How to improve every irrigation bay

An effective system for faster and more uniform irrigations

AGRICULTURE VICTORIA

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Billions of dollars have been invested to improve how water is delivered from dams to irrigation bays, but the investment will have little impact on production until we improve how water is delivered to plants.

WHAT'S THE PROBLEM WITH CONVENTIONAL IRRIGATION BAYS?

Border-check is a very common irrigation practice. It is relatively inexpensive to set up and to operate, which is why over 90% of irrigated dairy farms in the southern Murray-Darling Basin use border-check systems[1]. It is very commonly used on sites that have elevation gradients of less than 1 in 250 and soils that have relatively low permeability. Border-check does have a shortcoming, though, particularly on these relatively flat sites with low permeability soil profiles.

The problem arises because drainage of excess surface water from bays is very much slower that the process of applying the water. Excess surface water at the top of bays must find its way to the drain by flowing across the entire downslope surface of the bay. With modernised systems, applying irrigation water can be relatively quick, but once the supply is cut off, system energy rapidly dissipates. This leaves the excess surface water slowly finding its way down the length of bays in a process that can take days to complete.

In 2016 we measured residual surface water after irrigating a one hectare perennial pasture bay. The bay had been laser landformed in the previous year and the bay surface at the time of measurement looked in excellent condition. The new pasture was not yet fully established (Figure 1). The measured durations of surface water ponding at different distances down the bay are summarised in Figure 2. The much longer duration of inundation experienced at the bottom end of the bay is a characteristic of conventional bays due to slow drainage of the excess surface water from higher in the bay. The effect is more pronounced on longer, flatter bays with dense pasture and low permeability soils.

Longer duration of ponding provides greater opportunity for infiltration, so the problem that conventional border-check bays have is that they inherently produce non-uniform irrigations. Longer periods of ponding also increase the duration of saturation in the rootzone each irrigation. This can reduce root zone oxygen, stressing pasture and crop species while favoring weeds adapted to waterlogging. Longer periods of root zone saturation also increase vulnerability to damage by stock and machinery.

Figure 1: The measured irrigation bay

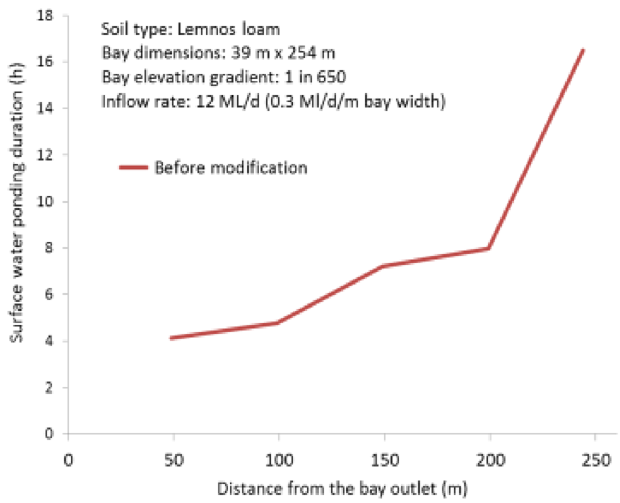

Figure 2: Measured duration of water ponding on a conventional bay after a border-check irrigation

.WHY IS THIS IMPORTANT NOW?

Non-uniformity and irrigation scheduling

Modernised irrigation supply systems provide substantially higher, more uniform and more accurately measured irrigation flow rates that can be delivered at much shorter notice. For the first time in regulated irrigation areas,

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irrigators have the opportunity to more precisely schedule irrigations to better meet plant water need.

At the same time, new and improved systems for irrigation scheduling continue to appear and are the focus of active ongoing research, development and extension.

A limiting factor for precision scheduling of border-check systems is the conventional irrigation bay itself. An optimal schedule for the top of a conventional bay will favour unproductive swamp plants at the bottom of the bay, while optimising for the bottom will cause regular periods of water stress at the top.

Deep drainage losses

Research[2] done at Tatura prior to the millennium drought showed that there is a complex interaction between surface irrigations, root zone soil moisture and watertables less than 2 metres deep. The interaction causes deep drainage initially lost below the root zone after an irrigation to return to the root zone by capillary rise as the root zone dries, leading to much less net deep drainage.

In many areas, particularly in the southern Murray Darling Basin, watertables have not returned to the less than 2 m deep levels that were common before the millennium drought, so deep drainage losses are now likely to be much greater than before the drought, and under these conditions reducing the duration of surface water ponding on bays can save a substantial volume of applied irrigation water, provided surface drainage and reuse systems are efficient.

