# IMPROVING WATER USE EFFICIENCY: THE COLEAMBALLY IRRIGATION AREA MODERNIZATION PROJECT

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## ABSTRACT

This paper provides an overview of the Coleambally Irrigation Area (CIA) modernization project. The CIA irrigation district is located in the southern Murray-Darling Basin of Australia. The district comprises 477 irrigation farms containing 79,000 ha (hectares) of irrigated land supplied through 700 km of earthen open channel. Development of the CIA modernization project commenced in 2000 with the objective of improving channel conveyance efficiency, reducing operating costs and enhancing water supply services. To date, some AU$16 million (AU$1 ≈ US$0.75) has been expended on capital works for the modernization project. Conveyance efficiency has been improved from 75% before the project, to around 89% in the 05/06 irrigation season saving approximately 60 billion litres of water per year. The cost of the project has been recovered by selling water savings to district irrigators and to government for use as an environmental flow. This paper focuses on two key areas of the modernization project: automation of canal operations and accurate flow measurement in farm turnouts.

## INTRODUCTION AND BACKGROUND

Much of the Murray-Darling Basin of southern Australia is experiencing the worst drought on record (MDBC 2007). With increasing water scarcity, improving the efficiency of water resource usage has become a priority issue. As irrigation is a major consumer of water, the minimization of losses in the conveyance of water through irrigation canals has become a key focus of efforts. This paper describes a project undertaken in the Coleambally Irrigation Area in south-eastern Australia to reduce conveyance losses in the district's earthen canal network.

The Coleambally Irrigation Area (CIA) is located in the southern Murray Darling Basin of south-eastern Australia (see Figure 1). Irrigation water is sourced from the Murrumbidgee River, one of the major tributaries of the Murray River. Water supplies are regulated from two major dams with a combined storage capacity of approximately 4,000 GL (Gigalitre or 1 billion litres).

The Coleambally irrigation district was developed over the period 1958 to 1970. The supply system consists of 41 kilometers of main canal, 477 kilometers of supply canal, and a further 734 kilometers of constructed drainage. The system is gravity supplied and the canals are of earthen construction. The commanded irrigation area is 79,000 hectares of which about 35,000 hectares is effectively irrigated. The district contains 477 individual irrigation farms.

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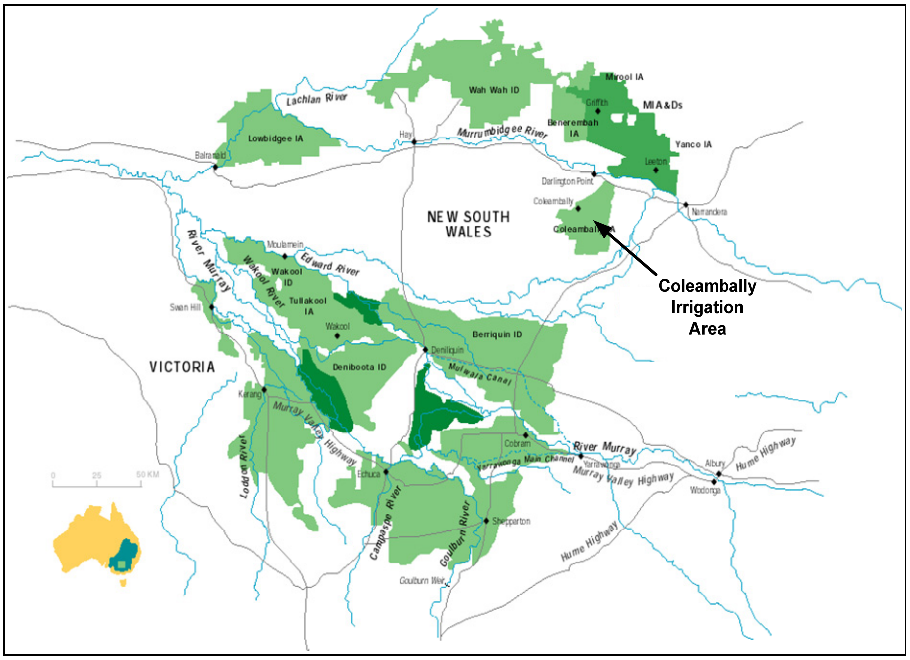


