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Estimation of seepage losses from automated irrigation distribution channels during periods of shutdown

A dissertation submitted by

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ABSTRACT

Irrigated agriculture is the largest water consumer all over the world as well as in Australia. Therefore, managing water more effectively in irrigation distribution systems is one of the most important and urgent challenges facing Australia. The correct estimation of conveyance water losses from an irrigation system is vital for the proper management of the system. The loss of water due to seepage, leakage and evaporation from irrigation channels constitutes a substantial part of the usable water. The scarcity of water resources and inefficiency of irrigation infrastructures convinced the Australian government to pursue modernization and automation of irrigation distribution supply networks in major irrigation districts of the country. The automation includes installation of automatic control structures with remote monitoring, one example of which is the total channel control technology (TCC) of Rubicon Water. Main objectives of using automation are to supply water near-on-demand and to control channel water levels. TCC includes supervisory control and data acquisition (SCADA) technology which will result in integrated databases of real time measurements of flow and water levels for the whole system. This data has the potential to be used to identify sections of channel with high rates of seepage or leakage. Pondage tests are acknowledged as the best direct method for seepage measurement, and the recorded water level data from automated systems during periods of gate closure can be treated as pondage test data. A comprehensive review of seepage studies identified examples of the successful application of TCC data from a limited number of selected channels during certain periods of season. However, no study was located that used TCC data collected over the whole irrigation district or for whole irrigation seasons to estimate seepage and leakage losses during periods of gate shut down. Given that Coleambally Irrigation Corporation Limited was the only scheme able to provide data for three irrigation seasons, this study aimed to estimate seepage and leakage losses for the entire channel network of CIA using TCC data during periods of gate closure. Using Microsoft SQL server, a database containing the TCC data in the form of individual tables was created. A model consisting of the database and code written in C# was developed to identify all pondage conditions for any given pool in the network, to sort the pondage data into rejected and accepted samples based upon set criteria. Linear regression was used to give an estimate of the seepage rate for any gauge in a pool during a pondage condition. The

model was tested for the 2010/11 irrigation season and identified 1073 pondage conditions for different pools on the network, among which 295 were rejected as they did not meet the specified criteria. The model was also applied for 2009/10 and 2011/12 seasons and average seepage rates for each pondage and pool were estimated.

The results clearly showed that seepage losses from the CIA are significant, with approximately 20% of the estimated seepage rates in all three seasons greater than 0.5 mm/hr (12 mm/d). A number of cases with significantly high loss rates were observed during each season. The median seepage rate for 2011 was lower in comparison with the other two seasons, while the median seepage rates were similar between the 2009 and 2010 seasons.

A number of pools with several pondage conditions were identified and the possible factors affecting the estimation of seepage rates were evaluated. These include, duration of gate shut down, surface water elevation at the start of the pondage condition and its relation to supply level of the channel at each gauge, accumulated depth of rainfall during the pondage period, seasonal variations in seepage rate, number of water level measurements in the pondage, suspected unauthorized water usage, noise associated with measurements and leakage through macro pores in banks of the channels.

Pools with very high rates of water loss indicative of leakage were addressed and the application of a polynomial trend line rather than linear regression for modelling the seepage rate in those samples was assessed.

Given that higher loss rates occur at higher channel water elevations similar to operational levels, the corresponding seepage estimates were used to:

- identify pools with high loss rates which require remediation works, and
- give an estimate of the possible water loss during normal operation in each channel.

The loss rates at occurring at higher channel water elevations were compared with seepage estimates from an earlier study in the CIA which identified several locations potentially with high seepage losses. Results of the comparison showed a good agreement in those pools with moderate seepage losses. On the other hand, in pools where the present study indicated high loss rates and possible leakage at higher channel water elevations, the loss rates estimated from the TCC data were greater than in the earlier study.

CERTIFICATION OF DISSERTATION

I certify that the ideas, designs, experimental work, software code, results, analyses and conclusions presented in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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ABBREVIATION

ABS	Australian Bureau of Statistics
AWS	Automated Weather Station
ANCID	Australian National Committee on Irrigation and Drainage
CIA	Coleambally Irrigation Area
CICL	Coleambally Irrigation Corporation Limited
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EM	Electro Magnetic
FoES	Faculty of Engineering and Surveying
GMW	Goulburn-Murray Water
LOC	Level Of Confidence
LOCP	Level Of Confidence Pool
NCEA	National Centre for Engineering in Agriculture
NMPP	Number of Measured Points per Pondage
NMPPP	Number of Measured Points Per Pool
NSW	New South Wales
Post	After remediation
Pre	Before remediation
SCADA	Supervisory Control And Data Acquisition
SDR	Sequential Decline Ratio
SKM	Sinclair Knight Merz
SQL	Structured Query Language
TCC	Total Channel Control
TDR	Total Decline Ratio
USQ	University of Southern Queensland

PUBLICATION ARISING FROM THIS RESEARCH

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Chapter 1: Introduction

1.1. Background

Water is essential to sustain life. It plays an important role in food and energy production, determining the quality of life, and in the integrity and sustainability of natural environments as well. It is also considered central to social and economical development and represents an important input into Australia's economy, particularly agriculture.

Australia’s economy has traditionally been reliant on the agriculture industry. The agriculture industry is the largest consumer of water, consuming 52% of total water use in 2009–10 (ABS, 2010a). In the year 2009-2010 Australia’s total water consumption was 13,476 GL, with the agriculture industry being the single largest user by far at 6,987 GL or 52% (ABS, 2010a). Generally speaking, agriculture industry is the biggest water consumer in most countries that are economically dependent on this sector. For instance, the agriculture industry in Pakistan, consuming almost 97% of all river water is the biggest water consumer in the country (Kahlown and Majeed, 2002).

The main sources of water for society comes from surface water in the forms of rivers, lakes, reservoirs, dams and rainwater tanks, and from underground aquifers via wells and bores.

Given that Australia is an island continent, precipitation (rainfall and snow) plays an important role in supplying water.

Long-term drought in many parts of Australia as well as adverse effects of increased water use on river health has changed the way Australians regard water.

With the exception of Antarctica, Australia is considered to be the driest inhabited continent (in terms of runoff per unit area) on the planet and requires the most efficient water use management. More than a third of the continent is desert area and over two-thirds of the continent is classified as arid or semi-arid. This is further exacerbated by the highly variable nature of rainfall. Average annual rainfall varies considerably across Australia. Large areas of the country receive average annual rainfalls of 600–1,500 millimetres (mm), while about half of the continent experiences an average annual rainfall of less than 300 mm (ABS, 2010a).

Due to the variability and seasonality nature of annual rainfall and river flows in Australia, successful ongoing production of many crops and pastures is dependent on irrigation. Irrigation is an artificial application of water to the land or soil with the aim of providing a pasture or crop with the amount of water it requires for optimal growth.

Although in 2009–10, irrigated agricultural land comprised only less than 1% of all agricultural land in Australia, the gross value of production from irrigated land was $11.5 billion, which represented 29% of the total gross value of agricultural production in 2009–10. Therefore the irrigation industry contributes a major part in the Australian economy (ABS, 2010b).

The development of large scale irrigation schemes has made agricultural activities possible in areas inland of Australia. Irrigation in Australia started in the early 1800s, mainly through the initiative of individuals who developed water resources to ensure feed for livestock. During the 1880s, in response to drought the first large scale irrigation schemes in Australia limited to individuals or small groups of individuals were introduced. The first major development occurred in 1882 with the formation of the Loddon Irrigation Works (Hallows and Thompson, 1995). Other schemes soon followed in nearby catchments as the area surrounding Mildura and Shepparton were suitable for agricultural production while the development was partly funded by income from the Victorian Goldfields. This development later spread downstream to South Australia and upstream into the Murray, Murrumbidgee and various tributaries of the Darling River. Still to this day, the Murray-Darling irrigation system remains the largest of its type in Australia.

The required water for irrigation is supplied from two main sources, river systems and underground aquifers. Major river systems used for irrigation in Australia include the Murray-Darling system, the Ord River in the Kimberley region of Western Australia and many rivers along the east coast of Australia.

Managing water more effectively is one of the most important and urgent challenges facing Australia. Due to severe and extended droughts that have caused considerable changes in water supplies, the irrigation industry has faced many challenges over the past decade, struggling to fill the gap between the supply and demand for water. At the same time, climate change and increasing climate variability are likely to increase the uncertainty of water supply. As a result, irrigation industry is under considerable pressure to adopt best practice methods to increase efficiency in terms of water use and productivity.

In response to reduced water availability in 2008–09, the Australian irrigation industry consumed 31% less water, equivalent to 7286 Gigalitres (GL) —to agricultural land compared with water usage in 2004–05 (11 147 GL) (ABS 2010b). However, the gross value of irrigated agricultural production increased from an estimated $13.97 billion in 2000–01 to $14.99 billion in 2005–06 (Mackinnon et al., 2009).

1.2 Conveyance water losses in irrigation distribution system

An irrigation distribution system is comprised of delivery systems, which receives water that has been abstracted from the different water sources before delivery to irrigation farms. An extensive irrigation distribution system consists of a network of open channel conveyors, distributaries, field channels, pipes, pumps if a higher level branch is to be supplied from the conveyor, regulators for water level control, offtake structures to supply distributary or lateral canals, outlets and culverts for road or railroad crossing. The correct estimation of conveyance water losses from an irrigation system is vital for the proper management of the system.

In most cases, irrigation delivery systems are inefficient and much of the water diverted into the irrigation channels and pipes does not reach end users.

Depending on the irrigation infrastructure, methods, scheduling and the management practices of irrigators, the conveyance efficiency of Australian irrigation areas ranges from 67 to 90 per cent (Khan et al., 2008). Conveyance losses in the distributaries and field channels in Pakistan are reported to be around 25 and 30%, respectively (Kahlown et al., 2005). In the context of irrigation-water supply, conveyance losses are reported as the difference between the volume of water supplied to irrigation customers and water delivered to the system. In general water losses in an irrigation distribution system consist of the following components:

- Seepage
- Evaporation
- Leakage
- Spill
- Unrecorded usage
- Outfalls
- Water meter inaccuracy

The loss of water due to seepage and evaporation from irrigation channels constitutes a substantial part of the usable water. By the time the water reaches the field, more than half of the water supplied at the head of the channel can be lost due to seepage and evaporation (Sharma et al., 1975). Measurements conducted in Pakistan also indicate that about 50% of the water delivered from canals to farm channels, does not reach the farmers' fields (Kahlown et al., 2000). Seepage is the most dominant process by which water is lost in the canal as well as evaporation which can attribute a high proportion of losses in arid areas. Seepage is a significant issue in water resources management as it not only reduces fresh water resources but also causes water logging, salinization and groundwater contamination (Swamee et al., 2000a). Water logging refers to the saturation of soil with water. In some situations, the groundwater level (which is the surface where the water pressure head is equal to the atmospheric pressure), may be too high to permit any agriculture. Reducing seepage is particularly beneficial in areas with saline groundwater and high watertables.

Water may also be lost by leakage, flowing through larger openings in the canal bed or sides. Water can also be leaked due to inefficiency of gates and other control structures as well as spilling when the water elevation in channels surpasses the maximum level. Outfalls are referred to water flowing from downstream end of a delivery system. Outfalls often flow back into rivers or to downstream users. Unrecorded usage usually refers to unmetered water received through outlets and unauthorized water consumption or water theft. Metering inaccuracy refers to conditions where flow meter device, systematically under-record the volume of water flowing through the meter. Many authors tend to believe that one of the greatest potentials for increasing water supplies for agriculture industry is to control and decrease the water loss in irrigation channels (Corey, 1973; Kemper et al., 1975; Trout et al., 1977; Reuss et al., 1979). Recognizing the inefficiency of irrigation systems, remedial and modernization works on the irrigation infrastructures have since started.

1.3 Modernization of irrigation distribution systems

In each irrigation distribution system, older parts including pipes or unlined channels are generally built to a lower standard and have greater leakage and seepage losses. Conveyance loss measurements in unlined channels highlighted that most of the water loss takes place through the upper portions of the channel banks (Kahlown and Kemper, 2004).

Most important irrigation districts in Australia were built almost 100 years ago. Significant water losses have been experienced in these districts, partly due to ageing irrigation infrastructure but also the available technology at the time the districts were built. In the same way, no pumping was used in most Australian irrigation channels and water was delivered only under the power of gravity. Therefore, water was kept above supply levels which led to large distribution losses due to spillage and outflows. The scarcity of water resources and inefficiency of irrigation infrastructures convinced the Australian government to pursue modernization and automation of irrigation distribution supply networks in major irrigation districts of the country. The irrigation modernization involves the following works:

- Rationalizing irrigation channels that are unused
- Lining irrigation channels to reduce seepage and leakage
- Replacement of irrigation channels with pipelines to reduce seepage, leakage and evaporation

- Automating irrigation channel gates to better control and measure the flow of water
- Replacing manual water meters with automated meters to measure water flows to farms more accurately.

As part of the modernization project, in order to reduce and control seepage and leakage losses and improve the efficiency of the water delivery system, some irrigation channels are subjected to lining technology. Lining is a remediation technology that has been widely practiced on irrigation channels all over the world.

A perfect lining is considered to be able to control the seepage. It is possible to reduce seepage about 30 – 40% in a well-maintained canal with a 99% perfect lining, however, seepage from a canal cannot be controlled completely (Wachyan & Rushton, 1987, Akkuzu, 2012). Significant seepage losses from a canal are inevitable even if it is lined (Chahar, 2001; Swamee et al., 2002). On the other hand canal lining deteriorates with time and as the hydraulic conductivity increases, becomes severely ineffective in controlling the seepage (Swamee et al. 2000b). Moreover, when cracks develop in the lining, the water loss is likely to approach the quantity of seepage from an unlined canal (Wachyan and Rushton, 1987). Channel automation is a way of improving the efficiency of irrigation networks by using new technology to control the flow of water from the storage through the distribution system to the irrigator. It involves replacing manual flow control structures in channels with updated gates that accurately measure flows and provide real time measurement data. Controls include pneumatic and electronic sensors positioned at each gate; timers that open and close irrigation gates at set times; and fully automated centralized control of multiple gates and channels using hydraulic control.

The major south-eastern irrigation companies including Coleambally Irrigation Cooperative Limited (CICL), Goulburn-Murray Water and Murray Irrigation have invested in remedial and modernization works and have employed automatic control structures in order to improve their operational efficiency and minimizing water losses. The evolution of control systems in Australia has now progressed to the stage where automation is being applied to the operation of entire irrigation distribution supply networks.

1.3.1 Total channel control

One of pioneer companies in providing channel automation technology in irrigation is Rubicon Water. The commercial name of their technology applied in major irrigation districts in Australia is called Total Channel Control (TCC).

Total channel control (TCC) is a breakthrough in both irrigation management and flow measurement as it transforms the inefficient manually operated open channel networks (Figure 1.1) into automated, integrated and remotely controlled systems with high efficiencies (Figure 1.2 , 1.3 and 1.4). The system is based on two aspects:

- The control of large networks of solar-powered canal regulators and gates, which are linked through radio telemetry
- Advanced computer software, which enables the automatic and remote operation of the entire canal network.

This technology brings a whole new range of automatic control gates as well as control software that delivers smart control of multiple regulating sites, rather than individual control of standalone sites, as is common across the rural water authorities within Australia. Automated irrigation network operation eliminates the significant limitations that come with manually operated networks and assists in the detection of leaks and provides an alert for repair.

Fig 1.1 Inefficient manually operated Dethridge Wheel meter outlets

Fig 1.2 Automated, integrated and remotely controlled systems with high efficiencies

Fig 1.3 Real time control of flow measurements with automated gates

An important feature of TCC technology is supervisory control and data acquisition (SCADA). With the main objective of supplying water near on demand and controlling water levels in different channels of the system, SCADA technology enables the system operators to monitor the behavior of the irrigation supply system and to control the key system components from the office computer. The control center computer is based on the real-time development environment, which enables full integration of real-time data into production of flow and water level databases for the entire channel system. The database includes a variety of measurements, including water flow measurements for each gate and water level elevations upstream and downstream of each gate.

Fig 1.4 Precision water measurement instrumentation combined with wireless communications networks

1.4 Hypotheses

The main hypotheses for this research are:

- Combined losses (seepage, leakage and evaporation) from irrigation channels under ponded conditions can be determined from TCC data during periods of shut down,

- Individual component losses (seepage, leakage and evaporation) can be separated from the total combined loss, and
- Combined losses under dynamic conditions can be predicted from the knowledge gained under ponded conditions.

1.5 Objectives

The main objectives of this work are to:

1.5.1. Objective 1: "Estimation of combined losses"

Automation of irrigation channels potentially allows large numbers of pondage tests. Based on the data which comes from TCC, any reaches of any channels during periods of shut down of irrigation gates can be treated as pondage tests. Pondage testing is a direct way of recording the losses through a section of channel that uses a water balance approach to determine seepage losses in an isolated section of channel. The drop in water level over time in the pond can be defined as total amount of losses including seepage, leakage and evaporation.

1.5.2 Objective 2: "Estimation of seepage and leakage"

After estimating the magnitude of evaporation loss, it is possible to separate the sum of seepage and leakage from the total loss. Using the hypothesized nature of the seepage process which exhibits a gradual decline with time and the nature of leakage which has a sharp drop through the time, attempts will be made to separate these two components from each other.

1.5.3 Objective 3: "Investigation of factors affecting the estimation of seepage rate in each pool"

In an automated system the shut-downs or pondage conditions occur in an apparent random fashion as a response falls in consumer demand. Consequently they occur at various times throughout the season, are of varying duration, and occur at different water levels relative to full supply. Further the TCC system only records water levels when a change occurs hence the water level data is spaced unevenly in time. All of these and any noise in the data itself affects the ability to extract accurate seepage rates from the data.

1.5.4 Objective 4: "Development of a model capable of real time seepage assessment for the entire irrigation system"

A model capable of analyzing data from the entire irrigation network and estimating the seepage rate based on real time measurements will allow integrated databases during periods of shut down to be built and pools with high losses to be identified.

1.6 Outcomes and significance

1.6.1 Outcomes

A number of outcomes are expected from this study which are:

- Evaluation of pondage test method for the measurement of combined losses in irrigation channels.
- A process by which channel seepage can be estimated from routine TCC measurements.
- Evaluation of different factors affecting estimation of the rate of seepage in a pool.
- Establishment of an appropriate model to estimate the seepage losses during normal channel operation.
- Identifying the locations with high magnitude of losses which require remediation.

1.6.2 Significance

Most of the previous research on combined losses has been conducted based on the field data measurements. Historically only small numbers of pondage tests have been monitored manually some of which have included a high percentage of human error. In recent years, automation of irrigation channels has provided a large number of pondage conditions able to be used for estimation of losses. The present study aims to have an accurate estimation of combined losses in order to identify reaches of irrigation channels with high possible loss rate. Furthermore the different factors affecting estimation of the rate of seepage will be investigated in order to build up a model to estimate the seepage rate during normal channel operation.

1.7 Structure of the Thesis

This chapter has provided a brief background to the subject area and introduced the objectives of the remaining seven chapters of this dissertation. Chapter 2 serves as a comprehensive review of seepage and evaporation estimation techniques, summarising previous findings with a conclusion of most suitable method for estimation of each of the combined losses. Chapter 3 introduces Coleambally Irrigation District the case study of this project. General information regarding major commodities produced in the area, annual rainfall, temperature and TCC data is also provided in this chapter.

Chapter 4 describes the development of an improved model to detect all possible pondage conditions and calculate a first estimate of seepage rate for all the historical data throughout the entire channel network.

Chapter 5 reviews results of the model and the algorithm applied to give a first cut estimate of seepage per each pondage sample and for each pool. While Chapter 6, provides a detailed evaluation of different factors affecting the estimation of seepage rates from the model as well as the feasibility of using other models instead of linear regression in estimation of seepage rate. Chapter 7 covers a comparison of the findings of the model with results of previous studies to demonstrate the capability of the model in seepage rate estimation. Finally, Chapter 8 discusses the key findings of this work and presents a number of recommendations for further research in this area.

Chapter2: Literature review of conveyance water loss measurement in irrigation channels

2.1 Introduction

Earthen channels are undoubtedly one of the most important elements in each irrigation distribution system. They are one of the main mechanisms for the transport and delivery of water that have mostly been constructed using local materials, often with poor water-retaining characteristics in Australia. High quality soil for channel construction is often limited by availability or cost. Despite attempts to reduce permeability, construction methods have often failed to achieve a watertight barrier, particularly in older channels.

Between 1% and 14% of the total water supplied for rural use via earthen channels is lost due to seepage (Brinkley, et al., 2004). Previous surveys also indicated that, around 4% of total water supplied for rural consumption is lost through seepage (ANCID, 2000b). Moreover, according to preliminary estimates the magnitude of seepage losses in east coast states of Australia could sum up to approximately 300 GL/annum (ANCID, 2003). Therefore, seepage from earthen channels remains an Australia-wide issue in most irrigation distribution systems.

2.2. Seepage Losses

Seepage is usually defined as the slow movement of water through small openings and spaces in the surface of unsaturated soil into or out of a body of surface or subsurface water (Meinzer 1923). Seepage in channels involves the relatively uniform passage of water through the wetted perimeter of the channel profile often due to poor quality of substrate material.

A major impact of continuing seepage from irrigation channels is the gradual increase of watertables to quite a high level in some areas which ultimately led to land degradation in many regions. Reduced irrigation efficiencies, increased operational cost and water shortages downstream are other consequences of seepage impacts (Upadhyaya and Chauhan, 2002; Çakmak et al., 2004; Jansen et al., 2006).

2.2.1 Channel Leakage

Usually the measured seepage loss in channels includes a leakage component. Therefore seepage in channels refers to both seepage and leakage as separating them is not easy in practice. Leakage is usually referred to loss of water through macro pores in the banks of a channel (Fig 2.1)

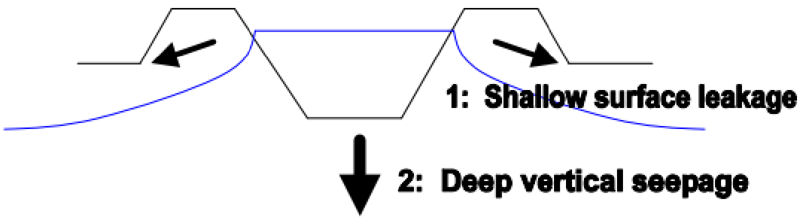


Figure 2.1 Mechanism of seepage from channels (ANCID, 2003)

It was observed that 80% of leakage occurred within the top 8 cm of the maximum operating level of the banks of old channels (Kahlown et al., 2004). Generally the wetted permeable layers of top portions of channel banks provide ideal growing conditions for vegetation which furnish a rich supply of food for worms, crayfish and other insects, causing macro pores in the bank of the channel. Consequently, as the channel banks become densely populated, their permeability increases 2-10 times that of the adjacent field soil and as well as their roughness coefficients, with the rise of water level in channel causing leakage to increase exponentially

(Kahlown et al., 2004). Removing vegetation from channels can decrease the operating level of water to the designed value by reducing the roughness coefficient of the channel (Akram et al., 1981, Kahlown et al., 2004). Deteriorated channel junctions, overtopping of the banks, dead storage in over excavated sections of the channels and leakage through highly permeable upper portions of the channel banks are the most important factors contributing to leakage losses in irrigation channels (Trout, 1979, Kahlown et al., 2004).

Leakage also refers to loss of water through stoplog regulating structures, poor gate seals, Dethridge wheels and piping along structures that have inadequate cut off walls. Leakage often starts on a small scale, but the moment water has found a way through a channel bank a hole will develop through and if not stopped in time, the tunnel becomes larger and the channel bank may ultimately be washed away. Therefore in channels where leakage is happening, there is a distinctive pattern in the water level drop such that leakage can be separated from seepage, but usually there is no clear way of splitting the two components from each other.

2.2.2 Factors Influencing Seepage

Comprehensive studies of seepage have itemized the predominant variables affecting seepage rates in irrigation channels as being (Hotes, 1985; Akbar, 2003; Alam and Bhutta, 2004; Swamee et al., 2000; Swamee, 1994, 1995; ANCID, 2003):

- Soil characteristics (type, permeability, particle size)
- Chemistry of soil and water (viscosity of water, salinity of soil and water)
- Sediment load carried and deposited by water
- Hydraulic characteristics of the channel (channel water level, wetted perimeter of the channel and depth to ground water)
- Length of time water has been in the channel
- Age of the channel
- Velocity of flow
- Presence of other constraints such as wells, drains and impermeable soil layers

Channel seepage is influenced by the permeability of the layers forming or adjacent to the wetted perimeter of the channel. Water seeps quickly through a sandy soil and slowly through a clay soil, and so channels constructed in sandy soils will have greater seepage losses than channels in clay soils. The magnitude of seepage rates in unlined channels varies for different soil types with about 150 L/m^2/day in clay loam, 250 L/m^2/day in sandy loam, and respectively 750 L/m^2/day or more in sandy or gravelly soil (Swan, 1978; ANCID, 2003).

The results of seepage through the sides of a channel can sometimes be very obvious, such as when fields adjacent to a channel become very wet, and even have standing water. On the other hand, seepage loss through the channel bed is difficult to detect because water goes down and does not appear on the nearby ground surface.

Seepage is also affected by the hydraulic characteristics of the channel and surrounding area. Hydraulic characteristics of the channel are the channel water level, wetted perimeter of the channel and depth to ground water. Depth to ground water or the difference between the channel water level and the groundwater elevation in the bores close to the channel, defined as net available head is one of the most significant factors in determining the seepage loss rate from a channel (McLeod et al., 1994). Generally the seepage rate increases with greater water depth in the channel as well as greater net available head.

The significant depth below the channel bed, affecting the seepage rate is considered to be approximately five times the bed width of the channel. While at a distance of approximately ten times the bed width of the channel, the effect of seepage losses on the original water table elevation is considered to be minimal (ANCID, 2003).

The salinity of water will also affect seepage rates. Waters with low salinity are likely to decrease the permeability of the channels. The quality of the channel water can also influence seepage rates because considerable amounts of suspended particles seal soil pores and create a sediment lining, thereby reducing seepage in a relatively short time. Permeability of lower portions of channel banks and the bed decrease with deposition of sediments (Kahlown et al., 2004). Even small amounts of sediment will affect the seepage rate over a long period of time (ANCID, 2003). The combination of weeds and sediment deposition may be the major factor for reduction of seepage from 15-30 year old channels (Akbar, 2003).

2.3 Quantifying Seepage Losses

Seepage rates are obtainable either by direct measurement or by estimation. Numerous studies have been conducted over the past sixty years with the objective of quantifying seepage rate. The mentioned affecting factors are the predominant focus of either analytical methods or predictive models.

Seepage measurement techniques can be categorized in the following groups (ANCID, 2000, 2003):

1) Point measurements
2) Direct measurements
3) Geophysical techniques
4) Soil classification
5) Remote sensing
6) Groundwater techniques
7) Mathematical modeling
8) Hydrochemical and isotopic methods

2.3.1. Point measurement techniques

Point measurement refers to techniques that measure infiltration or hydraulic conductivity of a soil at a given point by adding water to the channel and measuring the rate of water loss. The hydraulic conductivity of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient. It is presumed that the water used for measurement is similar in chemical characteristics to the water that normally runs in the channel. The infiltration rate has a direct relationship to potential seepage. Therefore results are used to infer the point distribution of seepage potential at a point. To obtain a broad coverage of the infiltration variability, many point tests are usually required. In Australia, the most commonly used techniques are those with relevant available equipment and experienced operators to undertake the field tests and analyse the field data to provide a valid infiltration rate.

Point measurement techniques can be undertaken either when the channel is operating or not, depending on the particular technique to be used. The most applicable point measurement techniques for channel seepage measurement in Australia are Idaho seepage meters for operating channels and ring or disc infiltrometers for empty channels (ANCID, 2003). Bell-type seepage meters are another type of point measurement equipment that should be installed while the channels are out of service.

The most commonly used devices for point measurement of seepage rate are seepage meters. Their technology development goes back to the 1940’s when they were initially used to measure water loss from irrigation channels (Israelson and Reeve, 1944). The process for seepage rate measurement using a seepage meter is to push the cylinder part of the device into the channel bottom (Figure 2.2). If the pressure head inside the seepage meter becomes equal with the pressure in the channel, the outflow from the seepage meter is a measure of the seepage through the portion of the bottom that is enclosed by the seepage meter (Bouwer, 1965).

Initially it was demonstrated that the seepage meter can be used to rapidly locate sections of channel with a high seepage loss and economically obtain an estimate of the total seepage loss from a section of channel (Bouwer, 1961; Smith, 1973; Byrnes & Webster, 1981).

Later on, several seepage meter measurement studies with the objective to broaden the range of conditions under which the meter could be tested were accomplished. It was shown that due to the variable nature of soil and bed lining, point measurement techniques are not sufficiently reliable for seepage rate estimation and numerous point measurements are required to obtain a reliable seepage estimate (Bouwer, 1965; Kolupaila, 1964; Smith, 1973; Smith & Turner, 1981; Smith, 1982; SKM, 1997a; ANCID, 2000, 2003; Brinkley et al., 2000, 2004). Common reasons behind the inaccuracy in measurements of earlier meters were due to disturbance of channel bed on insertation and the pressure difference between the interior of the meters and the outside water (Bouwer 1965; Smith & Turner 1981). At the same time, a skilled operator or technician with suitable expertise in the equipment being used is required to conduct the tests reliably. Seepage meters were shown to measure flows with an error of 2-3 % or less when tests are conducted by an expert operator (Carter, 1970). However, it was concluded earlier by Kolupaila (1964) that point measurement techniques may result in estimates with high error percentages whether or not tests are conducted by an expert operator. Reliability of bell-type seepage measurement was also shown to be highly variable and subjected to high user error, and therefore does not represent a viable method for determining channel seepage (Hotchkisss et al., 2001; Worstell and Carpenter, 1969).

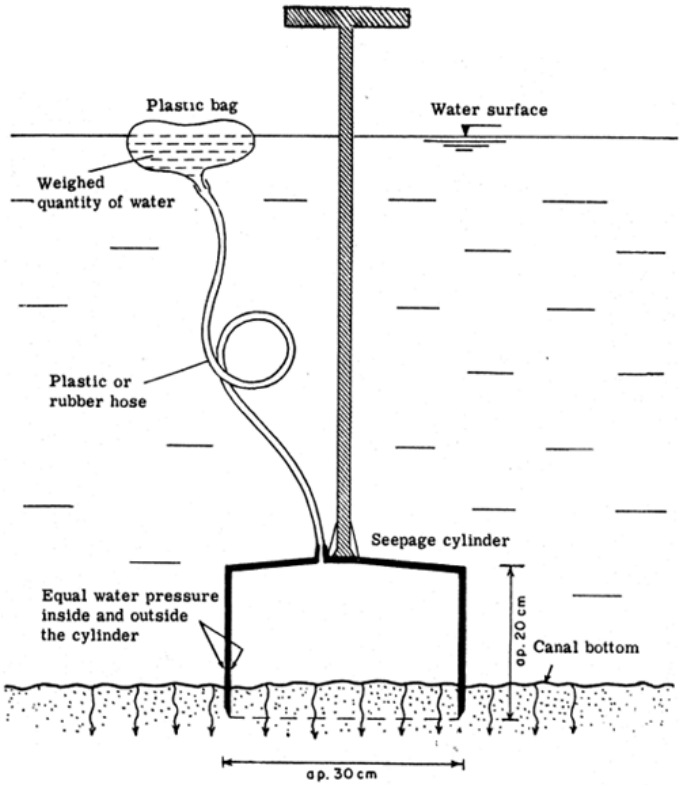


Figure 2.2 Seepage meter with submerged plastic bag (ANCID, 2003)

Given the fact that seepage occurs through a small proportion of the channel, it was demonstrated that point measurement techniques are considered to be best for determining the distribution of seepage losses generally over short lengths of channel (SKM, 1997a; ANCID, 2000; 2003; Brinkley et al., 2000, 2004) and cannot be reliably extrapolated to other locations (ANCID, 2000& 2003).

2.3.2. Direct measurement techniques

Seepage rates have been traditionally determined using direct measurement methods, rather than indirect methods which involve monitoring the water table adjacent to channels or by using predictive models which involve the application of developed equations or relationships (Bakry and Awad, 1997). The common direct methods used to measure channel seepage rate include, ponding tests and inflow-outflow measurements (Engelbert, 1993; Engelbert et al., 1997).

The inflow-outflow method is based on selecting a channel or length of channel and measuring the rates of water flowing into and out of the section. Using water balance approach, after taking into account additional inflows and losses along the section of the channel being investigated, the difference between inflow and outflow is attributed to seepage. Accuracy in results depends on the accuracy of flow rate, rainfall and evaporation measurements. Moreover, there is a need for knowledge of any other possible losses such as outflow diversions. One of the most important issues with this method is providing flow measurements of sufficient accuracy, particularly for short sections of channel, channels with low flows or low seepage rates

Given the fact that accuracy of the inflow-outflow technique is dependent on accurate flow measurements, it is more suited to high flow channels where losses are likely to be much higher than measurement errors (ANCID, 2003). Traditionally, flow rate measurements were conducted using propeller or electromagnetic type flow meters, which were time consuming and did not allow for replicate measurements during an appropriate time frame (Herschy, 1999; Rhoads et al., 2003; Kinzli, 2010).

Flow rate measurement can be conducted using a number of techniques. The two most common techniques are the application of current meter to determine average velocity or using regulating structures such as flumes or weirs with automatic recording gauges. With fairly accurate current metering the errors indicated in the inflow and outflow measurements are reported to be as high as ±110% in the estimated seepage (Weller & McAteer, 1993). Similarly, Alam and Bhutta (2004) indicated that measurement errors of this method can often exceed the magnitude of measured seepage. In agreement to that, Smith (1982) also indicated that given the fact that the seepage is calculated as a small difference between two relatively large quantities, the seepage loss must be large or errors in the measurements make it meaningless. Similarly, Alam and Bhutta (2004), highlighted that any possible small errors in the flow measurement can lead to large errors in the calculated seepage. Dukker et al. (1994) also, found a wide range of variation in their estimated seepage rates due to errors and uncertainties in measurements and concluded that the actual seepage losses could deviate largely from the observed values.

The inflow-outflow method can be conducted at various scales, from an entire irrigation system, to an isolated section of channel. Nelson & Robinson (1966) used the inflow-outflow method for seepage determination in Northern Victoria and recommended this technique as it was capable of covering the entire channel system. Similarly, Weller and McAteer (1993) recommended the method for reaches long enough to have seepage losses at least 5% of inflows. This was supported by Alam et al. (2004), who suggested that inflow–outflow tests should be adopted for seepage measurements in the main irrigation channels with high discharge especially for longer reaches with a limited number of offtakes but should not be used for seepage investigations where seepage rates are fairly small and there is no possibility to use sufficiently long reaches. Therefore this method is considered to be more suitable for long sections of a channel, which contain appreciable seepage, preferably without any diversions and contain suitable structures to incorporate measuring devices (ANCID, 2003).

The inflow-outflow method is considered to be the only direct measurement technique which reflects actual operating conditions and permits measurement without interruption to system operations (Skogerboe et al., 1999; Dukker et al., 1994). While, Alam and Bhutta (2004) as part of introducing difficulties working with this method, mentioned that water levels are required to remain steady and constant during the test which may not be feasible for longer channel sections.

The basic equation for calculating seepage losses using the inflow-outflow method is:

$$S = \frac{Q_i - Q_o - E - D + I}{P.L} \qquad (2.1)$$

where S is seepage rate, Q_i is inflow rate, Q_o is outflow rate, E is evaporation along reach, D is diversions along reach, I is inflow along reach, P is averaged wetted perimeter and L is length of channel reach.

The application of this method has also been compared with point measurements techniques. Akbar (2003) made a comparison between the inflow-outflow and Idaho Seepage Meter measurement and results showed that there was no significant difference in the mean seepage rate per km between the two techniques.

Pondage tests are acknowledged as the most accurate direct method for seepage measurement in irrigation channels (Smith, 1973; Smith, 1982; McLeod, 1994; Akbar, 2003; ANCID, 2000a, b, 2001, 2003a, b; KTF, 1999, 2002; SKM, 1997a, b, 2006; Brinkley, 2000, 2004; Bodla et al., 1998; Sarki et al., 2008). A pondage test uses a water balance to determine seepage losses in an isolated reach of channel. This method relies on the construction of earthen banks to create leak-proof channel sections where the drop in water level can be measured. The location of the barriers depends on project objectives and might be determined by geophysical surveys or perhaps anecdotal information. However in many cases existing structures can be utilized. Any existing structures suitable for forming a sealed barrier should be utilised where possible to minimise the number of barriers required to be constructed. Pondage testing using the channel automation, is a potentially useful technique for routine appraisal of leakage and seepage, as the system effectively isolates pools, and provides water level data for the analyses (Poulton et al., 2007).

In general, a section of channel is blocked off with barriers at each end and filled with water up to, or slightly higher than, the level at which it usually flows during operation. As the water level in the channel section falls, the level is measured by an operator, hook gauge, or a water-level recorder. The time between measurements is also recorded, necessary corrections for evaporation and rainfall made, and the resulting seepage loss rate computed. As the water level is always filled up to or higher than operating level, this method has the advantage of accurately representing normal flow conditions but is very much dependent on accurate measurement of the pond depth.

Other advantages of using pondage testing are that the influence of localised conditions is reduced and the opportunity for human error is also diminished (SKM 2006). Brinkley et al. (2004) showed that pondage tests were the most accurate means of channel seepage assessment with a good degree of repeatability in the results, with a maximum difference of 25% between rates, which was attributed to changes in depth to watertable and channel bed properties. The pondage test method provides an average net seepage flux for the entirety of the surface water feature being considered. This is in contrast to other methods, such as seepage meters, which only measure seepage at a point.

An important disadvantage of pondage tests are that the test must be conducted outside of normal operating periods. In other words, the channel must remain out of use during tests, while from economic perspective the installation cost of embankments to isolate reaches of the channel can be high. A disadvantage of the pondage test is that it cannot identify specific locations of channel leakage or seepage within the reach. Another apparent drawback is that because the channels are closed and there is no through flow, sediment sinks to the bed of the channel and reduces permeability compared to operating conditions. However, under normal operational conditions there will also be periods of low flow and no-flow, during which sedimentation will take place. Hence in channel sections even those desilted recently, a layer of fine sediment is always expected (SKM 2006). Similar to other measurement techniques, seepage estimates may be misleading if any component of the water balance cannot be adequately accounted for or effectively measured.

The basic equation for calculating seepage losses using the pondage test method is:

$$S = \frac{W[(d_1 - d_2) - E + R]}{P(t_2 - t_1)} \tag{2.2}$$

where S is seepage rate, W is average surface width between t_1 and t_2, d_1 and d_2 are water levels at t_1 and t_2 respectively (averaged between u/s and d/s gauges), R is rainfall along reach between t_1 and t_2, t_1 is time at first measurement of water levels and t_2 is time at subsequent measurement of water levels.

Estimates of evaporation and rainfall can be obtained from the nearest weather station. However for more accurate results a rainfall gauge is usually established adjacent to the ponds especially if the nearest weather station is a significant distance from the site. As well as basic data concerning the soil and the basic channel hydraulic data, it is very important for the interpretation of the results that the extent of any silt layers lining the channel is known. The typical duration of a pondage test is in the range of four to ten days. If rainfall during the test causes significant unmeasured runoff into the ponds, the test will need to be cancelled as this inflow will not be accounted for effectively in the water balance.

The most appropriate time for conducting pondage tests is at the end or beginning of the water distribution season, so as to minimise disruption to the system. Of these two options, the ideal time is at the end of the water distribution season, immediately before the shutdown of the system, as sub-surface conditions are closest to those encountered during operation. However, pondage tests can be conducted at the beginning of the season which can be an advantage if initial channel starts up losses are of special interest. The analysis of pondage test results conducted by McLeod et al. (1994), who carried out several pondage tests at various times (August-May) over two irrigation seasons in northern Victoria, showed that the seepage tests nearer the middle of the irrigation season had a tendency for higher rates.

The application of pondage test as a useful technique for seepage estimation has been shown in several studies conducted in irrigation districts in Australia (Smith, 1973; Smith, 1982; McLeod, 1994; ANCID, 2000a, b, 2001, 2003a, b; KTF, 1999, 2002; SKM, 1997a, b, 2006; Brinkley, 2000, 2004; Bodla et al., 1998). Several studies also have been conducted in different irrigation districts in Pakistan to show the accuracy of results achieved through both pondage and inflow outflow methods (Bodla et al., 1998; Skogerboe et al., 1999; Dukker et al., 1994; Alam et al., 2004 and Sarki et al., 2008).

In most cases the ponding method was mentioned to be a more reliable method for seepage estimation compared to the inflow–outflow method (Smith, 1982; Bodla et al., 1998; Alam et al., 2004; Sarki, 2008; Schulz, 2009).

Smith (1982) indicated that pondage testing in relatively short sections of channel removes the larger items from the water balance equation giving a substantial improvement in the accuracy of the estimated seepage loss. Alam et al. (2004) also considered the pondage test method to be more accurate than the inflow–outflow method as variability of various statistical parameters from the ponding tests was comparatively less.

At the same time, Sarki et al. (2008) suggested that the actual seepage loss could be expected to lie somewhere between estimates of the two methods. Their study showed that a ponding test measured water losses 23% less than an inflow-outflow test. They indicated different reasons such as silt deposition in ponding test and the different section length for each method for this difference.

While, Skogerboe et al. (1999) considered the inflow–outflow the highly preferred method of measuring channel losses, because the losses were being measured under the normal operating conditions. However, they suggested the application of ponding method when channel losses are relatively low. They could not consider the pondage test a standard method for evaluating channel losses, contrary to some other authors. Some channels evaluated by them showed negative loss rates, which is unexplainable.

2.3.3 Geophysical techniques

Geophysical techniques involve measuring the reflected electrical current that has been sent into water or soil medium. From a cost perspective, these techniques are relatively inexpensive if using existing data or maps. On the other hand, in other cases when drilling and classification are required are moderately expensive (ANCID, 2003).

Geophysical techniques, including electromagnetic (EM) and electrical resistivity (ER), are suitable methods for qualitative distributed assessment of relative seepage along channels in contrast to direct and point measurement methods which require expert operators and are unable to quantify distributed seepage losses along the length of channel (Khan et al. 2008).

The preferred EM technique for geophysical channel seepage assessment directly detects the impact of seepage on the groundwater. In other words the instrument must focus on the zone immediately above and several metres below the watertable. The most relevant geophysical techniques to Australian conditions for channel seepage detection are electromagnetic (specifically EM31 and EM34) and resistivity (ANCID, 2003). EM31 is considered to be suitable for shallow watertables (surface to approximately 5m) and EM34 can be used for deeper watertables (ANCID, 2003). However, it must be assured that seepage is controlled by the unsaturated zone not the surface clogging processes. Otherwise the techniques will give a high percentage of errors (SKM, 2006).

On the other hand, ER techniques can be used to determine resistivity of the soil underlying the channel. Measurement of electrical resistivity of soils beneath a channel was shown to be an indicator of the likelihood of seepage (Wantland and Goodman, 1962). Correlating measured ER data of soil underlying the channel to channel depth and then to actual seepage rates measured with seepage meters, Hotchkiss et al. (2001), developed a procedure to quantify seepage losses in unlined irrigation channels. It is expected that areas with high seepage have a higher electrical resistivity (Hotchkiss et al., 2001; Street et al., 2003). Street et al. (2003) concluded that resistivity worked best where there was a diffuse seepage from the channel, especially near the watertable. However, Smith & Turner (1981) suggested that the resistivity traverse did not locate the zone of high seepage but only detected the shallow coarse sand aquifer that was coincident at that point. Furthermore, Hotchkiss (2001) indicated that the application of ER is very limited as it requires the development of a local quantitative relationship from actual measurements.

Geophysical techniques can be used in two ways for seepage assessment:

- Mapping the distribution of high and low seepage zones
- Quantification of seepage rates

Mapping the distribution of seepage rates can be achieved with the application of geophysical technique alone. However, it is more confident to validate them with limited direct or point testing (Brinkley et al., 2000, 2004; ANCID, 2003; Khan et al., 2008; Watt et al., 2008).

From 1998 onwards the application of EM31 equipment replaced the Idaho meter for primarily qualitative measurements along the banks of the channels and sections of the Main Canal of the Coleambally Irrigation Area given the highly variable results of Idaho meter due to location differences and operator error (SKM, 2006; CICL, 2008). Khan et al. (2008) used an Electromagnetic (EM31) survey for identifying critical sections of the irrigation supply channel system as part of qualitative seepage analysis. Similarly, Watt et al. (2008) used the geophysical technique to measures the resistivity of the soil in order to assess seepage points along irrigation channels in the Coleambally Irrigation Area. SKM (2006) also, used electrical conductivity measurements provided by Allen & Merrick (2003) and Allen (2005) and thermal imagery obtained from airplane to identify areas with potential high vertical and horizontal seepage and leakage hotspots in the first 18 km of the Coleambally Main Canal. At the same time, Akbar (2003) indicated that the EM-31 method was shown to be an important initial predictive tool as the electrical conductivity values obtained from the EM-31 surveys provided an insight into the most likely locations to have high seepage rates.

ANCID (2003) demonstrated that EM31 surveys combined with in-situ seepage monitoring are most effective in identifying the distribution of seepage. Similarly, Brinkley et al. (2004) demonstrated that geophysical techniques when calibrated against direct measurement techniques could provide a reasonably accurate quantitative assessment of seepage rates.

ANCID (2003) recommended the combination of geophysical surveys and pondage tests as the most suitable approach for intermediate to large scale investigations. SKM (2006) combined the results of electrical conductivity imagery assessment of the sediments below the channel bed of the Main Canal in Coleambally and pondage tests to quantify vertical seepage losses.

Due to the potential for rapid seepage assessment of long channel sections the application of geophysics has become an important aspect of natural resources management.

2.3.4 Remote Sensing

Remote sensing refers to any kind of data recording by a sensor which measures energy emitted or reflected by objects located at some distance from the sensor and includes aerial photography and satellite imagery. In contrast to direct and point measurement methods, capable of directly measuring a physical property at a single location, remote sensing techniques use high density sampling of sub-surface and near-surface properties to provide essentially continuous data along the channel. An important advantage of remote sensing techniques is that they can be conducted without interfering with channel operations. On the other hand, given the fact that it assumes that seepage has a surface expression, thus sites where moist soil occurs which are not affected by seepage will be detected as seepage sites.

Depending on the source of data, remote sensing techniques are considered to be relatively inexpensive. However, proper interpretation will increase the costs (ANCID, 2003).

Brinkley et al. (2004) and similarly ANCID (2003) showed that remote sensing could be best suited to investigations where the primary aim was identification of land degradation associated with channel seepage, and would be most useful where lateral seepage is predominant. McGowen (2001) and Nellis (1982) addressed the application of remote sensing techniques for detecting channel seepage losses in Australia and USA respectively. However, remote sensing techniques are not generally used to quantify channel seepage (ANCID, 2003).

