BENCHMARKING THE DISTRIBUTION EFFICIENCY OF AN IRRIGATION SUPPLY SYSTEM

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Wes Douglass, Kevin Preece and Derek Poulton,

Goulburn-Murray Water, Tatura, Victoria

GOULBURN-MURRAY WATER

National Program *for* Irrigation Research and Development

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Final report
Project GMW3

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Wes Douglass, Kevin Preece and Derek Poulton
Goulburn-Murray Water, Tatura, Victoria

Information

For information about this project, contact project investigators:

Wes Douglass
Goulburn-Murray Water
PO Box 165
Tatura VIC 3616
Phone: (03)58 335 608
Email: wesd@g-mwater.com.au

Kevin Preece
Goulburn-Murray Water
PO Box 183
Cobram VIC 3644
Phone: (03)58 710 100
Email: kevinp@g-mwamwater.com.au

Or project manager:

Derek Poulton
Goulburn-Murray Water
PO Box 165
Tatura VIC 3616
Phone: (03)58 335 690
Email: derekp@g-mwater.com.au

Project objectives

1. To benchmark the distribution efficiency (DE) of the various components of a small, open channel gravity irrigation system and irrigation return flows from farms to the surface drainage system.

2. To develop strategies to overcome water losses in the distribution system, including the implementation of smart systems for improved channel operations, system planning and services to improve the integration of distribution systems and farm systems, measure the improved DE and document the environmental benefits that result.

3. To improve the distribution efficiency of a small open channel gravity system by 5% over 10 years, and hence meet the future increases in demand.

Methods

Benchmarking Distribution Efficiency

To benchmark the DE of the CG 17/4 irrigation channel, each separate component of consumptive use or loss was quantified. Methods employed to measure each separate component of water use or loss identified within the system are described below.

Offtake/Outfall flows

Water entering the channel system (offtake) was measured using a STARFLOW ultrasonic doppler flow measurement device, installed in a 1.5 metre siphon, immediately downstream of the offtake structure. Flow rates were recorded every 15 minutes for the entire length of season. Estimated flow rates via visual inspection by a G-MW Water Distribution Officer were also recorded after each regulation.
Water escaping the end of the channel system (outfall) was also measured using a STARFLOW ultrasonic doppler flow measurement device, installed in a 0.6 metre siphon, immediately downstream of the outfall structure. Flow rates were recorded every 15 minutes for the entire length of season.

Deliveries via metered outlets

All deliveries were recorded using the pendent meter attached to each dethridge meter wheel. In addition, a logger was attached to the axle of the dethridge meter, which recorded the number of revolutions per 15 minutes, to show the water delivered over time. Start/stop times and requested flow rates were obtained from G-MW records.

Dethridge meter error

A flume device, to be attached to the headwall of a dethridge meter outlet, for calibrating dethridge meter error, was developed by RUBICON Systems Australia. The device uses ACCUSONIC ultrasonic sensors for flow measurement. Unfortunately, teething problems with the device meant that little usable data was able to be recorded. A single dethridge meter outlet was tested using the flume.
A separate study was undertaken to estimate inaccuracies in measurement due to varying operating conditions and excessive clearances between the wheel and emplacement.

Evaporation

Daily pan evaporation rates were recorded from weather stations at the Institute of Sustainable Irrigated Agriculture at both Kyabram and Tatura. These rates were applied over the known surface area of the CG 17/4 channel, based on the dimensions surveyed at the beginning of the project.

Leaks (through metered outlets)

Leaks occurring through metered outlets were quantified by removing all water from within an emplacement (a known volume), and timing how long it took for the emplacement to refill, hence deriving a flow rate. This test was conducted for all metered outlets within the system and repeated three times throughout a season.

Leaks (through channel banks)

Leakage occurring through channel banks was estimated using the G-MW Maintenance Management System. The system records all leaks attended to by G-MW staff, with an appropriate rating on severity and response time. Estimates on leakage per day were made for each rating, and this was multiplied against the total number of leaks for each separate rating.

Seepage

Lock-up pondage tests were conducted on two separate pools within the CG 17/4 system, both overlying different soil types. In total six pondage tests, where a pool was locked for at least 4 days, were conducted, with tests being undertaken at the beginning, during and end of season. Daily water level fall (in mm) was recorded at both the upstream and downstream ends of each pool. Allowances were made for evaporation and rainfall. The seepage volume was determined by multiplying against the known surface area of the pool, multiplied by the corrected fall in water level.

Domestic and stock outlets

A survey of all customers using water for domestic and stock (D&S) purposes on the CG 17/4 channel system was undertaken in January 1999 to provide an estimate of consumption. In addition to this work, a sample of six D&S outlets were selected within the CG 17/4 system and metered using DAVIES SHEPARD propeller actuated flow meters over the period February 1999 to the current day. D&S outlets to three dairy sheds, one poultry farm, one primary school and gardens and one farm house and gardens were metered. Using these meter readings, earlier estimates were amended for all D&S outlets within the system.