Figure 1. Coleambally Irrigation Area Location Map

The district's surface water license is for a volume of 620 GL per year. This includes a conveyance loss allowance of 130 GL and irrigation water rights of 490 GL. Groundwater pumping accounts for up to 100 GL of usage per year. Water is used to irrigate a range of crops including rice, wheat, barley, oats, canola, soybeans, maize, sunflowers, lucerne, grapes, prunes and pastures. Crops are predominantly flood irrigated although pressurized systems are becoming more common.

The district is owned and operated by the Coleambally Irrigation Cooperative Limited (CICL). CICL is a private co-operative that holds the district irrigation water licence and is responsible for providing irrigation water delivery and associated services to district customers. CICL's focus is the day-to-day operation of the irrigation scheme and the provision of water at the most affordable price to its member customers, consistent with its regulatory obligations and long-term business sustainability objectives.

## WATER SCARCITY

Like other irrigation districts in Australia, the CIA is licensed to divert an upper limit or maximum volume of water in any year. The actual volume of diversion into the district varies from year to year depending on water availability from the major storage dams. The state government ministry of water resources determines water allocation or the proportion of the licensed volume of water to be made available to irrigators. Historically, some 90% of CICL's surface water licensed volume, or 550 GL, has been available to the irrigation district on average. However, the introduction of environmental flow rules for the Murrumbidgee River in the late 1990s has resulted in a significant decline in water availability and as a consequence annual diversions from the river (see Figure 2 below). The decline in water availability has been exacerbated in recent years by a succession of low inflows into the major storages due to drought.

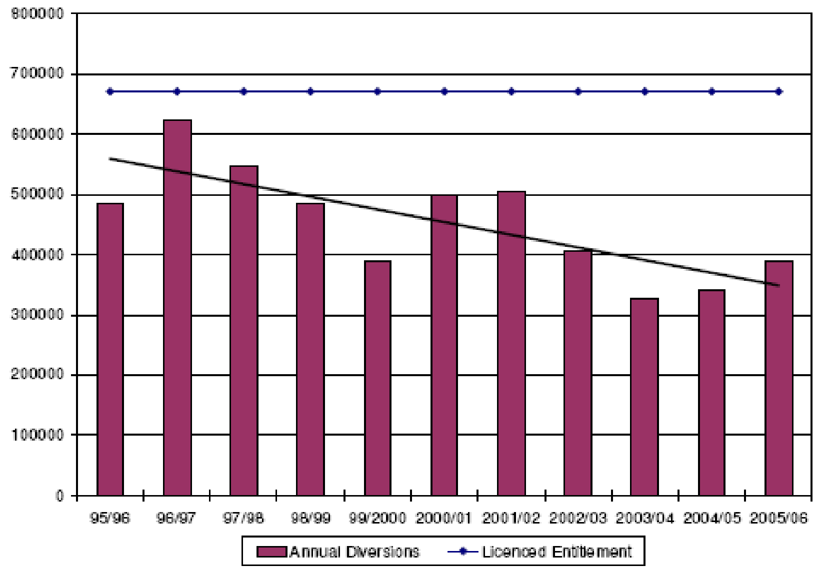


Figure 2. Coleambally Irrigation Area Annual Diversions (ML/year) - 1995/96 to 2005/06

The impact of drought culminated in the current water year with only 10% of the licensed allocation being made available to district irrigators.

## CIA MODERNIZATION PROJECT

Faced with a significant reduction in water availability, the Board and management of CICL made the decision to recover the water lost in conveying water through the district canal system to the farm gate. This lead to the development of the Coleambally Irrigation Area Modernization Project, with the objective of raising the efficiency of the conveyance system in order to save water for productive cropping uses.