SO WHAT IS THIS BAY MODIFICATION?

The bay modification consists of very shallow surface drains that run parallel with check-banks. The drains are installed only one to two centimetres deep. They are spaced 10 to 15 metres apart, and extend from the paddock drain at the foot of the bay to between 10 and 15 metres from the top of the bay (Figure 3).

The drains are installed with a tractor mounted rotary digger (Figure 4). Drains of this type have traditionally been used to improve surface drainage on poorly drained fields. In this application the drains are used to improve irrigation performance by providing faster surface drainage of the whole bay. Care is taken to cut shallow drains – they do not need to be any deeper than about 2 cm. By installing the drains at a shallow depth, they can be cut relatively quickly, reducing the cost of installation and reducing their impact on vehicles.

On bays in reasonable condition, the modification does not require any other earthworks. It can be implemented with minimal disruption to existing pasture and farm operations. In fact, on poor perennial pasture bays that require redevelopment, the current practice is to landform conventional bays and install the drains a year later, after the new pasture has established.

Advantages of the modification include its simplicity and relatively inexpensive installation which can be implemented in stages on a farm. Disadvantages include a requirement for ongoing maintenance of the drains. This is not insignificant, given that at the required spacing there is about 1 km of drain per hectare.

With the surface drains installed, all areas of the bay received a similar irrigation and experienced shorter durations of surface water ponding. The irrigation schedule for this bay can now be optimized and will be optimal for the whole bay.

Figure 3: Shallow surface drain installed on a pasture bay

Figure 4: Surface drain installation

Figure 5 shows the effect on ponding duration that the drains had on the bay shown in Figures 1 and 2. After modification the duration of surface water ponding was much more uniform down the length of the bay and substantially less at the bottom of the bay.

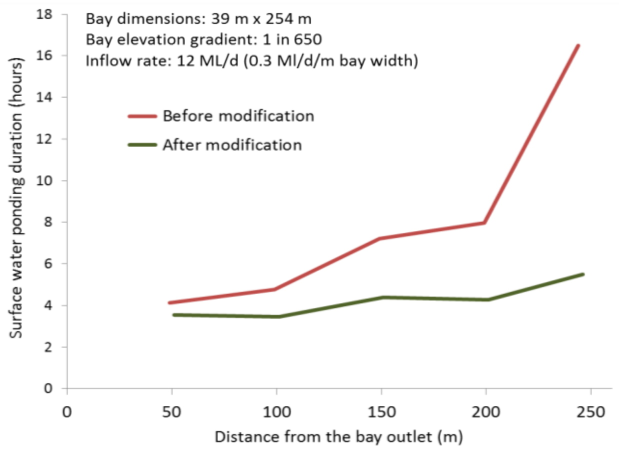

Figure 5: Measured average duration of surface water ponding after border-check irrigation on a bay before and after bay surface modification

Figure 6 shows the results of measurements made of water depth at 1 metre intervals on transects across the same bay before and after the modification. The measurements were made approximately 9 hours after initial inundation on transects at 75, 125, 175 and 225 metres from the top of the bay.

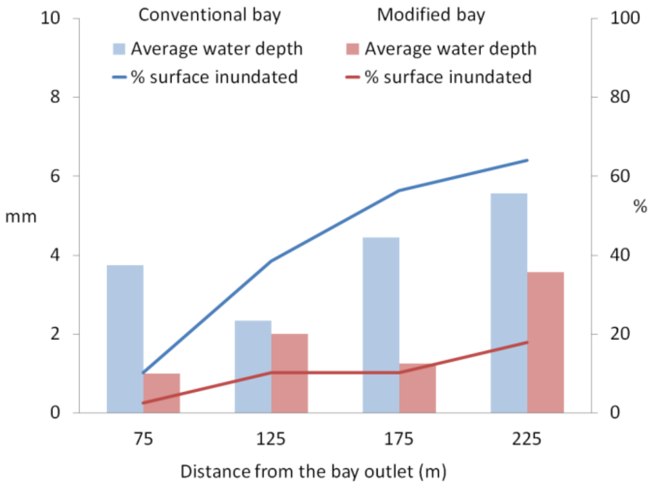

Figure 6: Surface water depth measured on transects across the bay 9 hours after inundation

Prior to modification, 60% of the bottom half of the bay remained inundated after 9 hours to an average depth of 4 to 6 mm. After modification less than 20% of the bay surface was still inundated after 9 hours, to an average depth of 1 to 4 mm.