Theft

During the time of the project, no irrigator was prosecuted for water theft on the CG 17/4 channel system. It is often difficult to distinguish between theft and substantial leakage through metered outlets. For this investigation, theft was considered negligible. That is substantial leaks were treated as leaks through outlets, as described above.

Strategies to overcome water loss

Development of strategies included:

- replacement of five standard drop-bar channel regulation structures with new proto-type PADMAN drop-leaf gates
- a computer hydraulic simulation model of the system (including possibilities for automation of regulators)
- maintenance on metered outlet door seals
- opportunity outfall sales
- stock and domestic metering or appropriate formulas to estimate use
- improved maintenance to minimise leaks through channel banks.
- maintenance on metered outlets with poor clearances

Improvement in distribution efficiency

Actual and future improvements in DE were quantified by estimating water savings from the above strategies.

Modifications

Drain flows were not measured in 1999/2000. Drain flows were only useful in determining on-farm water use efficiency, defined as Field Application Efficiency (Bos 1993 and LWRRDC workshop, Sydney, June 1999), and could not be reconciled as a component of DE for the CG 17/4 channel system. Data on surface drainage flows in both normal and dry years had been recorded between 1996 and 1998 and additional data was not required.

Results

While LWRRDC funding for this study was only for June 1998 to June 1999, baseline data collected in 1996/97 and 1997/98 is reported here also.

Table 1. Water Balance Central Goulburn 17/4 Channel 1996/97 to 1999/00

	1996/97		1997/98		1998/99		1999/00	
	ML	%	ML	%	ML	%	ML	%
Total water into system (offtake)	9318.2		7979.3		6433.1		5872.1	
Delivered via Metered Outlet	7249.4	77.8	5864.4	73.5	5162.5	80.2	4366.1	74.4
Potential Meter Outlet inaccuracy	465.9	5.0	399.0	5.0	321.7	5.0	293.6	5.0
Stock & Domestic Pipelines	#N/A	#N/A	#N/A	#N/A	99.0	1.5	95.3	1.6
Leaks Outlet	#N/A	#N/A	#N/A	#N/A	120.0	1.9	120.0	2.0
Leaks Channel	#N/A	#N/A	#N/A	#N/A	105.1	1.6	37.1	0.6
Theft	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Outfall	1223.0	13.1	738.2	9.3	679.3	10.6	892.3	15.2
Seepage Season	112.7	1.2	119.6	1.5	30.6	0.5	31.8	0.5
Seepage Channel Fill	#N/A	#N/A	#N/A	#N/A	6.8	0.1	6.9	0.1
Evaporation	96.2	1.0	97.8	1.2	89.0	1.4	91.0	1.5
Unaccounted for water	171.0	1.8	760.3	9.5	-180.9	-2.8	-62.0	-1.1

#N/A – data not available. Components of loss in 1996/97 & 1997/98 that had, at that time, not been verified are included in 'Unaccounted for water' for those years

Results against objectives

Objective 1. *To benchmark the distribution efficiency (DE) of the various components of a small, open channel gravity irrigation system and irrigation return flows from farms to the surface drainage system.*

Table 1 documents the DE of the Central Goulburn 17/4 channel system. In the final two years of the project, all components of delivery and loss were accounted for, with a small negative error shown in 'Unaccounted for water'.

Total water delivery

76.5% of water is accounted as delivered to the farm gate over the length of the study. A further 6.5% of water was delivered but not measured (stock and domestic outlets 1.5% and under-recording of dethridge meter outlets 5%). Incorporating these figures means actual deliveries to the farm gate are approximately 83%. This figure compares quite well with the DE of most urban (fully piped) systems, an interesting result given the system is an open, earthen channel.

Losses

Leaks through Outlets

Leaks through dethridge meter outlets accounted for 2% of water lost from the system over the length of the study (3). Leaks occurred due to three main reasons:

- Poor sealing around doors
- Customer rorting (it was often difficult to distinguish between a major leak and inappropriate customer behavior)
- Leaks undermining outlet (both through and around concrete emplacements)

This loss could be substantially reduced by implementing a more vigilant maintenance program or installing new meter types. To verify if this system was representative for the majority of G-MW, the same measurement technique was used on other channel systems in Irrigation Areas throughout northern Victoria. Results from these studies indicated that the CG 17/4 system was indeed representative (4).