As a first step, CICL sought to quantify the elements that constitute conveyance system losses (i.e. metering inaccuracy, un-metered diversions, evaporation, seepage, leakage and water theft). This was followed by a comprehensive options analysis which culminated in the development of the modernization project. The main components of the project are:

- canal automation system in 100% of the canal network replacing existing manually operated hydraulic gates and drop board structures;
- accurate water meters in farm turnouts replacing existing Dethridge wheel meters;
- increased maintenance of remaining Dethridge wheels, focusing on improved accuracy;
- metering of smaller uses including stock and tank-fill pipes;
- accurate metering at the district's bulk offtake on the river;
- increased investment in canal seepage/leakage works;
- increased fines and penalties for unauthorised water use (theft); and

- restricting the use of meter outlets to within the rated (accurate) operating range.

The development of the modernization project commenced in 2001. The impact of the project on conveyance efficiency has been marked. Figure 3 below provides a summary of the annual district conveyance loss and delivery efficiency since commencement of the project. CICL's bulk water license includes a component for conveyance losses within the irrigation scheme. The loss licence is on a sliding scale of up to 126,500 ML (Megalitre or 1 million litres) depending on the seasonal allocation. As a result of project works, conveyance efficiency is about 85% compared with 75% previously (see Table 1). In volumetric terms conveyance losses have declined by about 60,000 ML.

Table 1. Coleambally Irrigation Area Conveyance Losses And Efficiency – 2002 TO 2007

| Year | Bulk Diversion (ML) | Deliveries (ML) | Conveyance Losses (ML) | Conveyance Efficiency |
|---|---|---|---|---|
| 2002 | 505,804 | 405,844 | 99,960 | 80% |
| 2003 | 417,726 | 307,414 | 110,312 | 74% |
| 2004 | 325,285 | 235,162 | 90,123 | 72% |
| 2005 | 342,342 | 234,316 | 108,026 | 68% |
| 2006 | 391,842 | 349,658 | 42,184 | 89% |
| 2007 | 198,709 | 167,261 | 31,448 | 84% |

**Project Funding**

CICL has been able to offer its customers the 60,000 ML of water savings generated from reduced conveyance losses. This has more than offset the cuts to irrigator water allocations in recent years. CICL has distributed the water savings utilizing four methods:

- sale of water to customers at a fixed price of AU$35/ML per year;
- tendered approximately 11,200 ML of water has been sold by this method at an average price of AU$84/ML per year;
- distributed water to irrigators at no cost in recognition of the exceptional circumstances resulting from drought; and
- provided water free of charge as part of an incentive package to encourage irrigators to adopt a more accurate farm turnout meter.

Also, government has purchased some 3,500 ML of water savings generated by the modernization project for use as environmental flow. This yielded income for the co-operative of AU$1,400/ML.

## CANAL NETWORK AUTOMATION

A key component of the Coleambally modernization project is the automation of the canal network with the objective of reducing the operating cost of the canal system, reducing conveyance losses from escapes and improving the ability of the supply system to respond to irrigation demands. The main activities and outcomes of the project are discussed below.

**River Offtake and Main Canal Local Automation**

Historically, variation in river levels at the district's bulk river offtake lead to variable flow rates in the main canal creating major problems for district water operations. In 2001, the radial gates at the off-take were equipped with upgraded actuators and a Supervisory Control and Data Acquisition (SCADA) system. This allowed CICL to remotely monitor and regulate the flow from the river into the district's main canal. In addition, manually operated gates on eight main canal regulators (a mix of undershot and radial gates) were upgraded with local automation and more robust actuators. These gates were also connected into the SCADA system. The ability to remotely monitor and regulate the main canal resulted in a much improved standard of service to the district's secondary canal offtakes.

**Radio Network**

Building on the communications system installed for the main canal automation, a district-wide radio network has been implemented to manage the high data transfer rates associated with the planned deployment of automated regulator gates (Total Channel Control). The system provides 100% coverage of the district using broadband radios (Motorola Canopy, E Series and Darcom) It links four major backhaul sites to the base station at the CICL district office. The radio network provides 21 megabits per second (mbps) throughput.