Engelbert et al. (1997) used an integrated method of remote sensing and geophysics to locate channel seepage in the Nebraska Public Power and Irrigation district which was the basis for the Hotchkiss et al. (2001) study. The authors indicated that the method was adequate for locating the areas of seepage. However, the quantity of seepage was not validated.

2.3.5 Soil classification

As mentioned earlier, soil type is one of the most important variables effecting seepage rate. Considering the fact that seepage is primarily a function of hydraulic conductivity, soil and geological data can be used to access actual or potential seepage. Furthermore, soil categories of a channel, can be a basis for seepage categories of higher and lower seepage zone within the channel. However, the application of material properties and distributions alone is not effective in seepage rate estimation.

Soil and geological profiling are typically produced at regional scales and can be used to provide a preliminary assessment of the ground conditions. At the same time, they can be used to picture the conditions where seepage is more likely to happen. However, seepage rate estimation cannot be made just by using them solely. Watt et al. (2008) highlighted that the soil type affects the water movement only in the initial stages of saturation. Their simulation results demonstrated that once the profile becomes saturated the soil type does not affect the water movement.

Iqbal et al. (2002) used the Agricultural Region of Alberta Soil Inventory Database (AGRASID), a primary source of soils information, in conjunction with a GIS to estimate the total volume of seepage within a number of irrigation districts. They grouped seepage rates from each reach of 11 irrigation districts in southern Alberta into different soil textural classes. By using the measured seepage rates, they developed seepage curves based on channel capacity to estimate the seepage rate per channel segment.

The application of seepage rate for different soil types is considered to be a useful method for providing a first estimate of zones of seepage loss from a system. Nevertheless, any correlations made between soil type and seepage potential for more detailed assessment are likely to be of limited accuracy (ANCID, 2003).

2.3.6 Groundwater Assessment

The application of groundwater assessment techniques are based on changes in hydraulic and chemical conditions of the aquifer below a channel, after penetrated water reaches the watertable. The trends in groundwater levels in comparison with channel operating times can be used to indicate seepage and possibly estimate the loss rate.

Knowing the hydraulic conductivity of the aquifer, the seepage rate can be calculated from the water level information. A series of piezometers as tools to measure pressure of groundwater at a specific point, located at right angles to the channel are usually used to conduct a groundwater assessment. By determining the hydraulic conductivity of the aquifer from the water level information, the seepage rate can be calculated.

Groundwater information can be used either for seepage identification when using water levels in groundwater monitoring bores or seepage rate calculation by using analytical and numerical techniques or by using the chemical properties of channel water and groundwater to identify and estimate the seepage rate. Quantification of seepage rates can be done either by using simple analytical equations or by using complex numerical groundwater models. Simple analytical approaches to seepage quantification are only suitable for a first cut estimate as they require a large number of assumptions on the general properties of aquifers and results cannot be precise. Groundwater assessment techniques have the advantage that there is no limit to the size of channel as well as no interruption in channel operation and seepage losses will be determined under dynamic conditions (ANCID, 2003).

The main shortfall of seepage rate quantification using piezometric or hydrochemical groundwater data alone is that it is concentrated on a slice across the channel which may not be representative of broader channel conditions as well as the difficulty in accurately determining the hydraulic conductivity which may require specialist technical input (ANCID, 2003b).

Analytical methods for seepage measurement are equation based. Seepage estimation is based on knowledge of the relevant hydraulic properties of the soil and of the boundary conditions, such as depth to groundwater, channel cross section, and water depth (Kraatz, 1977). Analytical solutions for channel seepage estimation in a homogeneous isotropic porous medium of large depth for different sets of specific conditions have been given by Vedernikov (1934) ; Muskat (1982); Harr (1962); Polubarinova-Kochina (1962); Morel-Seytoux (1964); Bruch (1966); Chahar (2000) and Swamee (2001). Jeppson (1968) also presented a numerical solution for seepage measurement.

The application of adopted methods for specific conditions and channel dimensions are limited. An exact mathematical solution to the problem of seepage from channels of various shapes with water table at infinite depth in a homogeneous isotropic porous medium of large depth has been given by Vedernikov (1934).

Muskat (1982), Polubarinova-Kochina (1962), and Harr (1962) studied seepage losses by using mathematical analysis for triangular and trapezoidal channels. At the same time, Morel-Seytoux (1964) dealt with the case of a rectangular channel and the solution has been obtained by conformal mapping and the use of Green functions. For transient seepage, Collis-George and Smiles (1963) proposed a solution for rectangular channels.

With the application of finite differences method, Jeppson (1968) presented a solution for seepage from channels through layered porous mediums. He considered the layers to be anisotropic with different ratios of horizontal to vertical permeability.

Bruch (1966) and Bruch and Street (1967a,b) obtained an analytical solution for seepage from a triangular channel in a soil layer of finite depth overlying the drainage layer.

Bouwer (1978) presented solutions for channel seepage for various depths and shapes of the channels and of positions of groundwater table in three types of soil conditions, including, high hydraulic conductivity, low hydraulic conductivity and the hydraulic conductivity in which the thin layer of sediment below the channel is much lower than the underlying soil.

Chahar (2000) and Swamee et al. (2001) obtained an analytical solution for seepage from a rectangular channel in a soil layer of finite depth overlying a drainage layer using inversion of hodograph and conformal mapping techniques.

On the other hand, numerical methods are being used extensively to quantify and estimate the seepage rate. The benefit of numerical modeling is that the variability of aquifer properties can be taken into account. The flow system can be simulated and calibrated against variation of water levels in the aquifer under changed hydraulic conditions in the channel which enables the understanding of the way seepage occurs, the factors that affect seepage entering the groundwater, and the potential consequences of seepage for land degradation (ANCID, 2003).

2.3.7 Seepage predictive modelling

Seepage as mentioned earlier is a complicated process and depends on a number of factors. Thus, it is a difficult task to incorporate all the affecting factors in any calculation (Kraatz, 1977). From the modelling perspective, a physical model, which can incorporate all of these factors and accurately predict seepage rate, is not easy to develop. Even the development of a complicated model capable of predicting losses needs to have forecasts of independent variables affecting the seepage process (Hameed et al., 1996).

Hamid et al. (1996) noticed that due to climatic and other uncertainties, the water loss series observed over a period of time can be treated as a stochastic process and can be modeled by time series techniques. The authors mentioned that due to the difficulty to ascertain the fraction of total losses attributable to evaporation or seepage, from an operational point of view, evaporation and seepage should be treated under one single heading such as transmission losses in an irrigation system. They explored the possibility of the autoregressive integrated-moving average (ARIMA) process as a viable model option for transmission losses series. The authors used monthly discharge data from January 1971 to December 1990 recorded by the Imperial Irrigation District, California, USA for their study. They calculated the transmission losses in the district by inflow-outflow technique, and changed the data into percentage series to make it standardized as the inflow discharge was not constant for each month. Data from the first 19 years (January 1971-December 1989; 228 months) were used for the model development and data from the last year (January-December 1990; 12 months) were utilized for the validation of the final model. Their model showed 95% confidence bounds for the forecasts.

Khan et al. (2008) showed that artificial neural networks (ANNs) can be successfully applied to analyze distributed channel seepage. They conducted a study in the Murrumbidgee Irrigation Area for evaluating seepage losses in the irrigation channels. By using ANNs, Khan et al. (2008) combined qualitative measurements with local quantitative seepage estimates as a workable distributed quantitative technique. In order to identify critical sections with high seepage the authors used the EM31 survey technique while, for the purpose of bulk water losses measurement, the inflow-outflow method was used. After identifying hot spots as having potentially high seepage an Idaho seepage meter with the purpose of quantitative seepage rate measurement was used. Finally in order to train the ANN model, the data collected by the mentioned methods were used. Radial Basis Function (RBF) was used for the training purposes. The inputs to the model comprised of EM31 data, hydraulic conductivity, salinity and depth to groundwater table with actual seepage results from the Idaho seepage meter compared to predicted seepage rate as outputs. The trained ANN was subsequently used to convert qualitative distributed seepage data to quantitative distributed seepage rates. The authors divided the entire data set into three sets comprising 70%, 20% and 10% of data for training, cross-validation and testing purposes, respectively. The analysis clearly indicated that most significant seepage (>20 mm/d) occurred in less than 32% of the surveyed channel length, therefore the channel lining investments should be initially applied to the locations of the channel system identified as having potentially high seepage. Their study indicated that ANNs can be successfully applied to analyze distributed channel seepage by using key input variables.

Watt et al. (2008) used a geophysical technique to model channel seepage in the Coleambally Irrigation Area in NSW, Australia. To rapidly assess seepage points along irrigation channels the geophysical technique was used to measure the resistivity of the soil. Following the geophysical surveying, the resistivity data was compiled and sorted for the program ESAP-Response Surface Sampling Design (RSSD) from the USDA Salinity Laboratory (Lesch et al., 2000). This program was used to determine stochastically where the points for the soil sampling regime should be. In conjunction, soil sampling was conducted along the geophysical survey. In combination with the geophysical surveys the soils textural analysis was used for deciding the input parameters for the Hydrus 2D/3D model. Hydrus is a software package for the simulation of water, heat and solute movement in a two- and three-dimensional variably saturated medium (Šimůnek et al., 2006). The authors used this model to conceptualize the possible water movement below a channel after many years of use. Their analysis of the results indicated a higher hydraulic conductivity will yield a more rapid saturation of the soil profile and therefore the rising of the watertable in the irrigation area. The results showed the water tables under the irrigation areas will remain stable for the initial part of the irrigation. However at some point will show a rapid rate of increase leading to the risk of water logging and salinization.

2.4 Evaporation

Apart from seepage, the other major component of conveyance losses through an irrigation distribution system is the evaporation loss. For the case of lined channels, the evaporation component can be substantial in the total percentage loss. A considerable amount of water may be lost from a network of long channels through evaporation in arid or semi arid regions. Evaporation losses from irrigation channels in northern Victoria can be as much as 70 GL/year (Winter & Albrecht, 2011). Similarly, evaporation losses from agricultural water reservoirs can be potentially large and represent a significant portion of the total water managed for irrigation in arid or semi-arid climates (Hudson, 1987). Go¨kbulak and O¨zhan (2006) indicated that estimated evaporation losses from lakes and dams in Turkey are greater than the water consumed for domestic and industrial uses. Evaporation losses from storages in Queensland can potentially exceed 40 per cent of total water stored equal to 1000 GL/year which is enough to irrigate about 125,000 ha and generate an annual gross crop value of about US$ 375 million (Craig et al., 2005).

The most important factors affecting the evaporation process are, air temperature, sunshine hours, humidity, cloud cover, solar radiation and wind speed (Hameed et al., 1995). Initial measurement and experimentation of evaporation goes back to 18th century when Dalton (1802) started the empirical hydrodynamic approach to the evaporation problem. He stated that evaporation is proportional to the difference in vapor pressure between the surface of the water and in the air and that the velocity of the wind affects this proportionality. Subsequently, numerous researchers (Stelling, 1882; Fitzgerald, 1886; Carpenter, 1889; Meyer, 1915; Rohwer, 1931; Penman, 1948; Marciano and Harbeck, 1954) started investigating the evaporation process based on Dalton's description and proposed several equations on the basis of large amounts of experimental data, which all had the general form of (Sartori, 2000):

$$q_{ew} = (a+bV)(P_w - P_a) \qquad (2.3)$$

where q_{ew} is the heat fluxes by convection and evaporation, V is the wind velocity, P_a, P_w are water vapor partial pressure at the air and water temperatures and a, b are empirical coefficients.

Generally, the heat and mass transfer processes by evaporation from a free water surface take place according to two mechanisms:

- Transfer of heat and mass by the molecular motion (diffusion)
- Transfer of heat and mass by the gross motion of the fluid over the water surface (advection)

Near the water surface where the fluid velocity is low and advection is considered to be negligible, the dominant mechanism of heat and mass transfer is via molecular motion or diffusion. However, in a very thin layer of air immediately above the water surface, vapour is available which is regarded as being due to the action of molecular diffusion. With forced convection, the evaporation is caused by a combination of advection and diffusion, being the dominant component of the mechanism of heat and mass transfer generally made by the bulk or gross motion of the fluid (Li et al., 2005)

A large number of equations for estimating evaporative rate are available in the literature. Most of these empirical equations have resulted from regression analysis of large numbers of experiments. Nevertheless, these equations continue depending or being valid for only particular systems and climates similar to those when the measurements were made. Sartori (2000) carried out a critical review on several well-known equations employed for the calculation of the solar evaporation rate from free water surfaces. A number of publications in the scientific literature compare different methods for estimating open water evaporation rates. Finch and Hall (2001) presented a full review of these methods.

The common methods used for estimating evaporation rates are as follow:

- Pan factors

- Mass balance
- Energy budget
- Bulk transfer
- Combined methods

2.4.1 Pan factors

Evaporation pans have been traditionally used to estimate evaporation rates for many years. Pan evaporation is simply the depth of water evaporated from the pan during a day. These pans vary in dimensions but the most common one is the US Class A pan. The Australian Government Bureau of Meteorology (ABM) began installing Class A pans in the 1960s. Daily data from these devices have been collected at many meteorological stations for decades especially in rural areas where the information can be used for irrigation scheduling (Gifford, 2004). The application of pan factors in estimating evaporation in channel water loss studies has been cited by many authors (Nelson and Robinson, 1966; Mcleod, 1996; Iqbal et al., 2002; SKM, 1997a, 2006; Poulton et al., 2007; Shirsath and Singh, 2009; Schulz, 2009; Lang et al., 2009).

Given the fact that direct use of data from pans located some distance away from the water body can result in significant errors, in order to adjust the evaporation from pan with water body evaporation, pan coefficients which are simply the ratio of the water body evaporation to pan evaporation, have been applied (Winter, 1981). However, the most important shortfall of this technique is that coefficients are specific to the pan type, its location and the nature of the water body and so require calibration for individual applications.

Nelson & Robinson (1966) estimated evaporation from three different channels in Northern Victoria using class A pan with coefficient of 0.9. While SKM (2006) used a class A pan with a coefficient of 0.7 for estimating evaporation losses in Coleambally. Furthermore, Poulton et al. (2007) and Lang et al. (2009) estimated evaporation in Tatura with a class A pan using a pan coefficient of 1.

Due to the differences in size between the pan, the water body and overlying air, pan evaporation measurements are not recommended to be used directly for evaporation estimation. Observations of Purcell (2003) from monitoring small reservoirs in north-east NSW and southern Queensland showed that pan evaporation generally does not correlate very well with small reservoir evaporation using data collected on-site.

2.4.2 Mass balance

Mass balance is a simple method which calculates evaporation as the change in volume of water stored and the difference between inflows and outflows (Finch & Hall, 2001).

$$E = P + \frac{(Q_{ri} + Q_{gi}) - (Q_{ro} + Q_{go}) - \frac{dV}{dt}}{As} \qquad (2.4)$$

where E is the evaporation rate from the water body, P is the mean rate of precipitation over the sampling period, Q_{ri} is the surface inflow rate, Q_{ro} is the surface outflow rate, Q_{gi} is the groundwater and seepage inflow rate, Q_{go} is the groundwater and seepage outflow rate, V is the water stored and As is the surface area.

Although such a method is simple in principle it requires detailed and accurate measurements of surface and subsurface flows which are rarely available. Any errors in estimating components of the mass balance results in a direct error to the evaporation estimate (Gangopaghaya et al., 1966). A further complication can arise if bank or groundwater storage occurs which can increase the total storage capacity as much as 12% with the consequent error in the estimation of evaporation if not taken into account (Gangopaghaya et al., 1966). Leaney and Christen (2000) suggested this method for irrigation channels where evaporation and seepage are major components of total losses.

2.4.3 Energy budget

The energy balance method as applied to water bodies is based upon conservation of energy principles. In this method the evaporation from a water body is estimated as the difference between energy inputs and outputs measured at a site. In other words, evaporation from a water body is estimated as the energy component required closing the energy budget when all the remaining components of the budget are known. This procedure is the most data intensive of the standard evaporation procedures, but it has wide applicability to many differing water bodies for time periods of minutes to years. The energy balance for a water body may be expressed as (Jensen, 2010):

$$Q_t = R_n - \frac{\lambda \rho_w E}{1000} - H + Q_v - Q_w \qquad (2.5)$$

where Q_t is the change in energy stored in the water body in MJ $m^{-2}t^{-1}$, R_n is net radiative energy to the water body in MJ $m^{-2}t^{-1}$, $\lambda\rho_w E$ /1000 is the energy utilized by evaporation in MJ $m^{-2}t^{-1}$, ρ_w is density of liquid water in kg m^{-3} , λ is the latent heat of vaporization in MJ kg^{-1} , E is the evaporation rate in mm t^{-1} , H is the energy convected from the water body as sensible heat in MJ $m^{-2}t^{-1}$, Q_v is the net energy advected into the water body by stream flow or groundwater in MJ $m^{-2}t^{-1}$, and Q_w is the energy advected by the evaporated water in MJ $m^{-2}t^{-1}$.

The energy associated with evaporation is comprised of two categories, the heat required to convert water into vapor (vaporization) and the energy of the water vapor molecules carried from the water body (advection). This method is widely considered to be the most accurate method of estimating evaporation (Assouline & Mahrer, 1993; Hoy & Stephens, 1977). As such it is often used as a reference method against which other methods are validated or calibrated. Mcleod (1996) used the heat budget method for estimating evaporation from two irrigation channels in northern Victoria and compared the estimated results with the estimates provided by Class A pan data. Mcleod (1996) indicated that the heat budget method gave the best estimate of the evaporation from the irrigation channel during periods when data were available. Anderson (1954) and Stewart & Rouse (1976) also indicated that the energy budget method can give accurate estimates if suitable measurements are available. However, for each water body, special equipment is required. Large number of frequent measurements and difficulty in conducting some of them are some of the drawbacks of the energy balance method.

2.4.4 Bulk or mass transfer

Evaporation rate can also be estimated using the application of bulk transfer formulae. A simple version of such a bulk transfer equation is shown in Equation 6 (Sene, 1991):

$$E = CU(e_s^* - e) \qquad (2.6)$$

where C is a mass transfer coefficient, U is wind speed and $(e_s^* - e)$ is the difference between saturated vapour pressure at the temperature of the water surface and the vapour pressure at a specified height in the air above the water surface. The mass transfer coefficient is similar in concept to a drag coefficient incorporating transfer across the viscous skin layer at the water surface and through the turbulent flow above it.

Numerous studies have shown that the coefficient changes at wind speeds corresponding to the onset of capillary wave formation on the water surface. As well, the coefficient depends on the stability of the atmosphere (Liu et al., 1979). The coefficient may also vary depending on fetch across the water surface and vegetation of the surrounding land. This method requires measurements of wind speed, vapor pressure, and air and water surface temperature, as well as estimates or measurements of water temperature.

Singh and Xu (1997) used the climatological data of northwest Canada to test 13 mass transfer equations. After calibrating estimates for each site, a comparison was made between the estimated evaporation and pan data at four sites. The authors observed good agreement between the estimates and measurements for a particular site. However in case of sites where equations were not calibrated, agreements were poor. Fulford et al. (1984) also indicated that mass transfer equations are most convenient and useful for determining evaporation from flowing channels.

Simon and Mero (1985) did not recommend the mass transfer method to estimate evaporation from Lake Kinneret in Israel because of inconsistent results and large scatter in estimates of the transfer coefficient. On the contrary, Sacks et al. (1994) found good agreement (generally within 8%) between the energy-budget evaporation and monthly mass transfer evaporation for a shallow lake in Florida. However, for a similar but deeper lake compatibilities were low (mean monthly difference of 24%).

2.4.5 Combination method

The combination methods combine the mass transfer and energy budget principles in a single equation. Two of the most commonly known combination methods are the Penman equation (Penman, 1948) and the Penman-Monteith equation (Monteith, 1965). The combination equations require inputs of net radiation, air temperature, vapor pressure and wind speed. Undoubtedly, the most widely used formula to estimate evaporation in the last fifty years, has been the Penman equation (Penman, 1948). Its success when applied in many different locations is attributable to its physical basis. Penman combined the mass transfer and energy budget approaches and eliminated the requirement for surface temperature to obtain his expression for the evaporation in mm per day from open water which has the following form (Finch & Hall, 2001):

$$E = \frac{\Delta R_n}{\Delta + \gamma} + \frac{\gamma\, f(u)(e_a^* - e)}{\Delta + \gamma} \qquad (2.7)$$

where R_n is the net radiation in units of equivalent depth of water (mm/d), Δ is the slope of the saturated vapor pressure-temperature curve and γ is the psychometric coefficient (or C_p/λ) and f(u) is the wind function. Penman subsequently modified this to a form commonly known as Penman E_T , the evaporation rate expected from short well watered vegetation. A more general form of combination equation is given by the Penman-Monteith equation (Monteith, 1965). The evaporation rate is obtained from the simultaneous solution of diffusion equations for heat and water vapor, and the energy balance equation. When applied to open water it takes the following form:

$$E = \frac{1}{\lambda}\left\{\frac{\Delta A + \rho C_p (e_a^* - e)/r_a}{\Delta + \gamma}\right\} \tag{2.8}$$

where the aerodynamic resistance r_a is the resistance that the water molecules encounter in moving from the water surface to a reference height in the atmosphere and is inversely proportional to the wind speed. This equation has the same physical basis as the Penman equation but does not contain the empirical calibration factors inherent in the wind function used by Penman. It thus is often considered to represent the best description of the evaporation process (Finch & Hall, 2001).

An empirical approximation of the Penman combination equation was made by Priestley and Taylor (1972) to eliminate the need for input data other than radiation and is known as the Priestley-Taylor equation:

$$E = \frac{\Delta A}{\lambda(0.85\Delta + 0.63\gamma)} \tag{2.9}$$

Accuracy of assumptions made in the Priestley-Taylor equation has been validated by a review of approximately 30 water balance studies in which it was commonly found that, in vegetated areas with no water deficit or very small deficits, approximately 95% of the annual evaporative demand was supplied by radiation (Stagnitti et al., 1989). Moreover, both Penman and Priestley-Taylor equations when applied in areas of low moisture stress, produced estimates within approximately 5% of each other (Shuttleworth and Calder, 1979).

Mcleod (1993) used the Penman-Monteith method to estimate evaporation in Northern Victoria. The results were then compared with class A pan evaporation and no strong correlation was found between the two methods. Similarly, McJannet et al. (2008) used the Penman-Monteith method to develop a model for estimating evaporation from open water surfaces in the Murray-Darling Basin (MDB). The model was developed as part of the

Murray-Darling Basin Sustainable Yields Project which aimed to estimate the quantity and temporal variability of water resources across the MDB. The model was tested against measured datasets from seven different locations within the MDB and was shown to produce reliable estimates of the net radiation (difference in average daily values less than 5%), water temperature (difference in average daily values less than 6%), and evaporation (difference in average daily values less than 10%) from water bodies ranging in size from irrigation channels to large reservoirs. McJannet et al. (2008) compared their results with Mcleod (1993) and pan A evaporation with coefficient of 0.7 for the same period of time. In agreement to Mcleod (1993), the comparison revealed that the relationship between modelled and pan evaporation was not particularly strong. Moreover, the slope and intercept of the modelled dataset and the regression reported by McLeod (1993) were very similar giving confidence in the modelled results for irrigation channels. The annual average evaporation estimated from the McJannet et al. (2008) model was 1626 mm with 1491mm derived by McLeod (1993). Considering the comparison of measured with modelled evaporation rates for that location and given the fact that no measured time series data was available for that site, McJannet et al. (2008) suggested that the model was making reasonable evaporation estimates.

In many parts of Australia, especially in irrigated areas there are now many automated weather stations (AWS). Therefore, daily weather data, including solar radiation, humidity and wind speed, can be obtained for estimating evaporation. In major irrigation districts of Australia, evaporation values are calculated on the basis of the Penman-Monteith equation.

2.5 Previous combined losses studies in Coleambally and Goulburn-Murray

2.5.1 Goulburn Murray Irrigation District

Goulburn-Murray Rural Water Corporation trading as Goulburn-Murray Water (GMW) is a statutory Corporation constituted by Ministerial order under the provisions of the Water Act 1989. GMW services a region of 68,000 square kilometres, bordered by the Great Dividing Range to the south, the River Murray to the north and stretching from Corryong in the east to

Nyah in the west. A comprehensive review of channel seepage studies conducted between 1962 and 2011 across the Goulburn-Murray region was made and high potentials of seepage in different channels across the area as well as various seepage rates reported by different authors were highlighted.

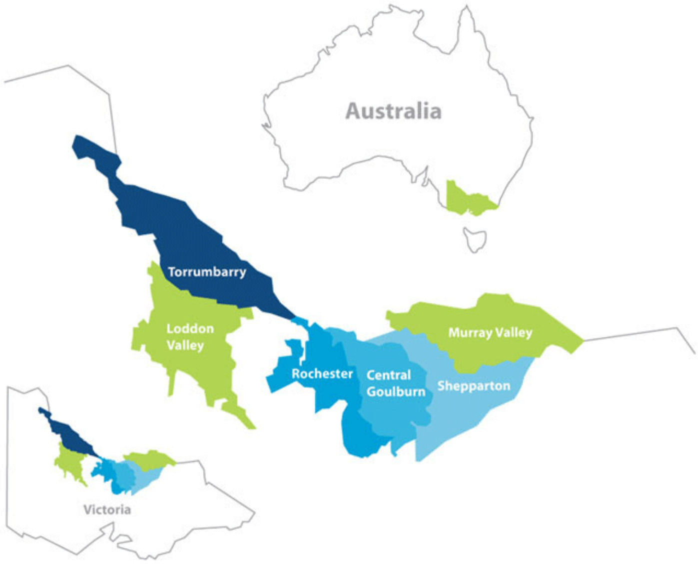


Figure2.3 Goulburn-Murray Irrigation District (Australian Gov., Dep. of Sustainability, 2013)

Nelson & Robinson (1966) highlighted seepage losses between 4.3% and 26% of the total inflow in 3 different channels in Northern Victoria. Robinson (1971) made a review of the distribution efficiency in the Goulburn Murray irrigation district and estimated the levels of efficiency and losses as follows:

Table 2.1 Levels of efficiency and losses in the Goulburn-Murray irrigation 1971 (Robinson, 1971)

Recorded efficiency	69%
Measurement loss	7%
Outlet leakage	1%
Other losses (Evaporation, Seepage, outfalls, theft)	23%

The author referred the measurement loss to a quantity of water delivered to farms but not recorded because of inaccuracy of measurement by Dethridge meter.

Smith (1982) reviewed different channel seepage measurement trials in different irrigation districts of Goulburn Murray area and highlighted seepage rates between 13 and 102 mm/d in different channels (Table 2.2). At the same time, Smith and Turner (1981) estimated seepage rate as low as 5.2 mm/d from an unlined irrigation channel in Northern Victoria.

Table 2.2 Sample results of seepage results (Smith, 1982)

Channel	District	Method	Seepage rate mm/d
Western(Nelson & Robinson, 1966)	Swan Hill	I/O	102
No.11(Nelson & Robinson, 1966)	Rochester	I/O	13
No.31(Nelson & Robinson, 1966)	Nth. Shepparton	I/O	25
E.G. Main (Anon., 1970)	Shepparton	I/O	13 to 19
2/10 (Smith, 1973)	East Shepparton	Pond	13
2/10 (Smith, 1973)	East Shepparton	Meter	17

Similarly, Dunstone (1998) made a comprehensive review of the previous seepage studies conducted between 1962 and 1983 in the Goulburn-Murray region and highlighted seepage rates from 2.4 to 116 L/m^2/day. Strong and Barron (1994) also estimated seepage losses between 2.7 and 23.5 mm/d from on farm channels in Goulburn-Murray region. Strong and Barron (1994) suggested that up to 50% of ground water recharge may come from on-farm and district channels. This was supported by Neeson et al. (1995) who suggested that on-farm channel seepage losses may be up to 3 ML/km/year equal to 6.75 mm/d on large area farms within the Murray Valley irrigation area. McLeod et al. (1994) also, performed 19 pondage tests at two channel sites in northern Victoria and measured seepage losses of between 14 and 34 mm/d in the large Tatura East Channel and between 5 and 9 mm/d in the Dhurringle Channel. Brinkley et al. (2004) also, conducted total number of 81 pondage tests across different sites in Goulburn-Murray Water areas which returned seepage rates ranging from 0.1 mm/d to 48 mm/d.

SKM (2000) categorized the potential ineffiencies and losses in channel distribution systems in northern Victoria into nine different components (Table 2.3).

Table 2.3 Components of unaccounted for water in the Goulburn-Murray Water irrigation System from 1989/90 to 1998/99 (SKM, 2000, SKM, 2006)

Component of the system	1989/90 to 1998/99 - Whole of G-MW		Adopted Error Range		
	Average ML/yr	%	Low (5 percentile)	High (95 percentile)	Adopted error range
Outfalls	298 ,281	30%	244,762	701,914	-10% to +100%
Leakage	84,865	9%	52,099	243,200	-50% to +200%
Seepage	54,010	6%	41,798	65,916	-25% to +25%
Evaporation	100,610	10%	78,761	121,302	-25% to +25%
System filling	64,292	7%	52,469	75,695	-20% to +20%
Theft	5,500	1%	3,407	15,768	-50% to +200%
Domestic & Stock	37,573	4%	39,151	73,055	0% to +100%
Measurement Error	110,178	11%	110,178	110,178	0%
Unaccounted for Water (UFW)	224,970	23%			
Total UFW	980,277	100%	622,625	1,407,028	

Considering the results of several conducted pondage tests in certain channel sections in northern Victoria, SKM (2000) concluded that leakage losses comprised 9% of the total unaccounted flows, while seepage was 6% of the total. They stated that in the case of outfalls and measurement error, since the implementation of Total Channel Control, outflows have been reduced to almost zero and metering accuracy has improved by around 2%.

However, higher seepage rates have also been reported in other parts of Northern Victoria. Lawler (1990) highlighted seepage losses as much as 400 mm/d from on-farm channels in the Campaspe Region of Northern Victoria when channels were filled up to their supply level and 50mm/d at the end of the irrigation period. Similarly, Watts and Thompson (2001) estimated seepage loss of 81000 m^3 over three seasons (807 days) from one of the channels diverting water from the Murray River in Victoria.

From 1998 onwards the Australian National Committee on Irrigation and Drainage (ANCID) conducted major channel seepage studies in different channels in the Murray–Darling system, focusing on how to quantify seepage; channel seepage remediation in order to find the best way to treat seeping channels, and channel seepage management decision support to look at how to make the difficult decisions on whether expensive remedial works should be carried out or not (ANCID, 2000a, b, 2001, 2003a, b; KTF, 1999, 2002).

At the same time, the application of TCC data has been addressed in a number of small scale studies. Poulton et al. (2007) conducted a trial water savings project involving channel automation over the duration of 2004-2007 irrigation seasons across 20% of the Central Goulburn Irrigation Area and showed that leakage and measurement error represent a greater part of the system loss than previously thought. Poulton et al. (2007) highlighted that due to the errors of measurement (± 2% at each regulator) sufficient precision of measurement was not possible. Thus, the difference between inflow and outflow measurements taken at adjacent regulators during the irrigation season have not been successful in determining losses in an individual pool. Poulton et al. (2007) introduced an improved method called 'inflow tests' for more accurate assessment of system loss in individual pools during channel filling, in which the downstream regulator is closed, and a small inflow to the pool is used to just balance the leakage and seepage rate. However, given that only a few preliminary inflow tests have been conducted till 2007, no result was reported in this study. Poulton et al. (2007) used the channel automation data to apply pondage testing on isolated pools for a period of 7-10 days. To carry out the pondage tests, each pool was brought up to full supply level and the regulator gates closed. Poulton et al. (2007) suggested that the rate of recession during the first 24-48 hours represents the total leakage, seepage and evaporation, which assumes that leakage, occurs mainly in the eroded section of the bank within 150mm of the full supply level of G-MW channels. While, loss measurements several days later after the pondage test commenced are taken to represent seepage and evaporation (Figure 2.4).

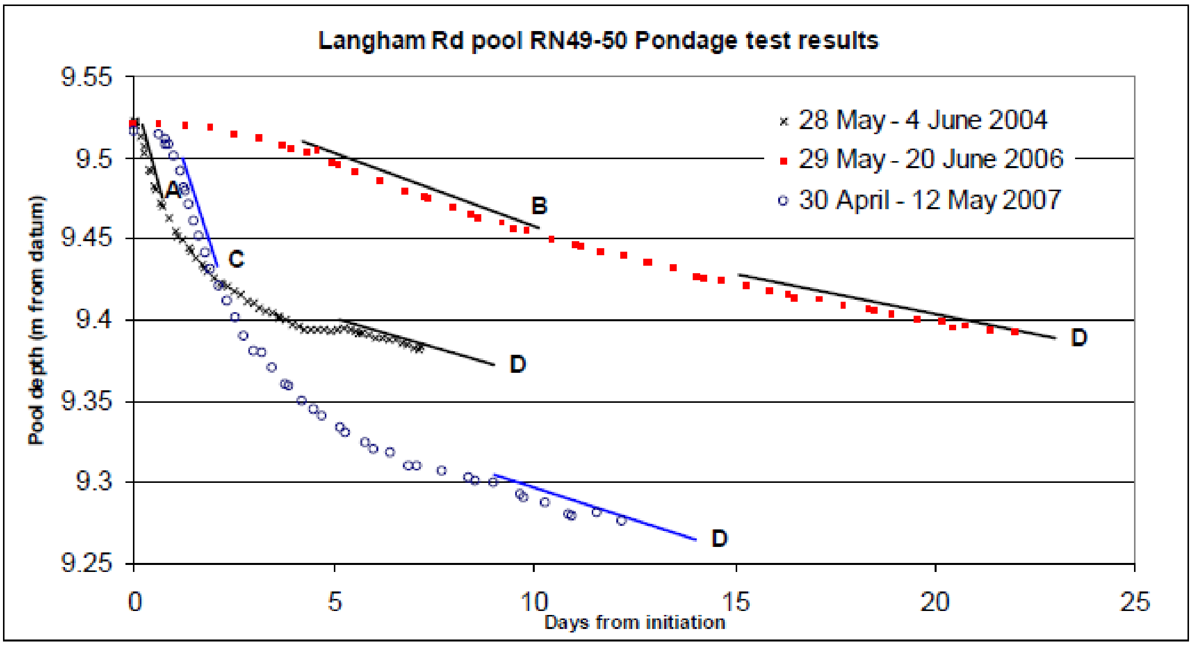


Figure 2.4 Example of analysis of pondage test data (Poulton et al., 2007)

Figure 2.4 shows a high leakage rate in May 2004 during the first day of the test (A). Given that, leaks were repaired between February and April 2006, a substantially lower leakage rate was then recorded in the pondage test in May 2006 (B). The pondage test in May 2007 shows that without further leak repair, the pool again has a high leakage rate (C). In all tests the estimated seepage rate was between 3-6 mm/d (D). The components of loss, expressed in terms of the fall in channel water level, are shown in the table below.

Table 2.4 Estimation of leakage and seepage – Langham Rd pool RN49-50 (Poulton et al., 2007)

Year	Seepage, Leakage and Evaporation (mm)	Leakage (mm)	Evaporation (mm)	Seepage (mm)
May-04	91	84	1.3	5.7
May-06	9	4	1.3	3.7
May-07	78	71	2	5

To provide additional confidence in the estimation of leakage and seepage from pondage tests, in May 2006, Poulton et al. (2007) operated the CG234 system without planned water delivery in the system. The inflow to the system, after adjustment for evaporation, was 43.3

ML/d while the total loss recorded in the pondage tests, in the period immediately after the test was 25.1 ML/d. Therefore the leakage and seepage measurement, based on pondage tests, only accounted for about 58% of the system inflow. Poulton et al. (2007) indicated some of the difference due to authorized (and non-authorized) extraction from channels by customers, included in the system inflow, but excluded in the pondage test results. Poulton et al. (2007) suggested that the best estimate of leakage and seepage is at least 20% higher than pondage test results. The reasons behind this suggestion were:

- Corporate records of channel dimensions are thought to underestimate the actual dimension and
- loss rates are likely to be higher under normal operating conditions, given that in a pondage test the hydraulic head is always less than that at full supply level.

Schulz (2009) introduced the application of automated channel control data of G-MW in conjunction with the pondage test method to estimate seepage losses in some random irrigation channels. Schulz (2009) suggested that noise associated with measurement errors and other factors should be eliminated before any analysis (Figure 2.5 and 2.6).

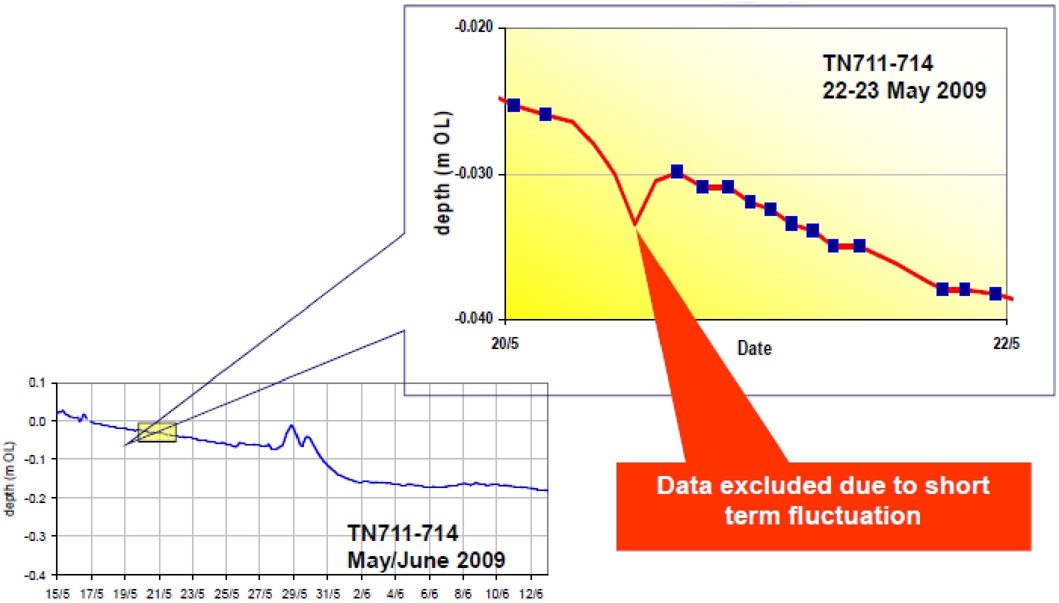


Figure 2.5 Data cleansing due to short term fluctuations (Schulz, 2009)

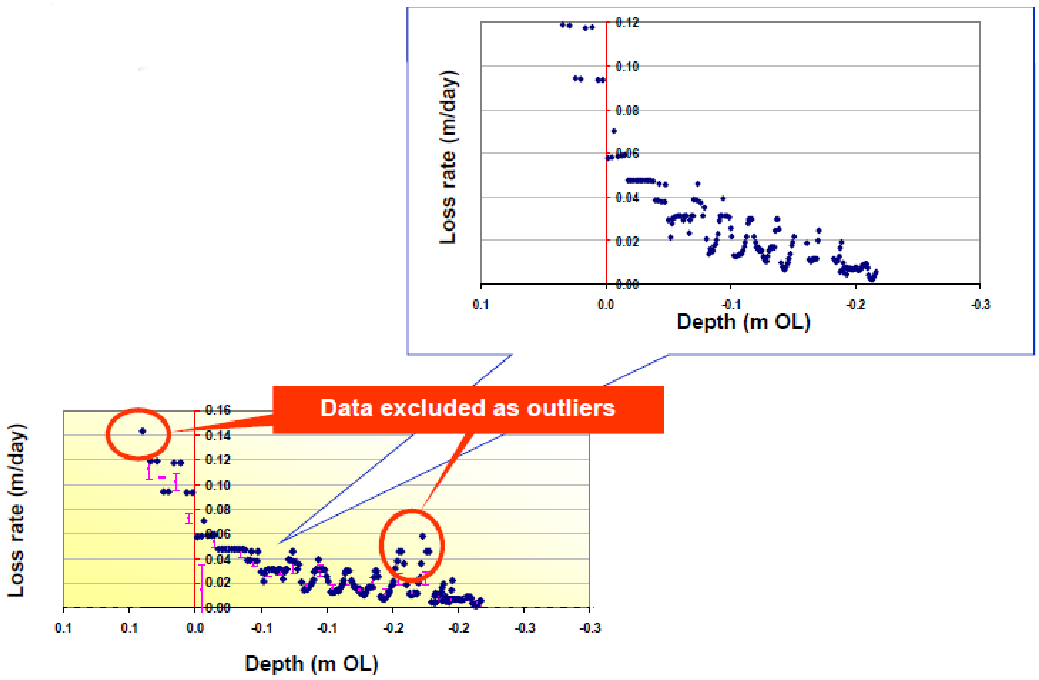


Figure 2.6 Data cleansing due to outliers (Schulz, 2009)

Furthermore, Schulz (2009) suggested variable loss rates instead of one constant seepage rate during a pondage test (Figure 2.7)

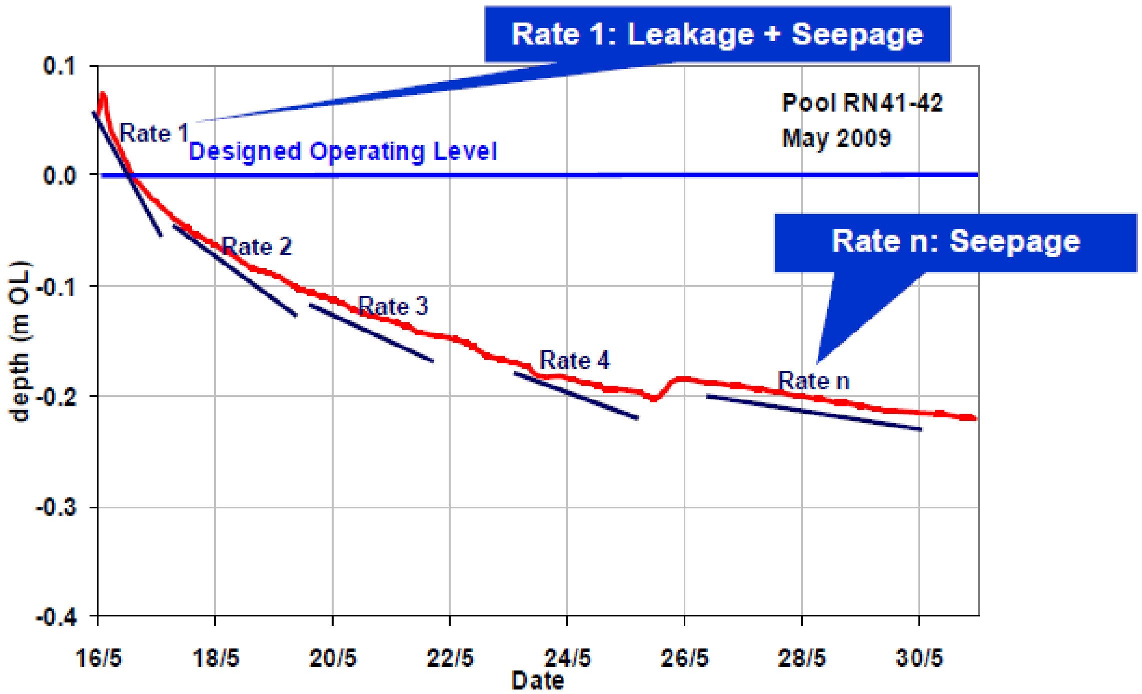


Figure 2.7 variable loss rates during a pondage test (Schulz, 2009)

Schulz (2009) suggested that testing on pools in which the loss rate varied with water table elevations should be done after hydraulic conditions were stabilized in that area. Finally for the issue of adjusting the ponding results with dynamic conditions, Schulz (2009) suggested that correction factors should be applied to the results. However, no result was provided in his study.

Another study that addressed the application of TCC data in a number of selected channels was conducted by Lang et al. (2009) who used TCC data from No. 2 channel in the Central Goulburn Irrigation Area to show how daily measurements of metered deliveries and total system off take can be used to characterize the temporal distribution of leakage and seepage losses. Assuming theft is negligible and any bias in measurement inaccuracies has been eliminated by the installation of TCC, Lang et al. (2009) compared the daily total of metered deliveries passing the 136 flume gates that regulate flow onto farms with the daily off take (or diversion) to CG2 plus the flow passed to CG3 and attributed the difference between these numbers to a daily record of the water lost to evaporation, un-metered use, leakage and seepage (Figure 2.8).

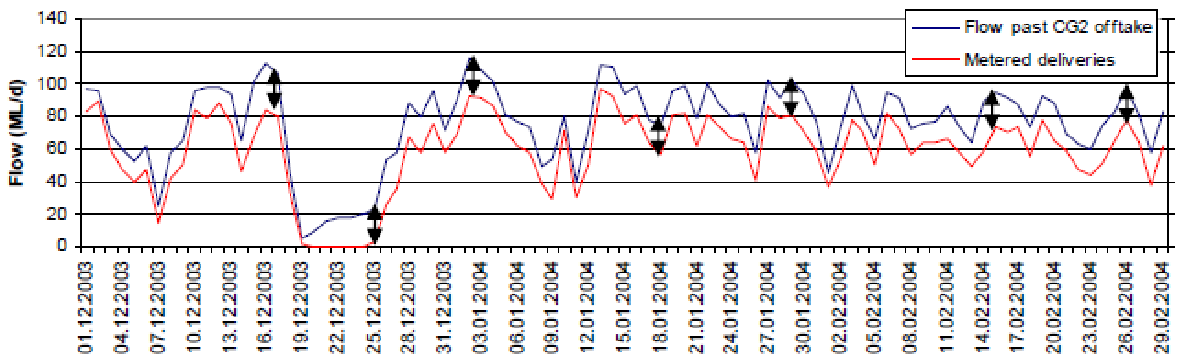


Figure 2.8 An example period of total metered deliveries and offtake to the CG2 (Lang et al., 2009)

Taking in to account the difference between the metered deliveries recorded to May 15th and the system use reported as un-metered use, in order to estimate the seepage and leakage losses in CG2, Lang et al. (2009) separated the net evaporation loss and un-metered use out for the period between the end of channel filling and May 15^{th} (Figure 2.9). Given that the Goulburn Weir evaporation record was only available to August 2008 and both the rainfall and evaporation records contained short periods of accumulated or missing data, Lang et al.

(2009) used an appropriate regression equation in conjunction with the pattern of rainfall or evaporation at other nearby stations to infill the missing data.