Leaks through Channels

Leaks through channels accounted for 1.7% of water lost from the system over the length of the study. Leaks occur when water passes out of the channel via a crack, cut, depression or hole in the channel bank, while seepage (accounted for below) is water actually passing through the soil of the channel earthen banks and bed/foundation. Leaks are difficult to quantify, as small leaks can go un-noticed for long periods of time, while the amount of water lost through a major leak (channel bank blow out) is particularly difficult to estimate. There is potential for G-MW to be far more proactive with respect to leaks from channels. A technique of spotting leaks using remote sensing is a potential avenue for further research.

Outfalls

Outfalls accounted for 12.1% of water lost from the system over the length of the study. Outfall from the bottom end of a distribution system is normally considered as a loss, and taken into account in the efficiency of the system. However, it has been argued that water outfalled may add to river flows and therefore be beneficial for the environment and other users downstream. The key issue then is whether the water outfalled is beneficial (for instance outfall to a river or wetland in autumn) or detrimental such as outfall to a drain with high nutrient or salt load, or to a wetland in summer.

For the purposes of this study all outfall was considered as a loss when estimating distribution efficiency. Much of the outfall is unavoidable – for instance rainfall rejection occurs when irrigation stops after a period of summer rainfall. While this water will always be construed as a loss to the system, many farmers may be willing to build a farm storage and collect this water for future use. If the outfall of water from the distribution system is to a creek or wetland, where such outfall flows are construed detrimental, it may be to the mutual advantage of the environment and farm productivity to retain water on farm for irrigation. As a direct result of this study G-MW has developed a policy for 'Opportunity Outfall Sales' (1) and initiated several trials to understand how such a new service would operate (GMW file 1998/00619). A customer on the CG 17/4 channel system was identified as being in a situation to accept outfall water, and an Opportunity Outfall Sales Agreement with the customer was developed. However, at the time of writing no sales water has been provided. To date some 32 outfall sales agreements have been established with a total usage of 3,000-5,000 ML per year.

Outfalls are reasonably consistent in volume throughout the season. However, outfall is a much higher proportion of the total channel flow early and late in the season. Hence, there is a lower DE at the start and finish of the irrigation season. While in the past the entire CG 17/4 system was fitted with drop-bar type regulators, in 1998/99 five Padman drop-leaf type regulators were retro-fitted to existing regulator structures at various points along the system. These new regulators gave a completely water-tight seal, dramatically reducing the amount of water passing through the system (and eventually outfalling) via leaks through regulators. The past operational practice has been to add a "top-up" flow throughout the season to counteract for losses. This top-up flow, usually 5 to 10 ML/day depending on climatic conditions and demand, could be reduced into the future as a result of installing the Padman regulators.

Also included in outfalls is the draining of the channel system at the end of the season. Draining the channel reduces the potential for weed problems and allows easier access to the channel for maintenance works in the off-season. Draining the channel is an unavoidable loss in the system.

Seepage

Seepage accounted for 0.6% of water lost from the system over the length of the study. Seepage is the loss of water through the soil in the channel banks and bed.

This study recognised channel seepage may be significantly higher during the channel filling process. Seepage tests were therefore conducted at the start of the season and on several occasions through the season. The study demonstrated seepage was higher at the start of the season and accounts for approximately 0.1% of total loss (11). Steady state seepage during the season accounts for approximately 0.5% of total loss.

Notwithstanding the generally low seepage rate found in the study area, it is envisaged there will be localised high channel seepage in areas of light soils, and where shallow aquifers are present close to the surface. A research project funded by MDBC and LWRRDC will investigate methods for location of localised areas of high channel seepage over the next three years.

Evaporation

Evaporation accounted for 1.3% of water lost from the system over the length of the study. Evaporation is a small portion of the irrigation water delivered, and it will therefore be hard to justify measures to reduce evaporation on economic grounds. Notwithstanding, pipelining of small irrigation spurs will eliminate evaporation losses and may be justified given there are other benefits such as reduced seepage and leakage, and improved metering. A Melbourne company has proposed a technique for constructing shade cloth covers over large channels to reduce evaporation, and a pilot trial has been proposed.

Unaccounted for Water

Unaccounted for water is the net error of all measured components of delivery and loss compared with the water entering the system. In the final two years of the study, the unaccounted portion was negative, indicating that the sum of losses and deliveries was in excess of the amount of water entering the system. The small error term involved provides confidence that all major sources of loss were measured and accounted for in the water balance.

Objective 2. *To develop strategies to overcome water losses in the distribution system, including the implementation of smart systems for improved channel operations, system planning and services to improve the integration of distribution systems and farm systems, measure the improved DE and document the environmental benefits that result.*

During the study, five standard drop-bar channel regulation structures were replaced with new proto-type Padman drop-leaf gates. The Padman gates provided a water-tight seal between regulated pools, reducing the amount of outfall water at the end of the system. As yet water savings derived from the use of the new regulators has not been quantified. However it is reasonable to expect that the top-up flow put on the system will be reduced, leading to a saving of 20%. This does not take into account additional savings during a system shut-down after a significant rainfall event.