In the future the radio network will provide the backbone supporting low-cost distributed sensor networks on-farm. Indeed, $AU6 million of funding from the Australian government has been secured to implement sensor networks to aid irrigation decision making as part of Stage 2 of the CIA modernisation project. A range of solutions are being investigated for the low-cost radio network including products developed locally (NICTOR and Agrilink).

Figure 3. Repeater Tower: CICL SCADA Radio Network (left) and Canal Regulating Structure Equipped with Automatic Gates (right)

## Secondary Canal Local Automation

Stop logs and sluice gates in some 200 secondary and tertiary canal regulating (check and drop) structures have been replaced with automatic gates from Rubicon Systems Pty Ltd. The automatic gate or Flumegate is a bottom hinged overshot gate with an integrated drive mechanism, control console and solar panel power supply. Gate operation is positive actuation in both directions. The deployment of automatic gates in regulators commenced in 2003 and will be completed in 2007.

## Computer Control

Progressive deployment of Flumegates allowed traditional manual irrigation planning (scheduling) to be phased out in favour of computer control. The control system used is Total Channel Control (TCC), developed by Rubicon Systems Australia Pty Ltd.

The TCC software system is installed on host computers in the Coleambally district head office. The software system controls the opening and closing of gates automatically in response to irrigation demands and channel levels. The system provides a graphical user interface that allows the user to configure, view and report on the network (see Figure 4). The canal system can be operated manually, in upstream control mode or in fully automatic mode.

The TCC system also features a computerised water ordering system and a demand management system whereby a continual assessment is made of the capacity of the channel network and the ability to supply customer orders. Alarms play a key role in the operation of TCC, with alarms monitoring water levels in each channel pool and the operating status of gates and the communication system. As an outcome of the project, the intensive daily manual planning and operations of the canal system is no longer required.

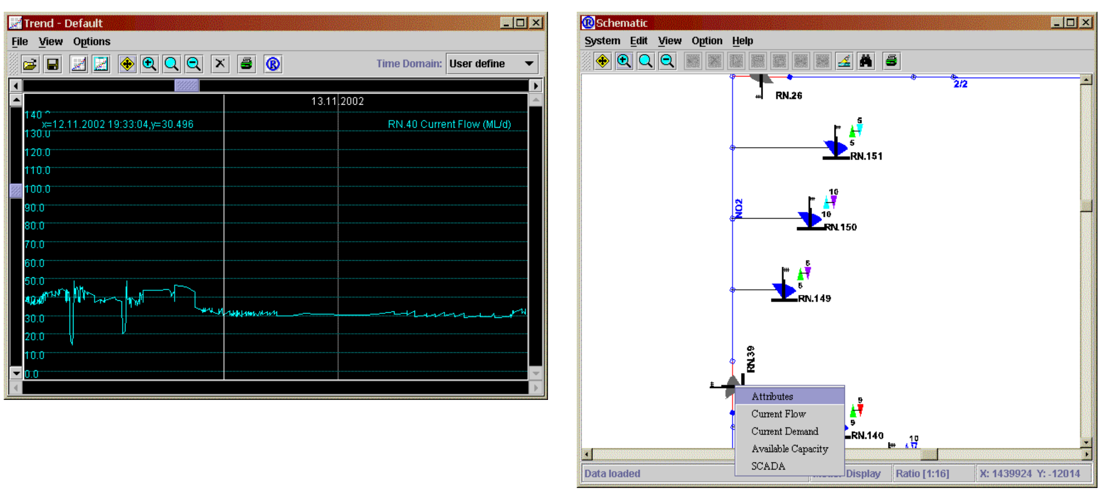


Figure 4. Elements of the Total Channel Control User Interface – Pool water level monitoring (left) and Network schematic (right)

As of 2007, the secondary and tertiary canals are being operated in full automatic mode. Successful deployment of the new technology embodied in the TCC system, however, didn't come easily or quickly, with several years of frustration with TCC caused mainly by problems with the sensor technologies in the automated regulators and tuning parameters associated with automating the regulators. This tested the relationship between CICL and its customers and also the relationship between CICL and the supplier.