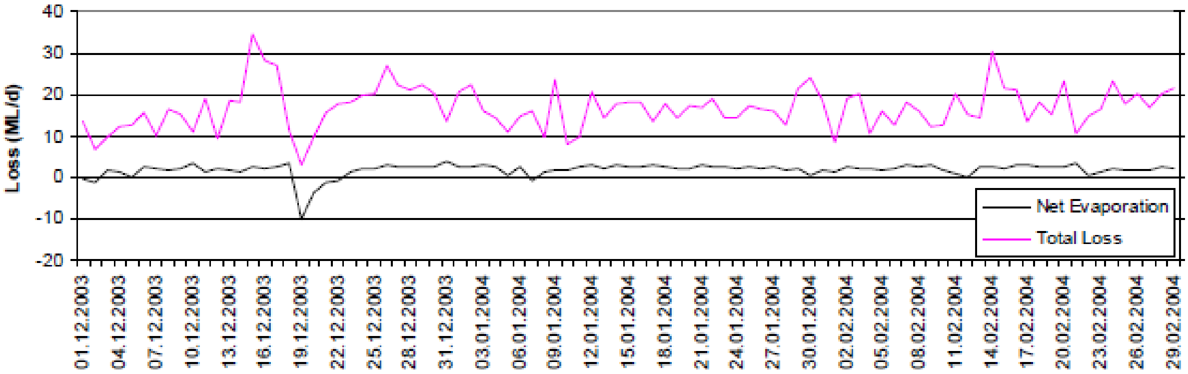


Figure 2.9 An example period of net evaporation losses and total losses (Lang et al., 2009)

Lang et al. (2009) excluded periods adjacent to and including the channel filling and end of season phases, where the relationship between metered deliveries and CG2 offtake appeared to be affected by changes in system storage from their datasets.

Based on seepage rates derived from previous pondage tests undertaken by Poulton et al. (2007) in June 2006 and May 2007 that showed that seepage rates remain relatively constant from year to year in order to estimate the portions of system losses attributable to seepage and leakage, Lang et al. (2009) adopted a fixed seepage rate of 6 mm/d equivalent to a 2 ML/d loss across the CG2. Afterwards, Lang et al. (2009) calculated the median daily leakage losses of 9 ML/d – 11 ML/d between 2003/04 and 2005/06, and 3.5 ML/d – 5.5 ML/d between 2006/07 and 2007/08 (Table 2.5).

Table 2.5 Estimates of un-metered use and losses to evaporation, seepage and leakage for CG2 (Lang et al., 2009)

Season	Un-metered Use (Average)	Net Evaporation (20th - 80th percentile)		Seepage (Average)		Leakage (20th - 80th percentile)	
	ML/d	ML/d	mm/d	ML/d	mm/d	ML/d	mm/d
2003/04	1.8	0.7 - 2.4	2.2 - 7.2	2	6	4.9 - 14.2	14.7 - 42.8
2004/05	0.9	0.9 - 2.3	2.6 - 6.8	2	6	4.8 - 13.8	14.5 - 41.8
2005/06	0.5	0.6 - 2.4	1.8 - 7.2	2	6	5.7 - 16.0	17.2 - 48.2
2006/07	0.9	1.0 - 2.6	3.0 - 8.0	2	6	2.7 - 8.7	8.1 - 26.2
2007/08	2	0.7 - 2.6	2.2 - 7.8	2	6	0.7 - 8.0	2.1 - 24.1

2.5.2 Coleambally Irrigation District

The Coleambally Irrigation District (CID) located south of Griffith, New South Wales is one of the major irrigation districts of Murray-Darling Basin. Numerous channel seepage studies have been performed in the (CIA). Most of the quantitative measurements were based on Idaho seepage meter measurements (Akbar, 2003; SKM, 1997a, b; SKM, 2006; Morton et al., 1994; Kinhill, 1995; Stewart, 1996; Maher & Smith, 1997) and a few on pondage tests (SKM, 2006). EM survey data were also used in identifying locations with high seepage potential in the area (Harding, 2002; Allen & Merrick, 2003; Allen, 2005).

The majority of seepage studies in the CIA were done only for the Main canal or a few identified locations with high potential seepage. However with the completion of electrical conductivity imaging of all the irrigation supply channels in CIA, Allen (2005) identified locations with high potential seepage rate throughout the entire network and divided them into 5 different priorities.

From the seepage magnitude prospective, different total amounts per year have been highlighted by various authors. Van der Lely (1994) suggested that 15 GL/year of water being recharged to water tables from cropping in 333 farms in CIA is lost via seepage from leaky supply channels. This was supported by Pratt Water (2004), CSIRO (2005) and Tiwari (1995) who suggested that channel seepage contributes 12 GL/year from 1,400 hectares of channels.

Pratt Water (2004) conducted their study based on annual environment reports prepared by Coleambally Irrigation Corporation Limited (CICL) and Khan et al. (2004) and claimed that for the CIA, the combined savings could amount to as much as 53,000 ML from near-farm losses and 120,000 ML/yr from on-farm losses (Table 2.6). In agreement to that, CSIRO (2005) also demonstrated that around 38 GL/year of water is lost due to seepage from channels and rice farms (Table 2.7).

In addition, having reviewed the previous seepage studies and considering a total channel length of 466 km and average wetted perimeter of 18 m, SKM (1997a) concluded that seepage and leakage loss from all channels excluding the Main Canal in the CIA amounted to 9.8 GL/year.

Seepage rates have also been estimated in other studies with a focus on Main Canal or number of channels. Akbar (2003) estimated seepage losses between 11 and 27 ML/year from selected farms in CIA during the irrigation seasons of 1997/98, 1998/99 and 1999/2000. With the application of existing automatic water level records, SKM (2006) estimated seepage loss in the first 18 km of the Main Canal and the results were between 2800 – 3900 ML/year.

Table 2.6 Accounted losses and water savings in the on-farm and near farm zones (Pratt Water, 2004)

Component	Previous losses estimates	Combined water Savings ML/yr (Pratt Water 2004)
On-farm zone		
Seepage	10,000	10,000
Deep percolation	35,000	35,000
Irrigation technology conversion		45,000
Reduced area of rice growing		30,000
Total	45,000	120,000
Near-farm zone		
Seepage	15,000	38,000
Evaporation	15,000	15,000
Total	30,000	53,000

Table 2.7 Accounted losses and water savings (GL/yr) (CSIRO, 2005)

	Off – farm[1]		On – farm[2]	
Component of system	**Previous knowledge**	**New assessment**	**Previous knowledge**	**New assessment**
Coleambally Irrigation				
Seepage	15	30–45	4–16	4–16
Deep percolation	-	-	29-41	29-41
Evaporation	15	15	-	-
Irrigation technology conversion	-	-	-	15-74
Total	**30**	**45–60**	**33–57**	**48–131**

1 Within and near the jurisdiction of the irrigation corporations. Evaporation losses from channels and dams.
2 Including rice

From 1998 onwards qualitative measurements using EM31 equipment took place along the banks of the channels including sections of the Main Canal, 17 kilometres along sections of the Bundure 3 supply system and 2 kilometres along sections of the Boona Main Supply Channel in CIA (Table 2.8).

Based on the results of electrical conductivity imagery assessment of sediments below the channel bed of the Main Canal (Allen & Merrick, 2003; Allen, 2005), SKM (2006) assessed the scale of water losses in the first 18 km of the Coleambally Main Canal to identify areas with potential high vertical seepage (Figure2.10) and thermal imagery obtained from airplane to identify areas with potential horizontal seepage and leakage hotspots respectively.

Table 2.8 Summary of seepage investigations and treatments since 1993/94 (CICL, 2008)

	Pondage Testing	Idaho Meter	EM-31 bank	EM-31 pontoon	Thermal Image	Hydrogeophysics	SPOT Tubes	Total	Clay Lining	Bank Rebuild	Total
1993/94*	0	54.3	0	0	0	0	0	54.3	0.0	0.0	0
1994/95	0	72.5	0	0	0	0	0	72.5	8.7	1.0	9.7
1995/96	0	66.1	0	0	0	0	0	66.1	3.8	3.3	7.1
1996/97	0	56.3	0	0	0	0	0	56.3	0.0	15.3	15.3
1997/98	0	0	0	0	0	0	0	0	0.5	4.1	4.6
1998/99	0	0	178	0	0	0	0	178	1.6	1.2	2.8
1999/00	0	0	17	0	0	0	0	17	1.0	1.7	2.7
2000/01	0	0	2	0	0	0	0	2	0.8	0.1	0.9
2001/02	0	0	0	145	0	0	0	145	0	2.5	2.5
2002/03	0	1	0	0	0	12	0	13	0.2	0.4	0.6
2003/04	0	0	0	0	0	60	0	60	1.2	0.6	1.8
2004/05	0	0	0	0	55	12	2	69	0	1.3	1.3
2005/06	0	2	0	0	0	4	2	8	0.35	1.4	1.75
2006/07	0	0	0	0	0	428	0	428	2.5	0.9	3.4
Total (km)		252.2	197	145	55	516	4	1169.2	20.65	33.8	54.45

*=Channel maintenance data for 1993/94 unavailable

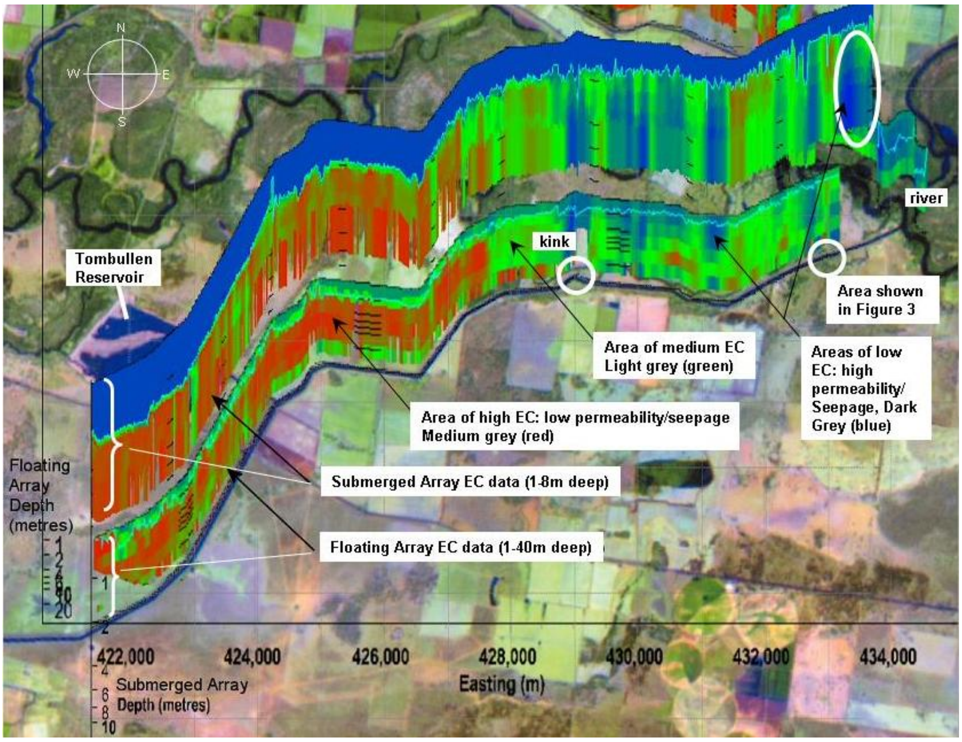


Figure 2.10 Submerged and floating array results in Coleambally Main Canal (Allen, 2005; SKM, 2006)

Pondage testing was used to quantify vertical seepage losses, while horizontal seepage and leakage assessment was done using site specific infiltration measurements. One large pondage test was performed during the winter closure period of the Coleambally Main Canal (Figure 2.11).

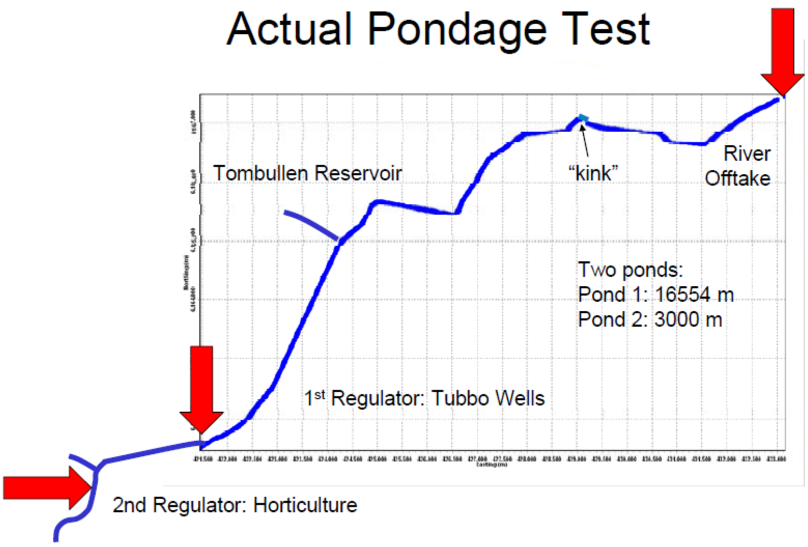


Figure 2.11 The pondage location on the Main Canal, Winter 2005 (SKM, 2006)

The pond was 16,550 m long including the branch to Tombullen Reservoir. When the water depth in the channel was between 1.7 m and 2 m, combined seepage and leakage was observed over a 9 and 28 day period, resulting in observed losses of 100 ML and 275 ML respectively. The measured loss range was 2,800 ML to 3,900 ML per irrigation season, similar to the loss of 2860 ML/season determined by SKM (2000). The loss rate during the first period was 20 mm/d and 15 mm/d during the second period (Figure2.12). SKM (2006) highlighted that the difference might have been caused by different relative levels of water in the channel and the ground during the observation periods. The results suggested that 80% of the losses may occur in 20% of the channel length or even over a smaller length.

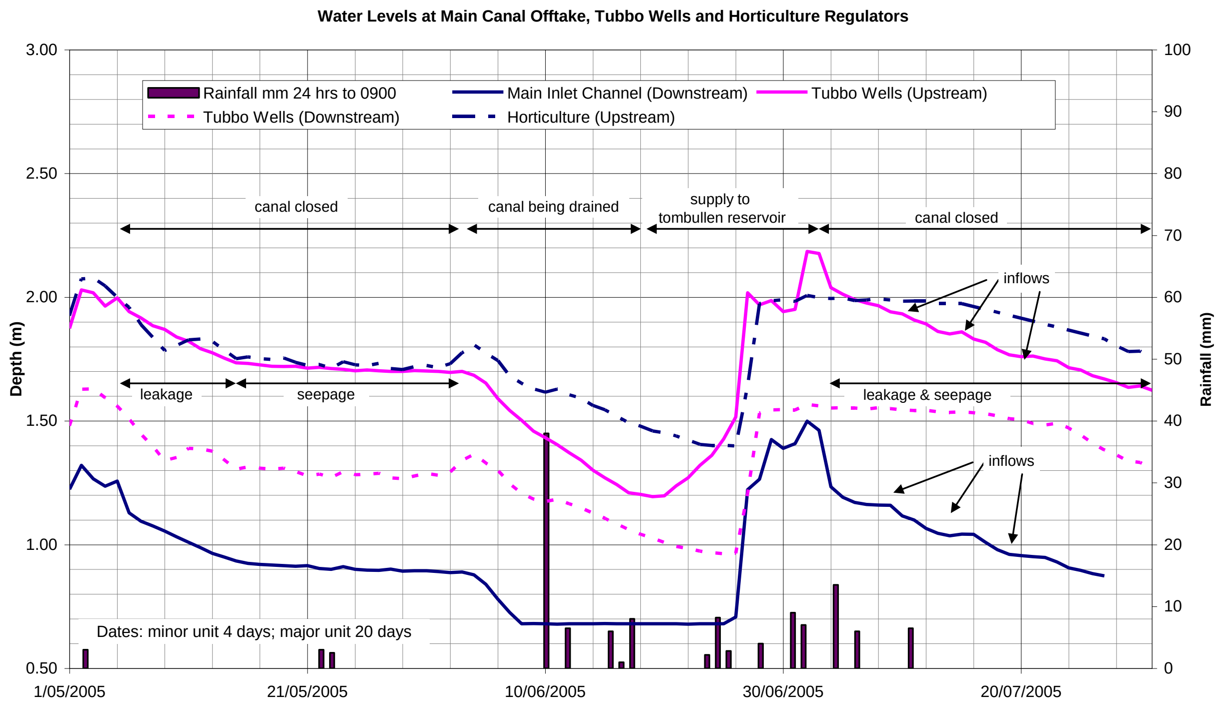


Figure 2.12 Water level drop in ponded first 18 km of Main Channel (SKM, 2006)

Using GPS positioned vertical electrical conductivity imaging along with depth recording, Allen (2006) conducted towed geo-electric surveys on different channels of the CIA. Allen, (2006) used the results of the resistivity images to select seepage hot spots in channels. It was followed by placing Seepage Penetration Observation Tubes (SPOTs) in channels identified from geo-electric imaging of aquifers beneath the channels. The SPOT measurement is a form of infiltrometer test (Figure 2.13).

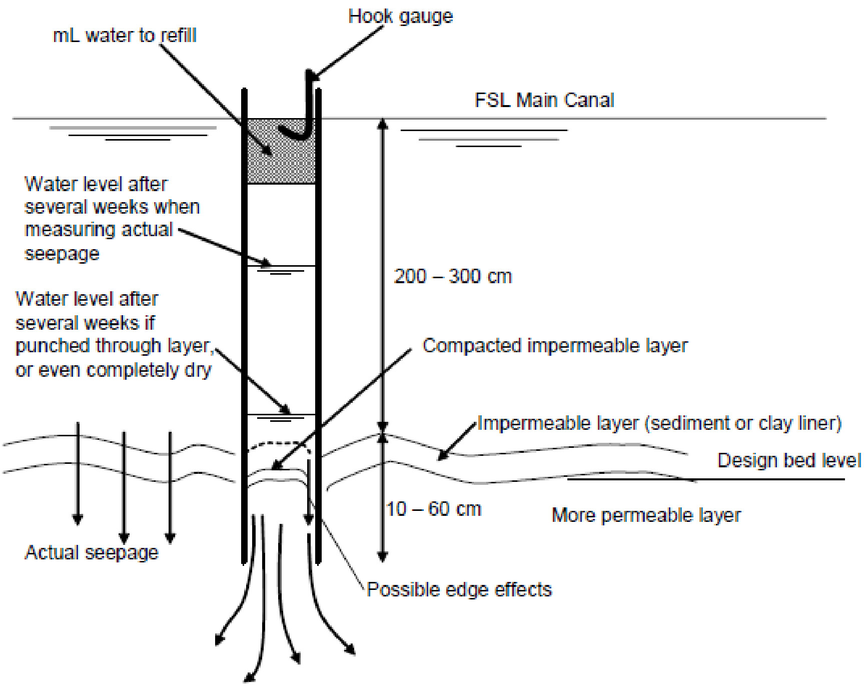


Figure 2.13 Principal of SPOT seepage measurement (SKM, 2006)

Based on the conductivity levels in the bed of the channels Allen (2006) prioritized the suspect locations with high potential seepage loss into 5 different groups (Table 2.9). Figure 2.14 and 2.15 illustrate the seepage test sites and the measured rates in the Main Canal.

Table 2.9 Priorities of hotspot channels in Coleambally (Allen, 2006)

Priority	Criteria	Seepage mm/d
1	Blue (EC<400uS/cm) from 0 to 12 m and >500m wide continuously	40
2	Blue (EC<400uS/cm) from 0 to 12 m and <500m wide continuously	20
3	Aqua (EC<800uS/cm) from 0 to 12 m or blue in most depth slices	10
4	Blue (EC<400uS/cm) in several but not all depth slices or aqua in most slices	10
5	Green (EC<1000uS/cm) from 0 to 12 m and >1km wide continuously	10

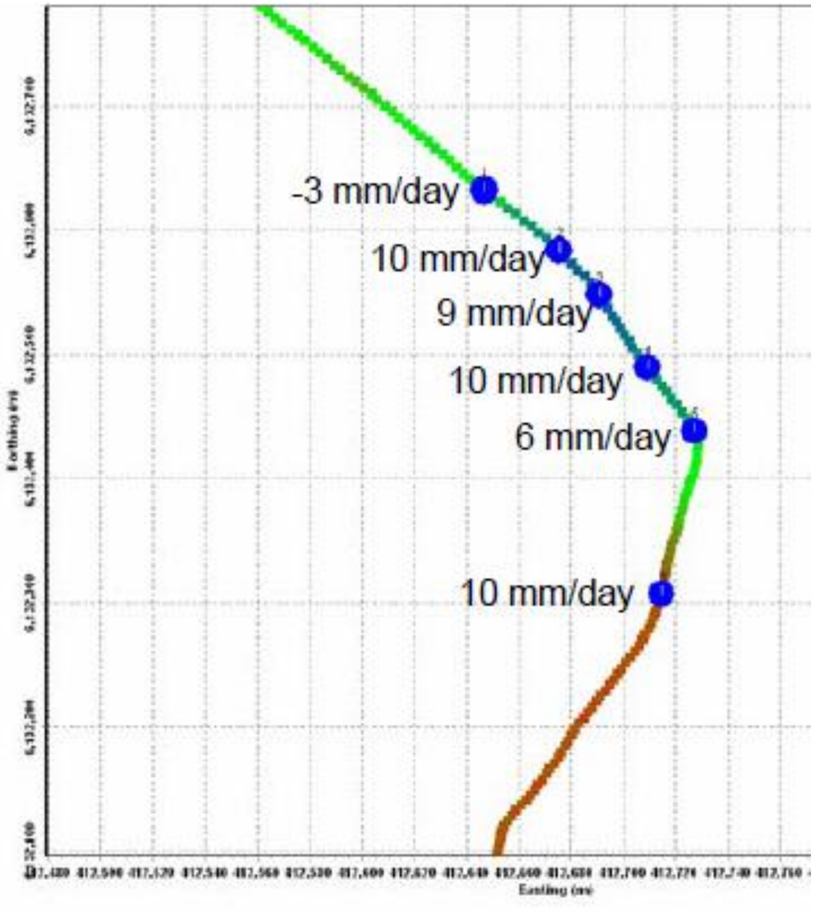


Figure 2.14 Main Canal seepage test sites and the rates measured in preliminary observations (Allen, 2006)

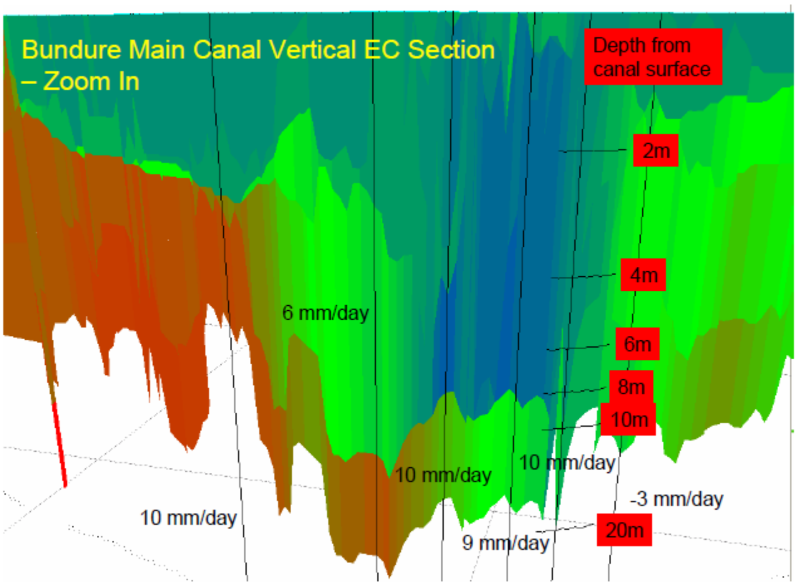


Figure 2.15 Main Canal seepage test sites superimposed over a vertical EC section of sediment beneath the channel (Allen, 2006)

Approximate locations of any given channel reach classified in each priority were identified. Moreover, considering length and width of the wetted perimeter section of each leaky channel, the total amount of water loss per six month period and the cost required for channel remediation were estimated (Table 2.10)

Table 2.10 Summary of total amount of seepage in each priority (Allen, 2006)

Priority	Length (m)	Area (m2)	COSTS	Seepage Loss (ML) per six month irrigation season
1	12,200	507,600	$15,228,030	3,655
2	8,910	185,540	$5,566,200	668
3	14,770	173,520	$5,205,600	312
4	19,180	417,800	$12,534,000	752
5	8,850	104,500	$3,135,000	188
Total	63,910		$41,668,830	5575

2.6 Conclusion

A comprehensive review of applicable seepage measurement techniques as well as previous seepage estimates in two of the biggest irrigation districts of Australia was undertaken. For the purposes of channel seepage estimation the pondage test method is considered to be most suitable technique. The key factors making this technique most appropriate are:

- it uses a simple water balance to determine seepage losses in an isolated reach of channel,
- the influence of localised conditions is reduced,
- the opportunity for human error is diminished,
- pondage tests provide an average net seepage flux for the entirety of the surface water feature being considered, this is in contrast to other methods, such as seepage meters, which only measure seepage at a point, and
- it has a good degree of repeatability in the results.

Pondage testing using channel automation data, has the promise to be a useful technique for routine appraisal of leakage and seepage, as the system effectively isolates pools, and provides water level data for the analyses.

At the same time, utilizing the existing regulating structures in automated systems instead of earthen bank construction eliminates some of the disadvantages of this technique, for example:

- it decreases the cost of applying this technique, and
- it effectively allows simultaneous pondage testing in each pool throughout the channel system without taking the channels out of use as it previously used to do.

A comprehensive review of various water losses studies in different parts of Northern Victoria was done and for the purpose of evaporation estimation, the application of different techniques was evaluated. It was shown that in majority of recent studies evaporation was estimated using a class A pan with various factors for different locations. Combination methods also proved to be an effective means for evaporation estimation. The key factors making this technique most appropriate are:

- Calculations are based on readily available data, and
- The model has a physical basis.

In addition, in many parts of Australia, especially in irrigated areas there are now many automated weather stations (AWS). Therefore, daily weather data, including solar radiation, humidity and wind speed, can be obtained for estimating evaporation. Given that in major irrigation districts of Australia, evaporation values are calculated on the basis of Penman-Monteith mathematical equation, it was decided to use the evaporation estimates from the AWS instead of class A pan evaporation.

A comprehensive review of channel seepage studies conducted across the southern Murray Darling region was performed and high potentials of seepage in different channels across the area as well as various seepage rates reported by different authors were highlighted.

The review highlighted seepage rates as high as 400 mm/d in some parts of Northern Victoria before remediation and 48 mm/d combined seepage and leakage losses after channel remediation works. Channel seepage losses as much as 15 GL/year and 10 GL/year pre and post channel remediation works have been estimated in CIA. Thus, it can be concluded that high seepage rates are occurring, even after remediation.

The successful application of TCC data for the purpose of seepage and leakage estimation in Northern Victoria has been reported previously (Poulton et al., 2007, Schulz, 2009, Lang et al., 2009). Despite the success, these studies were limited in that they used a small number of selected channels as well as preplanned pondage conditions. The work proposed in the current research is unique in that it uses the entire TCC data for a whole irrigation scheme during entire irrigation seasons to estimate seepage and leakage losses during periods of gate shut down. This approach will therefore offer a mean of continuous automated monitoring of seepage losses that facilitates real time identification and control of leaky channels. Given that Coleambally Irrigation Corporation Limited was the only scheme able to provide that data (for three irrigation seasons), this study aims to estimate seepage and leakage losses for the entire channel network of CIA using TCC data during periods of gate closure.

Chapter 3: Coleambally Irrigation Area

3.1 Introduction

The Coleambally Irrigation Area was chosen as the principal study area due to it being one of the first fully automated irrigation districts in the world and having three years of historical data. The Coleambally Irrigation Area (CIA) is located within the Riverina in the South-West of New South Wales, Australia (Figure 3.1).

Irrigation water within the Riverina region is sourced from both surface water and groundwater. Surface water is the major water source and used predominantly in the mid-catchment region around Griffith, Leeton and Coleambally. Groundwater is mainly used in the upper catchment, east of Wagga and also in the mid-catchment near Darlington Point. The region includes the Murrumbidgee Irrigation Area, Coleambally Irrigation Area and single license holders, referred to as private diverters. Irrigation commenced in the Murrumbidgee area prior to World War I and expanded across the region during the subsequent 60 years.

CIA was established between 1958 and 1970, when the Water Conservation and Irrigation Commission acquired pastoral lands to make use of the water being diverted from the Snowy Mountains Hydro-Electric Scheme. This area is located at about 650 kilometres south-west of Sydney and was developed for the sole purpose of irrigated agriculture. The Coleambally town was opened in 1968 and the area surrounding it has a population of about 1200 people.

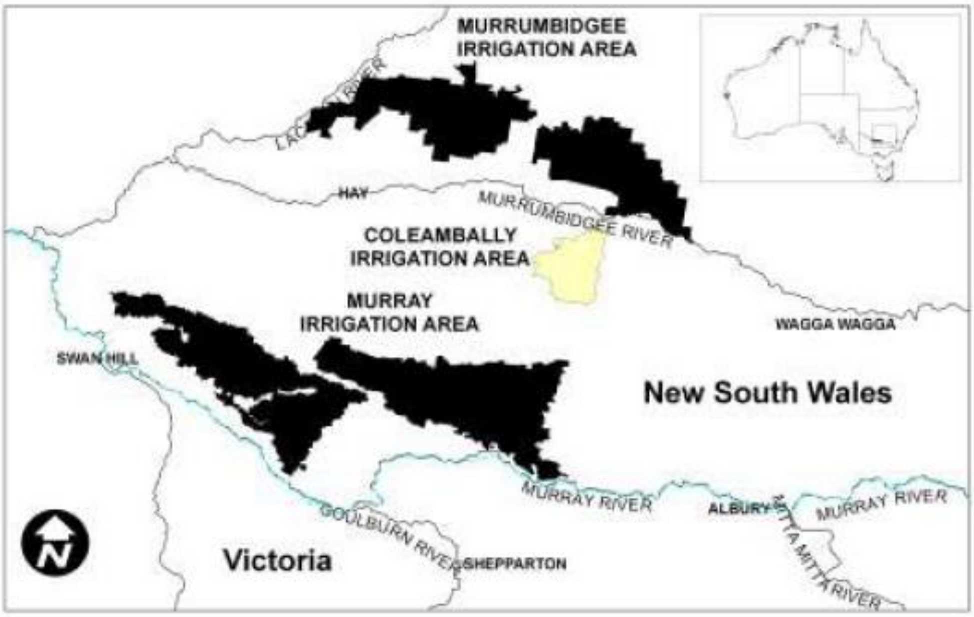


Figure 3.1 The Coleambally Irrigation Area in relation with Australia (Khan S, 2008)

The majority of the irrigation water for the area is diverted from the Murrumbidgee River and is accessed from the Gogelderie Weir pool. The water is supplied via a 41 kilometre main canal and 477 kilometres of supply canals (Figure 3.2). The area has 734 kilometres of drainage channels that flow to the Billabong and Yanco Creeks.

Prior to 1991 the Department of Land and Water Conservation managed all irrigation water across the state of New South Wales. After 1991, the Coleambally Irrigation Area was managed as part of the Murrumbidgee Irrigation Area and Districts. During 1997, the Governor of New South Wales declared the irrigation Corporation to be a State owned corporation under the State Owned Corporations Act 1989. On December 6th 1999, the Coleambally Irrigation Limited was established as a medium to assist with the transfer of the state owned corporation to becoming a locally owned entity. The following day saw the Minister for Land and Water Conservation transfer all assets, rights and liabilities for the previous corporation to Coleambally Irrigation District, making the company irrigator owned and operated. Over this period a general meeting with the shareholders was held and it was voted unanimously for Coleambally Irrigation Limited to become Coleambally Irrigation Co-operative Limited.

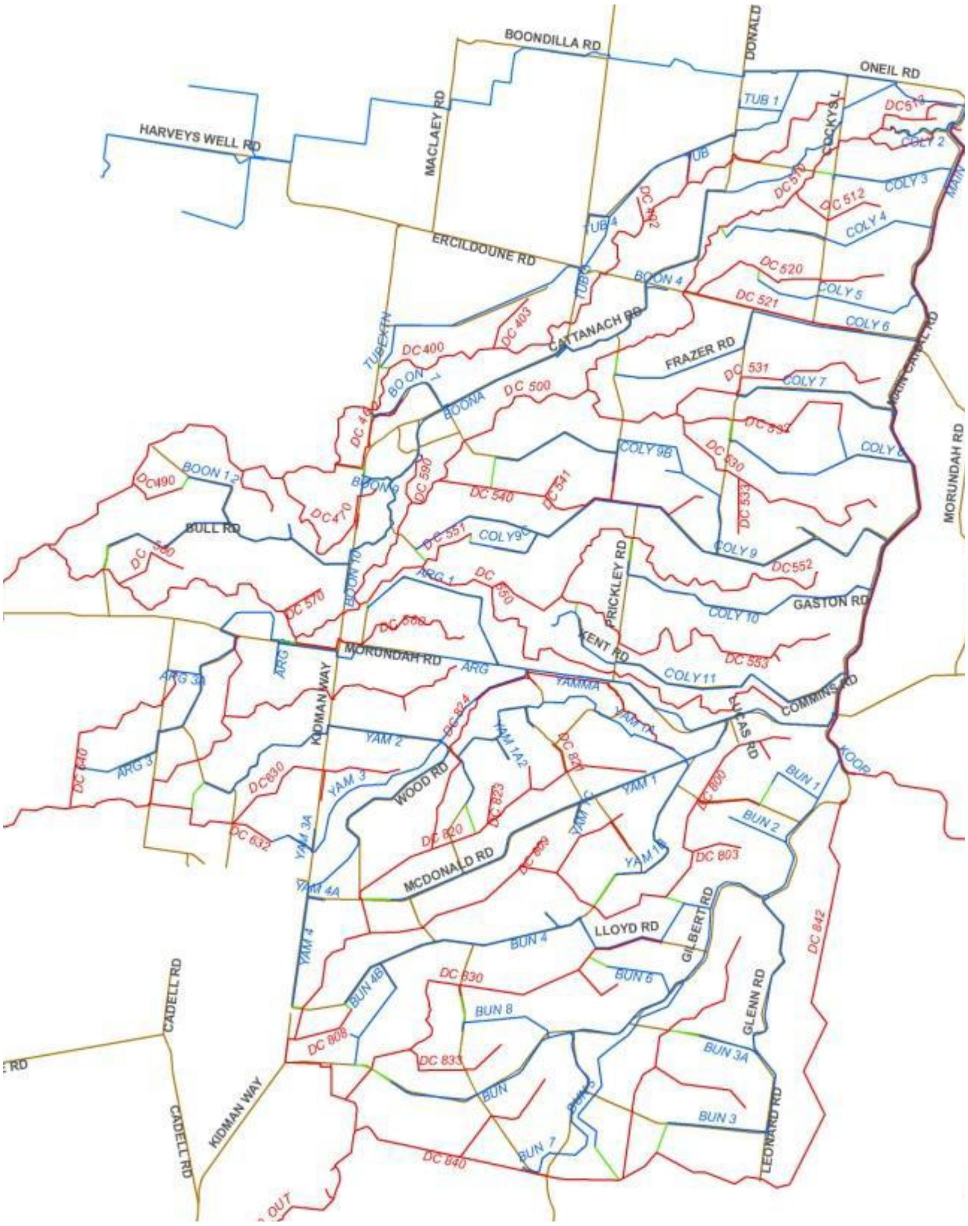


Figure 3.2 **Schematic map of supply and drainage systems in Coleambally (CICL, 2012)**

The Coleambally Irrigation Area is known for its production of rice. Other crops grown in the area include wheat, barley, oats, canola, soybeans, maize, sunflowers, lucerne, grapes, prunes and pastures for sheep and cattle.

3.2 Climate

The Coleambally Irrigation Area is located in the South-West area of New South Wales, within the Riverina. This area is particularly known for its unremittingly dry semi-arid status

(Stern et al, 2000), which is evident with the cool winters and hot summers. There are two weather stations in the area (Figure 3.3). At both stations potential evaporation (mm/hr) is calculated using the Penman-Monteith equation (CICL, 2006), while daily rainfall in mm and maximum and minimum temperature and wind speed are also measured.

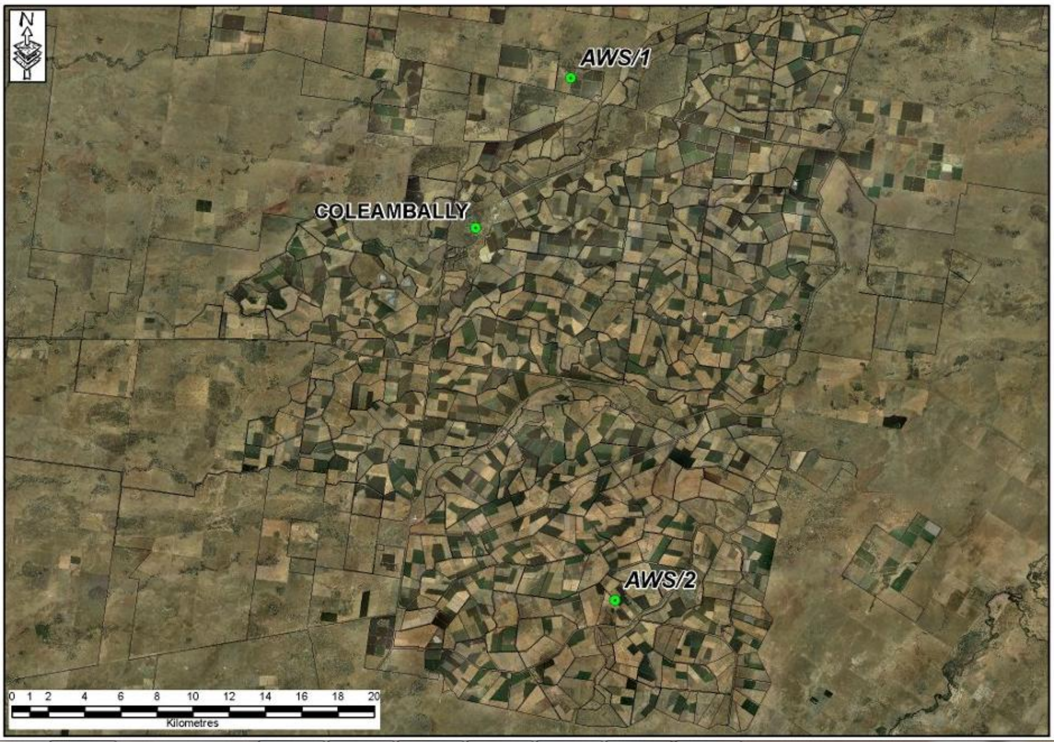


Figure 3.3 Location of weather stations in the CIA (CICL, 2013)

Figure 3.4 and 3.5 show the average temperature and rainfall during 2009-2011 at AWS/1 and AWS/2. The temperature distinctly displays a summer and winter change, with summer experiencing average temperatures of about 22 °C and winter temperatures averaging 11°C.

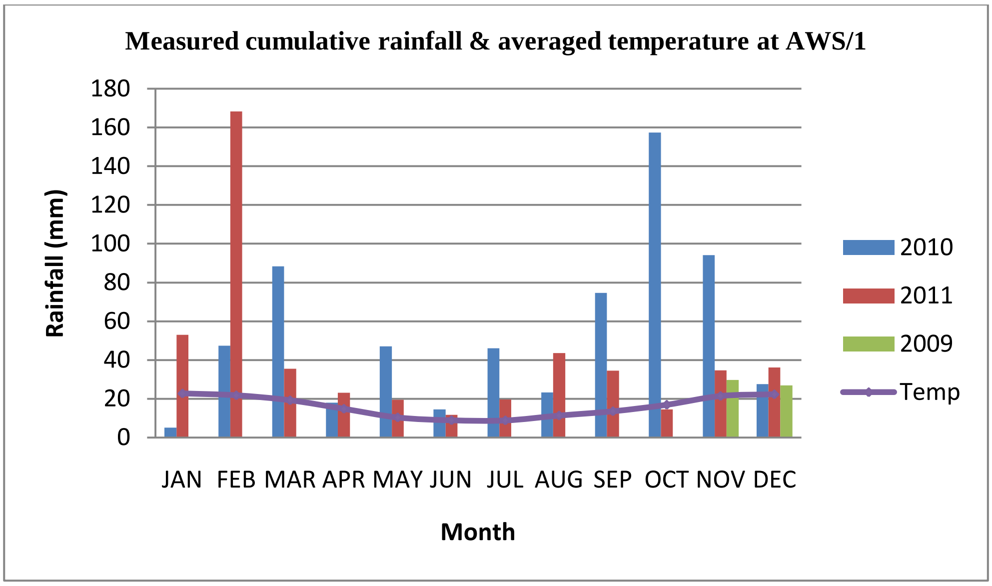


Figure 3.4 The average temperature and rainfall for CIA at AWS/1

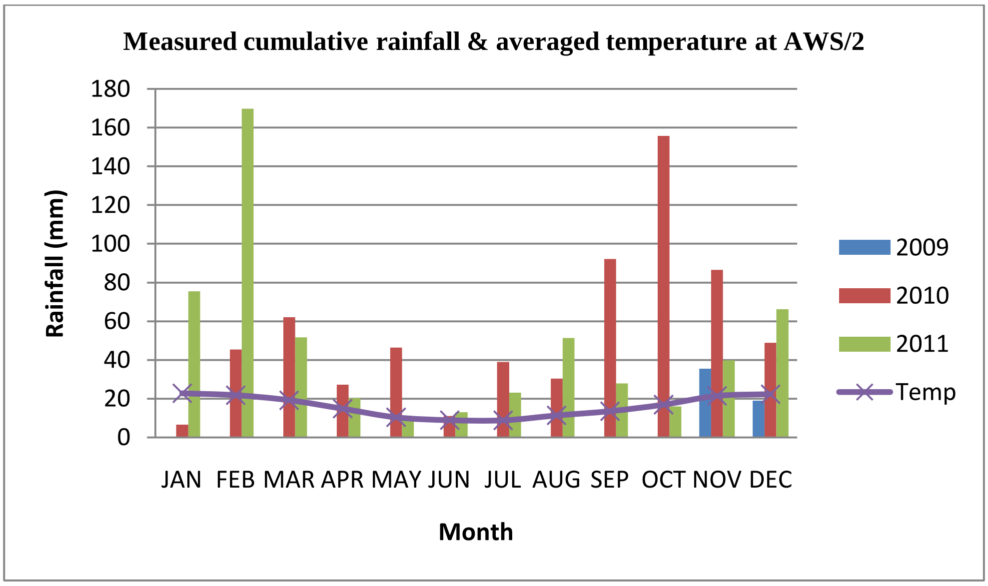


Figure 3.5 The average temperature and rainfall for CIA at AWS/2

Due to the seasonal temperature changes, it is expected the evaporation is similarly seasonal. Figure 3.6 and 3.7 indicate there is a definite seasonality to the evaporation rate calculated using Penman-Monteith equation in the CIA. This area experiences high rates of evaporation in summer with significantly lower rates during winter.

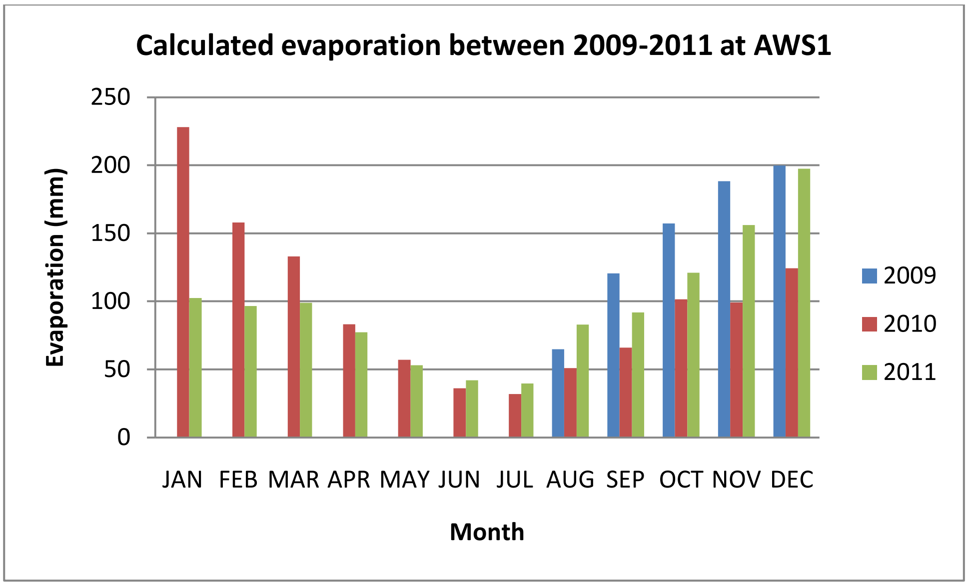


Figure 3.6 The calculated evaporation rate for the CIA during 2009-2011 at AWS/1

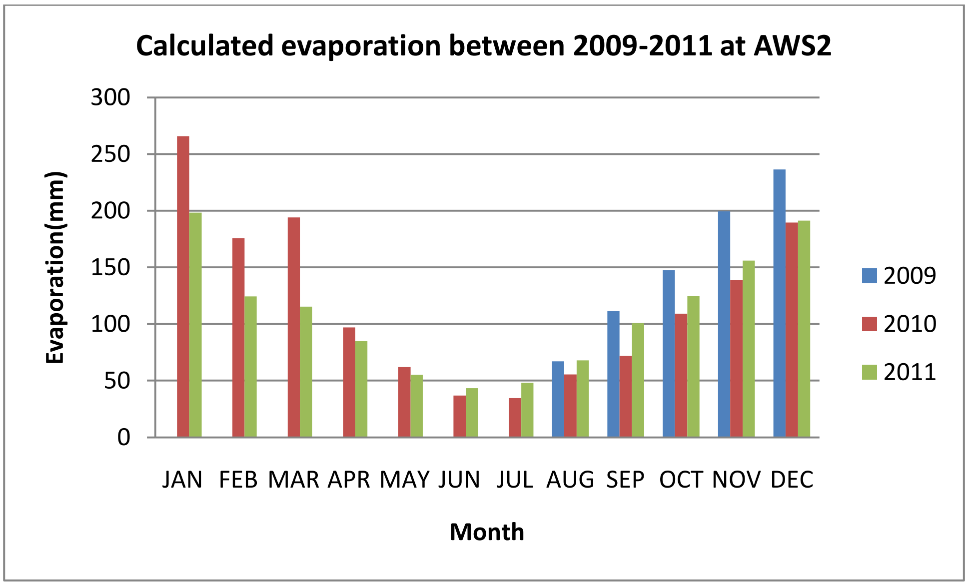


Figure 3.7 The calculated evaporation rate for the CIA during 2009-2011 at AWS/2

The climate of the CIA is highly conducive to extensive crop production with the aid of irrigation water, predominantly due to the high amounts of solar radiation. However, soil type may affect the type of crop grown on a farm.

3.3. Soil Types

Five different soil types can be found in the CIA. These five soil types are: Sand hill formations, Red Brown Earths, Prior Stream Formations, Non-Self Mulching Clay and Self Mulching Clays (Watt, 2008). The spatial distribution of these soil types is presented in figure 3.8.