Typical cumulative infiltration on this bay is shown in Figure 7. The bay soil profile infiltration curve has a shape that is characteristic of cracking soils like Lemnos loam[3][4]. On the basis of this curve, the modified bay was inundated for 4 to 5 hours and infiltrated between 41 and 43 mm as a result of the irrigation, while the conventional bay was inundated for between 4 and 16 hours and infiltrated between 42 and 49 mm.

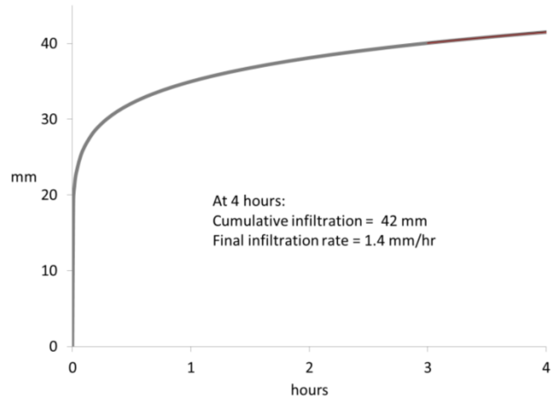

Figure 7: Typical cumulative infiltration curve on the bay that was modified

In this instance, the estimated reduction in infiltration due to the bay surface modification was about 4% of the volume of irrigation water applied.

HOW DID YOU ARRIVE AT THIS BAY SURFACE MODIFICATION?

The modification has been used on a small number of dairy farms in northern Victoria for more than a decade, and farmers who have implemented the design are convinced of its value.

In 2015 we adapted the ANUGA inundation model to use as a two dimensional surface irrigation model. The adapted ANUGA model is able to simulate the spread, flow and drainage of water on an irregular surface, and we were able to validate its use for simulation of border-check irrigations[5][6]. This allowed us to investigate the potential for bay modifications to improve irrigation performance (Figure 8).

We used the model to compare a wide variety of potential bay surface modifications, including the shallow drains modification, under a wide range of bay dimensions, slopes, inflow rates, soil types and crops.

Farmers with practical experience and using trial and error, and researchers taking a theoretical, computer modelling approach have independently arrived at the same modification to improve the performance of irrigation bays.

The simple modification described here was the stand-out of all the bay modifications we tested, achieving rapid surface drainage and high irrigation uniformity.

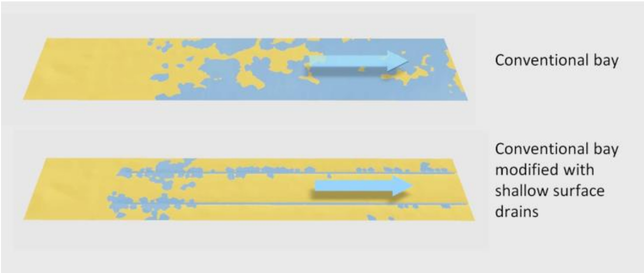

Figure 8: Model output for conventional and modified bay surfaces at 5 hours after the start of the same simulated irrigation

Importantly, our computer simulations indicated that this bay modification is very robust and will work well on a wide range of bay slopes, dimensions, inflow rates, surface roughness and soil types, reducing both the ponding duration and the variation in ponding duration within irrigation bays. It will have greatest effect on flatter bays with relatively low permeability soils.

WHAT IS REQUIRED?

Surface drainage and reuse

When compared to a conventional bay, the modified bay surface will increase surface runoff from a given irrigation.

For any given irrigation, the volume of runoff will be greater from a modified bay because

- less water is lost to deep drainage,
- less water remains ponded on the bay surface
- early in the irrigation some water completely bypasses the bay surface in the surface drains.

The relative contributions of these will depend on site conditions such as slope, soil infiltration and the depth of the surface drains.

Runoff volumes can to an extent be managed with accurate irrigation scheduling. Modernised irrigation supply systems provide irrigators with more timely deliveries of irrigation water at consistent and known flow rates. By irrigating modified bays at a consistent moisture deficit and with a consistent flow rate each irrigation, it is feasible to use simple cut-off timers to achieve uniform and consistently efficient irrigations.

The peak runoff flow rate will also be higher because drainage from the bay surface will be much faster.

For these reasons an efficient drainage and reuse system is essential with these bays.