## Reduced Overflow Losses

Historically, the district's canals were operated at slightly above ordered flow rates in order to ensure customer water orders were delivered in line with expectations. As a result, the canals continuously overflowed into the district drains. CICL effectively lost the escaped water as it was debited against the district's water allocation for that year. The introduction of automated channel operations greatly reduced the overflow during periods of normal operations (see Figure 5). No trade-off in reduced irrigation customer service levels was required to achieve this outcome. Indeed the TCC system has reduced fluctuations in canal water levels and improved the stability of flow rates at farm turnouts. The reduction in overflow volumes is also reflected in improvements in district conveyance efficiency.

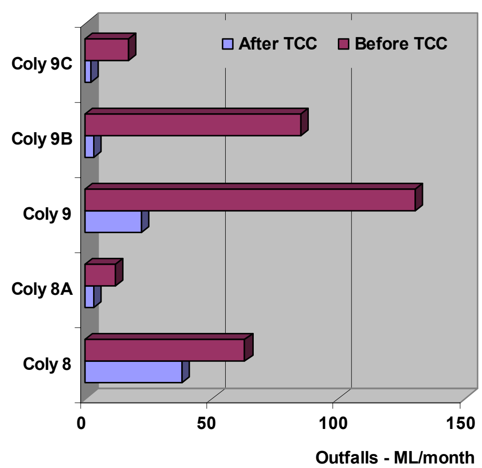


Figure 5. Monthly Volume of Overflow Water – Before and After TCC Automation – Coleambally Irrigation Area

Further tuning of TCC has now completely eliminated all overflows.

## Customer Water Ordering

In common with many other gravity irrigation districts, the practice within the Coleambally area is to supply water in response to customer water orders. Up to the late 1980s, irrigators placed written water orders in roadside boxes which were collected by a water bailiff and subsequently processed in the CICL central office. In the early 1990's, written orders were replaced by telephone ordering using an answering machine. In 1999, the answering machine system was replaced with an IVR (interactive voice response) system that enabled touchtone and voice input of orders directly to a water ordering computer database. In 2003, a web site was set up for water ordering. Irrigation customers currently use both the web site and IVR. The advantage of the web site is it is easier to use than the IVR. In addition, irrigators can easily access water account and meter reading information from the website.

## Reduced Operating Costs

The full cost of operating the canal system is recovered from the water charges levied by CICL on its customers. Prior to the deployment of the modernization project, the CICL employed 11 water bailiffs and two water planning officers for day to day canal operations. Staff numbers have subsequently been reduced to four customer service officers and one technology officer. The use of automatic gates has eliminated the need for heavy, manual handling of stop-logs in regulating structures (see Figure 6 below). This has significantly reduced the district's workers compensation risks (back, limb and joint injuries). Eliminating the need for a water bailiff to visit every regulator in the canal network at least once a day has markedly reduced fuel, vehicle and access track maintenance costs.

Figure 6. Manipulating Stop Logs in a Canal Regulator – Goulburn-Murray Irrigation District

## Improved Customer Service

The automation of canal regulators has allowed the district to introduce almost on-demand water ordering. The time lag between the irrigator posting a water order and actual delivery of the water to the farm turnout has been reduced from 4 days to two hours.

## FARM TURNOUT WATER METERING

Improving farm turn-out metering is the second element of the modernisation project. Prior to the modernisation project, the volume of water supplied to farm turnouts in the Coleambally district was metered using a Dethridge wheel (see Figure 7 below). The Dethridge wheel consists of a wheel with vanes, a flume like concrete emplacement, a pendant counting device and an upstream control sliding gate. Dethridge wheels are the basis for customer water billing and the water accounting in many Australian irrigation districts.