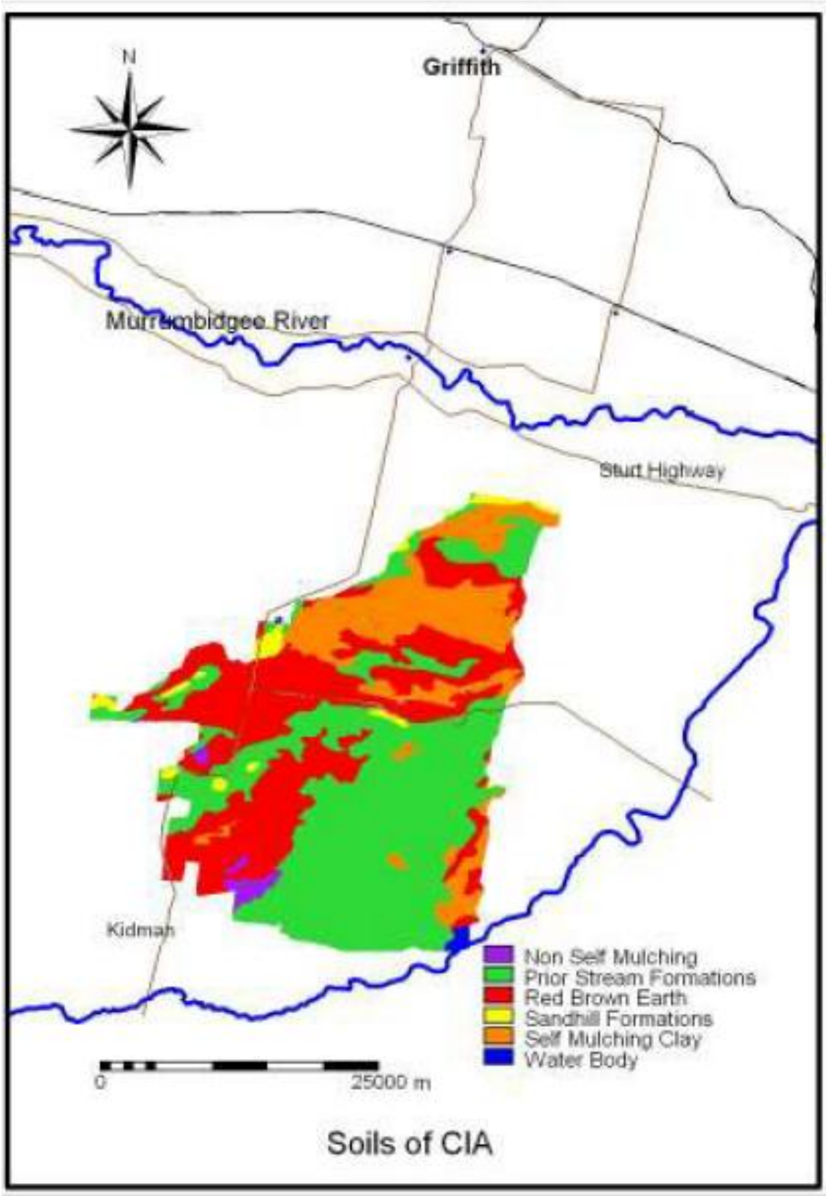


Figure 3.8 Soil types of the Coleambally Irrigation Area (Watt, 2008)

3.4. Geology and Topography

As it can be seen in Figure 3.9 the topography of the area is reasonably consistent, with minor variations throughout the area. The area is known for the flatness as there are no significant hilly regions, which ranges from 128 meters above the Australian Height Datum to 108 meters. This indicates the water movement in the CIA will be from the East towards the West.

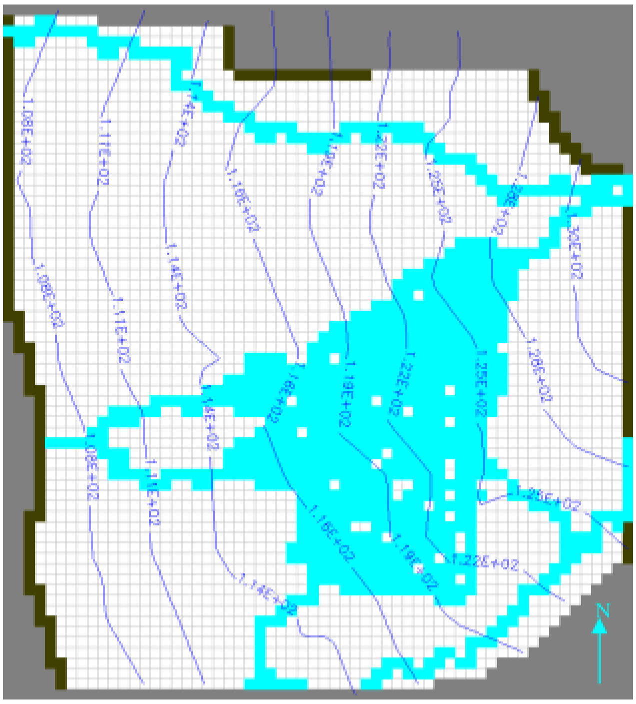


Figure 3.9 Topography of the CIA (Watt, 2008)

3.5. Crop production

As previously mentioned the CIA was setup as a means of utilizing the excess water from the Snowy Hydro-Electricity Scheme. Due to the soil types and volume of the water available the CIA and Murray Irrigation Area became Australia's leading rice production areas. Table 3.1 illustrates the area of the six major crops grown in the CIA and their proportion of the delivered water for the whole area. The effect of the drought (2000 to present) is noticeable with the present area of the rice production decreasing and the area of wheat and pasture production increasing.

Table 3.1 The area and the proportion of production for the highest producing crops in the CIA (CICL, 2006)

	Rice		Soybeans		Corn		Wheat		Pastures		Canola	
Year	Area (ha)	Proportion of delivery (%)	Area (ha)	Proportion of delivery (%)	Area (ha)	Proportion of delivery (%)	Area (ha)	Proportion of delivery (%)	Area (ha)	Proportion of delivery (%)	Area (ha)	Proportion of delivery (%)
2005/06	18025	62.8	2106	2.91	3306	6.96	13610	8.36	15440	8.69	1748	0.89
2004/05	8142	43.98	1495	2.24	3671	7.19	20287	18.8	12865	10.8	2681	1.27
2003/04	12597	55.8	1938	3.5	3545	5.7	21192	14.98	12131	7.5	1763	0.7
2002/03	11395	46	1788	1	4788	9.3	21346	20.4	10183	7.4	2095	1.7
2001/02	27493	67.5	3297	3.4	3808	4.2	21103	9.2	11581	6.1	2191	0.6
2000/01	30440	73.9	4551	5.9	4074	5.7	14276	4.6	11998	4.7	2153	0.4
1999/00	24138	77.7	2185	3.9	1178	3.1	12649	6.1	7485	4.4	2152	0.7
1998/99	24491	73.8	4339	5.7	1059	1.3	13963	1.7	13879	8.1	2184	1.7
1997/98	24624	70.4	4998	7.5	1678	2.4	14943	7.4	9964	6.1	2053	0.4

As it can be seen in Table 3.1 with approximately 63%, water in the CIA is predominantly consumed in rice production. Pasture and wheat water consumption are the next largest consumers of water with each consuming about 8% of water.

3.6. TCC technology in CIA

Prior to the implementation of TCC technologies, CICL operated a traditional gravity channel supply system where water officers, through manual operation of drop logs and doors, attempted to balance supply and demand and minimise water losses through escapes to the drainage system. To ensure an expected level of customer service, the tendency was to run channels at slightly above ordered flows to ensure customers were delivered in line with their expectations. As a consequence the system escapes tended to run continuously throughout the irrigation season leading to large volumes of escape flows lost to the channel system. The operating policy also led to land being commanded more than initial design.

Fig 3.10 Dethridge Wheel meter outlets prior the installation of TCC technology in CIA

In response to declining water availability, in 2002, CICL made the decision to install TCC automation technologies to improve the efficiency of the channel delivery system. TCC involves the replacement of manually operated gates (Figure 3.10) and drop logs in channel with automatic control gates (Figure 3.11) with the objective of supplying water near-on-demand, maintaining tight water level control and with zero outfalls or escape flows. Through the employment of TCC technology in CIA, 322 gates and 435 farm outlets were installed.

Fig 3.11 Replacement of new gates in different sizes instead of drop board checks and Detheridge wheels

As of September 2007 CICL's entire channel system controlling 514 km of channels with flow capacities ranging from 15 ML/day to 6,000 ML/day is remotely operated. The CID is the first open channel system in the world to largely automate regulators in its entire channel delivery system (CICL, 2008).

3.7. Data provided from TCC technology in CIA

As mentioned in the first chapter, an important feature of TCC technology is the real time control of the entire channel network which leads into production of water level elevation and flow measurement databases for the entire network. Given the fact that this study aims to estimate the seepage rate throughout the whole system, the input data provided from TCC technology consisted of:

- Flow measurements at all automated main gates and farm outlets, recorded irregularly at changes in the flow rate.

- Water level elevations at all automated main gates and farm outlets, usually recorded irregularly at changes in the flow depth; each main channel gate has two water level records (upstream and downstream). The data used in this project is the upstream side only as the downstream data was considered by the data provider to be poor quality (Figure 3.12). Water sensor on the downstream side being out of water more often might be the case for the poor quality of the data.
- Rainfall data usually recorded regularly every 30 min
- Evaporation data usually recorded regularly every 30 min

Rainfall event is only measured once a day at 9 am and recorded against the same day. However, the measured rainfall is recorded and repeated at 30 min intervals for the entire day. Considering the weather data, including solar radiation, humidity and wind speed, the hourly evaporation rate (mm/hr) is estimated based on Penman-Monteith equation.

The data was provided for 3 irrigation seasons between 2009 till 2012 in Microsoft excel CSV format. Each irrigation season starts at June 30th and ends at 29th of June next year. This include 3 Microsoft excel files for each of rainfall and evaporation records during 2009-2012, 56 Microsoft excel file for flow measurement records of all gates and farm outlets during 2009-2012 and 20 Microsoft excel file for upstream elevation records of all gates and farm outlets during 2009-2012.

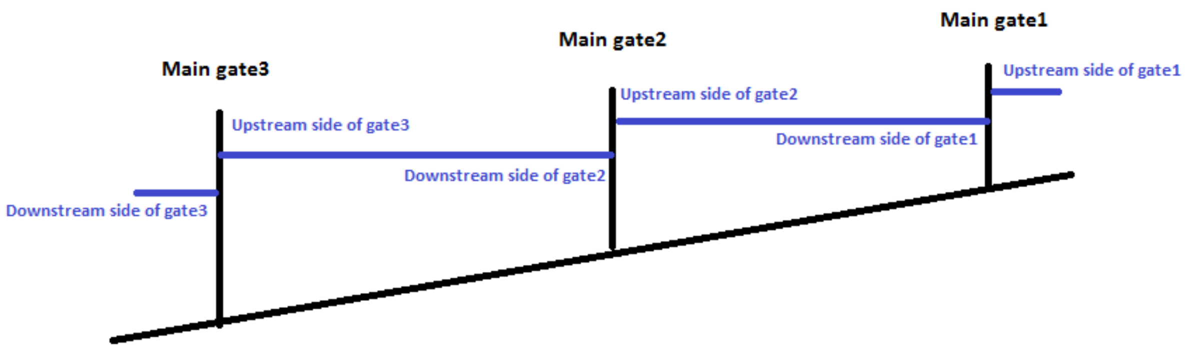


Figure 3.12.Schematic cross section of gates incorporating pools on a channel

The cumulative value of rainfall and estimated rate of evaporation is provided from the two automated weather stations located at Northern and Southern side of the district. Rainfall is measured in millimeters and evaporation is calculated, using the Penman-Monteith equation in mm per hour.

3.8. Conclusion

CIA was chosen as case study for the purposes of this project due to being one of the first automated irrigation districts in the world and having several years of historical data. Through the employment of TCC technology in CIA, 322 gates and 435 farm outlets were installed.

The data provided for the present study includes flow measurements for each of main gates and farm outlet comprising a pool, enabling the no flow conditions to be detected. Water level elevations on the downstream side of the upstream gate and the upstream side of rest of the gates in a pool (including one main gate and one or more farm outlets) were also provided. The daily rainfall and hourly evaporation rate were provided from two automatic weather stations located at Northern and Southern side of the district. Consequently based on the location of each channel the required data for the no flow periods is extracted from the automatic weather station that is closer to the channel.

Chapter 4: Model Development

4.1 Introduction

Chapter 2 introduced a number of different techniques that have been applied for seepage rate estimation in channels. From the discussion in section 2.5 it is clear that the pondage test method is the most appropriate technique for seepage rate estimation in channels due to its simplicity and being able to provide an average net seepage flux for the entirety of the surface water feature, compared to other techniques many of which only measure seepage at a point.

It is hypothesised that the recorded water level data from automated channel control systems during periods of gate closure can be treated as pondage test data for seepage rate estimation.

This chapter discusses the development and operation of a new model that applies pondage test methodology to automated channel control data during periods of shut down in order to estimate seepage rates in different channel reaches.

4.2 Overview

Considering the objectives of this project and the format of the data provided from the TCC system, it was decided to create a database containing the provided data in form of individual tables and link those tables together.

Due to the fact that Microsoft excel is unable to link tables together and Microsoft access had size limitations for databases, it was decided to work with Microsoft SQL Server to build the required database. The created database consists of 9 tables. In order to extract all possible pondage conditions from throughout the entire channel network, a model in C# platform was developed (Appendix A). Considering the input data and by using a water balance equation, the model is able to calculate seepage rate for each individual gate during pondage periods in any given pool.

The algorithm applied in the model is illustrated in Figure 4.1.

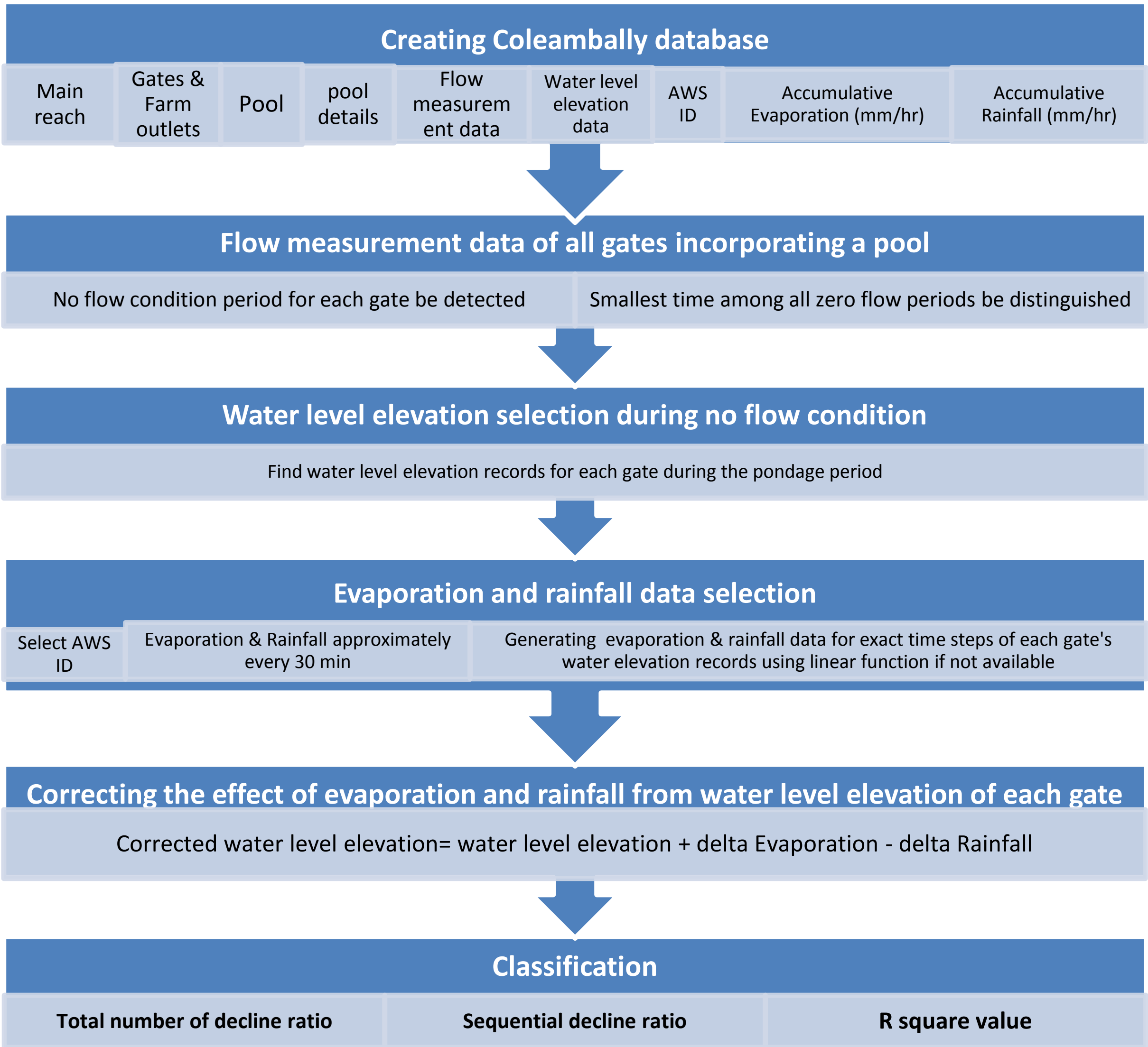


Figure 4.1 Algorithm applied in the computer model

As it can be seen in Figure 4.1 the steps needed to be applied to the provided data to obtain an estimate of the seepage rate include:

- Identify zero flow periods
- Extract water level data for each individual gate during pondage periods
- Adjust for rainfall and evaporation
- Correcting the effect of rainfall and evaporation for each individual gate
- Estimate the seepage rate using linear regression trend line for each individual gate

By allocating weights to individual rates, the seepage rate for each pondage period is averaged from the weighted individual rates. The model is also able to calculate seepage rates for all individual gauges and all possible pondage periods in one reach of the network. The output of the model is in the form of a table summarized general information of the studied pondage conditions including, start and end date of pondage period, number of measured water elevation of each gate during the pondage period, value of several criteria that is defined for the model to categorize each pondage condition, seepage rate for each gauge and finally an averaged seepage rate for the pondage condition.

4.3 Microsoft SQL Server

Microsoft SQL Server is a relational database management system (RDBMS) that can store and retrieve data as requested by other software applications (LearnrPro, 2013). The data can be retrieved from a SQL server database by query mechanism. A query consists of various kind of questions presented to the SQL database in a predefined format.

Microsoft SQL server express 2008 is a free version of Microsoft SQL server with the maximum database size of 4 gigabyte and high speed query processing that was chosen to built up the required database to serve the purposes of this study.

4.4 Coleambally Database

The input data for seepage analysis provided on behalf of CICL by Rubicon Water consisted of:

- Flow measurements at all automated main gates and farm outlets, recorded irregularly at changes in the flow rate,
- Water level elevations at all automated main gates and farm outlets, usually recorded irregularly at changes in the flow depth; each main channel gate has two water level records (upstream and downstream). The data used in this project is the upstream side only as the downstream data was considered by the data provider to be poor quality,
- Rainfall data usually recorded regularly every 30 min and
- Evaporation data usually recorded regularly every 30 min.

The data were provided for 3 years between 2009 till 2012 in Microsoft excel CSV format. These include 3 Microsoft excel files for each of rainfall and evaporation records during 2009-2012, 56 Microsoft excel files for the flow measurement records for all gates and farm outlets during 2009-2012 and 20 Microsoft excel files for the upstream water elevation records for all gates and farm outlets during 2009-2012.

Using the Microsoft SQL server express 2008, the input data was defined in the form of number of tables (Figure 4.2). Furthermore the relations between each of the tables were defined. Since the basis of this study was to analyse the TCC data during pondage conditions or periods of shut down, the first primary definition in table's relation was to identify the pondage conditions.

Based on a schematic map of Coleambally Irrigation District (CID), the following tables were defined in the database:

- Main Reach
- Gate Name
- Pool Name
- Pool Detail
- Flow data
- Water level elevation
- Automatic weather station (AWS) ID
- Evaporation
- Rainfall

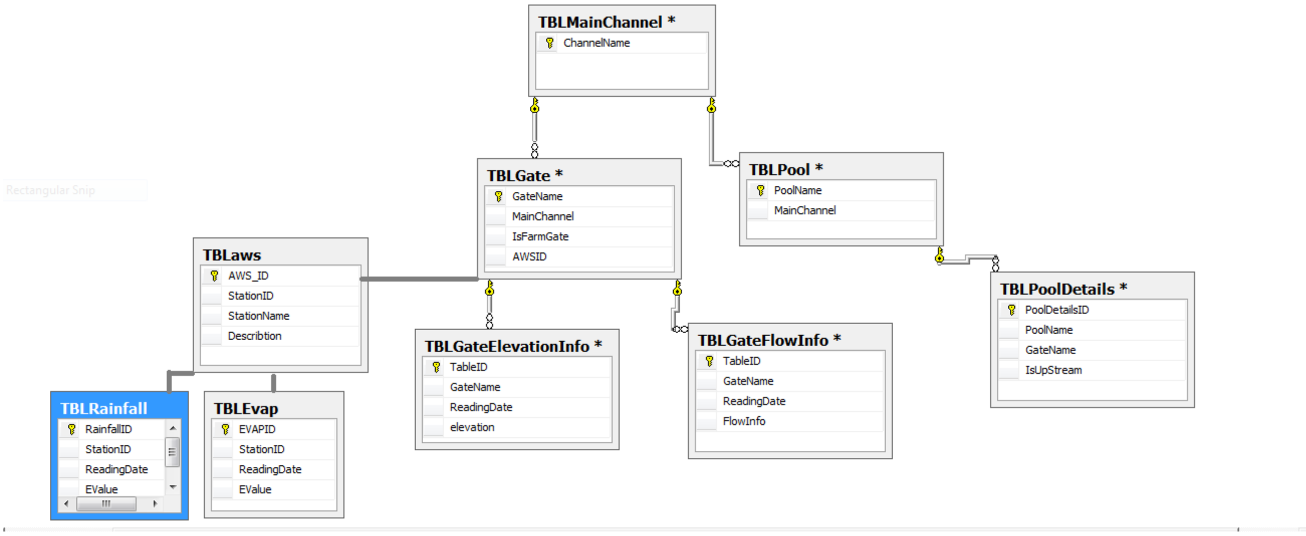


Figure 4.2 Diagram of tables in Coleambally data base

The following section defines each of the tables depicted in Figure 4.2:

4.4.1 Main channel table

The first table defined for the database was channel table. Based on the schematic map of CID (Figure 3.2, Chapter 3), the whole district was divided to 22 main channels. The main channel table (Table 4.1) has only one column which is the channel name.

Table 4.1 Main channel table

	Channel Name
1	ARGOON
2	BOONA
3	BUNDURE
4	BUNDURE 3
5	BUNDURE 4
6	BUNDURE 5
7	BUNDURE 6
8	BUNDURE 7
9	BUNDURE 8
10	COLY 10
11	COLY 11
12	COLY 2
13	COLY 3
14	COLY 4
15	COLY 5
16	COLY 6
17	COLY 7
18	COLY 8
19	COLY 9
20	MAIN
21	TUBBO
22	YAMMA

4.4.2 AWS table

The second table defined for the database was AWS table (Table 4.2) which has two columns including station ID and Station name. Since there were only two weather stations available in the district the table has only 2 rows.

Table 4.2 AWS table

	Station ID	Station Name
1	AWS1	AWS1
2	AWS2	AWS2

4.4.3 Gate table

The next table defined for the database which is the first table related to the previous tables is gate table. It consists of four columns including, gate name, main reach, farm gate and AWS ID. The table consisted of 316 main gates and 410 farm outlets of CID (Appendix B). Table 4.3 is a sample of part of gate table.

Table 4.3 Sample of part of Gate table

Gate Name	Main Channel	Farm outlet	AWSID
98/2	COLY 10	1	AWS1
99/1	COLY 10	1	AWS1
ARGOON	ARGOON	0	AWS2
ARGOON 1	ARGOON	0	AWS2
BUNDURE 3-7	BUNDURE 3	0	AWS2
BUNDURE 3-8	BUNDURE 3	0	AWS2
BUNDURE 3-9	BUNDURE 3	0	AWS2
COLY 9C-3 ESC	COLY 9	0	AWS1
ESC ARGOON 1	ARGOON	0	AWS2
ESC 10	COLY 10	0	AWS1
ESC 11	COLY 11	0	AWS2

From Table 4.3 it can be seen that the first column represents name of the gate, the second column represents the main reach on which the gate is located, the third column shows whether the gate is a farm outlet, indicated by 1 or a main gate, indicated by zero and finally the forth column, the AWS ID which is the nearest AWS ID to the gate, determined based on the locations of each main reach and the two weather stations.

4.4.4 Rainfall table

Rainfall data provided from each of the weather stations, is usually recorded regularly every 30 minutes. Accumulative value of rainfall was calculated prior to rainfall table definition. The table has 4 columns including, rainfall id, station id, reading date and value. Table 4.4 is a sample of part of the rainfall table.

Table 4.4 Sample of part of Rainfall table

Rainfall ID	Station ID	Reading Date	Value
991	AWS1	24/11/2009 10:08	4.6
992	AWS1	24/11/2009 10:38	4.6
993	AWS1	24/11/2009 11:23	4.6
994	AWS1	24/11/2009 11:53	4.6
995	AWS1	24/11/2009 12:23	4.6
996	AWS1	24/11/2009 13:08	4.6
997	AWS1	24/11/2009 13:38	4.6
998	AWS1	24/11/2009 14:23	4.6
999	AWS1	24/11/2009 15:08	4.6
1000	AWS1	24/11/2009 15:53	4.6

As it can be seen in Table 4.4, the first column represents rainfall id, which counts in future calculation as an id for each rainfall value. The second column indicates the station from where the data was provided. The third column presents the date when each value was recorded and finally the fourth column represents accumulative value of each record.

4.4.5 Evaporation table

Evaporation data provided from each of weather stations is usually estimated in mm per hour unit, using Penman–Monteith method, regularly every 30 min. Accumulative value of evaporation was calculated prior to table definition. The table has 4 columns including, evaporation id, station id, reading date and value. Table 4.5 is a sample of part of evaporation table.

Table 4.5 Sample of part of Evaporation table

EVAPID	Station ID	Reading Date	E Value
71134	AWS1	4/08/2009 12:01	0.0810838
71135	AWS1	4/08/2009 12:25	0.1629621
71136	AWS1	4/08/2009 12:49	0.2446133
71137	AWS1	4/08/2009 13:01	0.2931137
71138	AWS1	4/08/2009 13:25	0.3897113
71139	AWS1	4/08/2009 13:49	0.4862418
71140	AWS1	4/08/2009 14:07	0.5584683
71141	AWS1	4/08/2009 14:31	0.6545923

As it can be seen in Table 4.5, the first column represents evaporation id, which counts in future calculation as an id for each evaporation value. The second column indicates the station from where the data was provided. The third column presents the date when each value was recorded and finally the fourth column represents accumulative value of each record.

4.4.6 Pool table

Considering the location of different gates and flow direction based on the schematic map, any possible pool resulted during periods of shut down was defined for the database (Appendix B). Table 4.6 is a sample of part of the pool table.

Table 4.6 Sample of part of Pool table

Pool Name	Main Channel
ARGOON-1,2	ARGOON
ARGOON-2,3	ARGOON
ARGOON-3,4	ARGOON
ARGOON-4,5	ARGOON
ARGOON-5, ARGOON 3	ARGOON
BOONA 9-1, ESC BOONA 9	BOONA
BOONA 9A, ESC BOONA 9A	BOONA
BOONA0,1	BOONA

As it can be seen the table consists of 2 columns including pool name and the main reach on which the pool is located. Names of pools were defined considering the only the upstream and downstream gates incorporating each pool.

4.4.7 Pool details table

The next table defined for the database was pool detail table. The main purpose of defining this table was to introduce all gates and farm outlets incorporating each pool. Furthermore, upstream gate of each pool was defined in the table (Appendix B). A Sample of part of the pool details table is presented in Table 4.7. As can be seen the table has 4 columns. The first column shows the id of each pool detail. The second column presents the name of pool, while the third column presents a gate included in that pool and finally the fourth column indicates if the gate is the upstream gate or not.

Table 4.7 Sample of part of Pool details table

Pool Details ID	Pool Name	Gate Name	Is Up Stream
8	TUBBO1,2	5-Mar	0
9	TUBBO1,2	TUBBO-1	1
10	TUBBO1,2	TUBBO-2	0
15	TUBBO3,4	120/3	0
16	TUBBO3,4	639/1	0
17	TUBBO3,4	TUBBO-3	1
18	TUBBO3,4	TUBBO-4	0
19	TUBBO4,5	11-Mar	0

4.4.8 Gate flow info table

Information regarding each gate consists of flow and water elevation measurements. Table 4.8 presents a sample of part of gate flow info defined for the database. It consists of 4 columns including table id, gate name, date when the flow was recorded and finally flow value for all the gates during 2009 to 2012.

Table 4.8 Sample of part of Gate flow info table

Table ID	Gate Name	Reading Date	Flow Info
891	MAIN CANAL INLET	25/09/2010 3:38	272.948
892	MAIN CANAL INLET	25/09/2010 8:42	363.716
893	MAIN CANAL INLET	25/09/2010 10:51	363.19
894	MAIN CANAL INLET	25/09/2010 17:20	427.364
895	MAIN CANAL INLET	25/09/2010 17:29	458.191
896	MAIN CANAL INLET	25/09/2010 19:51	453.931

4.4.9 Gate elevation info table

The last table defined for the database was gate elevation info (Table 4.9). Similarly to gate flow table, it has 4 columns including table id, gate name, date when the elevation was recorded and finally the elevation value for all the gates during 2009 to 2012.

Table 4.9 Sample of part of Gate elevation info table

Table ID	Gate Name	Reading Date	elevation
1592505	YAMMA 2-6	4/09/2010 14:05	1.469
1592506	YAMMA 2-6	4/09/2010 14:11	1.458
1592507	YAMMA 2-6	4/09/2010 15:07	1.468
1592508	YAMMA 2-6	4/09/2010 15:30	1.478
1592509	YAMMA 2-6	4/09/2010 15:52	1.489
1592510	YAMMA 2-6	4/09/2010 16:16	1.499

4.5 Model

In order to be able to retrieve and analyse the large quantity of TCC data efficiently a model was built up in C# environment in conjunction with the SQL server software to produce a stand-alone executable program that can be operated on any personal computer running under Microsoft Windows. The graphical user interface (Figure 4-3) has been designed to be simple and user friendly.

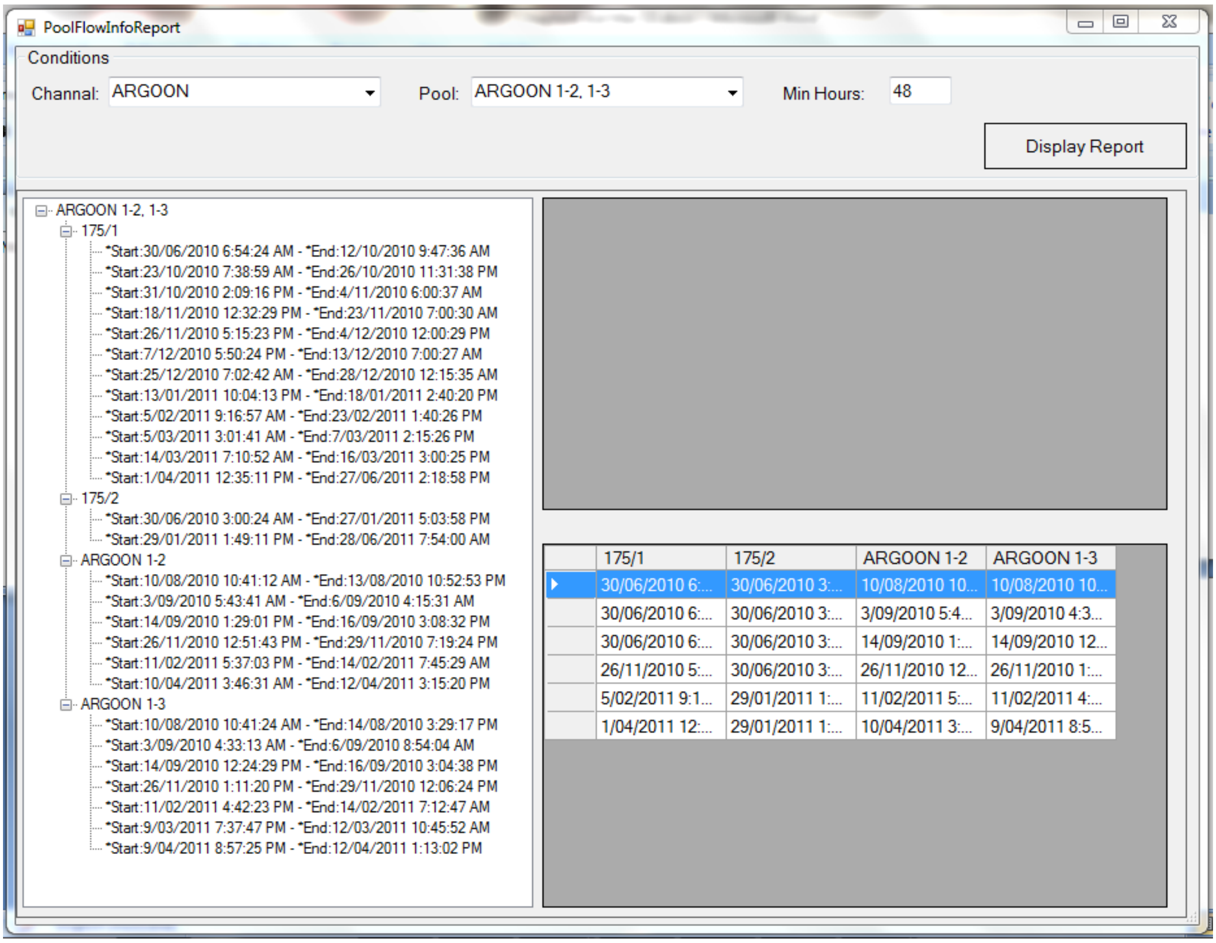


Figure 4.3 Screen shot of main user interface for the computer model

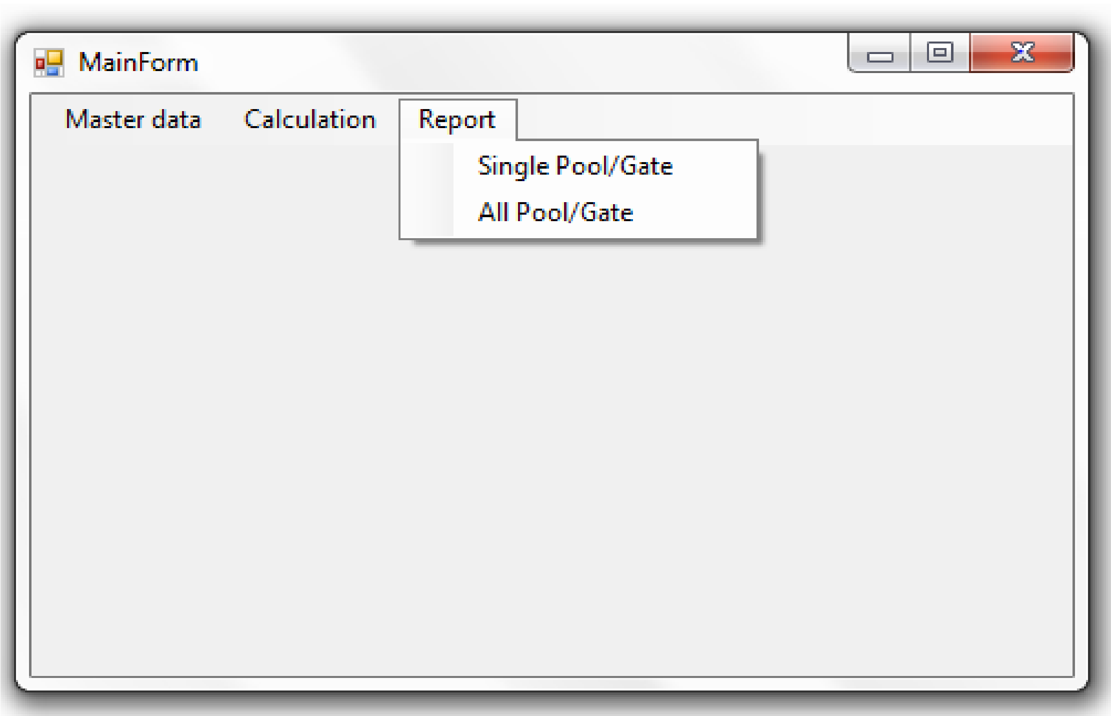


Figure 4.4 Screen shot of main user interface to report the analysis

With the main objective of extracting all possible pondage conditions for each pool from TCC data, the model is enabled to report the analysis for single pool or all pools located in one main reach (Figure 4.4). Furthermore, an option for minimum pondage period is designed for the model.

The main steps in the model are outlined in the following sections.

4.5.1 Zero flow period detection

After the whole district was defined for the system, the next step was to define a pondage condition for each pool. First a table containing the flow measurement data for all gates for the year 2010 was defined in the database as gate flow table. Afterwards a minimum optional time for pondage duration was defined for the model and it was expected that if the flow information for all the gates in each pool were available, the model starts to find and show zero flow duration for each of the gates. Consequently if all the gates in a pool had a zero flow time in common, there is a period when all gates are closed, then that common time is identified and introduced as the pondage condition. To gain a better understanding of each step, all the required calculations will be presented for a sample pool. The selected pool is situated between ARGOON 1-2 main gate on upstream side, ARGOON 1-3 main gate on downstream side of the pool and contains farm outlets 175/1 and 175/2.

After all zero flow periods for each of the 4 gates incorporating the pool were detected by the model (Figure 4.5), considering a minimum of 48 hours pondage period, 6 possible scenarios are extracted from TCC data (Table 4.10). Selection of start and end date of pondage period among zero flow conditions for all the gates were made based up on the closure function as mentioned earlier.

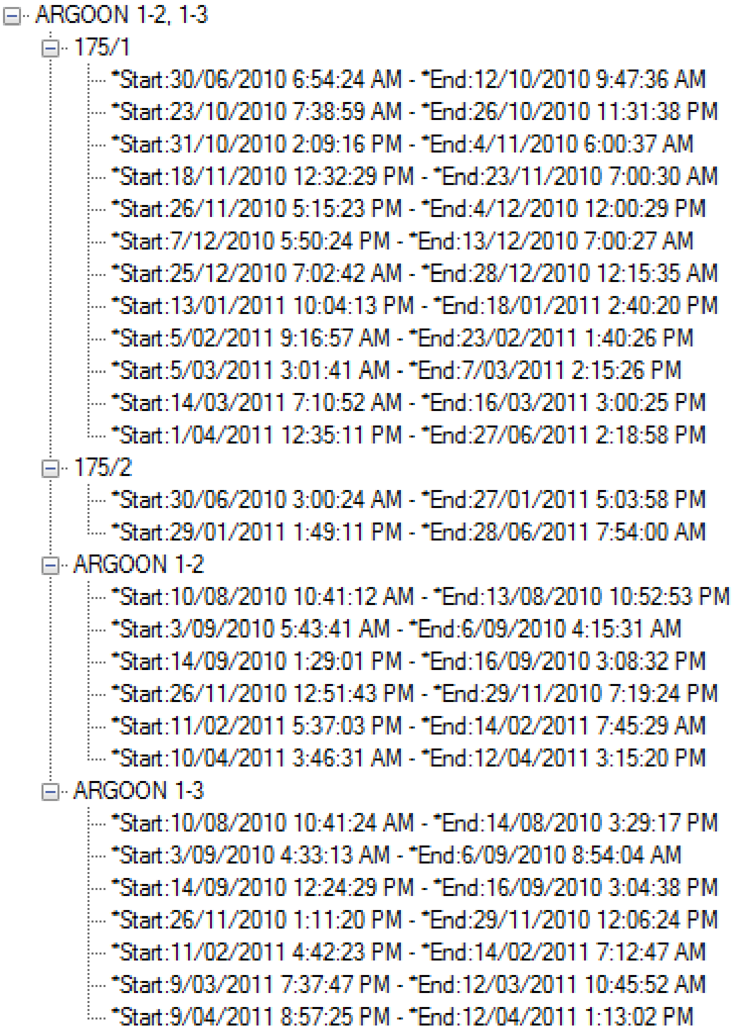


Figure 4.5 Screen shot of all zero flow periods for each of the gates incorporating Argoon1-2, 1-3 pool

Table 4.10 Zero flow periods for pool ARGOON 1-2, ARGOON 1-3

Pondage condition	ARGOON 1-2		Farm outlet no. 175/1		Farm outlet no. 175/2		ARGOON 1-3	
	Start date	End date	Start date	End date	Start date	End date	Start date	End date
1	**10/08/2010 10:41**	**13/08/2010 22:52**	30/06/2010 6:54	12/10/2010 9:47	30/06/2010 3:00	27/01/2011 17:03	10/08/2010 10:41	14/08/2010 15:29
2	**3/09/2010 5:43**	**6/09/2010 4:15**	30/06/2010 6:54	12/10/2010 9:47	30/06/2010 3:00	27/01/2011 17:03	3/09/2010 4:33	6/09/2010 8:54
3	**14/09/2010 13:29**	16/09/2010 15:08	30/06/2010 6:54	12/10/2010 9:47	30/06/2010 3:00	27/01/2011 17:03	14/09/2010 12:24	**16/09/2010 15:04**
4	26/11/2010 12:51	29/11/2010 19:19	**26/11/2010 17:15**	4/12/2010 12:00	30/06/2010 3:00	27/01/2011 17:03	26/11/2010 13:11	**29/11/2010 12:06**
5	**11/02/2011 17:37**	14/02/2011 7:45	5/02/2011 9:16	23/02/2011 13:40	29/01/2011 13:49	28/06/2011 7:54	11/02/2011 16:42	**14/02/2011 7:12**
6	**10/04/2011 5:06**	**12/04/2011 10:08**	1/04/2011 12:36	27/06/2011 17:34	29/01/2011 13:49	28/06/2011 7:54	9/04/2011 20:57	12/04/2011 13:08

4.5.2 Water elevation selection

Having selected the pondage condition period the next step is to find water elevation records for each gate during the pondage period. Since the time and number of water elevation measurement records do not match with flow measurement records (Table 4.12), the model will search among all water elevation records to find the data related to required gates and will find water elevation records for each gate during the detected zero flow condition. Number of water elevation and flow measurement records for different gates of a sample pool during several pondage conditions is illustrated in Table 4.12. Considering the first possible pondage condition the water elevation records are presented in Table 4.11.

Table 4.11 Water elevation records selection for pondage3 of ARGOON 1-2, ARGOON 1-3 pool

Gate name	Reading date	Water elevation(mm)
175/1	14/09/2010 18:18	1638
175/1	15/09/2010 16:15	1630
175/1	16/09/2010 14:12	1619
175/2	14/09/2010 13:54	1688
175/2	14/09/2010 14:04	1691
175/2	15/09/2010 11:51	1691
175/2	16/09/2010 7:04	1680
175/2	16/09/2010 9:48	1680
ARGOON 1-3	14/09/2010 14:55	1613
ARGOON 1-3	15/09/2010 5:46	1615
ARGOON 1-3	16/09/2010 3:43	1604
ARGOON 1-3	16/09/2010 5:50	1603

The water elevation records below the upstream gate of the pool have not been considered for the analysis as advised by Rubicon to only use the data upstream of each gate (Chapter3, section 3.7).

Table 4.12 Number of flow and water elevation measurement records for each gate during possible pondage conditions

Gate	Pondage condition 1		Pondage condition 2		Pondage condition 3		Pondage condition 4	
	Flow records	Water elevation records	Flow records	Water elevation records	Flow records	Water elevation records	Flow records	Water elevation records
ARGOON 1-2	158	Upstream	133	Upstream	94	Upstream	129	Upstream
175/1	4	4	3	3	3	3	3	7
175/2	4	4	3	24	3	5	3	7
ARGOON 1-3	158	4	134	6	94	4	130	8

4.5.3 Evaporation and rainfall data

The next step is to select the related value of evaporation rate and rainfall during the pondage period. Evaporation rate and rainfall values for the two weather stations in the district were provided for the period of 2009 until 2012. The purpose of accounting for the related AWS data at this stage is to calculate the water loss due only to the seepage. Since all the variables should be homogeneous and in the same units, using the time difference between two sequential rates, the evaporation rate was first converted from millimetre per hour into a cumulative depth in millimetres. Consequently both rainfall and evaporation were imported into the model in the form of accumulative value.

On the other side, since the water elevation recordings are per gate, it was necessary to find the related evaporation and rainfall data from the AWS database for the exact time steps as for water elevation recordings of each gate. CID has two weather stations, located in the North and South of the district (Figure 4.6). Based on longitudinal location, main channels were divided into two groups (Table 4.13) to apply weather station data into the seepage calculation. In the case of Main River, as it was the only main channel running east-west across the district, those of the pools located on the north side of the Main River were counted in AWS1 group and the rest of them in AWS2, respectively.

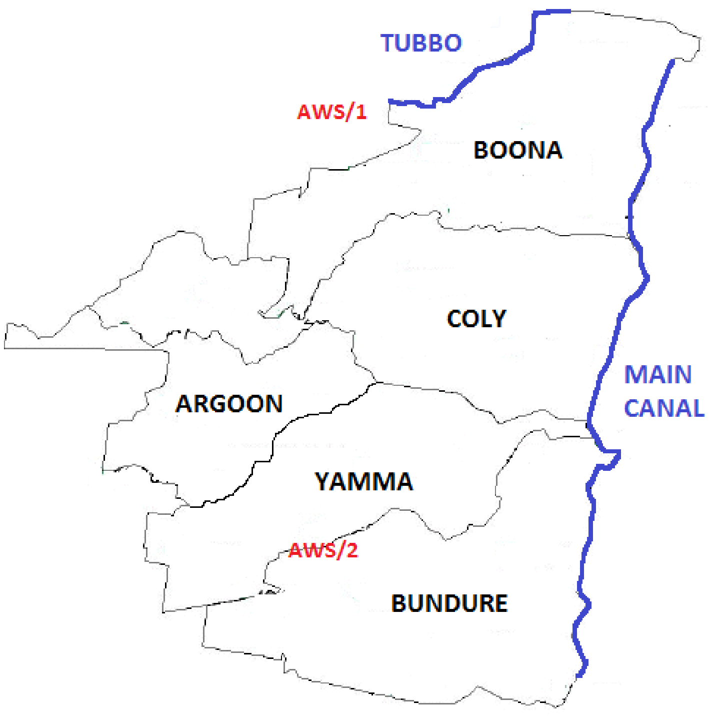


Figure 4.6 Locations of two AWSs in CID

Table 4.13 Distribution of main channels for usage of AWS data

AWS1	AWS2
TUBBO	BUNDURE 1
BOONA	BUNDURE 3
COLY 2	BUNDURE 4
COLY 3	BUNDURE 5
COLY 4	BUNDURE 6
COLY 5	BUNDURE 7
COLY 6	BUNDURE 8
COLY 7	COLY 11
COLY 8	ARGOON
COLY 9	YAMMA
COLY 10	MAIN 2
MAIN 1	

After identifying which weather station data were to be used for the calculation for each main channel and also identifying the homogeneous AWS data for the model, the next step is to find the evaporation rate and rainfall value for each time step for each of the gates during the zero flow period. As mentioned earlier, since the analysis is based on the information provided for each gate, required AWS data should be provided for the exact time steps for each of the main gates and farm outlets incorporating a pool. Therefore where time steps were different the value of AWS data was calculated using linear interpolation. To gain a better understanding of evaporation and rainfall selection from the AWS database, a sample of calculation for pondage condition 3 of ARGOON 1-2, ARGOON 1-3 pool has been provided in Table 4.14 and 4.15.