Installation

The drain layout is measured and marked out before the drain is installed. The surface drains are installed with a rotary drain digger set to a depth of about 2 centimetres. Because the drains are shallow and require relatively little material to be removed, they are relatively quick to install and have minimal impact on machinery and stock.

The recommended 10 to 15 metre drain spacing is based on the experience of irrigators using the system.

For bays between 40 and 60 metres wide (i.e. most bays) this works out to between 3 and 5 drains per bay.

Experience indicates that if there is a borderline choice, opt for more rather than fewer drains.

Maintenance

Drain maintenance is necessary to control plant growth in the shallow drains. On the farm where our experimental site was located in northern Victoria, the drains are cleaned with a rotary digger after every second grazing during the irrigation season. Care is taken to ensure minimal removal of material to prevent the drains becoming deeper, and bays modified seven years ago are still in reasonable condition. Some erosion is occurring at the ends of the surface drains, requiring minor maintenance.

On other sites, farmers have reduced maintenance costs by using herbicide to control plant growth in the surface drains, reducing the frequency of mechanical cleaning.

WHAT ARE THE BENEFITS?

Farmers using the modified bays believe their pasture production is more consistently high and more uniform in modified bays. Bays with surface drains are trafficable sooner after irrigations and after heavy rainfall, reducing damage.

We have attempted to measure and compare production of perennial pasture on modified and conventional bays at two sites, and measured production of forage sorghum at another. Unfortunately, pasture production data have too much noise for a statistical difference between conventional and modified bays to be determined without a large field experiment on many replicated modified and conventional bays, with tight control over all the factors that affect production other than the bay modification.

We have been able to measure substantial improvements in bay hydrology, and farmers report that improved drainage of bay surfaces allows grazing within 48 hours after irrigations and gets winter rainfall off bays quickly, reducing damage by cows.

With supply system modernisation and irrigation automation, these modified bays will enable more precise irrigation scheduling for the entire bay and make optimisation of irrigations across the entire bay area feasible.

WHAT DOES IT COST?

The following analysis is confined to the costs incurred to create and maintain modified bay surfaces by mechanical means. Chemical weed control could reduce the frequency of mechanical cleaning required and thereby reduce the maintenance costs presented here.

With respect to fixed tractor costs, such as age related machinery depreciation, insurance, interest and shedding, were not included because the tractor was assumed to be already owned.

Variable operating costs such as depreciation due to usage, fuel consumption, maintenance and labour costs arising from installation and maintenance of the bay surface drains were included. The proportion of tractor depreciation due to usage was assumed to be 40%[7]. This figure was also assumed for usage depreciation of the implement (Table 1).

Table 1: Variable depreciation costs

	Tractor	Implement
Ownership period (years)	10	10
Value at the start of the cost period ($)	55,000	2,700
Estimated value at end of the ownership period ($)	25,000	800
Straight line depreciation per year ($)	3,000	190
Depreciation due to usage ($)	1,200	76

Hourly tractor operating costs for surface drain installation (Table 2) and maintenance (Table 3) were based on estimates from Khairo and Davies (2009)[8]. Fuel was assumed to cost $1.40/L delivered to the farm, with a $0.403/L tax rebate. Implement repair cost allows for annual replacement of the cutter blades and blade bolts. Labour cost for drain installation is assumed to be $18 per hour.

Table 2: Estimated costs for surface drain installation on 100 hectares

	Tractor	Implement	Total
	$/hr		$/ha
Depreciation	2.11	0.76	
Fuel	14.96		
Lubrication	0.86	0.20	
Filters	0.48		
Tyres	1.96		
Batteries	0.29		
Repairs	1.64	1.50	
Labour	36.00	0.36	
Total	58.29	2.82	28.87

On a 100 hectare area, estimated total surface drain installation cost was approximately $29 per hectare, with ongoing drain maintenance costs of approximately $71 per hectare each year. Labour (43%) and fuel (36%) comprise 80% of this cost.

Table 3: Estimated ongoing costs for surface drain maintenance on 100 hectares

	Tractor	Implement	Total
	$/hr		$/ha/year
Depreciation	2.11	0.76	
Fuel	14.96		
Lubrication	0.86	0.20	
Filters	0.48		
Tyres	1.96		
Batteries	0.29		
Repairs	1.64	1.50	
Labour	18.00	0.36	
Total	40.29	2.82	70.82

FOR FURTHER HELP

Contact Mike Morris, Agriculture Victoria on 03 5833 5283.

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ACCESSIBILITY

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