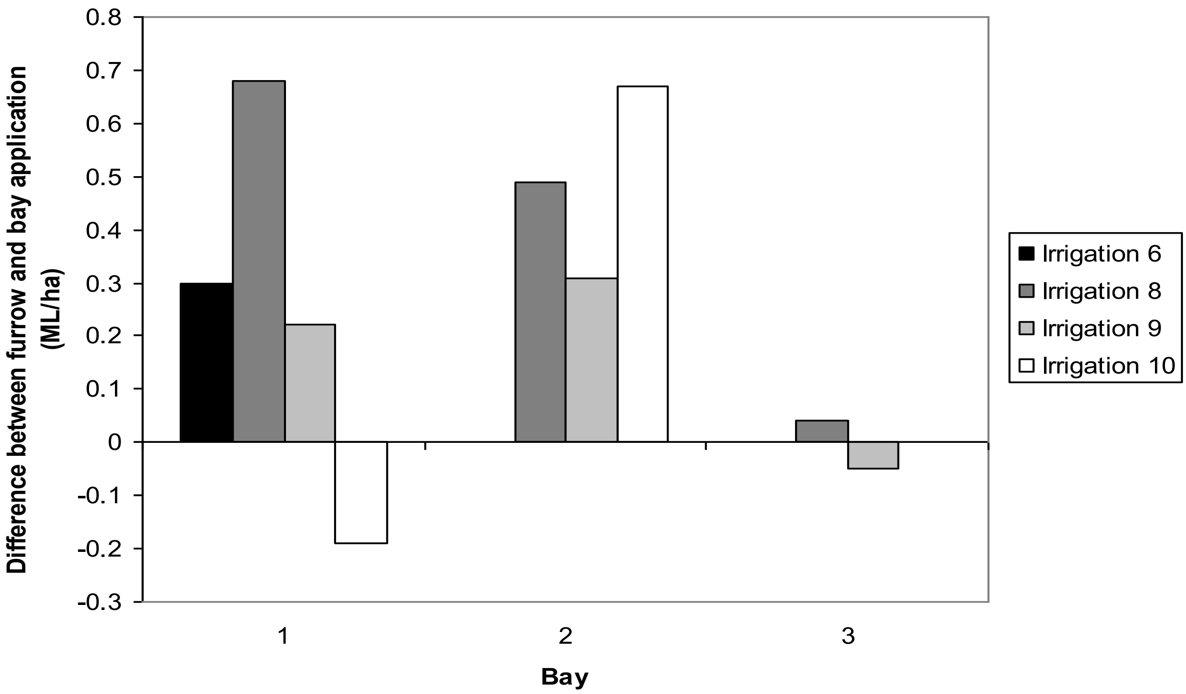

Figure 5: Bay and Furrow application rates for median elevation furrows in three bays for four irrigation events.

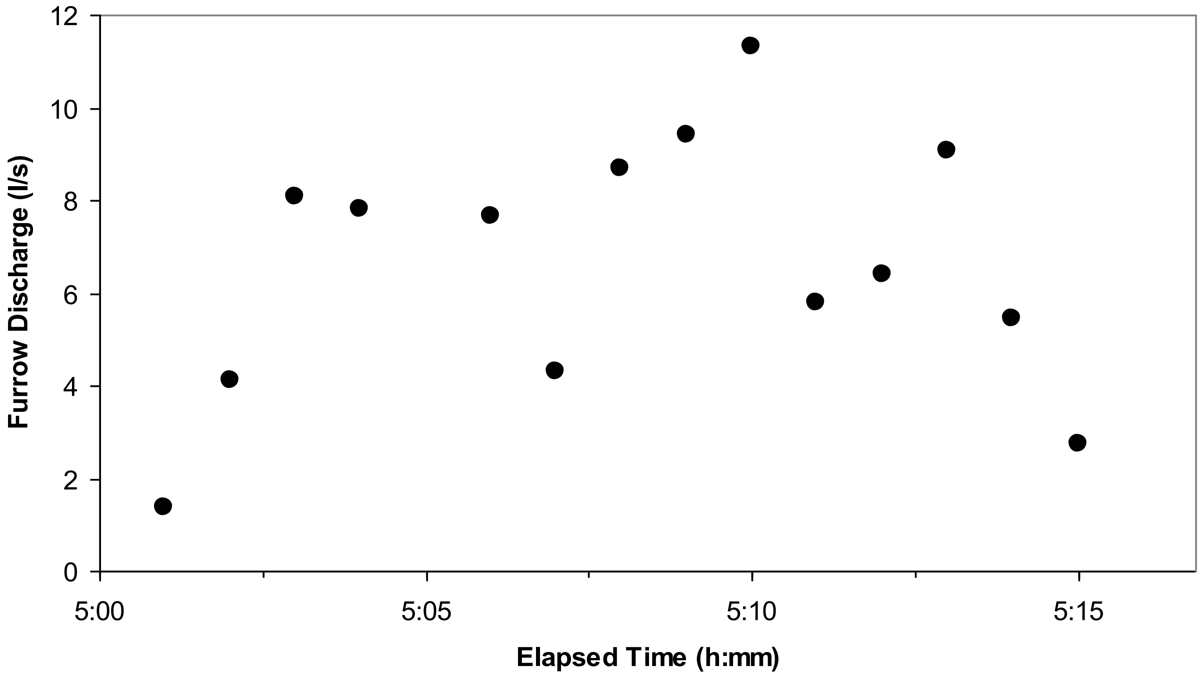

Figure 6: Furrow discharge from every third furrow in a 40 furrow bay during an irrigation event.

Evaluation of bankless systems at the field scale masks variability at both bay and furrow scales. To understand the irrigation performance of bankless systems, evaluation techniques which capture bay and furrow scale performance are important. Furthermore, a validated hydraulic simulation model for bankless systems will enable the development of design and management criteria, leading to improved irrigation performance of these hydraulically complex systems.

CONCLUSIONS

A variety of evaluation methods were investigated and a method developed for determining E_a of bankless systems. The evaluation method was then employed and used to successfully evaluate a system at several scales from the field, to the furrow scale. The evaluation revealed E_a at the field scale masks variation between bays, which in-turn masks variability between furrows. Across all bays the seasonal E_a was calculated at 93%. However, seasonal E_a of individual bays within the field ranged from 77 to 109%. Furrow discharge measurements identified extensive variability in application rates within bays. In siphon fed systems field E_a can be consistent between sets subject to the uniformity of field parameters and hydraulic supply. In bankless systems the preferential flow and variable discharge observed in bankless systems means application between bays and furrows can be substantial. This study shows that evaluation of bankless systems at the field scale is not representative of the performance of the system at finer scales. The ability to simulate the hydraulic operation of bankless systems using a validated hydraulic simulation model will enable optimum field design and management conditions to be identified.

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