Table 4.14 Accumulative values of evaporation and rainfall from AWS2 database

	Date	Accumulative Evaporation(mm)		Date	Accumulative Rainfall(mm)
AWS/2	14/09/2010 14:35	1710	**AWS/2**	14/09/2010 14:50	370
AWS/2	14/09/2010 15:05	1710	**AWS/2**	14/09/2010 15:20	370
AWS/2	14/09/2010 15:35	1710	**AWS/2**	14/09/2010 16:05	370
AWS/2	14/09/2010 16:05	1710	**AWS/2**	14/09/2010 16:35	370
AWS/2	-	-	**AWS/2**	-	-
AWS/2	-	-	**AWS/2**	-	-
AWS/2	-	-	**AWS/2**	-	-
AWS/2	16/09/2010 13:05	1713	**AWS/2**	16/09/2010 12:20	393
AWS/2	16/09/2010 13:35	1713	**AWS/2**	16/09/2010 13:05	393
AWS/2	16/09/2010 14:05	1713	**AWS/2**	16/09/2010 13:35	393
AWS/2	16/09/2010 14:35	1713	**AWS/2**	16/09/2010 14:20	393

Table 4.15 Calculated evaporation and rainfall value for each of the gates and farm outlets in ARGOON 1-2, ARGOON 1-3 pool

Gate name	Reading date	Water elevation(mm)	Evaporation(mm)	rainfall(mm)
175/1	14/09/2010 18:18	1638	1710	370
175/1	15/09/2010 16:15	1630	1712	393
175/1	16/09/2010 14:12	1619	1713	393
Gate name	**Reading date**	**Water elevation(mm)**	**Evaporation(mm)**	**rainfall(mm)**
175/2	14/09/2010 13:54	1688	1710	370
175/2	14/09/2010 14:04	1691	1710	370
175/2	15/09/2010 11:51	1691	1711	393
175/2	16/09/2010 7:04	1680	1712	393
175/2	16/09/2010 9:48	1680	1712	393
Gate name	**Reading date**	**Water elevation(mm)**	**Evaporation(mm)**	**rainfall(mm)**
ARGOON 1-3	14/09/2010 14:55	1613	1710	370
ARGOON 1-3	15/09/2010 5:46	1615	1710	370
ARGOON 1-3	16/09/2010 3:43	1604	1712	393
ARGOON 1-3	16/09/2010 5:50	1603	1712	393

4.5.4 Evaporation and rainfall corrected data

Having provided the AWS data for each gate, the next step is to eliminate the effect of evaporation rate and rainfall value from the water elevation measurement records at each time step. The evaporation and rainfall corrected data for each time step is calculated using the following equation:

$$\text{Corrected water elevation}_n = \text{measured water elevation}_n + (E_n - E_1) - (R_n - R_1) \quad (4.1)$$

where E is the evaporation along the channel (mm), R is the rainfall along the channel (mm), n represents any of the time steps during the pondage period and 1 represents the first time step in the zero flow period.

The result of the corrected water elevation for pondage 3 is provided in Table 4.16.

Table 4.16 Corrected water elevation data of 3rd occurred pondage in ARGOON 1-2, ARGOON 1-3 pool

Gate name	Reading date	Water elevation(mm)	evaporation(mm)	rainfall(mm)	corrected elev.(mm)
175/1	14/09/2010 18:18	1638	1710	370	1638
175/1	15/09/2010 16:15	1630	1712	393	1609
175/1	16/09/2010 14:12	1619	1713	393	1599
Gate name	Reading date	Water elevation(mm)	evaporation(mm)	rainfall(mm)	corrected elev.(mm)
175/2	14/09/2010 13:54	1688	1710	370	1688
175/2	14/09/2010 14:04	1691	1710	370	1691
175/2	15/09/2010 11:51	1691	1711	393	1669
175/2	16/09/2010 7:04	1680	1712	393	1659
175/2	16/09/2010 9:48	1680	1712	393	1659
Gate name	Reading date	Water elevation(mm)	evaporation(mm)	rainfall(mm)	corrected elev.(mm)
ARGOON 1-3	14/09/2010 14:55	1613	1710	370	1613
ARGOON 1-3	15/09/2010 5:46	1615	1710	370	1615
ARGOON 1-3	16/09/2010 3:43	1604	1712	393	1583
ARGOON 1-3	16/09/2010 5:50	1603	1712	393	1582

Having gone through all of these, the next step was to control the capability of the model in relating tables of the database together and furthermore check the quality of the data provided for this project.

4.6 Data quality assessment

Data quality assessment is a procedure for determining statistically whether or not a data set is suitable for its intended purpose. This assessment is a scientific and statistical evaluation of data to determine if it is of the type, quantity, and quality needed and may be performed either during a project to check the process of data collection or at the end of a project to check if objectives were met (EPA Quality System, 2013). Since one of the major tasks of the model is to extract the related data from different tables of the database, it was required to assess the capability of the model to link the related data and furthermore have a preliminary assessment of quality of the data provided for the purposes of this study. Data quality assessment of the project was first done using 2010-2011 data and then was completed for other years.

4.6.1 Missing data

A full assessment for all channels during 2010-2011 was completed. Pondage conditions for minimum of 48 hours throughout all main reaches were identified and related data was extracted by the model form the database. Results of the preliminary assessment show that out of total number of 210 pools, 35 of them had to be excluded from the study due to lack of data and 33 of them had no pondage condition as illustrated in Table 4.17. Lack of data occured when data of one or more of the gates in a pool were unavailable. Therefore, pools with missing data in each main reach were detected and then it was determined whether the missing data is the flow or the elevation data of the gate. Consequently a list of all missing data was provided. Furthermore, in case of pools without any possible 48 hours pondage condition, the optional pondage duration in the model was changed to see if a shorter duration pondage condition was possible or not.

Table 4.17 Summary of missing data for 2010-2011 data

Year	Missing data		Excluded pools because of missing data	pools without a minimum 48 hr pondage condition	No of pondage condition
	main gate	farm outlet			
2010-2011	14	60	35	33	1073

In response to the missing data list provided information of majority of main gates and some of farm outlets were provided by Rubicon Water. In case of rest of missing farm outlets, since there was no data available in the Rubicon database, in order to optimize the number of pondage conditions they were all assumed to be closed during the entire irrigation season. Table 4.18 shows the changes in number of possible pondage conditions during 2010 irrigation season after the missing data analysis.

Table 4.18 Changes in total number of pondage conditions for 2010 season after importing the missing data

Year	Total no. Of pondage condition before the analysis	Total no. Of pondage condition after the analysis
2010-2011	1073	1163

4.6.2 Preliminary data quality analysis

Following the missing data analysis, in order to assess the quality of the data provided for this study a quality assessment was done for data of 2010-2011 year. Considering an ideal seepage pattern which is a gradual declining curve with time, based on changes of the corrected water elevations of each gate, pondage conditions were divided into accepted and rejected samples. Furthermore, the accepted and rejected samples were classified into different groups.

4.6.3 Accepted samples

If corrected water elevations of all or some of the gates incorporating a pool during a pondage condition show to have a realistic decrease with time, the pondage is then classified as an accepted sample. Since at the start of assessment, no criteria was defined to configure whether a sample is an accepted or a rejected one, it was required to plot and observe the changes of corrected water elevations of all the gates in the pool with time. Accepted samples were then classified into 5 different groups as follow:

4.6.3.1 Priority 1

Depending on number of gates in the pool if all the gates have a same pattern for water elevations and 75 to 100% of numbers of recorded data for all the gates show a declining curve with time, the pond is treated as priority 1. An example of what might be deemed a priority 1 is given in Figure 4.7.

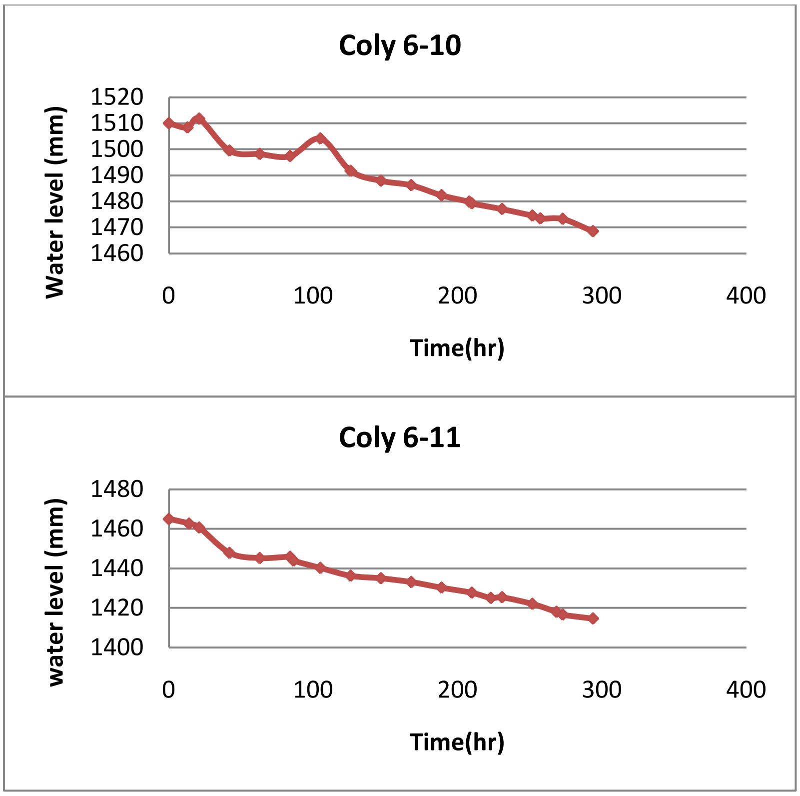


Figure 4.7 Example of priority 1, a pool between Coly 6-10 & Coly 6-11

4.6.3.2 Priority 2

If a pool only has the information of one gate and 75 to 100% of number of recorded data for the gate show a declining curve the pond is treated as priority 2 (for example Figure 4.8).

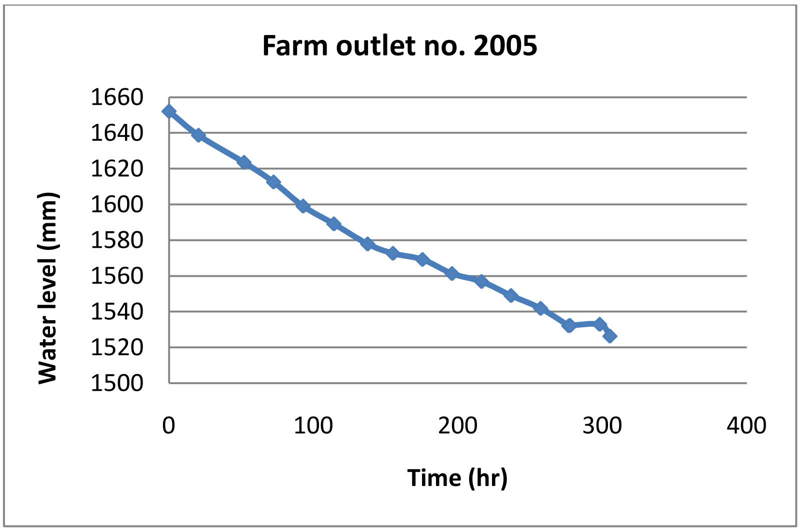


Figure 4.8 Example of priority 2, a pool between ARGOON 3-8 & farm outlet number 2005

4.6.3.3 Priority 3

Depending on number of gates in the pool if some of the gates but not all of them have the same pattern for water elevation and 75 to 100% of number of recorded data for the gates show a declining curve the pond is treated as priority 3 (for example Figure 4.9).

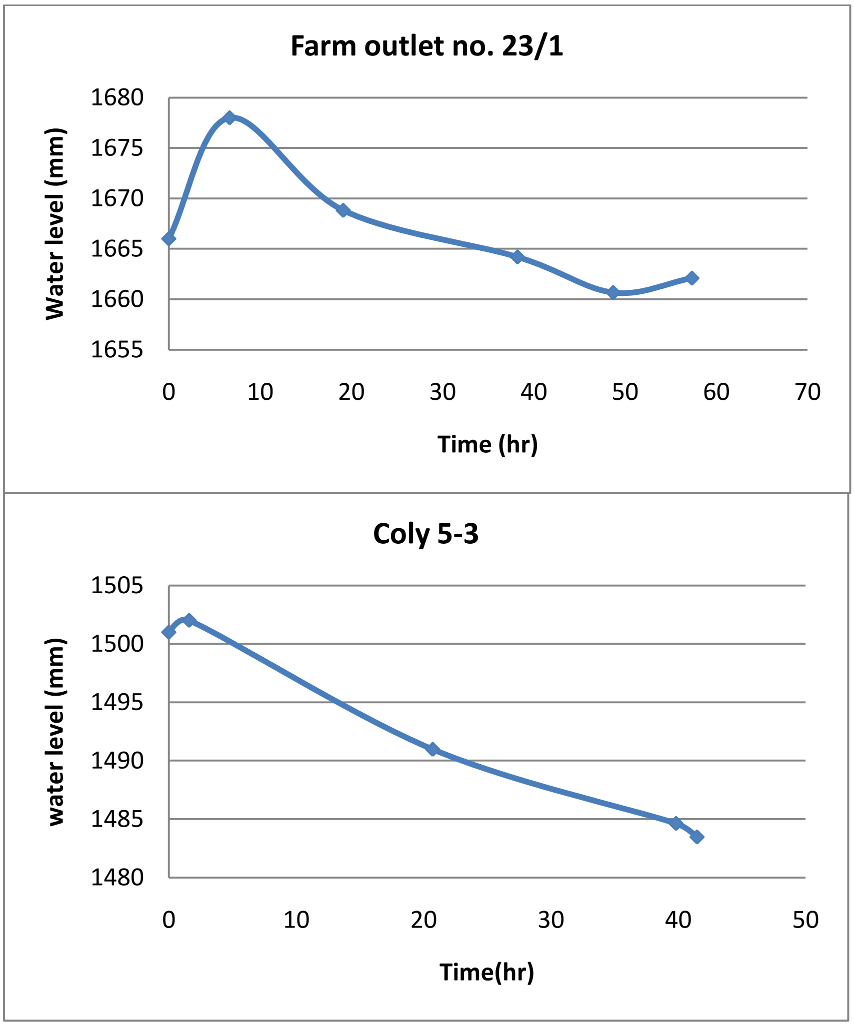


Figure 4.9 Example of priority 3, a pool between Coly 5-2 & Coly 5-3

4.6.3.4 Priority 4

A ponding condition is classed as priority 4 if the pool contains a number of gates, all gates show the same pattern for water elevation and 50 to 75% of the recorded data for all the gates show a declining curve.(for example Figure 4.10).

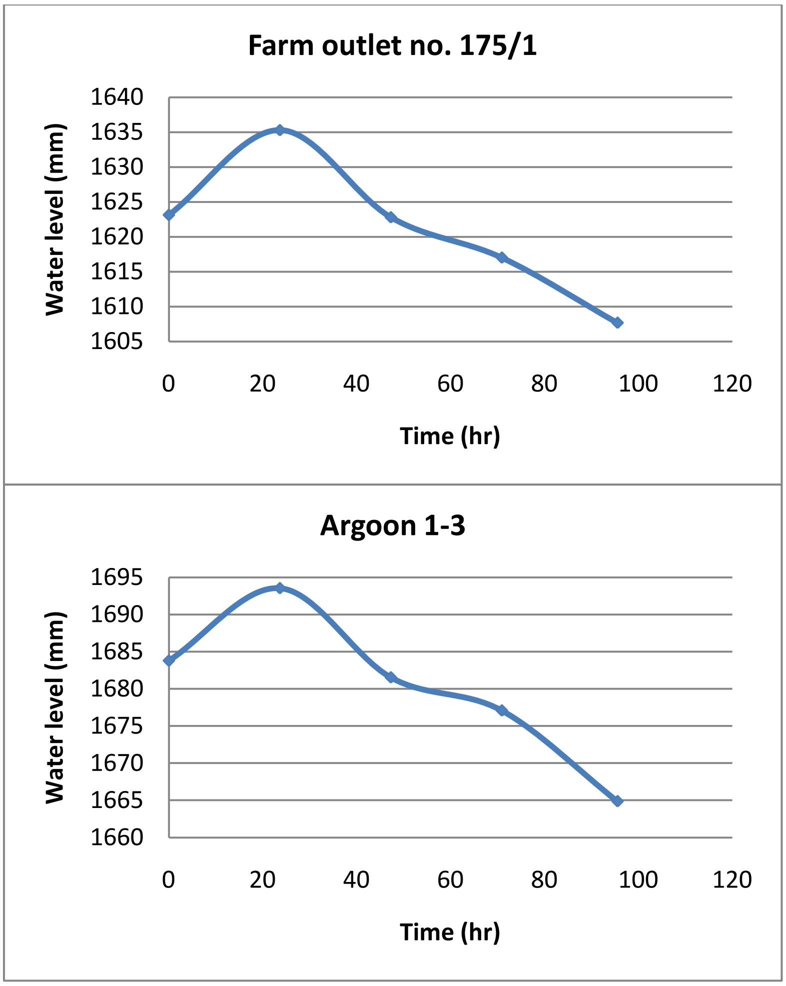


Figure 4.10 Example of priority 4, a pool between ARGOON 1-2, ARGOON 1-3

4.6.3.5 Priority 5

If a pool only has the information of one gate and 50 to 75% of the of recorded elevation data for that gate show a declining curve the pond is treated as priority 5 (for example Figure 4.11).

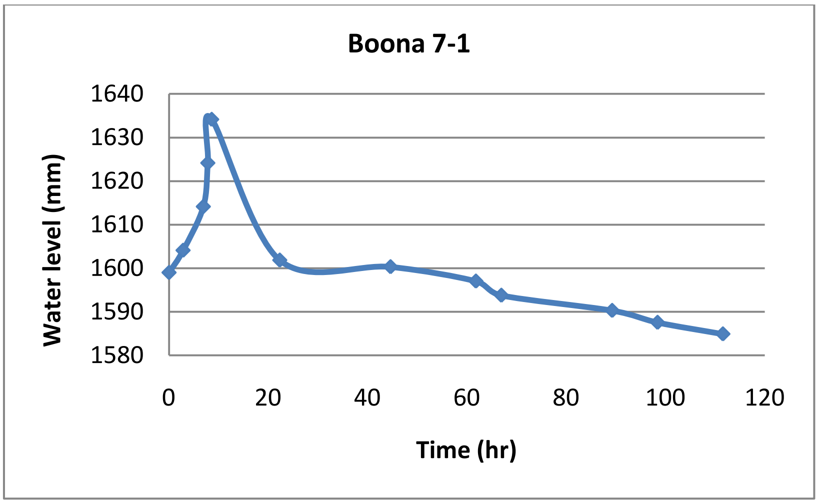


Figure 4.11 Example of priority 5, a pool between BOONA 7, BOONA 7-1

4.6.4 Rejected samples

If corrected water elevations of all the gates incorporating a pool during a pondage condition showed an increase with time or contained significant fluctuations or all remained constant, the pondage is then classified as a rejected sample. The causal reason behind a rejected sample is not clear but it might be due to noises in automation recording systems or having sensors out of water.

Results of preliminary analysis showed that out of 1073 possible pondage conditions in 2010, 73% of them were categorised as accepted samples in different groups and 27% of them were treated as rejected samples (Figure 4.12). Analysis of accepted samples showed that out of 778 accepted samples, 327 were classified as priority 1, 222 of them were grouped as priority 2, 105 of them were grouped as priority 3, 55 were grouped in priority 4 and 69 of them were classified as priority 5 (Figure 4.13).

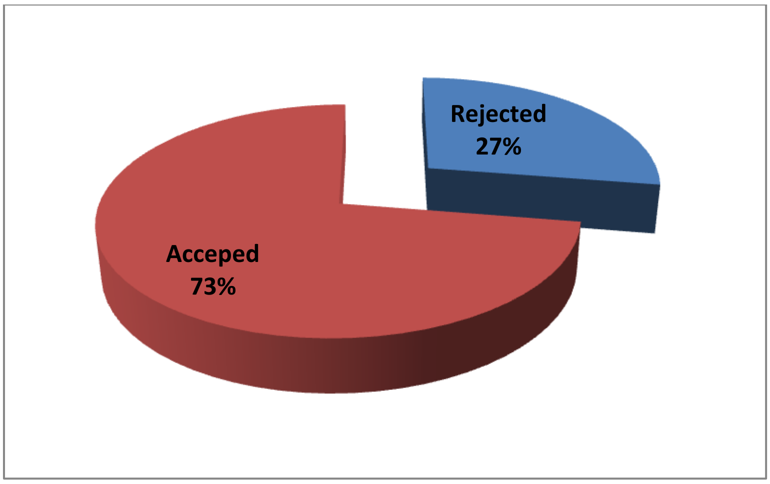


Figure 4.12 Proportion of accepted and rejected samples in 2010

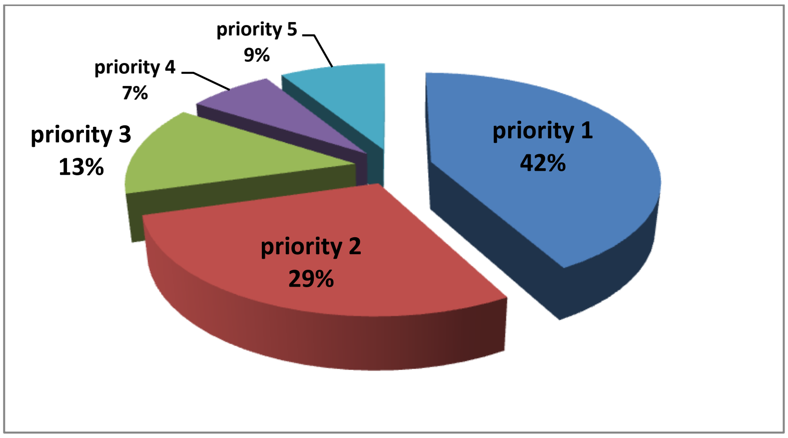


Figure 4.13 Statics of accepted samples

Results of preliminary analysis of 2010 data show that the model was capable to satisfy the required demands of the project and TCC data can be used as a reliable source for further channel loss investigation.

4.7 Improved analysis of pondage samples

Following the preliminary analysis of 2010 data, three ratios were defined for the model and an improved analysis was done for TCC data of 2010 irrigation season. Furthermore, using linear regression, the seepage rate was calculated for each water level gauge during a pondage condition.

4.7.1 Criteria

In order to classify the corrected water elevation data of all possible pondage samples throughout the whole district three criteria are defined for the model. These are:

- Total decline ratio
- Sequential decline ratio
- R squared

4.7.1.1 Total decline ratio

The first criterion applied in the classification of the corrected water elevation data, is called the total decline ratio. Using the following equation, the ratio is calculated for each gate and pondage condition.

$$\text{Total decline ratio} = \frac{\text{Total number of points showing a decline}}{\text{Total number of points} - 1} \qquad (4.2)$$

In order to define the ratio for the model the difference between each two sequential corrected elevation data values was calculated and if shown to have a decrease was counted in the dividend. Furthermore if there was no difference between two points, meaning that the elevation remained constant, it also was counted in the dividend. Since the first point cannot be counted in the calculation of the dividend, the divisor is one unit smaller than the total number of points.

4.7.1.2 Sequential decline ratio

The sequential decline ratio is the result of total number of points in a row showing a decrease divided by total number of points. Using the following equation, the ratio for each gate was calculated.

$$\text{Sequential decline ratio} = \frac{\text{Total number of points in a row showing a decline}}{\text{Total number of points} - 1} \qquad (4.3)$$

Total number of points in a row refers to highest number of decline measurement records in a consecutive fashion. For example if there are multiple slopes showing decline in one plot, the model will consider the slope with the highest number of measured points.

As there might be more than one possible ratio in a pondage, all are calculated and the maximum value among all ratios is selected as the sequential ratio.

4.7.1.3 R squared value

The final criteria used for the data classification was the R2 value, determined by application of linear regression to the plots of corrected water elevation readings versus time for each gate. The linear regression model also gave a first estimate of the seepage rate for each pondage. The rate of water elevation change (corrected for evaporation and rainfall) during pondage period is taken as the seepage rate. Therefore, the slope of the linear regression fit was used as the estimate of seepage rate for any given gauge.

After a pondage condition is identified by the model, the value of each criterion for each of the gates incorporating the pool is calculated separately (Figure 4.14).

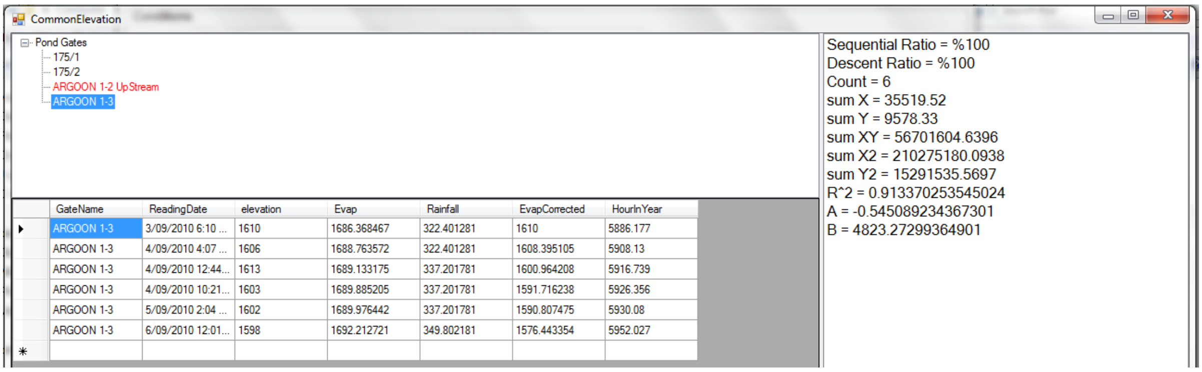


Figure 4.14 Screen shot of criteria calculation for each of the gates

4.7.2 Classification

The concept of classification was based on the behaviour of corrected water elevation changes for each gate in the pool during the pondage time, evaluated using the three defined criteria. A full assessment of all samples based on different main channels for all TCC historical data were done and accepted samples based on the criteria were classified in 5 different groups.

4.7.2.1 Group 1

In pools with several gates, if all gates have a total decline ratio and R^2 of more than 70%, the pool is classified as group 1. Figure 4.15 shows the corrected water elevation plots for two gauges in one of pools as an example of group 1 where both total and sequential decline ratio are 100%.

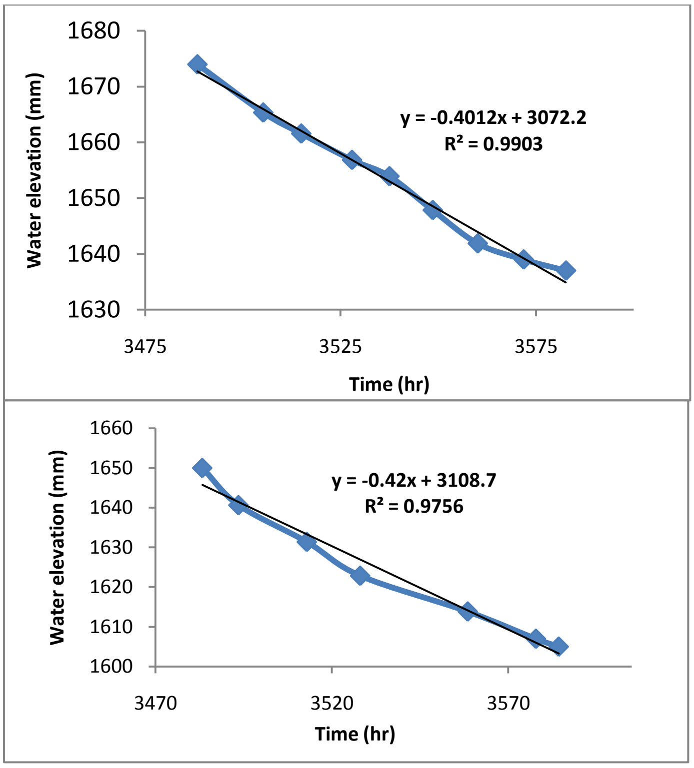


Figure 4.15 Example of a pool classified in group 1

4.7.2.2 Group 2

If a pool has information from only one gate and that gate has a total decline ratio and R^2 greater than 70%, it is classified in group 2 (for example Figure 4.16).

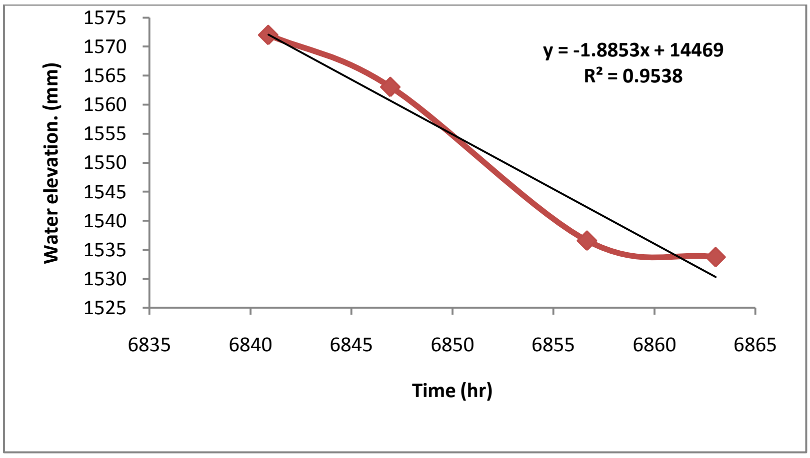
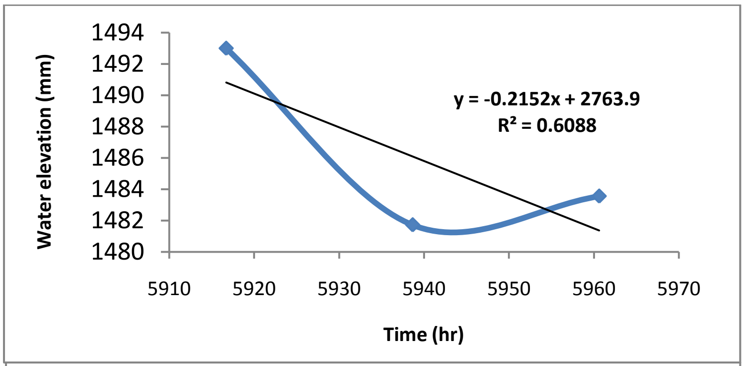


Figure 4.16 Example of a pool classified in group 2

4.7.2.3 Group 3

For a pool with multiple gates if some but not all of the gates have a total decline ratio and R^2 greater than 70%, the pool would be classified in group 3. Figure 4.17 shows the corrected water elevation pattern of gates from one example pool that is classed as group 3 where the values of total and sequential decline ratio are both 50% for the first gate while 80% and 60% for the second gate respectively.



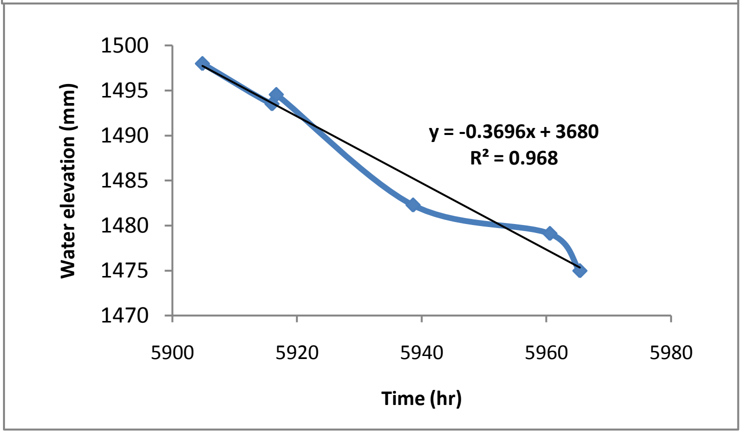


Figure 4.17 Example of a pool classified in group 3

4.7.2.4 Group 4

In pools with several gates, if all gates have a total decline ratio and R^2 greater than 50% but less than 70%, the pool is classified as group 4 (for example Figure 4.18). The values of total and sequential decline ratio are 62.5% and 37.5% for the first gate while 60% and 47% for the second gate respectively (Figure 4.18).

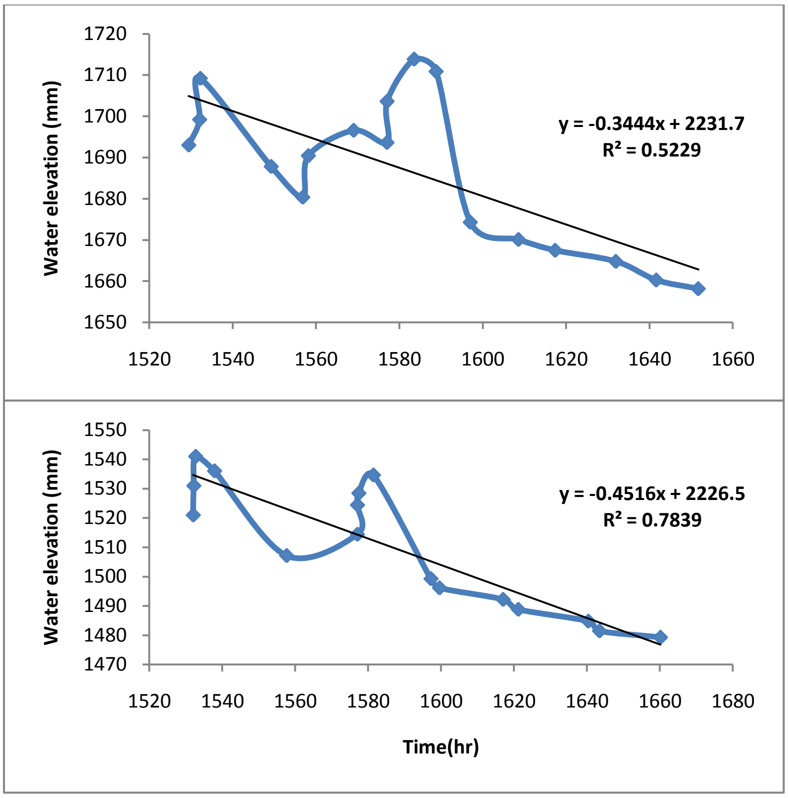


Figure 4.18 Example of a pool classified in group 4

4.7.2.5 Group 5

If a pool has only one gate and that gate has a total decline ratio and R^2 greater than 50% but less than 70%, the pool is classified in group 5 (for example Figure 4.19).

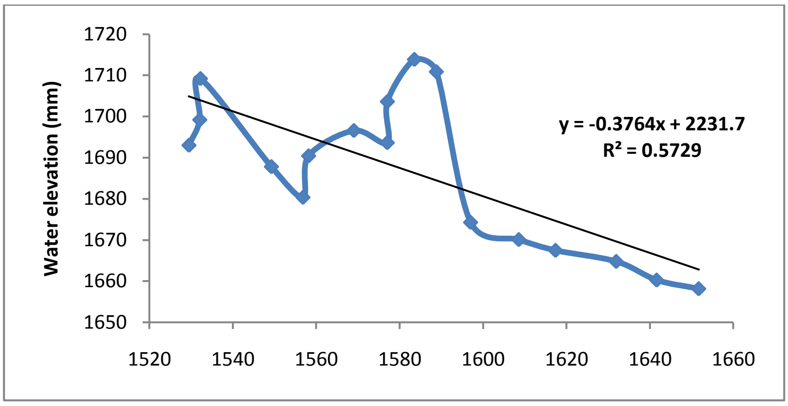


Figure 4.19 Example of a pool classified in group 5

Table 4.19.Distribution of accepted samples in different main reaches

Main channel	No. Of pondage condition	Accepted pondage conditions					Total no. of accepted samples	Total no. of rejected samples	Ratio of accepted to total samples	Group1 &2 to total samples
		Group 1	Group 2	Group 3	Group 4	Group 5				
ARGOON	54	7	19	4	9	1	40	14	74.07%	48.15%
BOONA	207	46	66	9	9	19	149	58	71.98%	54.11%
BUNDURE	201	74	31	20	8	9	142	59	70.65%	52.24%
COLY	366	114	65	40	13	27	259	107	70.77%	48.91%
MAIN CHANNEL	52	13	13	5	2	6	39	13	75.00%	50.00%
TUBBO	59	22	4	7	6	3	42	17	71.19%	44.07%
YAMMA	134	51	24	20	8	4	107	27	79.85%	55.97%
TOTAL	**1073**	**327**	**222**	**105**	**55**	**69**	**778**	**295**	**72.51%**	**51.16%**

Based up on new criteria requirements, pondage samples were categorized in different groups. Analysis of the results showed that Coly had the highest number of pondage conditions while the Main channel with only 52 had the lowest number/count of pondage conditions among all main reaches of the district. The analysis also showed that approximately 70% of the accepted samples met the criteria requirements of the first and the second group (Table 4.19), with 42% in first group and 28% in second group respectively (Table 4.19).

4.8 Model output

Having completed the analysis for each pondage sample, a summary table comprised of general characteristics of the sample plus values of required criteria will be reported by the model (Table 4.20).

As it can be seen in Table 4.20, the first column refers to name of the pool. The second and third columns refer to start and end date of pondage period. Every five columns after the 4th column (for instance 4th till 8th column) refer to characteristics of each of the gates incorporating the pool. These characteristics comprised of:

Number of points which refers to number of measured elevation values for each gate during the pondage period

SDR refers to value of sequential decline ratio calculated by the model

TDR refers to value of total decline ratio calculated by the model.

R square refers to R square value estimated from linear regression by the model.

Seepage rate refers to the gradient of the linear regression estimated by the model.

Priority refers to priority of the pondage sample based on values of required criteria.

Table 4.20 Model output for all occurred pondage samples on pool ARGOON 1-2, 1-3 in 2010 irrigation season

Pondage	Start	End	Farm outlet no. 175/1					Farm outlet no. 175/2					ARGOON 1-3					Priority
			No. of points	SDR	TDR	R Square	Seepage	No. of points	SDR	TDR	R Square	Seepage	No. of points	SDR	TDR	R Square	Seepage	
1	10/08/2010 10:41	13/08/2010 22:52	4	66.67%	66.67%	0.60	-0.13	4	66.67%	66.67%	0.59	-0.12	4	66.67%	66.67%	0.48	-0.09	4
2	3/09/2010 5:43	6/09/2010 4:15	3	100%	100%	0.92	-0.63	24	13.04%	56.52%	0.72	-0.69	6	100%	100%	0.91	-0.54	1
3	14/09/2010 13:29	16/09/2010 15:04	3	100%	100%	0.92	-0.88	5	50%	50%	0.97	-0.70	4	66.67%	66.67%	0.86	-0.90	1
4	26/11/2010 17:15	29/11/2010 12:06	7	16.67%	33.33%	0.01	0.10	7	16.67%	33.33%	0.00	0.01	8	42.86%	57.14%	0.06	-0.25	Rejected
5	11/02/2011 17:37	14/02/2011 7:12	4	100%	100%	0.96	-0.56	7	100%	100%	0.79	-0.75	7	66.67%	66.67%	0.84	-0.74	1
6	10/04/2011 3:46	12/04/2011 13:13	4	66.67%	66.67%	0.41	-0.19	3	100%	100%	0.99	-0.41	4	100%	100%	0.99	-0.46	1

4.9 Conclusions

Considering the objectives of this project and the format of the data provided from the TCC system, it was decided to create a database consisting of individual tables and link those tables together. Microsoft SQL server was selected to build the database to accommodate these linked tables and the large quantity of TCC data. Computer software was written in C# to interrogate the database and analyse pondage samples from TCC data. The completed result is a robust tool, for identification and analysis of all possible pondage conditions throughout the entire network. This tool is capable of analysis to classify pondage samples based upon set criteria and estimate seepage rates for each gauge, pondage and pool in each irrigation season.

The model was tested for 2010 irrigation season and it was shown to be capable of identifying all pondage conditions for any given pool in the network and classifying the pondages (rejected and accepted samples) based upon the set criteria. The accepted samples were categorized into 5 different groups. The results of the assessment showed that out of 1073 possible pondage conditions, 778 met the criteria for being suitable for identification of seepage. The remaining 295 samples were rejected due to having a low R^2 from the linear regression or low total decline ratio. The analysis also showed that approximately 70% of the accepted samples met the criteria for the first and the second groups, with 42% in the first group and 28% in the second group, respectively.

Chapter 5: Gauge, Pondage and Pool based Seepage rates

5.1 Introduction

Chapter 4 introduced the development of the computer model built up for the analysis of pondage samples. Furthermore, as introduced in Chapter 4, a database provided from the 2010 irrigation season TCC data of CICL was created to test and validate the capability of the computer model to identify any pondage condition throughout the entire network, classify the accepted samples based up on required criteria and estimate the seepage rate.

This chapter discusses the analysis of all possible pondage conditions during 2009-2011 after development of the Coleambally database by adding 2009 and 2011 irrigation season TCC data. Three different seepage rates were defined in the model:

- Gauge rate – based on the data from a single depth gauge
- Pondage rate – an average of the gauge rates in a single pondage test for a given pool
- Pool rate – an average of the pondage rates in a given pool in a single season

The linear regression model was used to give a first estimate of seepage rate for each gauge during each pondage condition. While evaluating various possible factors affecting the seepage rate for each pondage sample, two variables were defined for any given individual rate in the computer model and by allocating weights to individual rates, an average seepage rate for each pondage is calculated from the weighted gauge rates.

Similarly, two variables were defined for any given pondage rate and by allocating weights to pondage rates, an average seepage rate for each pool in each season is calculated from the weighted pondage rates.

5.2 Coleambally database development

The historical data provided from automated TCC systems of CICL as described in Chapter 3 covers the 2009-2011 irrigation seasons. While, for the purposes of model testing and validation, the database described in Chapter 4 only consists of 2010 irrigation season TCC data. In order to accomplish a comprehensive analysis of all pondage conditions during 2009-2011 and due to the large volume of data in each year, two more databases with the same format as the 2010 Coleambally database were created for the 2009 and 2011 irrigation seasons.

5.2.1 Missing data

After creating the 2009 and 2011 databases, a full assessment of all channels during 2009-2011 was done. Pondage conditions lasting for a minimum of 48 hours throughout all main reaches were identified and related data was extracted by the model from the databases. Results of the preliminary assessment in each year show that some of the pools have to be excluded from the study due to lack of data and some have no pondage condition (Table 5.1). Lack of data is the case when one or more of the gauges in a pool have no data available in the database.

In the case of pools without a minimum 48 hours pondage condition, the optional pondage duration in the model was changed to see if use of a shorter duration pondage condition resulted in an increase in the number of samples.

Consequently, pools with missing data in each year were identified and it was identified whether the missing data was the flow or the elevation information for the gauge. Finally a list of all missing data for each year was prepared and sent back to Rubicon Water.

Table 5.1 Summary of missing data for 2009-2011

Year	Missing data		Excluded pools because of missing data	pools without a minimum 48 hr pondage condition	No of pondage condition
	main gauge	farm outlet			
2010-2011	14	60	35	33	1073
2009-2010	6	94	75	26	668
2011-2012	95	3	86	19	604

In response to the prepared list of missing data, further information on the majority of main gates and some farm outlets was provided by Rubicon Water and the number of pondage conditions identified in each year increased (Table 5.2). However, there were still some farm outlets and main gates without any data in the database. Although the reason for this seemed to be due to gate closure it was decided to exclude those pools from the study.

Table 5.2 Changes in total number of pondage conditions after importing the missing data of all three seasons

Year	Total no. Of pondage condition before the analysis	Total no. Of pondage condition after the analysis
2009-2010	668	851
2010-2011	1073	1163
2011-2012	604	808

5.2.2 Analysis of accepted samples

A comprehensive analysis of all possible pondage conditions during 2009 and 2011 irrigation seasons was done separately for each year and accepted samples in each year were categorized in different groups based on set criteria. Results of the analysis showed that the 2010 irrigation season had the highest number of pondage samples and highest number of accepted samples respectively among the 3 years of historical data. While, the other two irrigation seasons had similar number of pondage conditions and accepted samples. Based upon the analysis, out of total number of 2758 pondage conditions 66% of them met the criteria and were grouped in different classes of accepted samples (Table 5.3).

Table 5.3 Summary of accepted sample analysis for 2009-2011 data

Year	Total no. Of possible pondage conditions	Group 1	Group 2	Group 3	Group 4	Group 5	Total no. Of accepted samples	Total no. Of rejected samples
2009-2010	851	243	178	63	9	29	522	329
2010-2011	1073	327	222	105	55	69	778	295
2011-2012	834	295	122	87	12	15	531	303
Total	2758	865	522	255	76	113	1831	927

5.3 Seepage magnitude

As described in Chapter 4, the linear regression model was applied to plots of corrected water elevation readings versus time for each gauge to estimate R^2 value as one of the defined criteria for the computer model. The linear regression model was also used to give a first estimate of seepage rate for each gauge during each pondage condition (Figure 5.1).

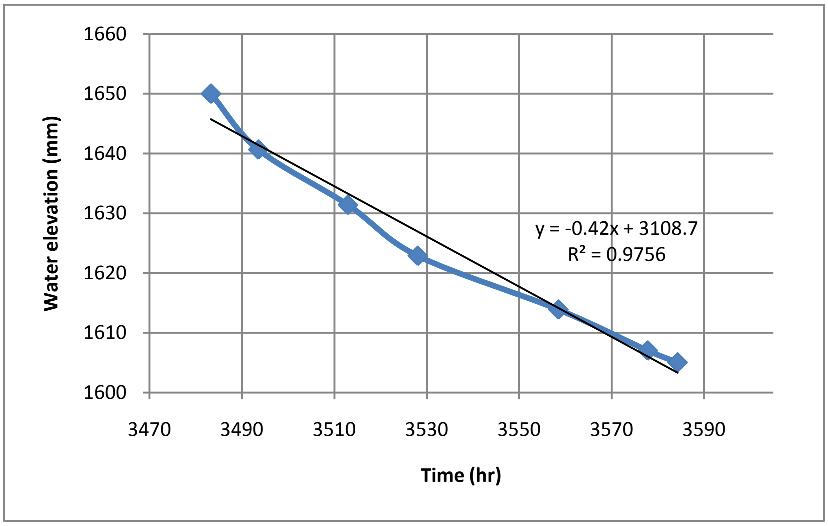


Figure 5.1 Example of application of linear regression to estimate seepage rate

As can be seen in Figure 5.1, the gradient of the linear regression, equal to rate of corrected water elevation changes during pondage period gives the average seepage rate at each gauge.

5.3.1 Seepage rate per gauge

As mentioned in the introduction section, using the linear regression model, the seepage rate for each of the gauges in a pool during any possible pondage condition is calculated individually (Appendix C, Table C1). Histograms of seepage rate magnitudes for all the gauges in accepted and rejected samples during each of the three irrigation seasons were plotted separately (Figures 5.2, 5.3 & 5.4).