A Computer Hydraulic Simulation Model was developed by Professor John Fenton of RUBICON Systems (8). The model predicts channel behavior for various operational scenarios and will allow simulation of partial or full automation of channel regulators. Automation allows a much quicker response and reduces the difference between actual flow and demand. It is reasonable to expect automation of the channel system will save up to 20% of outfall flows.

Opportunity outfall sales have already been taken up on other systems within G-MW, and while this is yet to be realised on the CG 17/4 system, it is reasonable to expect outfall savings of up to 10% will be achieved.

Leaks through wheels could be reduced by 50% by replacement of existing seals. This will be achieved by an improved maintenance program on the system over the coming seasons. As a result of this study a program has been initiated to account more accurately for water delivered through un-metered outlets, either by a formula or by direct metering (6). Further, this will be introduced in all G-MW channels by June 2002.

Improving the operating conditions on metered outlets with poor clearances between the Dethridge wheel and emplacement, some 6% of outlets, will lead to an estimated improvement in measurement accuracy for these outlets of 4% (5). This will be achieved by an improved maintenance program on the system over the coming seasons.

The possibility exists to be more proactive in maintenance of leaks occurring through channel banks using aerial surveying. This technique requires further research, but could reduce the loss by 50% for this component.

Objective 3. *To improve the distribution efficiency of a small open channel gravity system by 5% over 10 years, and hence meet the future increases in demand.*

Overall, the above strategies have the potential to improve DE over the next 10 years by some 9.6%. The original aim of the project will be exceeded in two respects; firstly the potential saving is greater than the 5% originally envisaged, secondly measures identified as part of the CG 17/4 project are already being implemented across G-MW.

Adoption

Already this project has lead to a number of changes to G-MW operations, both within this system and elsewhere. The development of opportunity outfall sales agreements, the development and implementation of the Padman drop-leaf regulator and improved maintenance of metered outlets door seals and wheel clearances are examples of adoption.

Another substantial benefit from the project has been an improved understanding of the demand for irrigation water within a channel system (9). An existing **pr**ogram for **i**rrigation **d**emand **e**stimation (PRIDE) was evaluated and refined as part of the project. An accurate forecast of irrigation demand is useful in estimating the bulk supply of water for an irrigation district, and as a tool in optimising the release of water from irrigation storages. Further, an accurate forecast of irrigation demand is important in improved methods for planning irrigation deliveries.

Project results have also been incorporated into the recent study "Water Savings in Irrigation Distribution Systems", June 2000, produced by Sinclair Knight Merz on behalf of the Department of Natural Resources and Environment, from which key initiatives for providing environmental flows to the Snowy River have been developed. It was extremely fortunate this project was reaching a conclusion at the same time the Sinclair Knight Merz report was being prepared. As such the project provided important technical information, and several of the major initiatives in water saving technology were developed directly as a result of this project.

Commercial potential

There are substantial commercial benefits arising from this project through more accurate measurement and accounting for irrigation water. Areas where there is commercial potential have been outlined above.

Publications

Douglass, W & Poulton, D (1998) 'Living with Limited Water' – Towards Efficient Water Use on Irrigated Dairy Pastures*. Proceedings of ANCID 1998 Conference, Sale, Victoria, Australia August 1998*

Douglass, W & Poulton, D (1998) 'Living with Limited Water' – Towards Efficient Water Use on Irrigated Dairy Pastures*. ICID Journal 2000, Volume 49 / Number 2 / May* ICID, New Delhi, India, pp 29-40

Additional information/supporting documents

Opportunity Outfall Sales Policy, November 1998

Benchmarking Distribution Efficiency on a Channel Supply System - Results of the Stock and Domestic Survey, February 1999, by Chelsea Hume

Investigation into the Leaking Outlets on Central Goulburn 17/4 Channel, February 1999, Jessica Stronge

Leaking outlet investigations (other G-MW Irrigation Areas), 1999

Dethridge Meter Accuracy Testing, January 2000, by Vincent Kelly

Determination of appropriate usage through D & S Pipes, July 2000, by Bill Heslop

Measurement of watertable levels in the area served by the 17/4 Central Goulburn channel, July 2000, by Derek Poulton

Hydraulic computer simulation model CG 17/4 results, July 2000, by Prof John Fenton (in press)

Forecasting Irrigation Demand, July 2000, by Derek Poulton & Chelsea Hume (in press)

Water Balance and channel flow figures 1996/97, 1997/98, 1998/99, 1999/00

Seepage test results Pool 5 for channel fill 1999