Dethridge wheels are relatively cheap, mechanically robust, produce small head losses and can pass debris. However, it has a number of weaknesses. One of the major weaknesses is inaccurate flow measurement as a result of excessive clearances and worn bearings and vanes. Wear and tear to the meter invalidates the calibration curve used to link the rotation of the wheel to the volume of water passed.

Figure 7. Dethridge Wheel Farm Turnout Meter – Goulburn-Murray Irrigation District

Another weakness of the Dethridge wheel in terms of accurate measurement include: irrigators using low flow rates outside the meter's rated operating range and drowning or submergence of the meter due to high tailwater levels. In-situ volumetric testing of Dethridge meters by CICL has shown that on average the devices under recorded in favor of the irrigator by approximately 19% of the actual rate. Of particular concern was the wide dispersion in measurement error with some wheels under recording by up to 30% and others over recorded by up to 20%.

Various options were considered for rectifying the measurement accuracy problems in Dethridge wheels including re-calibrating the wheel rating curve to remove the bias in favor of the irrigator. To implement a changed rating would require replacement of the pendant counter in the wheel. This option was assessed as being the least cost option but was rejected as it was deemed unfair to customers who currently have relatively accurate wheels. CICL were also concerned that the concept of correcting the rating in the wheel would be difficult for customers to understand and accept.

The option of equipping Dethridge wheels with upstream and downstream level sensors with continuous recording was also considered. Level sensors could be attached to the emplacement to improve the accuracy of the rating curve. This option was rejected for several reasons including: 1. undertaking sufficient testing to developing a new rating curve was considered problematic; 2. level sensors attached to walls and their electronics were not considered tamper proof; and 3. the cost of sufficiently accurate level sensors was high.

Increasing maintenance as a means of improving Dethridge wheel accuracy was also examined. This would involve increasing the rate and frequency of bearing and propeller maintenance thus reducing the incidence of excessive clearances and inaccurate wheels. CICL rejected the improved maintenance option on the basis that it was unlikely to provide a long term solution as experience had shown that over time priorities change and the importance of maintenance can be lost.

After consideration of the options CICL elected to tackle the problem of inaccurate Dethridge wheels in a two staged approach. First rules were implemented prohibiting the use of Dethridge wheels at inaccurate low flow rates of below 4 ML/day. Second, it was decided that all Dethridge wheels would progressively be replaced with modern accurate meters. Apart from reducing conveyance losses, CICL's decision recognised that modern accurate water meters improved canal network operations and provided critical information to assist irrigators make better irrigation decisions based on real time information about flow rates and water useage. The pending introduction of national standards for irrigation water meters also influenced the decision to replace wheels. (NMI 2006)

For the water meter replacement program, CICL elected to trial a number of different meter types and configurations in order to identify the preferred meter replacement option. This process was greatly assisted by the work undertaken by the Australian National Committee on Irrigation and Drainage (ANCID 2002) to guide industry on the selection of water meters to replace the Dethridge Wheels. An overview of water meters trialled by CICL is provided below.

## Propeller Meter

Propeller meters installed in pipes were first considered as a Dethridge wheel replacement in the mid 1990s. The meter transducer consists of a metal or plastic propeller mounted in a pipe. The pipe section is kept full by inverting the pipe. The co-operative trialled propeller meters from a range of vendors including products from Elster Metering and Water Specialities. Practical experience with the propeller meter showed that while the device was accurate it was susceptible to tampering as well as fouling due to the presence of aquatic weeds in the water supply. Tampering included placement of a steel stake in the pipe to stop the propeller and placing a sack over the propeller to slow down its rotation. It was found propeller meters needed constant inspection and maintenance to remove weeds and check for tampering and spindle wear.