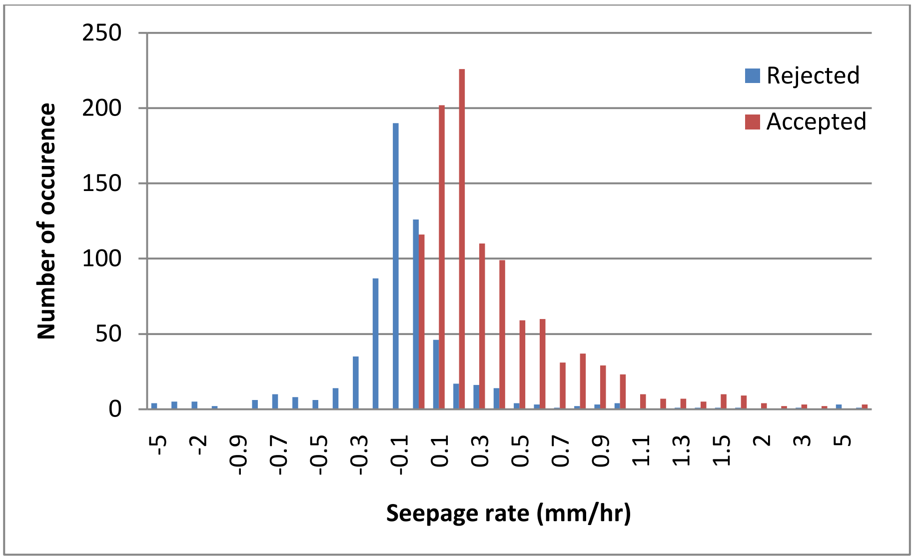


Figure 5.2 Histogram of gauge based seepage rates for all pondage samples during 2009 irrigation season

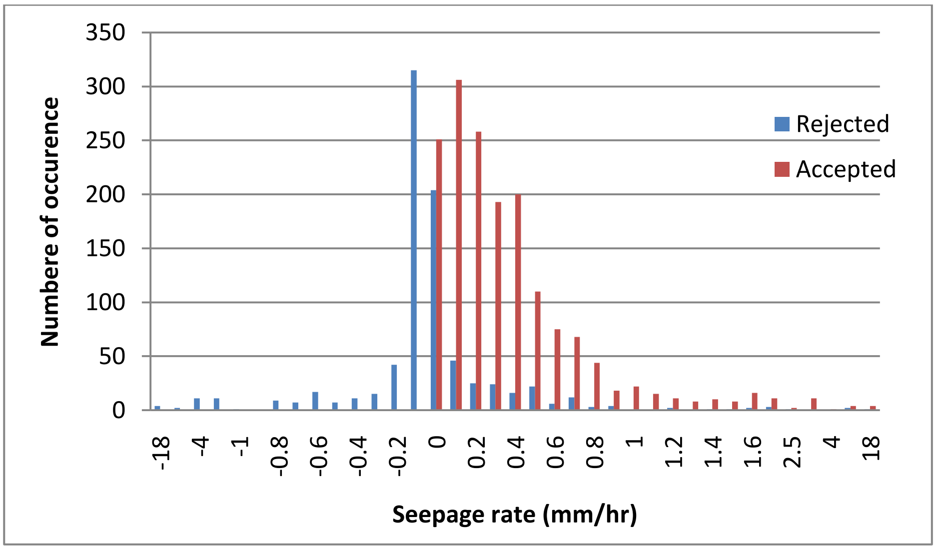


Figure 5.3 Histogram of gauge based seepage rates for all pondage samples during 2010 irrigation season

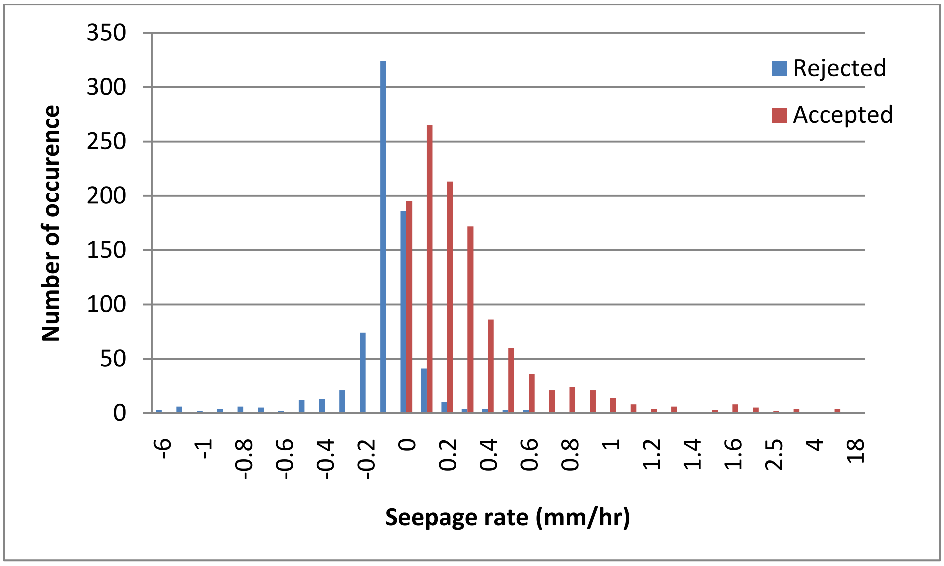


Figure 5.4 Histogram of gauge based seepage rates for all pondage samples during 2011 irrigation season

As can be seen in Figures 5.2, 5.3 and 5.4, the histograms of accepted samples showed a skewed distribution to the right in all three years while histograms of rejected samples in all three years showed a skewed distribution to the left. Moreover, analysis of seepage magnitudes showed that in 2009, 23% of the gauges gave seepage rates greater than 0.5 mm per hour (equal to 12 mm per day). Similarly in 2010 and 2011, 20% and 14% of the gauges gave seepage rates greater than 0.5 mm per hour. The 2011 data had the smallest median rate with 0.15 mm per hour while, the medians in 2009 and 2010 were 0.19 and 0.2 respectively.

On the other hand, the proportion of accepted gauges with seepage rates less than 0.2 mm per hour was greater in 2011 with 59% of the total compared to 49% in 2010 and 51% in 2009. Moreover, the ratio of rejected to accepted gauges was far greater in 2011 with 63% compared to 50% in 2010 and 58% in 2011.

At the same time, based on different groups of accepted samples and given that majority of the accepted samples belong to the first 3 groups, histograms of gauge based seepage rates for the first 3 groups during 2009-2011 are plotted in Figures 5.5 to 5.7.

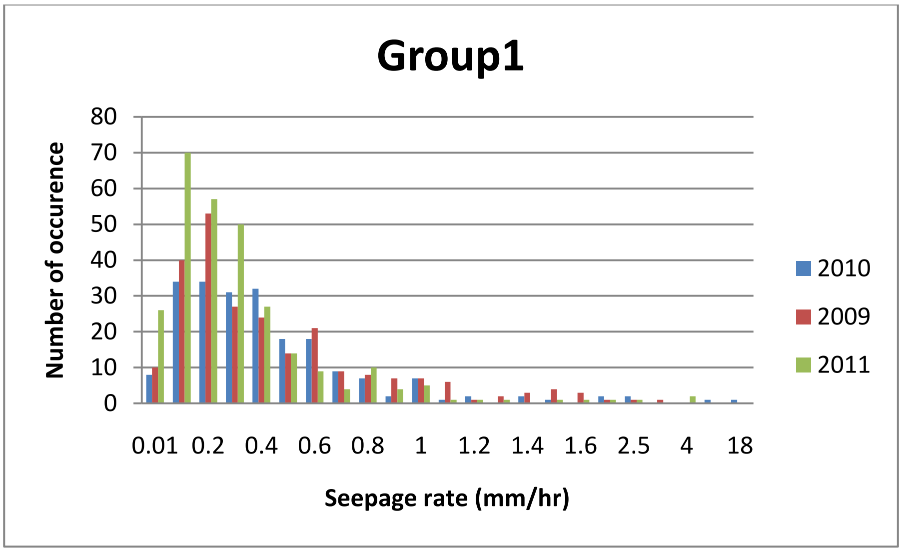


Figure 5.5 Histogram of gauge based seepage rates in 1st group during 2009-2011 irrigation seasons

As can be seen in Figure 5.5 all three histograms showed the same pattern with a skew distribution to the right. However, the histogram of 2011 seepage estimates had a greater proportion between 0 and 0.5 mm per hour (equal to 12 mm per day) with 86% compared to 74% in 2010 and 69% in 2009. In other words, the histogram of 2011 data had the lowest median with 0.18 mm per hour compared to 2009 with 0.26 and 2010 data that had the highest median with 0.3 mm per hour.

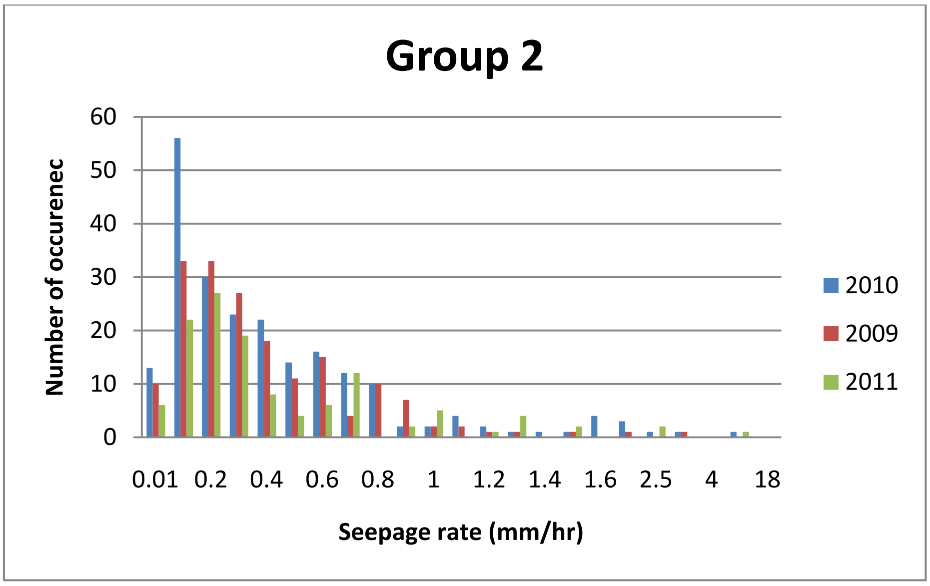


Figure 5.6 Histogram of gauge based seepage rates in 2nd group during 2009-2011 irrigation seasons

As can be seen in Figure 5.6 similar to group 1, all three histograms showed the same pattern with a skew distribution to the right. However, the histogram of 2009 seepage estimates had a greater proportion between 0 and 0.5 mm per hour (equal to 12 mm per day) with 75% compared to 72% in 2010 and 71% in 2011. The 2011 seepage estimates had the lowest median with 0.23 mm per hour while the medians for 2009 and 2010 were equal at 0.25 mm per hour.

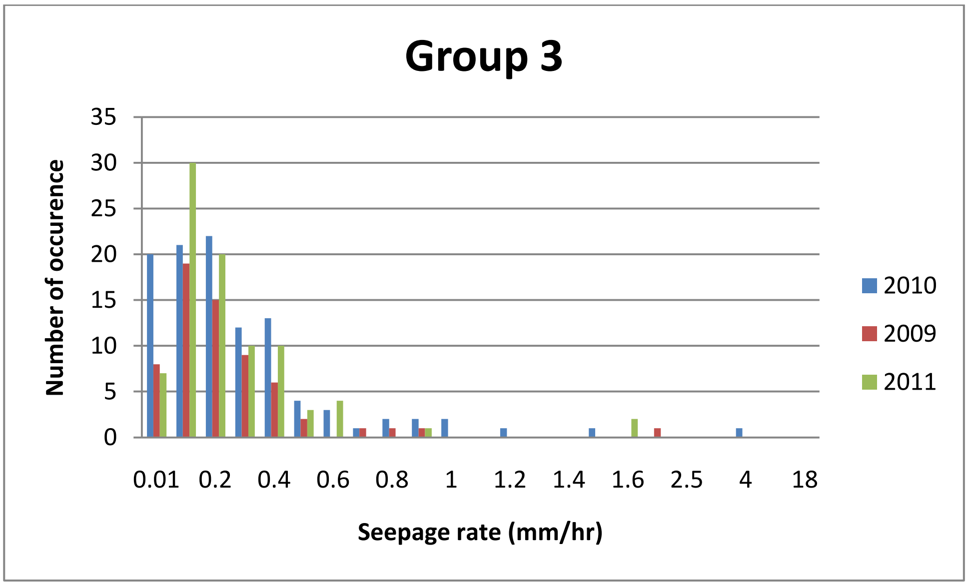


Figure 5.7 Histogram of gauge based seepage rates in third group during 2009-2011 irrigation seasons

As can be seen in Figure 5.7 all histograms showed to have a same pattern with a skew distribution to the right. However, due to low proportion of data at the tail of each histogram, especially in 2011, these data might be considered as outliers. Moreover, Figure 5.7 shows that the histogram of 2010 seepage estimates had a lower proportion between 0 and 0.5 mm per hour (equal to 12 mm per day) with 87% compared to 94% in 2009 and 92% in 2011. In other words, the number of seepage estimates greater than 12 mm per day in 2010 was greater than 2009 and 2011. However, both 2009 and 2011 had the same median value of 0.13 mm per hour while the median in 2010 was 0.15 mm per hour.

Comparing median values of all three group based histograms in different years, it can be said that the group 1 had the maximum median value in 2009 and 2010 and as the level of group increased, the median value decreased. On the other hand, the median of group 2 histogram of 2011 data had the maximum value, while group 1 had the second highest value and group 3 had the lowest median value.

5.3.2 Seepage rate per pondage

A causal factor affecting the estimation of seepage rates in each pondage sample is the number of measured water elevation points at each of the gauges in a pool. Since the numbers of measured points at gauges during pondage conditions were not necessarily the same, a weighting for each gauge based on this number was considered. The decision to choose the number of measured points as a deciding factor was made considering the fact that there is more confidence in the gauge based seepage rates with a higher number of points compared to those with only two or three points.

In order to estimate the pondage based seepage rate, a weighting was allocated to each gauge taking in to account the number of measured points at all gauges in each pool, and the pondage based seepage rate is calculated as a weighted mean of the individual gauge rates (Appendix C, Table C1).

In a pool with n gauges where a pondage condition occurred, the seepage rate for the first gauge is S_1 and number of measured points for the first gauge is equal to N_1. Similarly S_n and N_n stand for seepage rate and number of measured points for the n^{th} gauge during the pondage condition. The weight for each gauge will be calculated as:

$$W_i = \frac{N_i}{\sum_{i=1}^{n} N_i} \qquad (5.1)$$

Consequently the seepage rate for the pondage will be calculated using the weighted average (Equation 5.2).

$$S_{pondage} = \sum_{i=1}^{n} S_i * W_i \qquad (5.2)$$

In order to indicate the level of confidence in each estimated pondage based seepage rate, two variables were defined for each pondage sample:

- Number of measured points per pondage (NMPP)
- Level of confidence (LOC)

The definitions of NMPP and LOC differ depending on the group (as given in section 4.7.2) into which that ponding condition belongs as shown below in Figure 5.8.

Group 1 & 4

$$\text{LOC} = \frac{\sum_1^n {R^2}_i}{n}$$

$$\text{NMPP} = \frac{\sum_1^n N_i}{n}$$

Group 2 & 5

$$\text{LOC} = {R^2}_1$$

$$\text{NMPP} = N_1$$

Group 3

$$\text{LOC} = \frac{\sum_1^n {R^2}_i}{n}$$

$$\text{NMPP} = \frac{\sum_1^n N_i}{n}$$

Where gate_i met criteria requirement

Figure 5.8 Determination of LOC & NMPP variables for each pondage sample according to the group

Obviously the pondage rates in groups 2 and 5 were exactly the same as gauge based rates. However in groups 1 and 4 the seepage rate for each pondage sample was calculated using the explained mean average method. Similarly in group 3 averaging was performed between gauges that met group 3 requirements. The resulting histograms of seepage rate magnitudes for all possible pondage samples during each of the three irrigation seasons were plotted separately in Figures 5.9, 5.10 and 5.11.

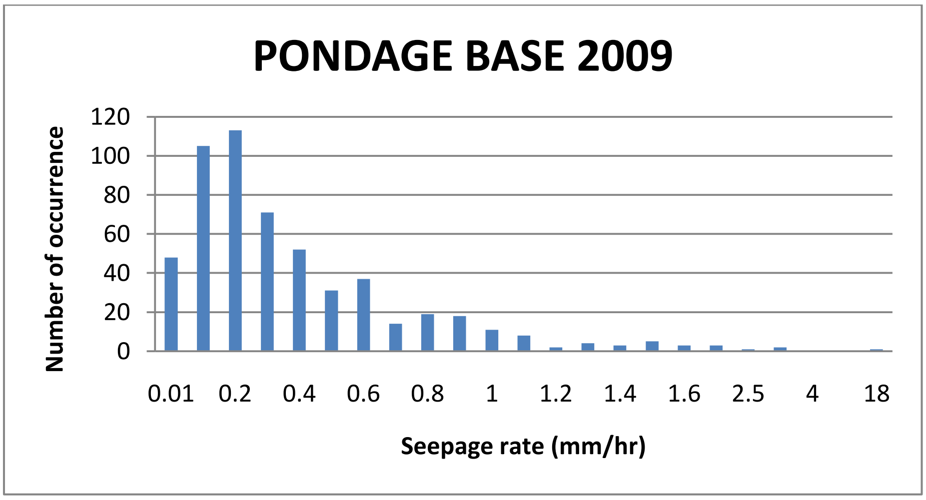


Figure 5.9 Histogram of pondage seepage rates during 2009 irrigation season

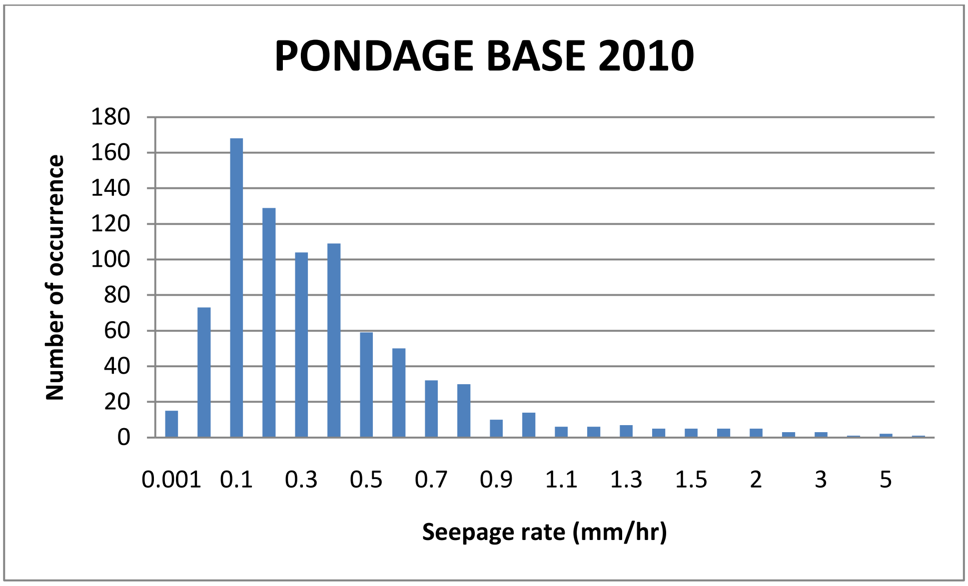


Figure 5.10 Histogram of pondage seepage rates during 2010 irrigation season

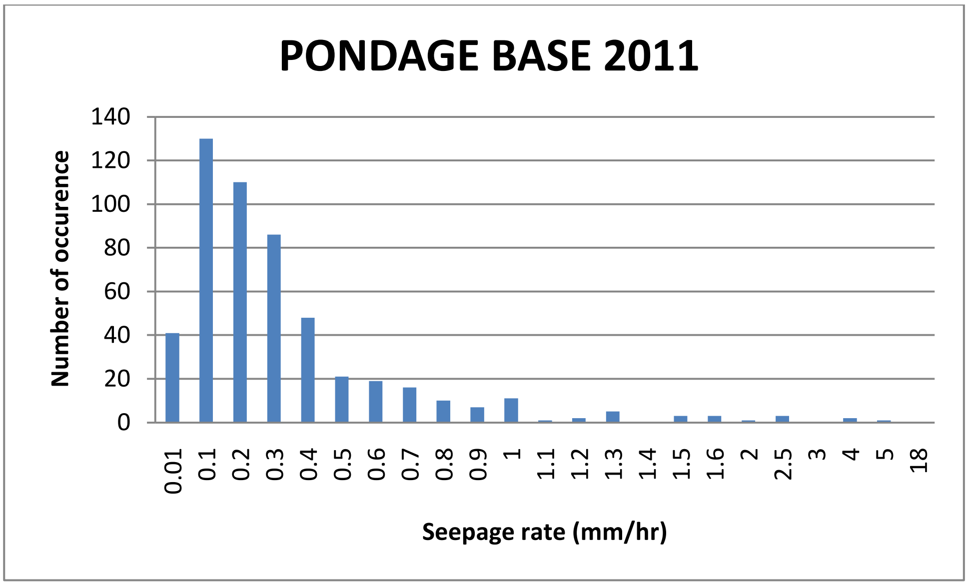


Figure 5.11 Histogram of pondage seepage rates during 2011 irrigation season

As can be seen from the histograms, the pondage rates also showed a skewed distribution to the right in all three years. However, the proportion of pondage rates less than 0.5 mm per hour was greater in 2011 with 84% of the total compared to 78% in 2010 and 76% in 2009. In other words, histogram of 2011 pondage seepage rates had the lowest median value with 0.18 mm per hour comparing to 0.22 in 2009 and 0.24 mm per hour in 2010.

Summary of median values for gauge, group and pondage based seepage rates in all three years are illustrated in Table 5.4.

Table 5.4 Summary of median values of estimated seepage rates during 2009-2011

Year	Median Value					
	Gauge rate	Group 1 rate	Group 2 rate	Group 3 rate	Average priorities	Pondage rate
2009	0.19	0.26	0.25	0.13	0.21	0.22
2010	0.2	0.3	0.25	0.15	0.23	0.24
2011	0.15	0.18	0.23	0.13	0.18	0.18

Table 5.4 shows that the median values for different estimated seepage rates in 2011 are considerably lower compared with 2009 and 2010. Furthermore, the average value of all three groups median is approximately equal to median of pondage rate. At the same time, group 3 seems to have a lower seepage rate in compare with the other two priorities.

5.3.3 Seepage rate per pool

Given the fact that seepage estimates from the only comprehensive study done in CIA area indicates locations with high seepage loss (Allen, 2006), in order to be able to make comparison between the findings of this study and Allen (2006), it was decided to define a set of rules to automatically estimate pool based seepage rates based on the pondage based rates in each pool. Again a weighted mean of the pondage based rates was applied to estimate the pool based rate.

In a pool where n accepted pondage conditions occurred, the seepage rate in the first pondage is S_1 and NMPP of the first pondage is N_1. Similarly S_n and N_n stand for the seepage rate and NMPP of n^{th} pondage sample in the pool (Appendix C). Weights for each pondage based rate and the pool based seepage rate were calculated using equations 5.1 and 5.2.

Moreover, in order to indicate the level of confidence in each estimated pool based seepage rate, using equations 5.3 and 5.4 two new variables were defined from averaging the LOC and NMPP of each pondage sample:

$$\mathrm{LOCP} = \frac{\sum_{1}^{n} \mathrm{LOC_i}}{\mathrm{n}} \qquad (5.3)$$

$$\mathrm{NMPPP} = \frac{\sum_{1}^{n} \mathrm{NMPP_i}}{n} \qquad (5.4)$$

where LOCP is the level of confidence in each estimated pool based seepage rate and NMPPP is the average number of measured points in each pool.

5.4 Conclusions

Two more years of historical data were added to the database, all pondages identified and classified, and seepage rates estimated for each gauge. Based on the individual gauge seepage rates estimated by the linear regression model for accepted samples in each pool during each season, an average seepage rate for each pondage and pool was estimated.

Histograms of seepage rate magnitudes for all the gauges in accepted and rejected samples during each of the three irrigation seasons were plotted separately. The histograms showed clear differences between the accepted and rejected samples and the clear similarities between the accepted results for the three years.

Results of the analysis showed that seepage losses from the CIA are significant, with about 20% of the estimated seepage rates in all three seasons greater than 0.5 mm/hr (12 mm/d). While a number of pondages with significantly high loss rates were observed during each season. The median seepage rate for 2011 was lower compared with the other two seasons, while the median seepage rates were similar between the 2009 and 2010 seasons.

Chapter 6: Evaluation of factors affecting the seepage rates estimated using TCC data

6.1 Introduction

As described in Chapter 5, the model uses a linear regression as a first estimate of the seepage rate for each gauge in a given pool during shut down periods. In order to clarify the quality of seepage estimates resulting from the model, an evaluation of all pondage conditions occurring in different pools during the three irrigation seasons was undertaken and possible causal factors affecting the estimated seepage rates were introduced. A number of pools with several pondage conditions were identified and correlations between the different seepage rates resulting from different pondage conditions were interpreted. Pools with very high rates of water loss indicative of leakage were addressed and the application of a polynomial trend line rather than linear regression for modelling the seepage rate in those samples was assessed. Finally a comparison with previous seepage studies that used TCC data is provided.

6.2 Causal factors affecting the estimated seepage rate from TCC data

A full detailed analysis of all pondage conditions for selected pools during 2009-2012 was done and various features affecting the estimated seepage rates were introduced. The evaluation consists of correlation assessment of the estimated seepage rates in different pondage conditions for each pool as well as evaluating various possible factors affecting the difference in rates if this is the case. These include, duration of gate shut down, surface water elevation at the start of the pondage condition and its relation to supply level of the channel at each gauge, accumulated depth of rainfall during the pondage period, seasonal variations in seepage rate, number of water level measurements in the pondage, suspected unauthorized water usage, noise associated with measurements and leakage through macro pores in banks of the channels. A number of examples for each feature are provided in each section.

6.2.1 Effect of rainfall

As previously described in Chapter 4, daily accumulative depth of rainfall measured in mm is applied for calculation of corrected water elevation for each gauge. Given the fact that only the total depth of daily rainfall not its distribution during each day is available, the removal of rainfall effect from measured water elevations can cause a sharp drop in corrected water elevations especially when a considerable amount of rainfall occurred and consequently affect the shape of corrected water elevation plots as well as the estimated seepage rate per gauge.

The rainfall may occur at the beginning, in the middle, toward the end or a combination of two in any pondage condition and will consequently reform the shape of the corrected water elevation plot respectively. This was observed in corrected water elevation plots of all gauges in BOONA 9, 9-1 pool during a pondage condition with one considerable rainfall at the beginning of the pondage condition followed by one slight one in the middle with total amount of 97 mm (Figure 6.1). However, given that the pondage condition lasted for 40 more hours after the last rainfall occurrence and a sufficient number of measurements were available, the seepage rate for the remaining part of pondage condition was re-estimated and compared with the seepage rate estimated by the model (Appendix D). At the same time a rise in the plot prior to the occurrence of rainfall as shown in Fig 6.13 can be due to the fact that any rainfall event was measured at 9 am and recorded against the same day. Therefore the imperfect knowledge of exact timing of the rainfall event could potentially cause the rise and fall in the corrected water elevation plot. Furthermore it is likely that the magnitude of the actual rainfall in the channel of interest will be different to the rain measured at the closest AWS. Rainfall can be highly spatially variable, and this variability will be highest for short duration high intensity events such as summer storms.

As shown in Figure 6.1, removal of this initial rainfall period from the ponding test changed the estimated seepage and increased the R^2 value of the line of best fit.

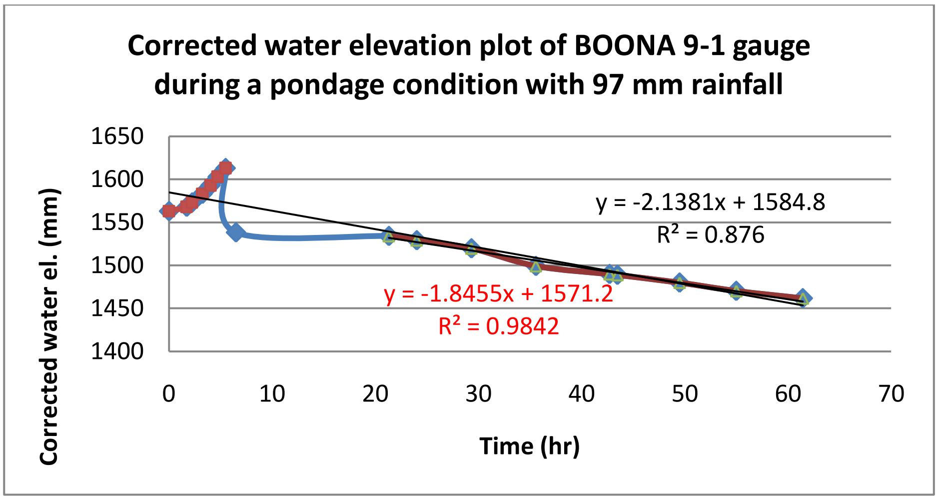


Figure 6.1 Rainfall effect on corrected water elevation plot of BOONA 9-1 in BOONA 9, 9-1 pool during a pondage condition with total amount of 100 mm rainfall

The same situation was also observed in corrected water elevation plots for all gauges in ARGOON 3A, 220/1 pool in form of two rises and falls during a pondage condition when three rainfall events with total amount of 110 mm occurred (Figure 6.2). However, given that enough measurements for the remaining part of pondage plot after elimination of the rises and falls were available, seepage rate was re estimated and reduced from 2.1 to 1.85 mm/hr (Appendix D).

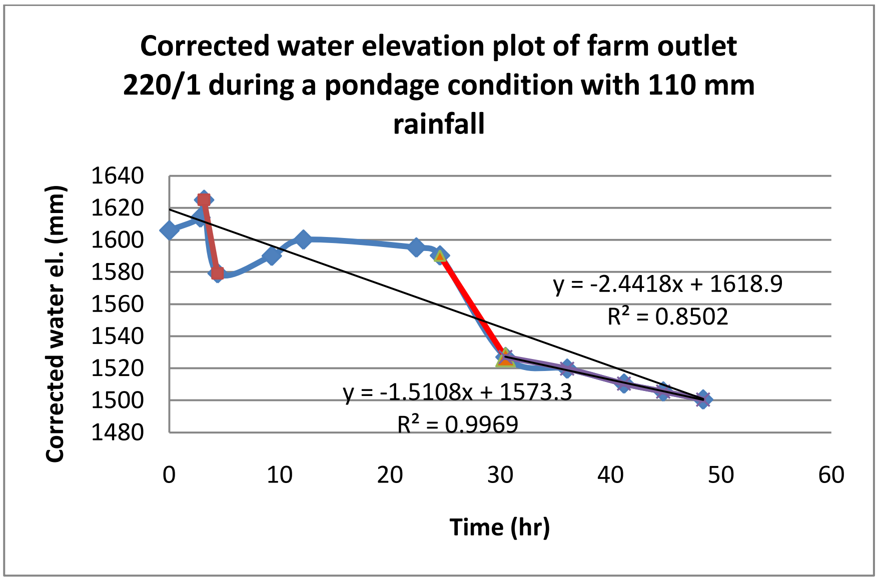


Figure 6.2 Rainfall effect on corrected water elevation plot of farm outlet 220 in ARGOON 3A, 220/1 pool during a pondage condition with total amount of 86 mm rainfall

On the other hand, when a sufficient number of measured points or sufficient pondage duration after the noise elimination was not available, the pondage sample was taken out from the analysis. A good example of this is illustrated in Figure 6.3 where 47 mm rainfall occurred during a 55 hour pondage condition on BOONA 7, 7-1 pool. From Figure 6.3 it can be seen that only three points are available in the remaining part after the rise and fall eliminations. Furthermore, due to short duration of pondage condition after the rainfall, this pondage sample was removed from the analysis (Appendix D).

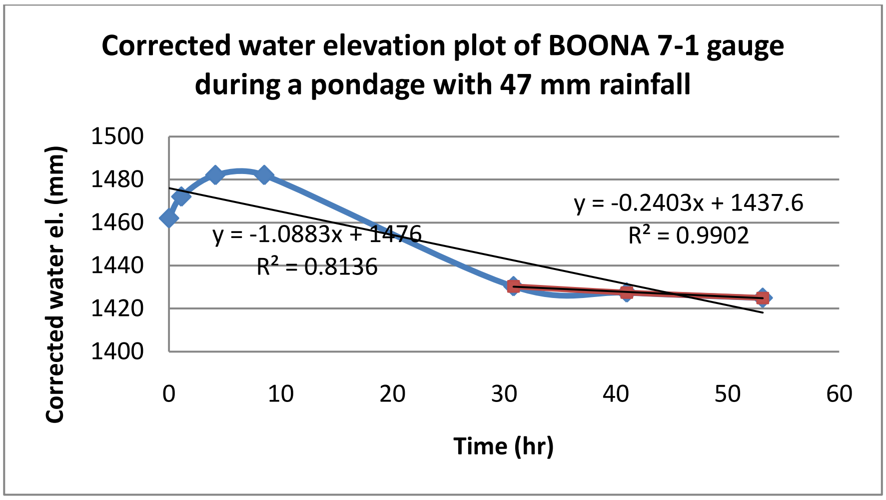


Figure 6.3 Rainfall effect on corrected water elevation plot of BOONA 7-1 gauge in BOONA 7, 7-1 pool during a pondage condition with total amount of 47 mm rainfall in 2010/11 season

Figure 6.4 shows another pondage condition on COLY 7, 7-1 pool with total amount of 30 mm rainfall which was removed from the analysis due to low number of measured points as well as short pondage duration after the eliminations of rainfall effect (Appendix D).

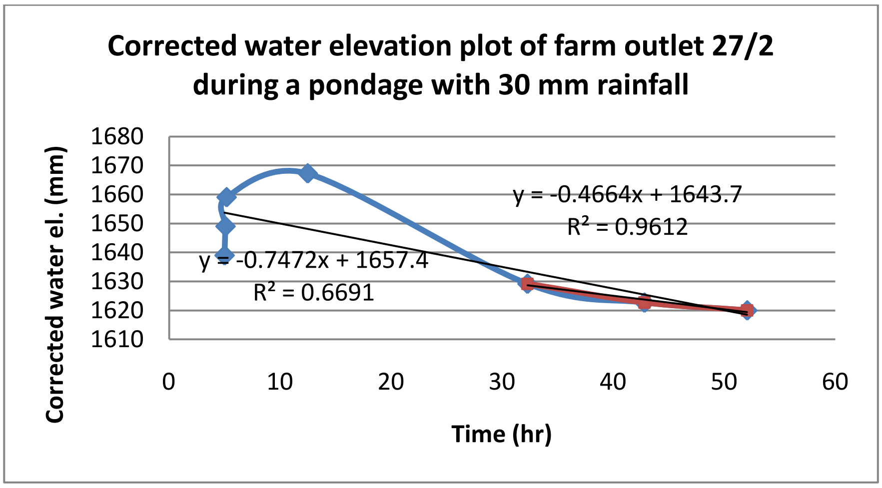


Figure 6.4 Rainfall effect on corrected water elevation plot of BOONA 7-1 gauge in COLY 7, 7-1 pool during a pondage condition with total amount of 47 mm rainfall in 2009/10 season

However, the results of the analysis showed that whenever the amount of occurred rainfall was low (Figures 6.5 and 6.6) or the pondage duration was very long (Figure 6.7), the estimated seepage rate was not affected by the existence of the rainfall (Appendix D).

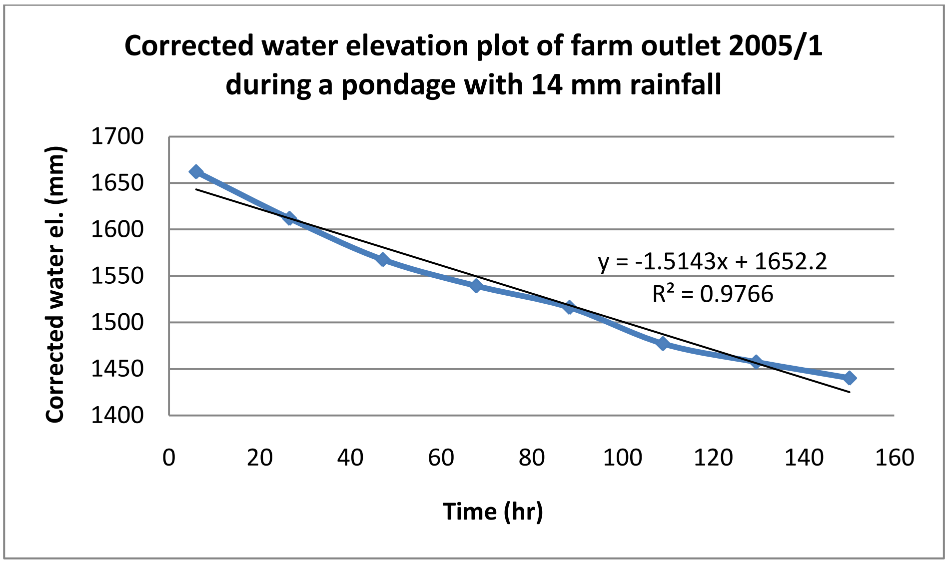


Figure 6.5 The estimated seepage rate not affected by the existence of rainfall due to low amount of 14 mm rainfall during a pondage condition on ARGOON 3-8, 2005/1 pool in 2009/10 season

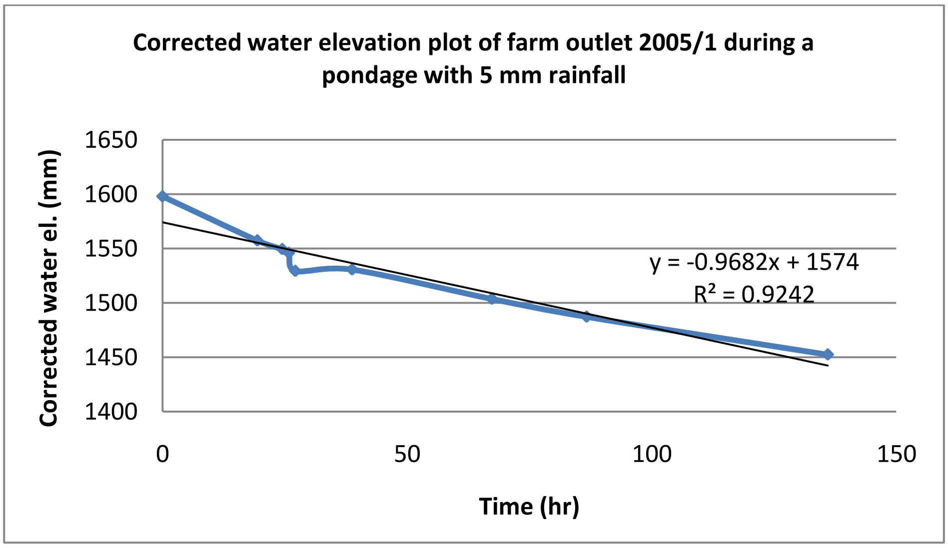


Figure 6.6 The estimated seepage rate not affected by the existence of rainfall due to low amount of 5 mm rainfall during a pondage condition on ARGOON 3-8, 2005/1 pool in 2009/10 season

From Figures 6.5 and 6.6 it can be seen that if sufficient number of measurements are available the occurrence of rainfalls up to 15 mm during a normal pondage condition (around 5 days) will have minimal effect the estimated seepage rate (Appendix D).

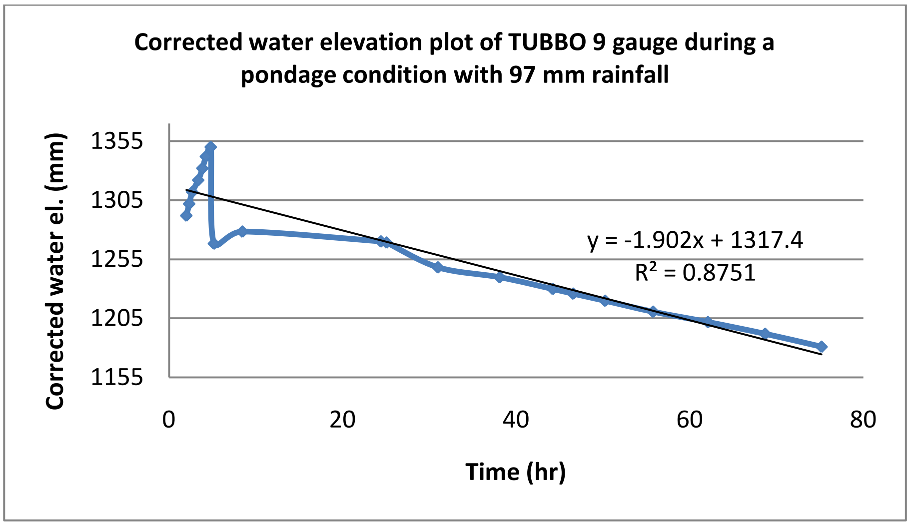


Figure 6.7 The estimated seepage rate not affected by the existence of 97 mm rainfall due to long duration of a pondage condition on TUBBO 8, 9 pool in 2010/11 season

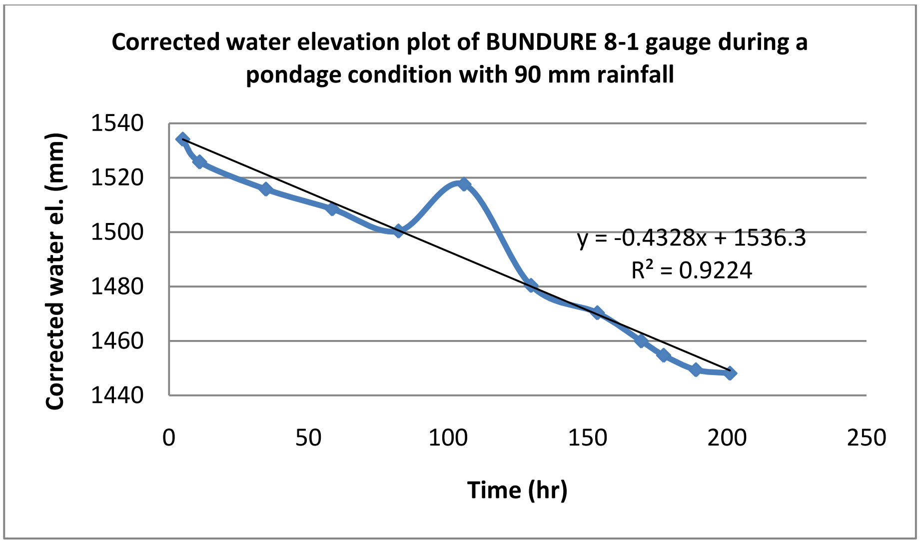


Figure 6.8 The estimated seepage rate not affected by the existence of 90 mm rainfall due to long duration of a pondage condition on BUNDURE 8-OT/ 8-1 pool in 2011/12 season

At the same time, whenever long enough pondage condition with considerable number of measured points after eliminating the rainfall effect was available (Figure 6.7) or the whole duration of pondage condition was very long (Figure 6.8), a considerable amount of rainfall up to 100 mm did not affect the estimated seepage rates (Appendix D).

6.2.2 Surface water elevation in the channel

It was anticipated that the seepage rate should be positively correlated with the depth of water in the channel. A detailed analysis of all pondage conditions in a number of pools was completed and the results of the analysis for all studied pondage samples showed that the maximum rate of seepage in each pool occured during a pondage sample starting at higher water levels in channel while the lowest estimated rate was related to samples starting at lower water elevations in the channel.

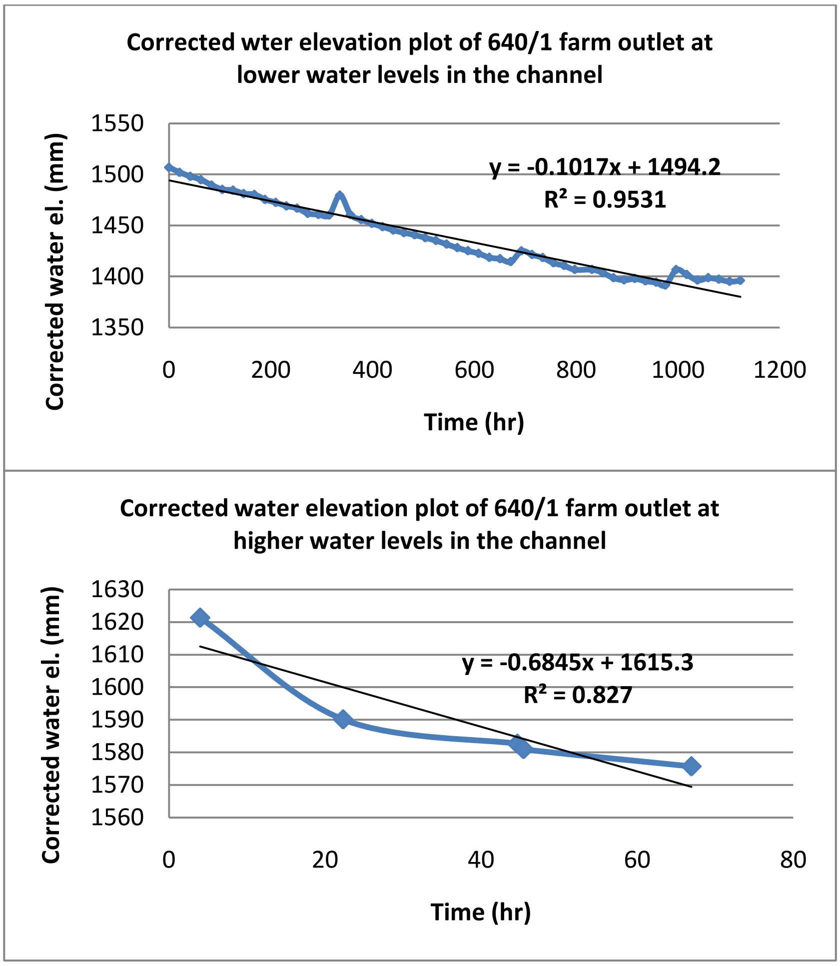


Figure 6.9 Initial water elevation effect on the estimated seepage rate of 640/1 farm outlet in BUNDURE 3-11, 3-12 pool during two pondage conditions in 2010/11 season

Figure 6.9 presents corrected water elevation plots of farm outlet 640/1 in BUNDURE 3-11, 3-12 pool during pondage conditions started at highest and lowest recorded channel water elevations compared to the channel supply level of 1789 mm. The estimated seepage rate for the pondage condition starting at the higher water elevation was higher compared to the estimated seepage rate of the other pondage condition (Appendix D).

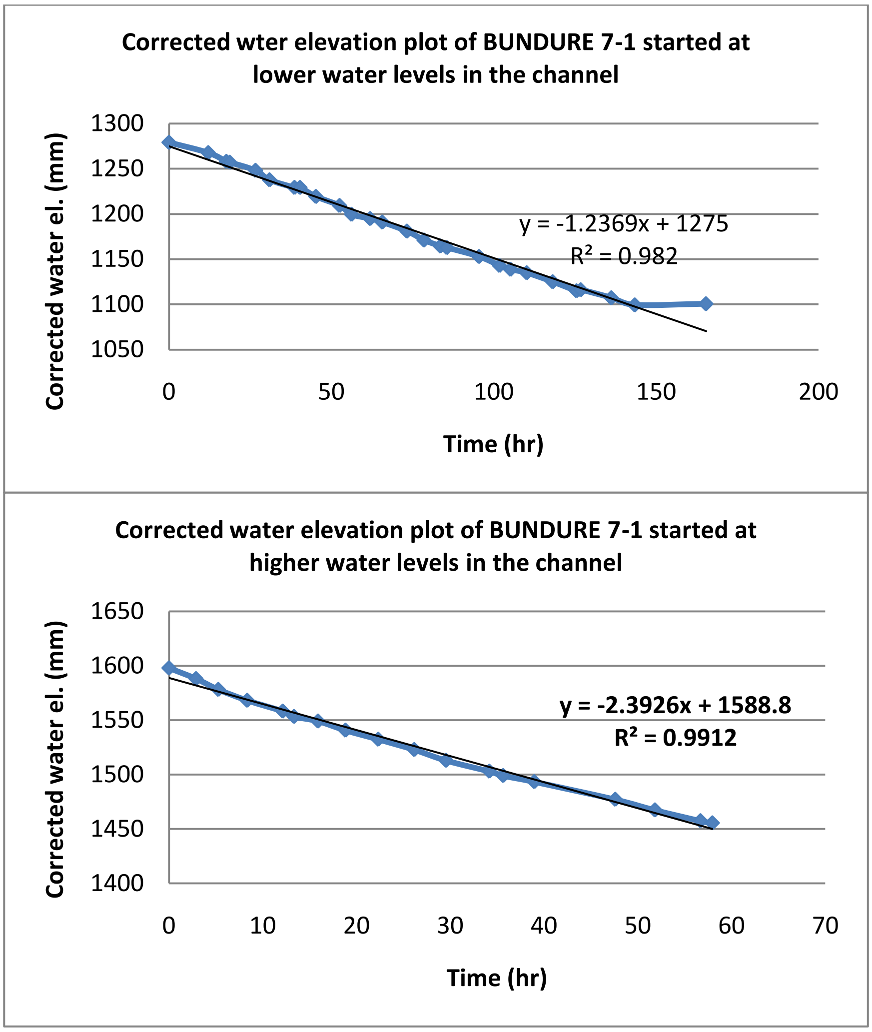


Figure 6.10 Initial water elevation effect on the estimated seepage rate of BUNDURE 7-1 gauge in BUNDURE 7OT, 7-1 pool during two pondage conditions in 2010/11 season

Figure 6.10 also shows a similar condition in BUNDURE 7OT, 7-1 pool during pondage samples with initial maximum and minimum recorded water elevations compared to a full supply level of 1708 mm at BUNDURE 7-1 gauge. The estimated seepage rate at the lower water elevation was almost half of the estimated seepage rate at the highest recorded water elevation (Appendix D).

6.2.3 Seasonal effect

It is believed that channel seepage increases with greater net available head (McLeod et al., 1994). Given the fact that water table elevation changes during different seasons, it is expected that seepage rates might decrease during winter when water table elevations are higher and increase in summer when water table elevations are lower.

Considering the observed variations of estimated seepage rates in different parts of the irrigation season, each season can be divided to three major periods including the initial, middle and the end periods of the season (Table 6.1).

Table 6.1 Distribution of months in different periods of each irrigation season

<table>
<tr><td rowspan="4">Initial</td><td>July</td></tr>
<tr><td>August</td></tr>
<tr><td>September</td></tr>
<tr><td rowspan="2">October</td></tr>
<tr><td rowspan="6">Middle</td></tr>
<tr><td>November</td></tr>
<tr><td>December</td></tr>
<tr><td>January</td></tr>
<tr><td>February</td></tr>
<tr><td rowspan="2">March</td></tr>
<tr><td rowspan="4">End</td></tr>
<tr><td>April</td></tr>
<tr><td>May</td></tr>
<tr><td>June</td></tr>
</table>

As previously introduced in Chapter 3, each irrigation season starts on the 30^{th} of June and ends at 29^{th} of June next year. The initial period of each irrigation season covers the last two months of winter and initial months of spring when water table elevations are higher and estimated seepage rates are expected to be lower. The middle period of each irrigation season is from the middle of spring till the end of summer when water table elevations below the channels are decreasing and consequently it is expected to have higher seepage rates during this period. In addition, the results of the investigation showed that in the majority of channels, water levels were approximately at operational elevations during this period. Finally the last period of each irrigation season starting at the end of summer and continuing towards the end of the irrigation season when water table elevations below the channels are increasing is expected to have lower seepage rates.

Figure 6.11 illustrates the difference between the estimated seepage rates in two pondage conditions, started in the initial and in the middle period of 2010 irrigation season in BUNDURE 5-4, 5-5 pool where the seepage rate for the initial period was lower compared to the one in the middle period (Appendix D). A closer look at Figure 6.11 shows that the initial water elevation in the pondage condition during the initial period is far lower than that for the middle period. At the same time the estimated seepage rate for the second pondage condition was re-estimated due to the occurrence of 45 mm rainfall.

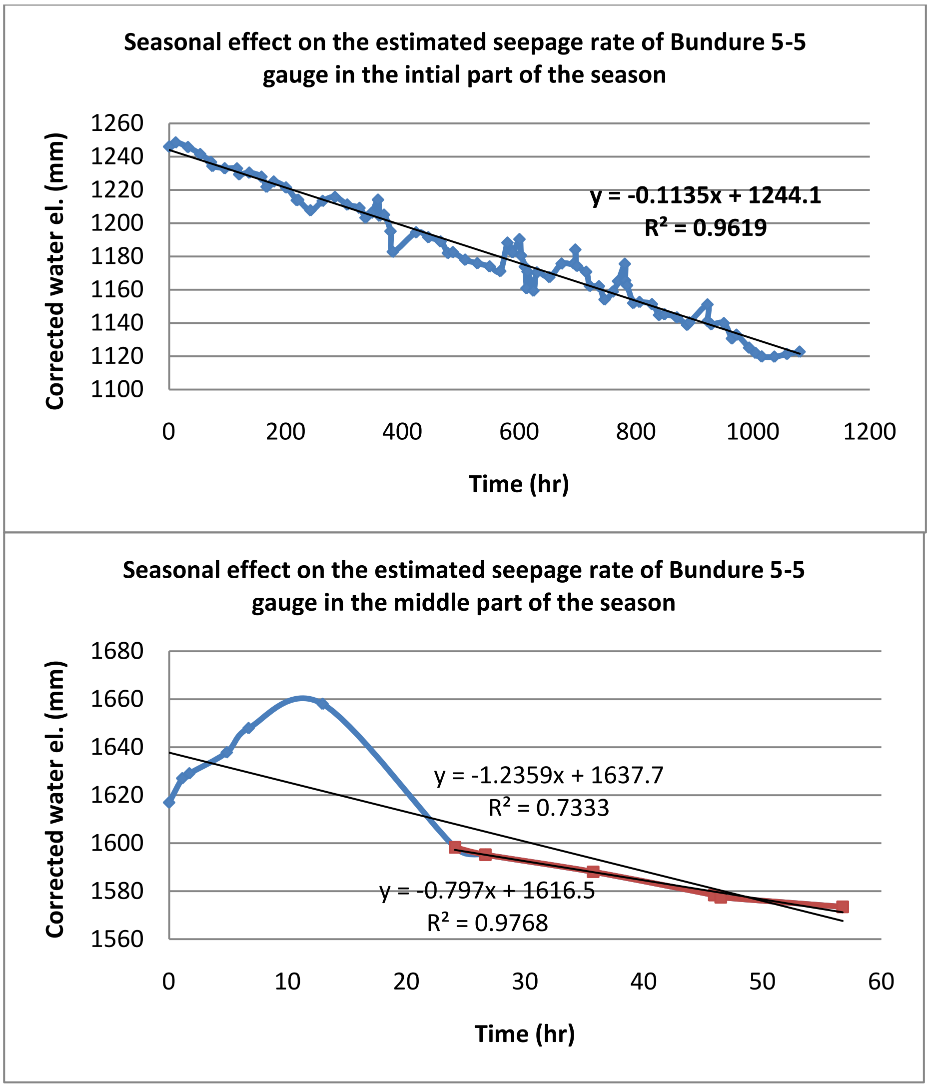


Figure 6.11 Seasonal effect on the estimated seepage rate of two pondage conditions in BUNDURE 5-4, 5-5 during the initial and the middle periods of 2010/11 irrigation season

Another example of two different pondage conditions occurring in the initial and in the middle period of 2010/11 irrigation season is illustrated in Figure 6.12 where the estimated seepage rate for the pondage condition that took place in the middle of the season was almost twice the magnitude of the seepage rate estimated at the initial period of the season. The gradual increase and sudden drop in the corrected water elevation plot during the mid October pondage condition is associated with the effect of 84 mm rainfall. Therefore, after re-estimating the seepage rate for the remaining part of the second pondage, the new seepage rate became equal with the estimated seepage rate during the initial period. The initial water elevation in the pondage condition during the initial period is far lower compared to the other initial elevation and the full supply level of 1723 mm (Appendix D).

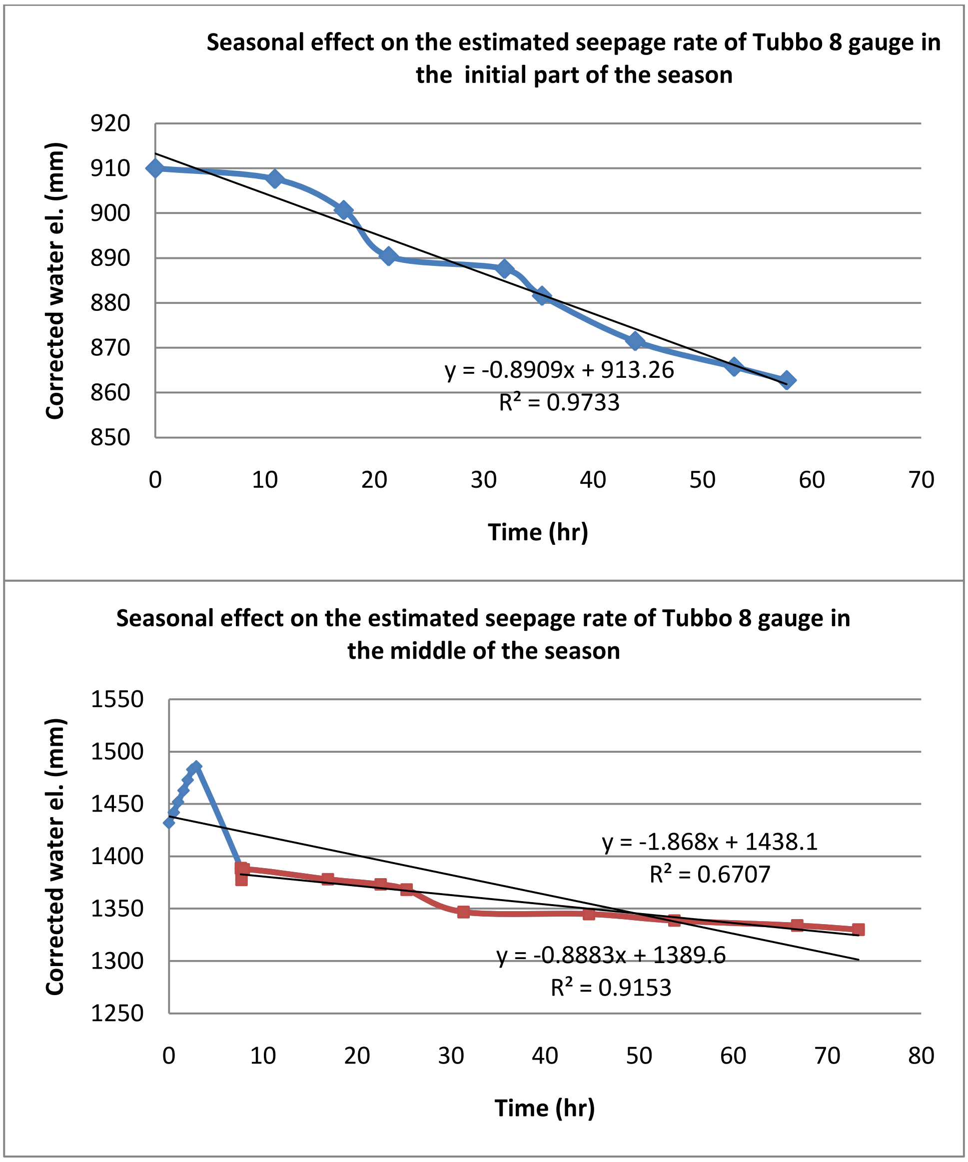


Figure 6.12 Seasonal effect on the estimated seepage rate of two pondage conditions in TUBBO 7, 8 pool during the initial and the middle periods of 2010 irrigation season

On the other hand, the estimated seepage rate in the beginning of the season is not always the lowest rate, especially when the initial channel water level is close to operational elevations.

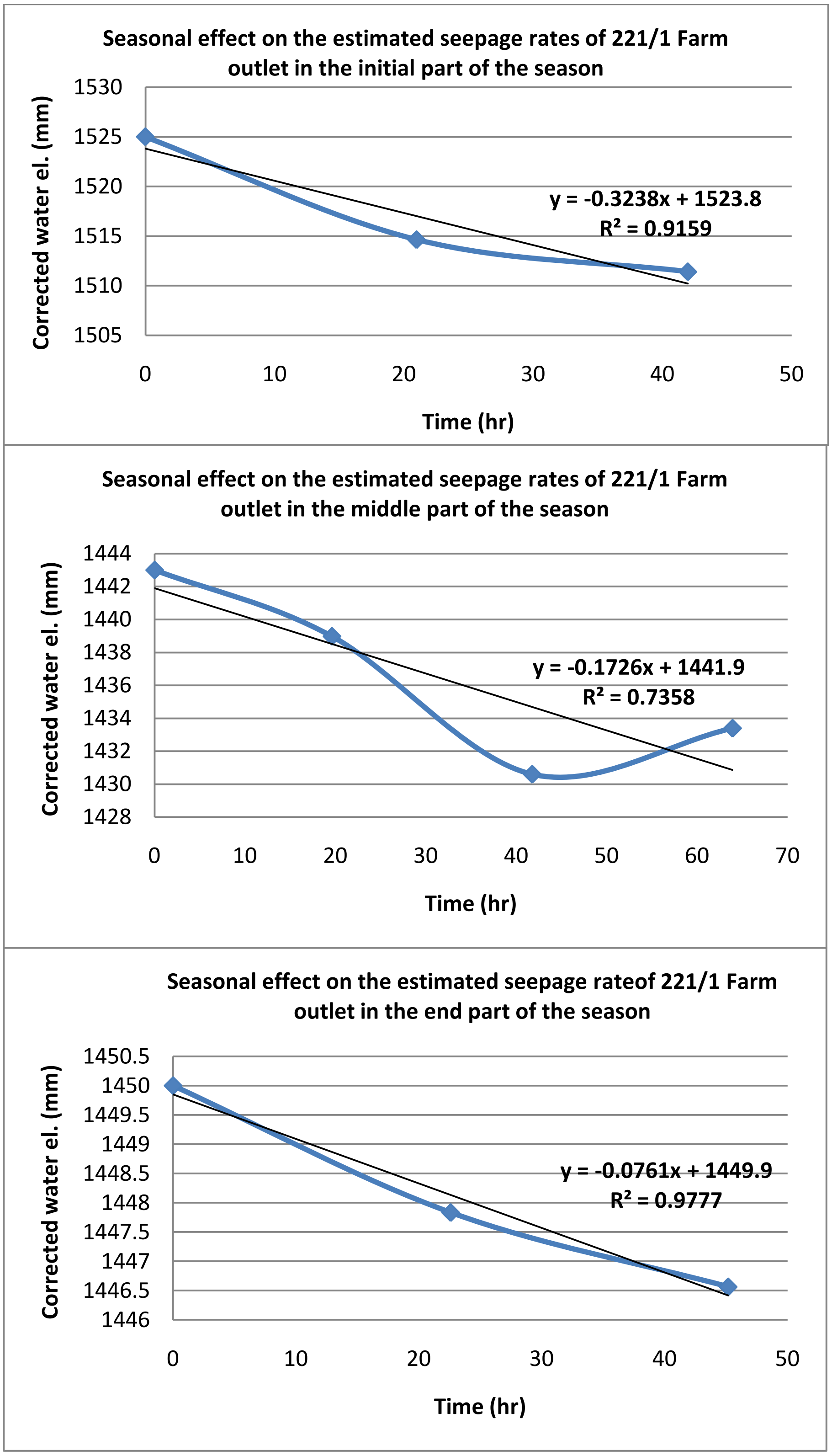


Figure 6.13 Seasonal effect on the estimated seepage rates in three pondage conditions occurred in TUBBO 6, 7 pool during the initial, middle and the end periods of 2010/11 irrigation season

An example of this situation is illustrated in Figure 6.13 where the initial water elevation in the channel during the pondage condition which occurred at the beginning period of the season is greater than the other two samples from the middle and towards the end of 2010/11 season on TUBBO 6, 7 pool. Subsequently the estimated seepage rate at the earliest pondage condition is greater than the other two rates. Moreover, the estimated seepage rate decreased towards the end of the season and reached the lowest rate in the last pondage condition occurred at late June 2011 (Appendix D).

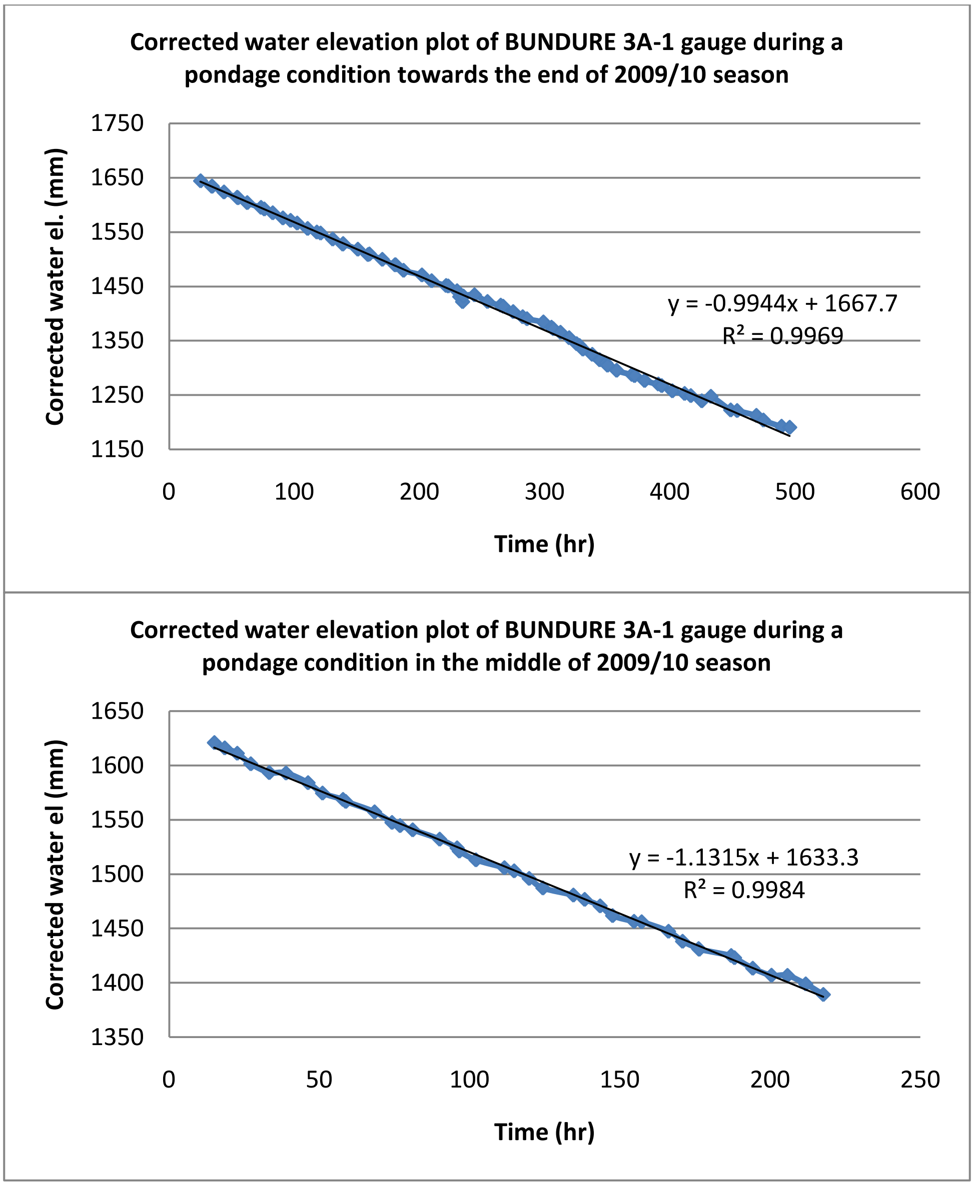


Figure 6.14 Seasonal effect on the estimated seepage rate of two pondage conditions in BUNDURE 3A O/T, BUNDURE 3A-1 pool during the middle and towards the end period of 2009/10 irrigation season

A comparison of estimated seepage rate during the middle and towards the end of the season is illustrated in Figure 6.14 where the seepage estimate for a pondage condition towards the end of the season was lower compared with a similar pondage condition occurring in the middle of the season.

6.2.4 Pondage condition duration

Another factor affecting the estimated seepage rates was the duration of the pondage condition.

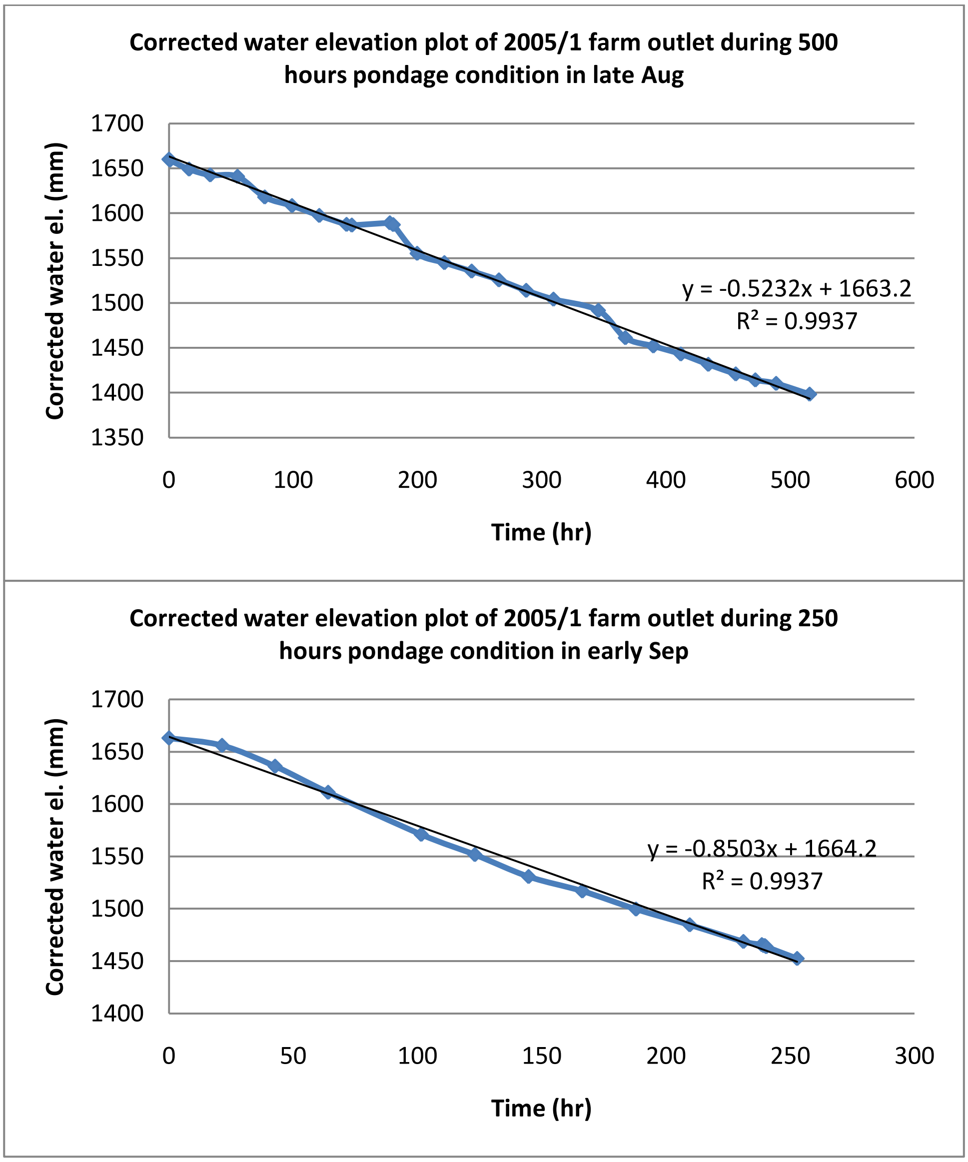


Figure 6.15 Duration effect on the estimated seepage rate of two pondage conditions in ARGOON 3-8, 2005/1 pool in 2010/11 irrigation season

Figure 6.15 shows two pondage conditions on ARGOON 3-8, 2005/1 pool starting at similar water elevations during similar periods of the 2010/11 irrigation season but with different durations. From Figure 6.15 it can be seen that duration of the pondage condition in September is approximately twice the duration of the August pondage. At the same time, the number of measured points in the September pondage was 27 and 16 for the August pondage condition. On the other hand, the estimated seepage rate for the August pondage condition was almost 60% higher than the rate estimated for September (Appendix D).

This was also repeated in the case of two long pondage conditions, started at similar water levels during October on BUNDURE 4-13, ESC 4 pool in 2009/10 irrigation season where the estimated seepage rate for the shorter pondage condition was almost twice the rate estimated for the longer pondage period (Figure 6.16). Similarly, the number of measured points was 55 for the longer pondage condition and 23 for the shorter one respectively (Appendix D).

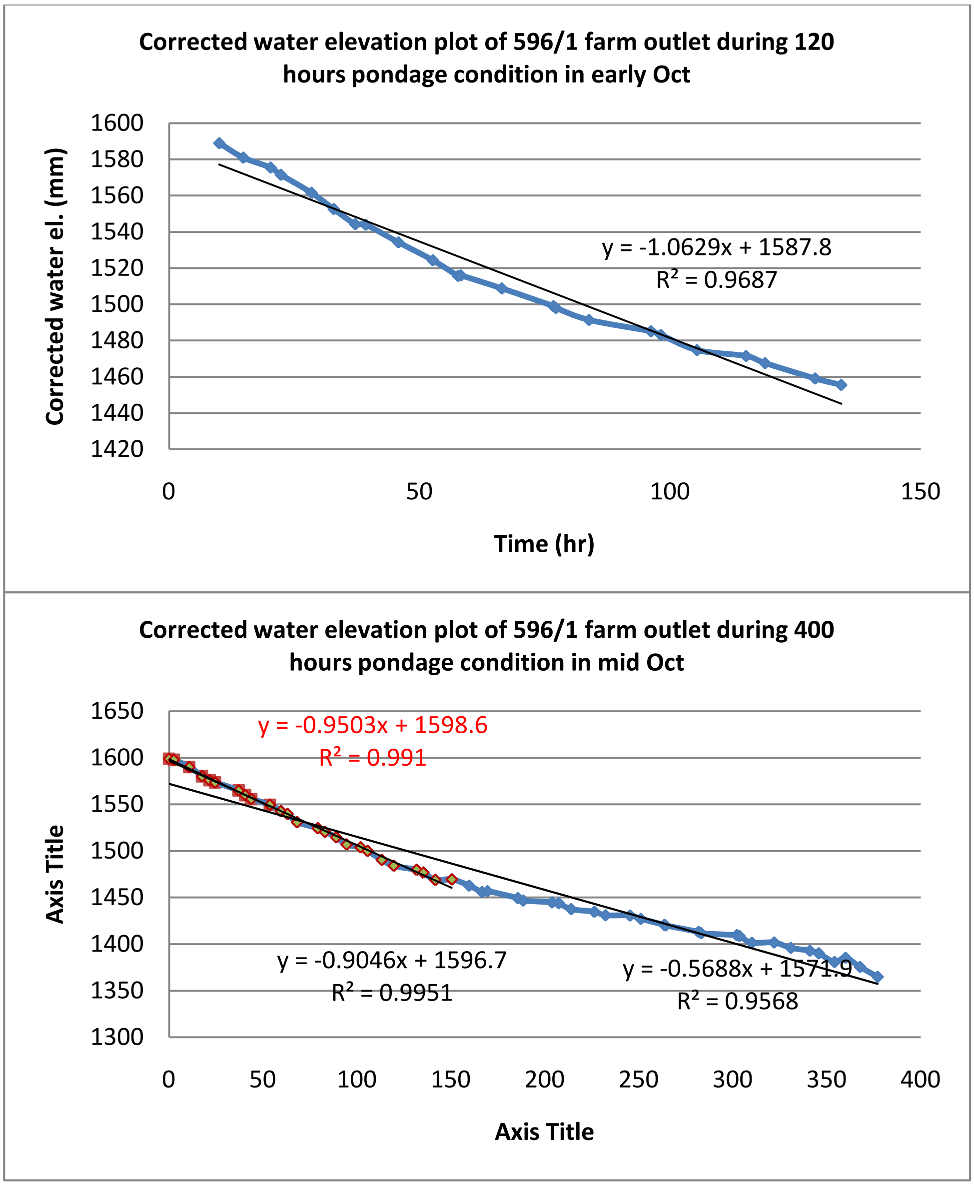


Figure 6.16 The effect of pondage duration on the estimated seepage rate of two pondage conditions in BUNDURE 4-13, ESC 4 pool during October of 2009/10 irrigation season

Furthermore, in order to evaluate the effect of pondage duration on the estimated seepage rate in a long pondage period, using the linear regression the seepage rate was estimated for the initial 60 and 150 hours and compared with the average seepage rate of the entire 380 hours pondage condition. It can be seen that the estimated seepage rate for the initial 60 and 150 hours pondage duration were 70 % and 60 % higher than the averaged seepage rate respectively. Comparison of the estimated seepage rates for the shorter pondage conditions and the whole pondage duration shows that the decrease in the water elevations in the longer pondage periods compare to shorter durations might be an explanation to the effect of pondage duration on the estimated seepage rate.

Results of the analysis suggest that the duration of a pondage condition has an inverse relationship with the estimated seepage rate while it has a direct relationship with number of measured points. Supposedly, between two pondage conditions occurred at similar channel water elevations during a same period of the season, it is expected to estimate lower rates of seepage for a longer pondage.

The effect of pondage duration on the estimated seepage rates in case of short pondage conditions can be substantial when number of measured points is small and variations between the estimates are high.

6.2.5 Number of measured points

Results of the detailed analysis of all pondage conditions revealed that water elevation measurements during shut down periods did not always commence exactly at the start and or finish exactly at the end of pondage conditions. This resulted in a smaller number of records and a water elevation record covering a shorter duration compared to the real pondage period which was a common problem in the majority of pondage samples less than 3 days (Figure 6.17). This was also highlighted as part of pondage duration effects on estimated seepage rate.

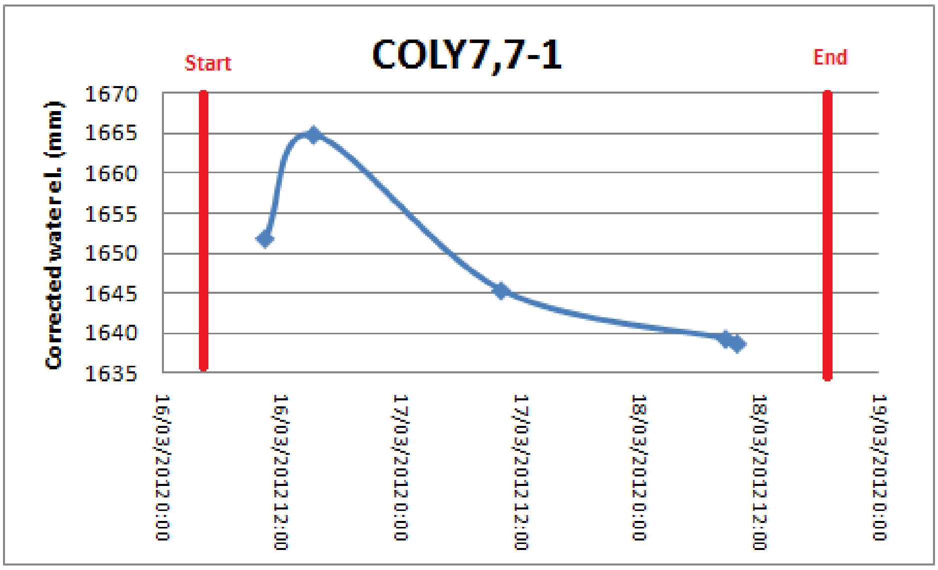


Figure 6.17 Water elevation measurements of COLY 7-1 gauge covering less duration compare to original pondage period with small number of measured points

However, some of the pondage conditions had a reasonable number of measured points despite the fact that they covered a shorter duration than original pondage period (Figure 6.18).

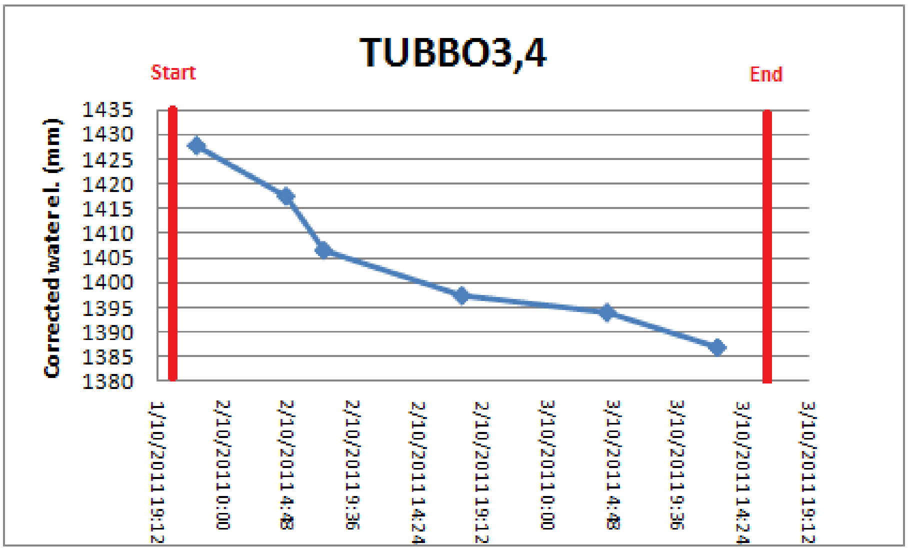


Figure 6.18 Water elevation measurements of TUBBO 4 gauge covering less duration compare to original pondage period with reasonable number of measured points

Therefore, it can be concluded that there is more confidence in estimated seepage rates in pondage conditions with high number of recorded points compared to samples with a lower number of recorded points. However, a high number of measurements do not always provide more confidence in a pondage condition as noise in the measurements may sometimes produce a large number of repeated elevations.

6.2.6 Noise associated with measurement devices

Analysis of the corrected water elevation plots highlighted the possible presence of a number of cases associated with potential noise in the measurement devices. Figure 6.19 presents an example of noise in water elevation measurements at BOONA 7 gauge in BOONA 8, 9 pool during a 44 hours pondage condition without any rainfall. As can be seen in Figure 6.19 the water elevation remained constant for half of the pondage duration and suddenly started to decrease rapidly (Appendix D). However, unauthorized water usage remains as another possible explanation for the rapid decline in the water elevation.

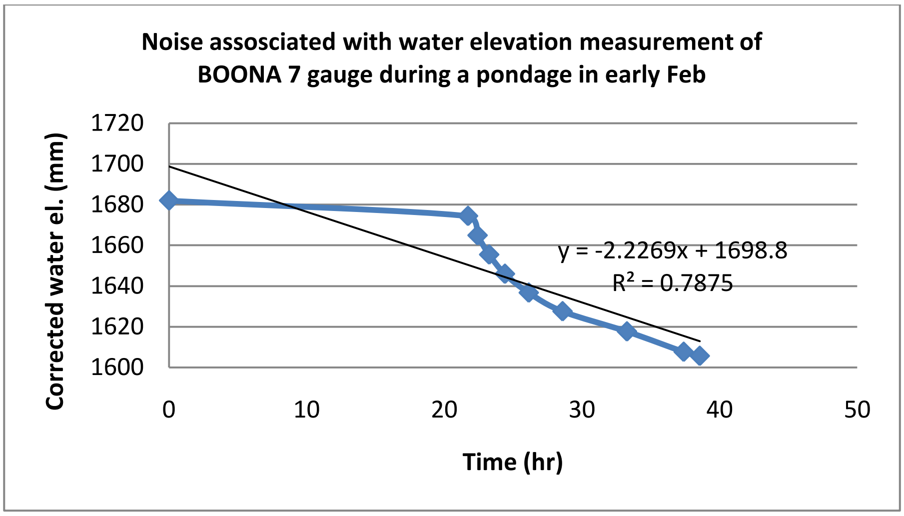


Figure 6.19 Noise associated with water elevation measurements of BOONA 7 in BOONA 8, 9 pool during a pondage condition without any rainfall

This was also observed during a pondage condition in late November 2010 in COLY 5, 5-1 pool as illustrated in Figure 6.20 where a considerable number of measurements were recorded in less than 10 hours (Appendix D). The question remains whether it can be related to the measurement device, a high possible leakage in the channel or it could be related to an unauthorized water usage.

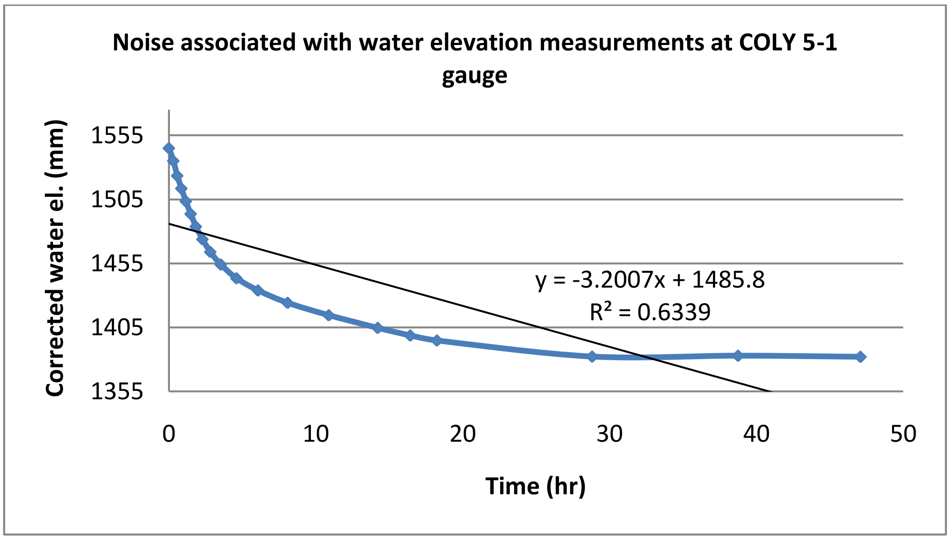


Figure 6.20 Noise associated with water elevation measurements of COLY 5-1 in COLY 5, 5-1 pool during a pondage condition without any rainfall

At the same time, noise was also observed in some other cases where a considerable number of measurements of repeated elevations were recorded for several times (Figure 6.21) (Appendix D).

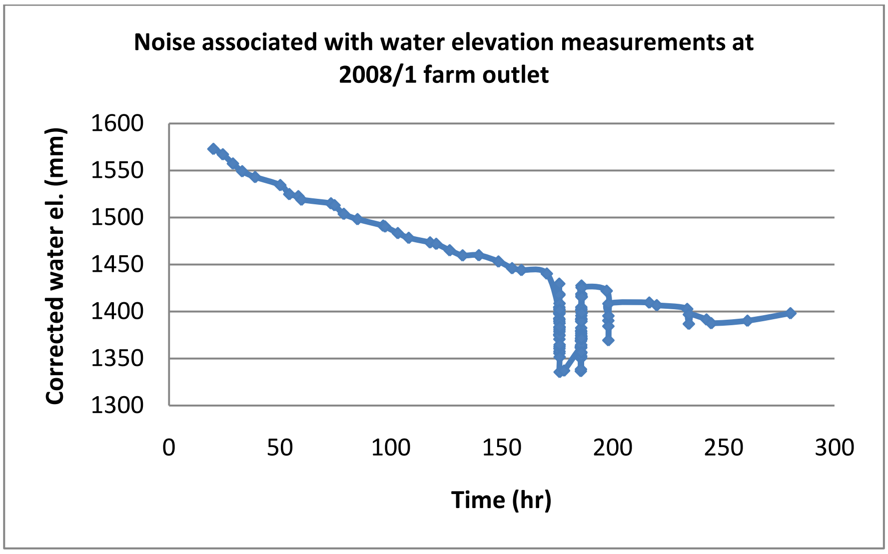


Figure 6.21 Noise associated with water elevation measurements of 2008/1 farm outlet in YAMMA 4-7, ESC 4 pool during a pondage condition without any rainfall in 2009/10 season

Error in the measurements was also observed at lower water elevations in the channel mostly at the beginning of the season where the recorded water elevations for some of gauges in the pool were equal to zero. This might be due to the lower elevation of surface water compare to the sensors level at some of gauges resulting in sensors being put out of the water and assuming no water was available in the measurements.

6.2.6.1 Noise in rejected samples

Apart from the highlighted noises in accepted group of pondage conditions, noises associated with measurement devices were also observed in some unexplainable and unusual plots in the rejected pondage conditions. In many cases this noise is the probable cause of the ponding condition being rejected.

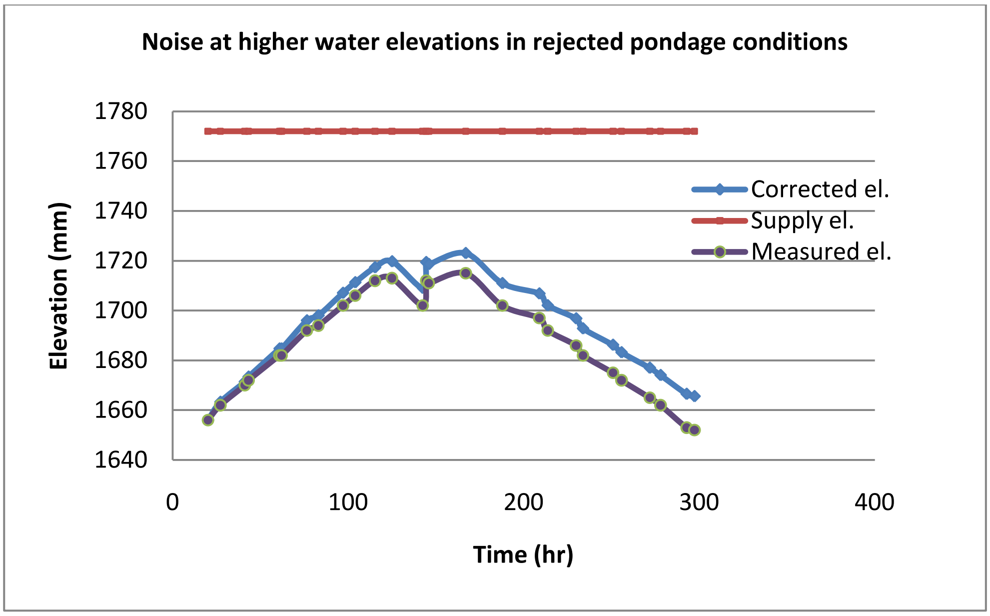


Figure 6.22 Noise associated with water elevation measurements of 182/1 farm outlet in YAMMA 1, 2 pool during a pondage condition without any rainfall in 2009/10 season

Figure 6.22 shows an example of an unusual water elevation plot at higher water levels in the channel during a pondage condition without any rainfall. The pool consists of 5 gauges where all of them had similar water plots during the pondage period (Appendix D).

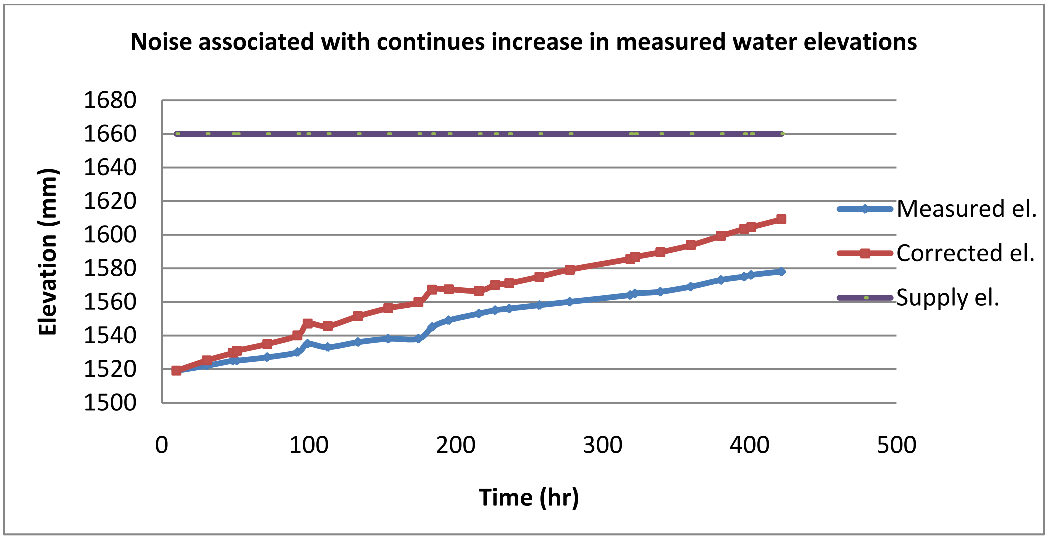


Figure 6.23 Noise associated with continuous increase in measured water elevations

Another common situation observed in majority of rejected pondage samples was the point that the measured water elevations continuously increased during the entire pondage period. Figure 6.23 shows the measured and corrected water elevations of TUBBO 12 gauge in TUBBO 11, 12 pool during a pondage condition with 10 mm rainfall where the measured water elevations continued to rise for the entire pondage duration (Appendix D).