## Doppler Meter

CICL has trialled Doppler ultrasonic meters as a replacement for Dethridge wheels. Locally, Doppler meters are widely used, especially in irrigation pumping installations. For irrigation turnouts, the typical meter installation comprises a Doppler transducer mounted in a concrete pipe connected to an electronics housing and solar power unit. The Doppler meter was found to be robust and accurate. The major advantages of the Doppler meter over the Dethridge wheel include: no moving parts to be maintained, minimal obstruction to the flow, ease of installation, tamper proof characteristics of the sensor and comprehensive diagnostics provided in the meter electronics.

Source: www.mace.com.au

Figure 8. Doppler Meter - Transducer (left) and Turnout Emplacement (right)

While the Doppler meter installation proved to be satisfactory in most instances, the accuracy of the meter was affected by water quality. CICL found that on occasions the water supply contained insufficient particles in the water to reflect the meter's signals. This typically occurred in the latter part of the irrigation season when there is little tributary inflow into the Murrumbidgee River and the water supply in the district is sourced from dam releases. Despite the advantages of the Doppler meter, CICL elected not to install any further examples of this meter in its gravity supply area. In contrast to Coleambally's experience, other irrigation districts in the Murrumbidgee Valley have successfully installed several thousand Doppler meters in farm turnouts.

## Electromagnetic Meter

As an outcome of the ANCID review of Dethridge wheel replacements, a number of meter vendors developed Electromagnetic (EM) meter emplacements to replace Dethridge wheels. The challenge was to build an EM meter that could handle the harsh environment and be powered using batteries and solar cells. A meter vendor, Tyco Environmental, developed a meter specifically for use in farm turnouts – the Tyco Irriflow. The meter is available either as a full bore meter in sizes 450mm and 600mm, or a specially designed insert for an existing Dethridge Wheel emplacement. The meter is fabricated in stainless steel and is designed to be fully submerged.

The Tyco meter has been used in various installations. The most popular arrangement is to mount the full bore meter to the downstream end of a pipe and enclosed in a pit to ensure a full pipe and equipped with a gate for flow control (see Figure 9). A major advantage of locating the meter at the end of the pit is the ease of access and inspection.

Figure 9. Tyco Irriflow EM Meter – Transducer (left) and Turnout Installation (right)

It is worth noting that CICL experienced problems with the electronics in the first batches of EM meters to be installed. These electrical problems appear to have been resolved by the meter vendor.

**Automatic gate**

The automatic gates used by CICL in canal regulators can also be installed in farm turnouts to replace Dethridge wheels. Indeed, some 126 automatic gates have now been installed in farm turnouts since 2003. The advantage of Rubicon Flumegates in turnouts include: accurate metering, remote operation, stable flow rates onto the farm, low head loss, and full integration into the existing Coleambally SCADA communications network.

CICL experienced some problems with drifting level sensors in the automatic gate. The consequent degradation of measurement accuracy eroded user confidence in the gate as a metering device. In response, Rubicon developed an ultrasonic level sensor which was retrofitted to farm turnout gates in 2005. Subsequently, the automatic gate has proven to be a robust and stable metering device.

## SUMMARY AND CONCLUSION

This paper provides an overview of the Coleambally Irrigation Area modernization project. Development of the project commenced in 2000 with the objective of improving channel conveyance efficiency, reducing operating costs and enhancing water supply services. To date, some AU$16 million has been expended on capital works for the modernization project. Conveyance efficiency has been improved from 75% before the project, to 89% in the 05/06 irrigation season saving approximately 60 billion litres of water per year. The cost of the project has been recovered by selling water savings to district irrigators and to government for use as an environmental flow. This paper focuses on two key areas of the modernization project: automation of canal operations and accurate flow measurement in farm turnouts.

Building on the success of the modernization project to date, Stage 2 of the project will commence in late 2007. Stage 2 will see the deployment of accurate meters in all farm turnouts, the installation of meters and telemetry on all groundwater bores, the construction of off-stream storage and the roll out of a program to install soil moisture sensors and telemetry in irrigation fields. It is expected that Stage 2 of the project will assist irrigators to improve the efficiency of on–farm water use complementing the gains in conveyance efficiency achieved in the canal network.

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