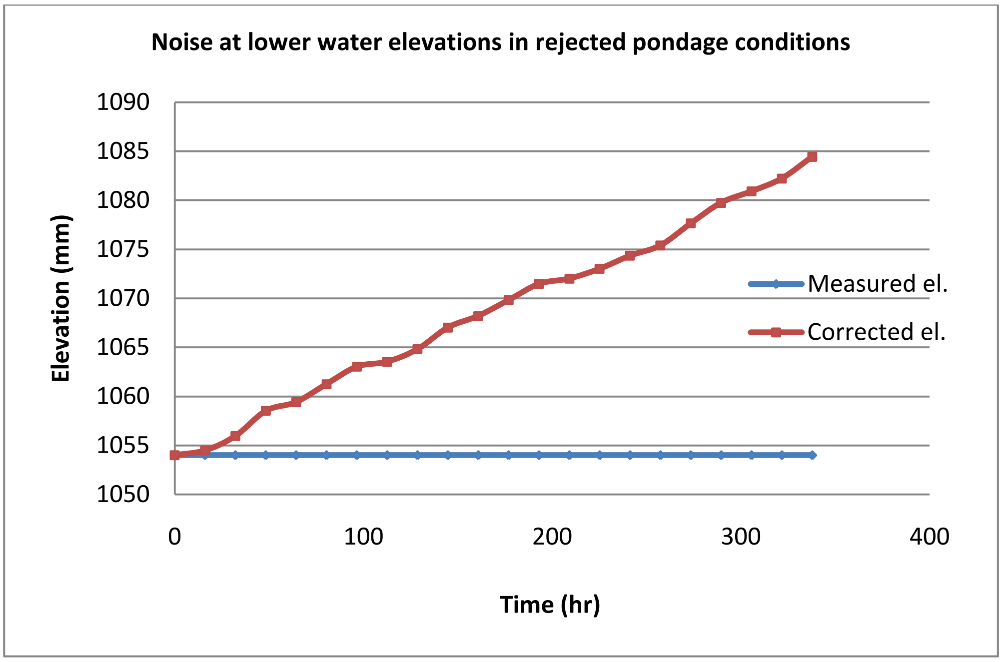


Figure 6.24 Noise associated with continuous increase in measured water elevations

Another common situation observed in majority of rejected pondage samples was where the measured elevations were constant during the entire pondage period. This suggests that the water level is below the bottom of the sensor and has nothing to do with noise in the system. However, in some cases based on the measured water elevation database, lower elevations were measured by sensors. An example is presented in Figure 6.24 where the measured elevation at YAMMA 2 gate remained constant at 1055 mm. However, the minimum measured water elevation at this gate based on the database was 450 mm which makes Figure 6.24 unexplainable.

6.2.7 Possible leakage

Another possible factor affecting the rate of seepage in different channels was the possible existence of macro pores in the bank of channels resulting in a high rate of water loss via leakage. This suggests that high rates of water loss at high water elevations in any given channel might be due to possible leakage.

A full detailed analysis of all pondage conditions was done and samples with high rates of water loss in different channels were identified. Results of the analysis showed that all high rates of water loss occurred at water elevations close to full supply level of different channels. However, the ideal curve of seepage rate showing a rapid rate of water loss via leakage at the beginning of the pondage condition was only observed in some of the pondage conditions that had a sufficient number of measured points as well as long enough pondage durations (Table 6.2). Furthermore, in a pool with several pondage conditions at high water elevations, the longer pondage condition might have a lower estimated seepage rate as the result of duration effect in compare with other pondage conditions. However, the long pondage conditions with high number of measured points at higher elevations close to full supply level in any given channel are of interest for any possible leakage detection.

Table 6.2 Identified pondage condition with possible leakage

No.	Pool	Season	Start date	End date	Estimated seepage rate with linear regression (mm/d)
1	TUBBO OFFTAKE, BOONA	2009	22/05/2010 21:01	25/05/2010 6:05	32.40
2	BUNDURE MAIN-13, 14	2009	23/09/2009 18:27	7/10/2009 7:27	34.08
3	BUNDURE 4-1, 4-2	2009	9/06/2010 19:52	28/06/2010 9:31	21.12
4	COLY 9C-1, 9C-3 ESC	2009	2/11/2009 13:15	4/11/2009 9:19	37.20
5	BUNDURE 1-1, ESC BUNDURE 1	2009	26/04/2010 10:40	29/04/2010 16:54	83.93
6	BUNDURE 4-13, ESC 4	2009	16/10/2009 15:52	3/11/2009 0:42	13.68
7	BUNDURE 4-13, ESC 4	2009	5/10/2009 13:24	10/10/2009 17:32	25.44
8	YAMMA 1A-5, 1A-6	2009	30/09/2009 18:45	6/10/2009 3:04	21.36
9	BUNDURE 7-1, 7-2	2009	28/05/2010 20:41	28/06/2010 6:17	19.44
10	BUNDURE MAIN-17, ESC 2	2010	21/09/2010 18:00	10/10/2010 21:23	23.52
11	BUNDURE 7 O/T, 7-1	2010	5/11/2010 18:59	8/11/2010 4:57	57.36
12	TUBBO1,2	2011	22/03/2012 10:49	26/03/2012 4:11	126.24

Figure 6.25 shows the corrected water elevation plot for one of the gauges in BUNDURE 7-1, 7-2 pool during a pondage condition identified with possible leakage started at higher water levels in the channel compared to full supply level of 1690 mm (Appendix D).

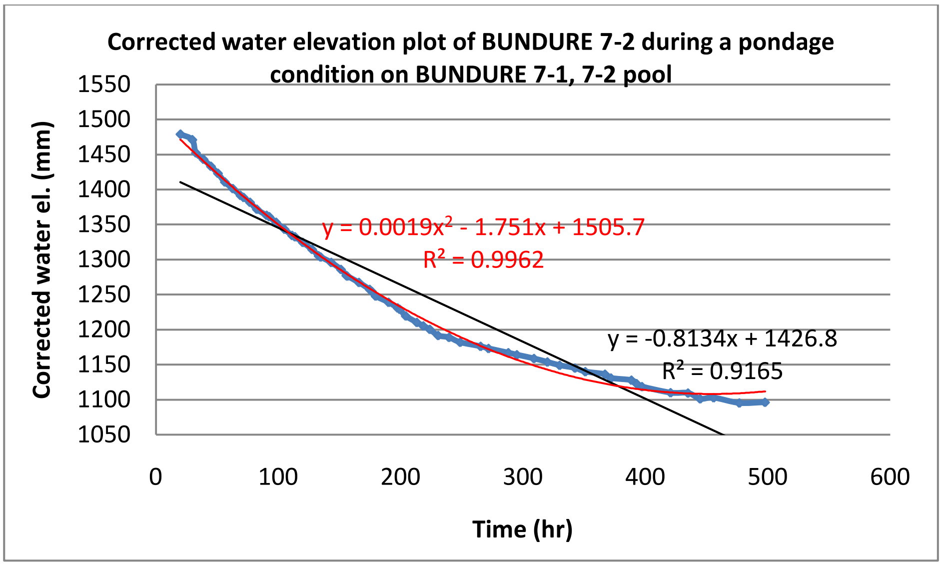


Figure 6.25 Possible leakage identified at BUNDURE 7-2 gauge during a pondage condition on BUNDURE 7-1, 7-2 pool in 2009/10 season

It can be seen from Figure 6.25 that the seepage rate did not remain constant during the pondage period and the corrected water elevations dropped rapidly in the initial part of the plot followed by a gradual decline in the elevations. Basically the sharp initial drop in corrected water elevation plot is due to leakage which is followed by a gradual decline that is due to seepage (Figure 2.7). Therefore, in order to find the most suitable trend line to model the water loss, a polynomial trend line was also applied to the corrected water elevation data. It can be said that polynomial trend line is more suitable to model the channel seepage in this case which is similar to the ideal seepage curve.

The variations of estimated seepage rate using the polynomial trend line at different water elevations at BUNDURE 7-2 gauge shows that the maximum seepage rate occurred at the highest water elevation and decreased gradually at lower water elevations (Figure 6.26).

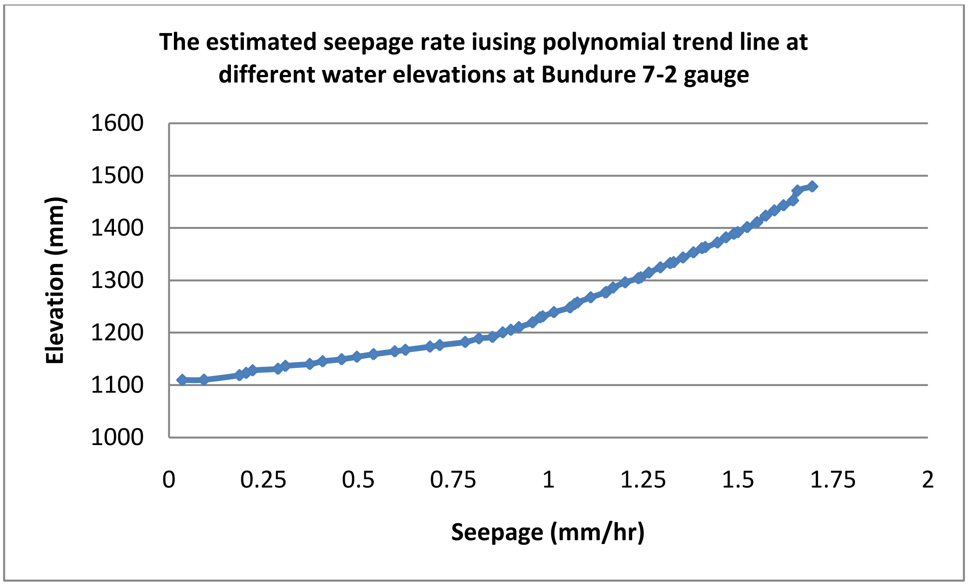


Figure 6.26 The estimated seepage rate using the polynomial trend line at different water elevations at BUNDURE 7-2 gauge

At the same time, the variation of the estimated seepage rate showed a linear association with different times of the pondage period (Figure 6.27).

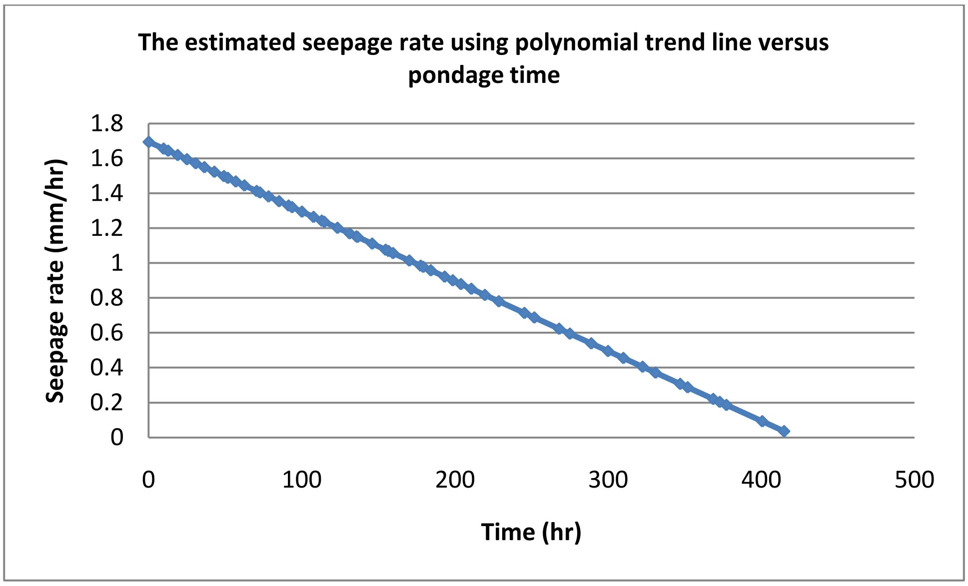


Figure 6.27 Linear variation of the estimated seepage rate using the polynomial trend line against time

Another example of a pondage condition with high rate of water loss is illustrated in Figure 6.28 where the estimated seepage rate via linear regression highlighted a high rate of water loss during this pondage condition (Appendix D). Similar to the previous plot, variable water loss rates were observed during the pondage period. Given the fact that the pondage condition happened at high water levels compared to the full supply level of 1717 mm in the channel, this high rate of water loss might be due to possible leakage as well as possible unauthorized water usage. At the same time, considering the form of the plot and different water loss rates during the pondage period, a polynomial trend line was also applied to the corrected water elevation data and compared with the linear regression model. Similarly, the polynomial trend line is seen to be more suitable to model channel seepage in this case.

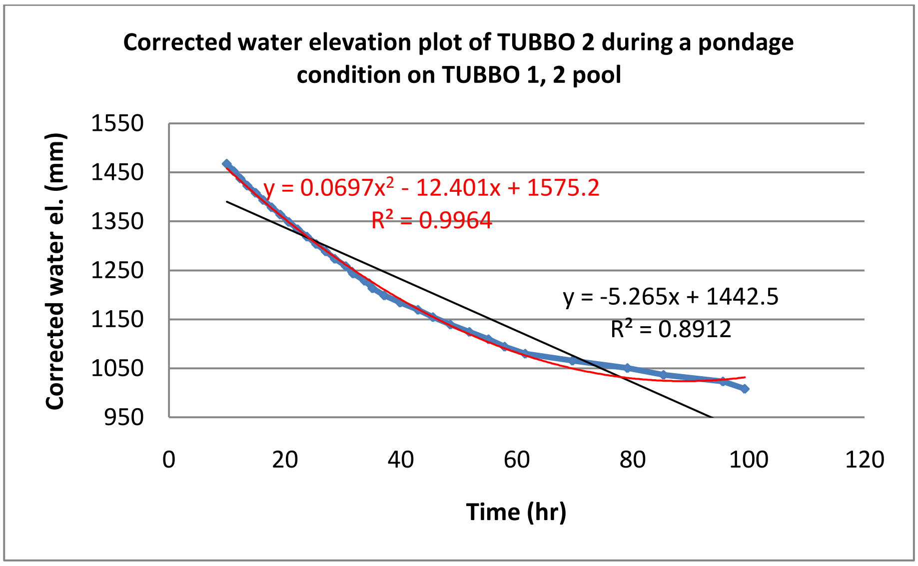


Figure 6.28 Possible leakage identified at TUBBO-2 gauge during a pondage condition on TUBBO 1, 2 pool in 2011/12 season

This was also observed in another pondage condition where possible leakage was suspected and where the polynomial trend line was seen to be more suitable to model the seepage similar to the previous condition (Figure 6.29) (Appendix D).

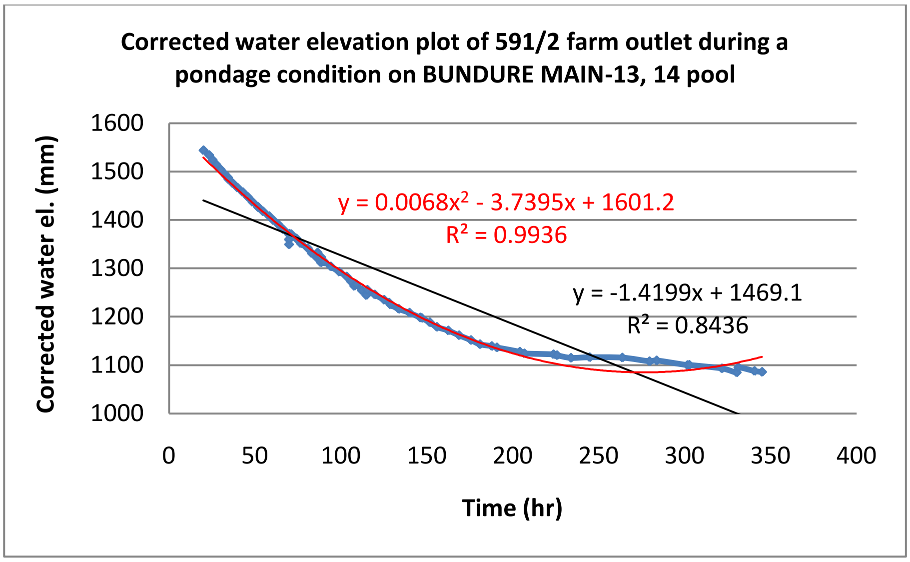


Figure 6.29 Possible leakage identified at 591/2 farm outlet during a pondage condition on BUNDURE MAIN-13, 14 pool in 2009/10 season

The variation plot of the estimated seepage rate by polynomial trend line at different water elevations highlighted the maximum rate of 3.5 mm/hr at the highest water elevation followed by a gradual decline at lower water elevations (Figure 6.30). Similarly, the variation of the seepage rate showed a linear decline during the pondage period (Figure 6.31).

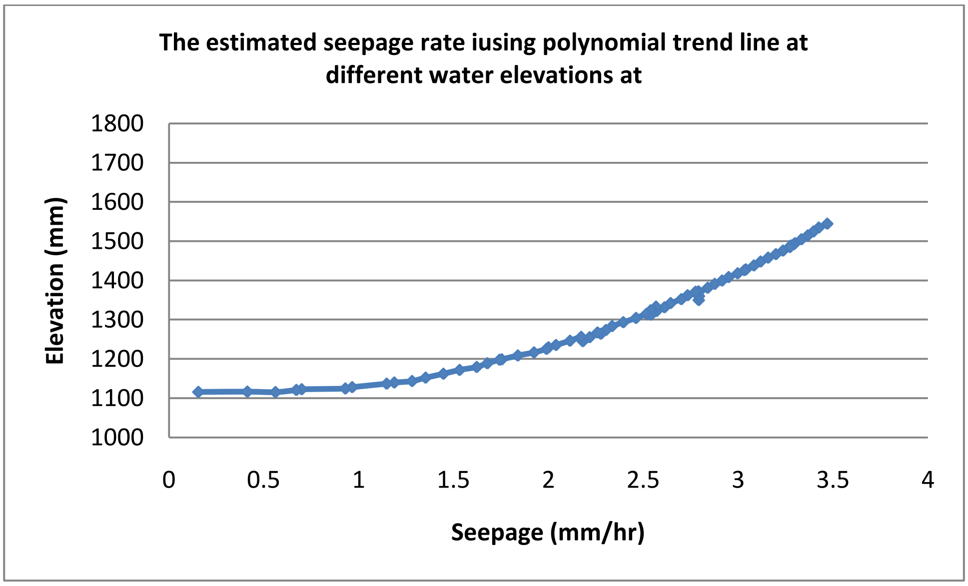


Figure 6.30 The estimated seepage rate using the polynomial trend line at different water elevations at 592/1 farm outlet

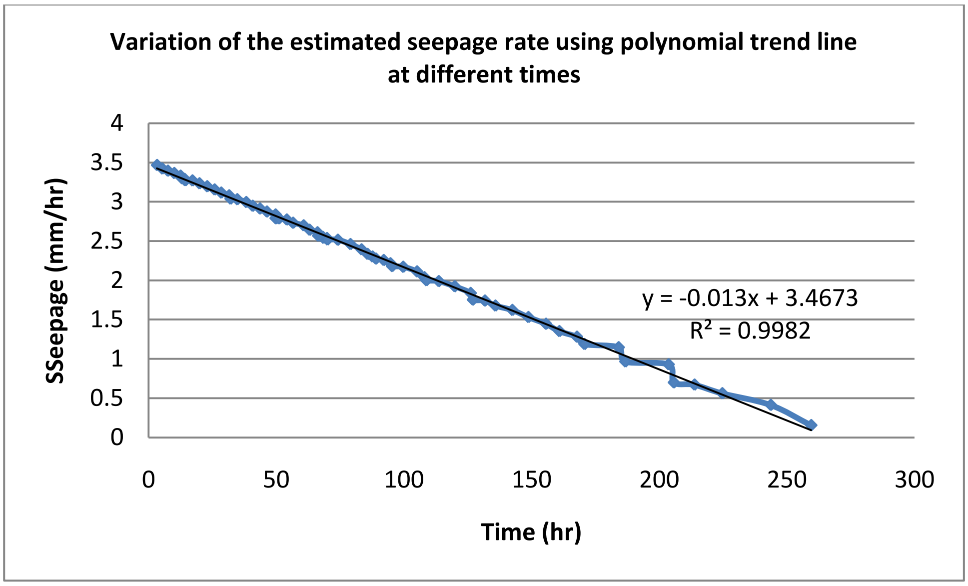


Figure 6.31 Variations of the estimated seepage rate at 591/2 farm outlet using the polynomial trend line at different times

6.2.8 Possible sources of uncertainty

Potential sources of error lie in seepage estimates resulted from TCC data. The first is the uncertainty in TCC flow measurements. This uncertainty is estimated to be ±5% prior to 2007/08 when pressure sensors were used in Flume gates and ±2.5% once the ultrasonic sensors were installed, verified by Manly Hydraulics Laboratory (Rubicon, 2013). The second source of the uncertainty is the potential error in TCC water level measurements. Maximum and minimum sensor levels are defined for each channel in the TCC system. Lower water elevations compared to the sensor's level result in sensors being put out of the water and assuming no water was available in the measurements. Similarly, higher water elevations result in sensors being drowned in the water and assuming water is kept at the fixed maximum elevation. Uncertainty in evaporation measurements (including uncertainty in wind speed, net radiation and air temperature) is another potential error in seepage estimates resulted from water balance approach. A greater uncertainty is the Penman-Monteith estimate itself and the fact that it ignores advected energy in the dry air blowing over the channel, resulting in a significant underestimate of evaporation on some days.

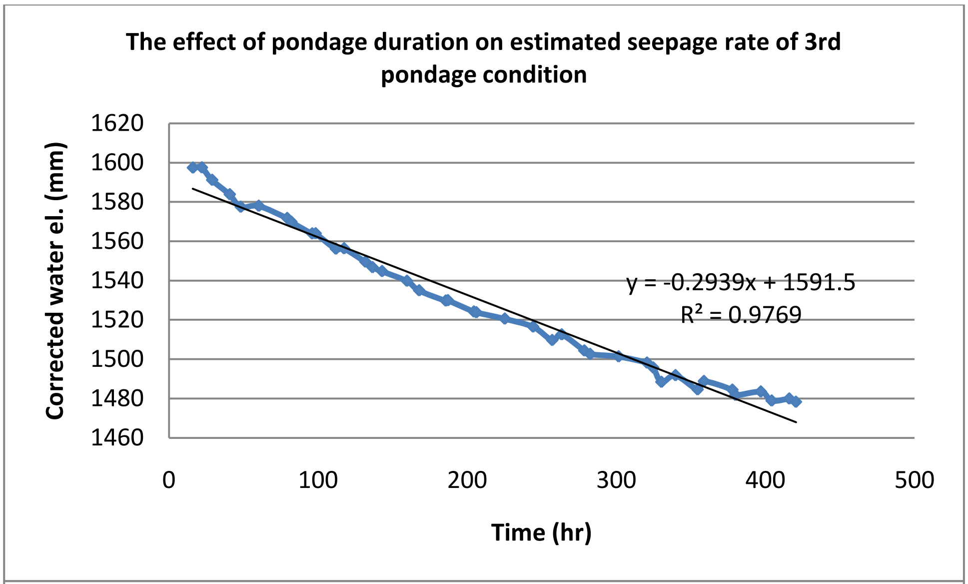
6.3 Interpretation of different seepage rates in any given pool

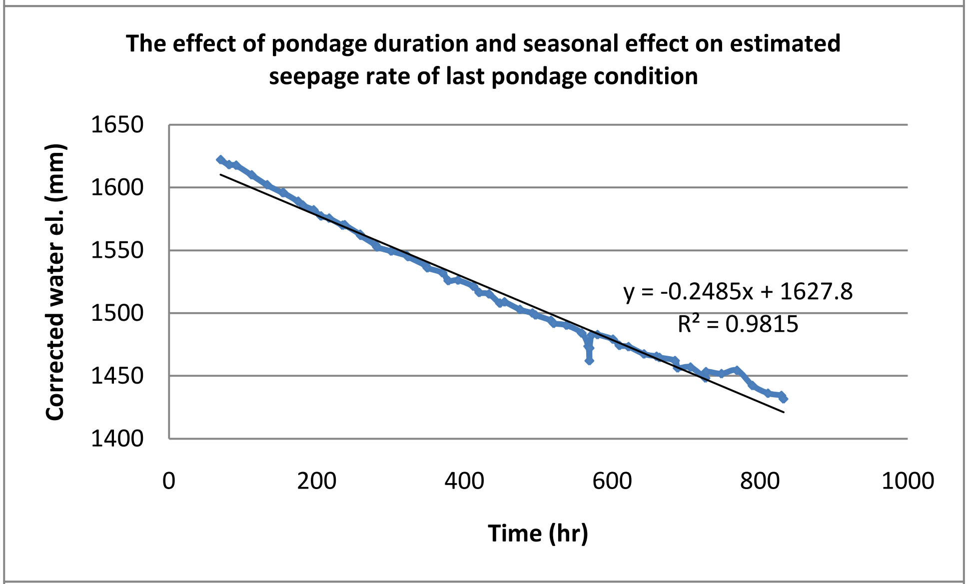
Based on all the causal factors described in the previous section, it is assumed that the variation in the estimated seepage rates for different pondage conditions in any given pool can be interpreted. Table 6.3 illustrates the estimated seepage rates as well general characteristics of all pondage conditions in the TUBBO 10, 11 pool during the 2009/10 irrigation season.

The data in Table 6.3 shows that no pondage condition occurred in the beginning period of the season at low levels of the channel. Furthermore, apart from the last pondage sample that took place during the end period, the rest of the pondage conditions occurred during the middle period. The highest rate of seepage was for the pondage condition which occurred at the highest water elevation in the channel. The effect of pondage duration on the estimated seepage rate can be seen in the 3rd pondage sample where the estimated seepage rate has decreased compared to other pondage conditions which took place at lower water levels (Figure 6.32). With the seasonal effect as well as the longer pondage duration coinciding, a lower seepage rate was estimated for the last pondage condition compared with the 3rd pondage sample which took place at a similar water elevation in the channel (Figure 6.32).

Table 6.3 General characteristics of all pondage conditions on TUBBO 10, 11 pool during 2009/10 season

Pondage Condition	Start	End	Priority	Seepage (mm/hr)	No. Points	Max EL (mm)	Supply EL (mm)	Duration (hr)
1	23/10/2009 13:10	29/10/2009 9:04	1	0.27	10	1555	1732	140
2	2/11/2009 8:01	20/11/2009 9:31	1	0.19	32	1513	1732	434
3	26/11/2009 8:31	14/12/2009 9:26	1	0.32	30	1627	1732	433
4	18/12/2009 8:53	21/12/2009 15:02	1	0.19	5	1365	1732	78
5	23/12/2009 14:11	30/12/2009 9:19	1	0.26	12	1375	1732	163
6	2/01/2010 8:01	5/01/2010 9:40	1	0.44	5	1539	1732	74
7	11/01/2010 12:14	13/01/2010 19:00	1	0.72	5	1598	1732	55
8	20/01/2010 7:59	24/01/2010 9:27	1	0.91	10	1668	1732	97
9	28/01/2010 16:38	3/02/2010 9:02	1	0.43	11	1583	1732	136
10	6/03/2010 21:57	10/03/2010 7:55	1	0.60	8	1640	1732	82
11	27/05/2010 8:44	28/06/2010 20:30	1	0.25	45	1622	1732	756
Pool rate (mm/hr)				0.34				





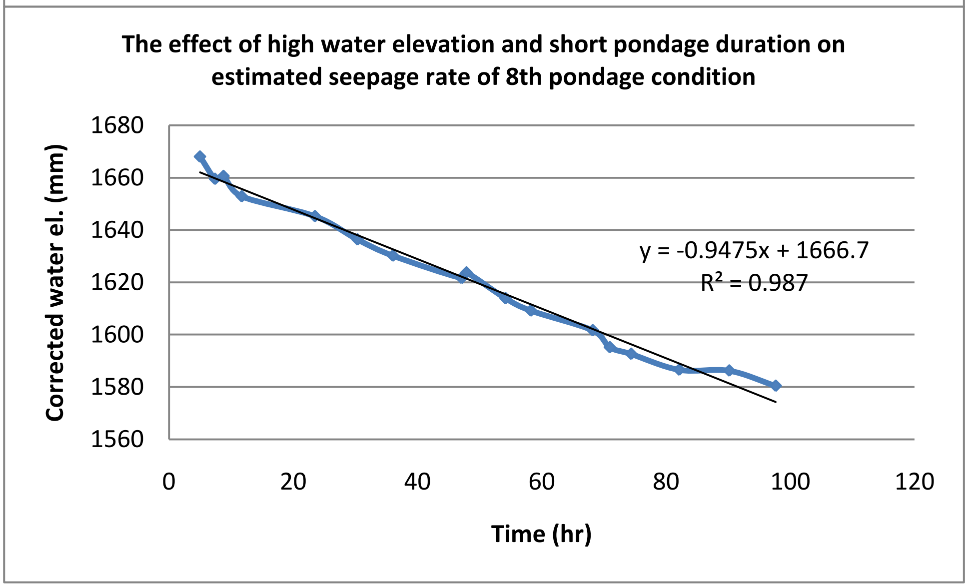
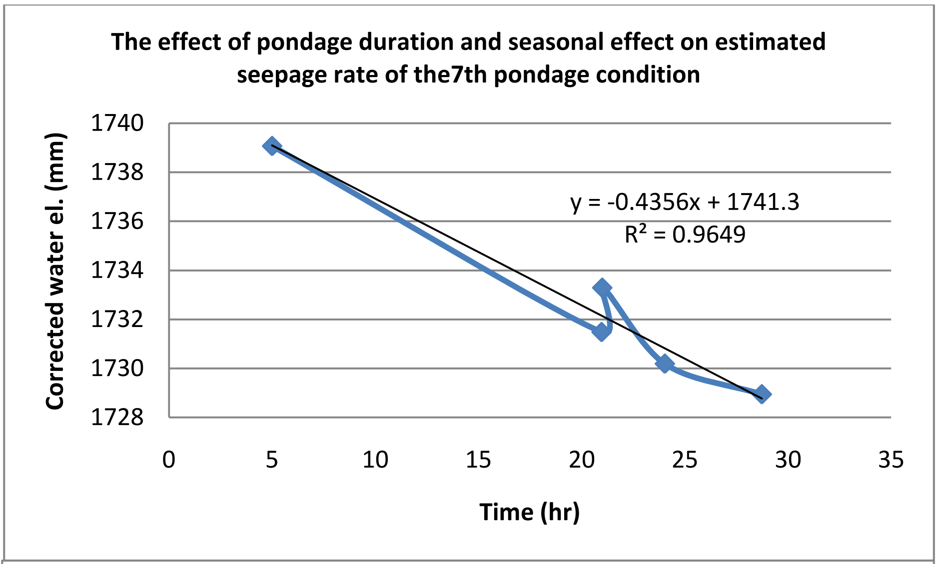


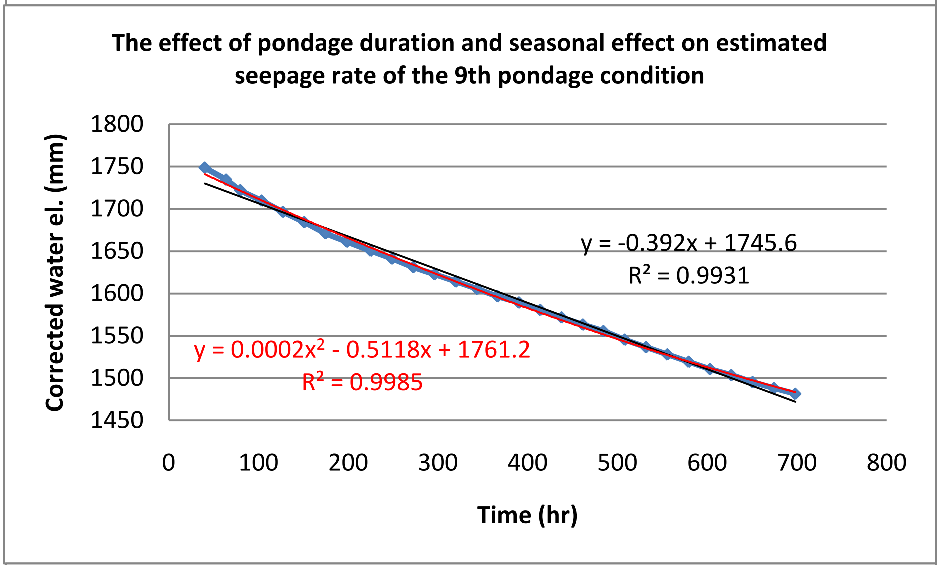
Figure 6.32 Corrected water elevation plots of TUBBO 11 gauge during 3 pondage conditions on TUBBO 10, 11 pool, occurred at higher water elevations in the channel (Appendix D)

Another example of a pool with several pondage conditions at high water levels in the channel is provided in Table 6.4. According to the information in Table 6.4, four pondage conditions which occurred at high water elevations in the channel can be highlighted. The first pondage condition had the highest water elevation compared to other samples, while as a result of the coincidence of the seasonal affect (being during the initial period of the season) and pondage duration, the lowest seepage rate was estimated for this pondage condition (Figure 6.33). At the same time, a higher estimated seepage rate for the 5th pondage condition might be due to it being in the middle of the season. The estimated seepage rate for the 7th pondage condition (that occurred in the middle of the season) was slightly higher than the 5th sample which might be due to the shorter pondage period. Finally the lower estimated seepage rate for the 9th pondage condition compared with the 7th sample might be due to pondage duration effect as provided in Figure 6.33. From the operational prospective it can be said that, although the highest rate was estimated for the 7th sample but considering the longer pondage period as well higher number of measured points the 9th sample might present the normal operational condition in the pool.

Table 6.4 General characteristics of all pondage conditions on TUBBO 4OT, 2026 pool during 2011/12 season

Pondage Condition	Start	End	Priority	Seepage (mm/hr)	No. Points	Max EL (mm)	Supply EL (mm)	Duration (hr)
1	19/08/2011 22:50	1/09/2011 5:34	1	0.27	20	1753	1785	295
2	5/09/2011 1:33	7/09/2011 7:22	1	0.23	3	1608	1785	54
3	16/09/2011 1:39	21/09/2011 8:34	1	0.26	7	1644	1785	127
4	29/09/2011 1:42	6/10/2011 9:40	1	0.23	7	1645	1785	176
5	29/10/2011 23:27	3/11/2011 17:57	1	0.39	4	1725	1785	115
6	4/11/2011 21:18	8/11/2011 16:00	1	0.38	4	1696	1785	91
7	20/12/2011 20:07	23/12/2011 15:30	1	0.44	5	1739	1785	67
8	16/02/2012 11:34	18/02/2012 19:46	1	0.47	3	1646	1785	56
9	17/03/2012 12:06	15/04/2012 20:44	1	0.39	29	1748	1785	705
10	16/04/2012 13:06	9/05/2012 12:00	1	0.31	23	1530	1785	551
11	21/05/2012 16:22	11/06/2012 22:39	1	0.31	21	1598	1785	510
Pool rate (mm/hr)				0.33				





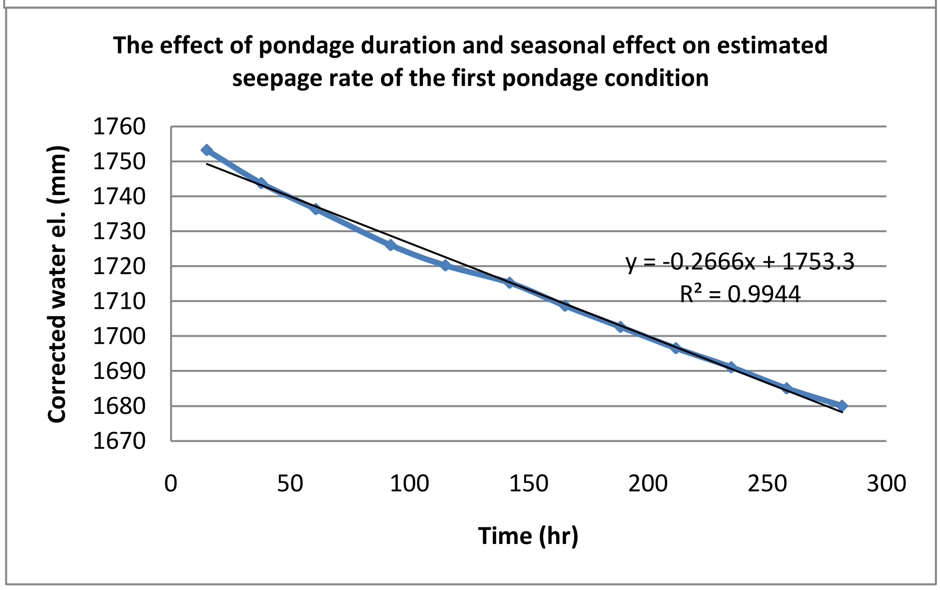


Figure 6.33 Corrected water elevation plots of 2026/1 farm outlet during 3 pondage conditions on TUBBO 4OT, 2026 pool, occurred at higher water elevations in the channel (Appendix D)

The detailed analysis of the 7th pondage condition showed that no rainfall occurred during the pondage period and the slight rise and fall in the plot might be due to noise in the measurement or the movement of surface water as a result of wind.

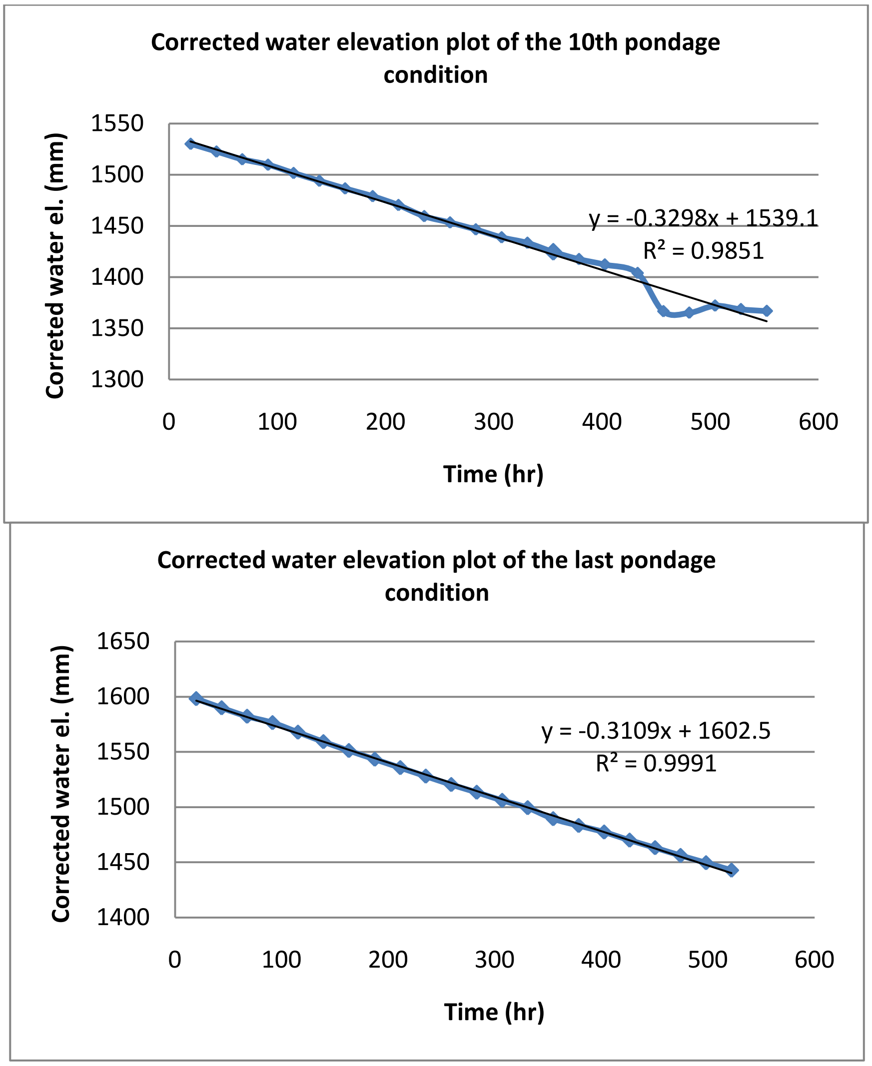


Figure 6.34 Evaluation of corrected water elevation plots of 2026/1 farm outlet in TUBBO 4OT, 2026 POOL during longer pondage conditions at lower water elevations in the channel to identify possible leakage (Appendix D)

Figure 6.33 shows that when the polynomial trend line was applied to the corrected water elevation data of the 9th sample it proved to be more suitable than the linear regression. At the same time, corrected water elevation data for the 10th and the last samples were plotted to check if a leakage component can be identified in any long pondage conditions at lower water elevations (Figure 6.34). As can be seen in Figure 6.34, none of the plots had any identifiable leakage components and the linear regression was the best trend line to model the seepage rate in both plots.

6.4 Discussion

In order to evaluate the quality and accuracy of estimated seepage rates from TCC data, a full detailed analysis of all pondage conditions in different channels from 2009 to 2011 was completed and the factors affecting the estimates were addressed.

Results of the analysis showed that the occurrence of rainfall during a pondage condition can influence the estimated seepage rate. Detailed examination of gauges corrected water elevation plots showed that the existence of a rainfall event caused a rise and fall in the corrected water elevation plot. Due to the fact that rainfall over a 24 hour period was measured at 9 am the next day and recorded against that day, the imperfect knowledge about the exact timing and rate of the rainfall may explain the occurrence of rise and fall in corrected water elevation plots whenever a considerable rainfall occurred.

Based on further consideration, it was decided to remove the period covered by this rise and fall from the corrected water elevation plot and re-estimate the seepage rate for the remaining part of the plot. However due to shortage of remaining measured points or short duration of the remaining part in some cases, it was necessary to entirely eliminate some of the pondage conditions from the analysis. Schulz (2009) also indicated that pondage tests during which rainfall has occurred should be eliminated from the analysis. On the other hand the results of the analysis showed that whenever the amount of rainfall was low or the pondage duration was very long, the estimated seepage rate was not affected by the existence of the rainfall. More rainfall occurred during 2010/11 than in the other two irrigation seasons, a greater number of pondage conditions in that season were affected by the occurrence of rainfall.

The initial water elevation in the channel in any given pondage condition is another important factor affecting the estimated seepage rates. This study showed that water elevation had a direct relationship with the estimated seepage rate.

The variation of estimated seepage rates during each irrigation season highlighted a seasonal affect which might be as a result of watertable levels. McLeod et al. (1994) also showed the importance of a seasonal effect on differences in seepage estimates. Schulz (2009) however suggested that testing on pools in which the loss rate varied with water table elevations should be performed after hydraulic conditions are stabilized in that area. In our study, each irrigation season was divided into three periods and it was shown that greater rates often occur in the middle of the season, while lower rates were observed at the beginning and towards the end of the season. Analysing all pondage conditions in any given pool in different periods of all three seasons, it was shown that the lowest initial channel water elevations occurred at the beginning period of all seasons, meaning that two causal factors coincide at the beginning of the season resulted in the lowest seepage rate among all pondage conditions in any given pool. Lang et al. (2009) excluded periods adjacent to and including the channel filling and end of season phases from their analysis.

Pondage duration was also seen as another feature influencing the rate of seepage. Results of the analysis showed that pondage duration has an inverse relationship with seepage estimates, meaning that between two similar pondage conditions in terms of initial water elevation and time of occurrence, a higher seepage rate is expected in the shorter pondage. At the same time, it was shown that water elevation measurements during a shut down period did not commence exactly at the start of pondage condition which resulted in small number of records covering a shorter duration than the actual pondage period. Consequently the number of measured points during any given pondage condition was introduced as another factor affecting the reliability of the estimated seepage rates.

As a number estimated seepage rates were postulated to be inaccurate possibly due to the effect of noise in the water elevation data, the analysis required data cleaning. Schulz (2009) also noted that noise was associated with measurement errors in their study and therefore such factors must be eliminated before conducting the analysis. Conversely, Lang et al. (2009) assumed that installation of TCC completely eliminates any bias in measurement inaccuracies.

In addition, some evidence of possible unauthorized water usage was observed in the analysis. This was also supported by Schulz (2009) and Poulton et al. (2007), while Lang et al. (2009) claimed water theft to be negligible.

Results of the analysis suggested that whenever several factors coincide, the initial water elevation is the most important factor affecting the differences in estimated seepage rates for different pondage conditions in any given pool.

Apart from the pondage conditions at the beginning of the seasons at lower water levels which result in lowest estimated rate, analysis of all pondage conditions in number of selected pools suggested that the estimated seepage rates for the remaining pondage conditions with similar initial water elevations should stand in a certain range. However, high rates of water loss are expected whenever the initial water elevation increases and is closer to full supply level. This was also supported by Poulton et al. (2007) who estimated a fixed range of seepage rates at different channels as well as Lang et al. (2009) who adopted a fixed rate of seepage for certain channels in their study.

Moreover, our findings suggest that any high rates of water loss occurring at higher water elevations in different channels might be due in part to leakage through macro pores in the channel bank at or near the full supply level. Several pondage conditions with high rates of water loss in different pools during the three irrigation seasons were identified and the corrected water elevation plots were provided. However, the ideal seepage curve (showing a decline in the loss rate with time or with lower water level) which indicates a leakage component was only observed in some of the samples. Results of the analysis suggest that the ideal form of water elevation plot can sometimes be found in longer pondage conditions with a high number of measured points and at higher channel water levels.

A polynomial trend line was applied to corrected water elevation data of pondage samples where leakage was suspected. It was observed that whenever the ideal seepage curve was available, the polynomial trend line was the best model to estimate the rate of water loss while for all other pondage conditions the linear regression was the simplest and preferred approach.

6.5 Conclusion

Considering the detailed analyses of all pondage conditions in number of selected pools during three years of historical data, the following conclusions can be made.

- Data cleaning is necessary for pondage conditions during which a considerable amount of rainfall has occurred. However, in the case of longer pondage periods with a high number of measurements, the effect of rainfall on the estimated seepage rate is negligible.
- Pondage duration has an inverse relationship with seepage estimates, meaning that the estimated seepage rate decreases with increasing duration.
- The number of measurements of water elevation is greater during longer pondage conditions, which means that there is more confidence in estimates from pondage conditions with a higher number of measured points.
- Considering the seasonal changes in water table elevation below the channels, lower rates of seepage can be expected at the beginning and towards the end of each irrigation season, while higher rates are likely to be found toward the middle of the season.
- The initial water elevation in the channel is one of the most important factors affecting the variations in different seepage estimates in any pool.
- Any possible leakage in channels can sometimes be traced in longer duration pondage conditions with high number of measurements and which occurred at high water elevations.
- Application of polynomial trend line to plots of data with possible leakage were shown to be more realistic to model the seepage compared to linear regression. On the other hand, linear regression proved to be the most reliable means to estimate the seepage rate for the remaining pondage conditions.

Chapter 7: Identification of pools with high seepage rates and comparison of results with previous seepage estimates in CIA

7.1 Introduction

This chapter contains a detailed evaluation of pool seepage rates and pools with high seepage rates are identified. For a better understanding of changes in estimated pondage results at different water levels in each pool, the estimated seepage rate for the most ideal pondage condition (with high number of measured points and long pondage duration) if available or the pondage sample with the highest seepage rate and high channel water levels is selected. Analysis of the two rates is used to highlight pools that require remediation works. Pools with high seepage rates are classified in four different categories.

In addition, the averaged pool and selected pondage results are compared to the most recent and the only comprehensive seepage study in CIA, completed by Allen (2006).

7.2 Identification of pools with high seepage rates from analysis of TCC data

The procedure used to analyse the pool seepage rates is outlined in Figure 7.1. This consisted of: (i) identification of the most ideal pondage condition (in terms of long duration, high channel water level and sufficient number of points) if available or simply the pondage condition occurred at the highest channel water level in the channel, and (ii) comparison with the average seepage rate for the pool.

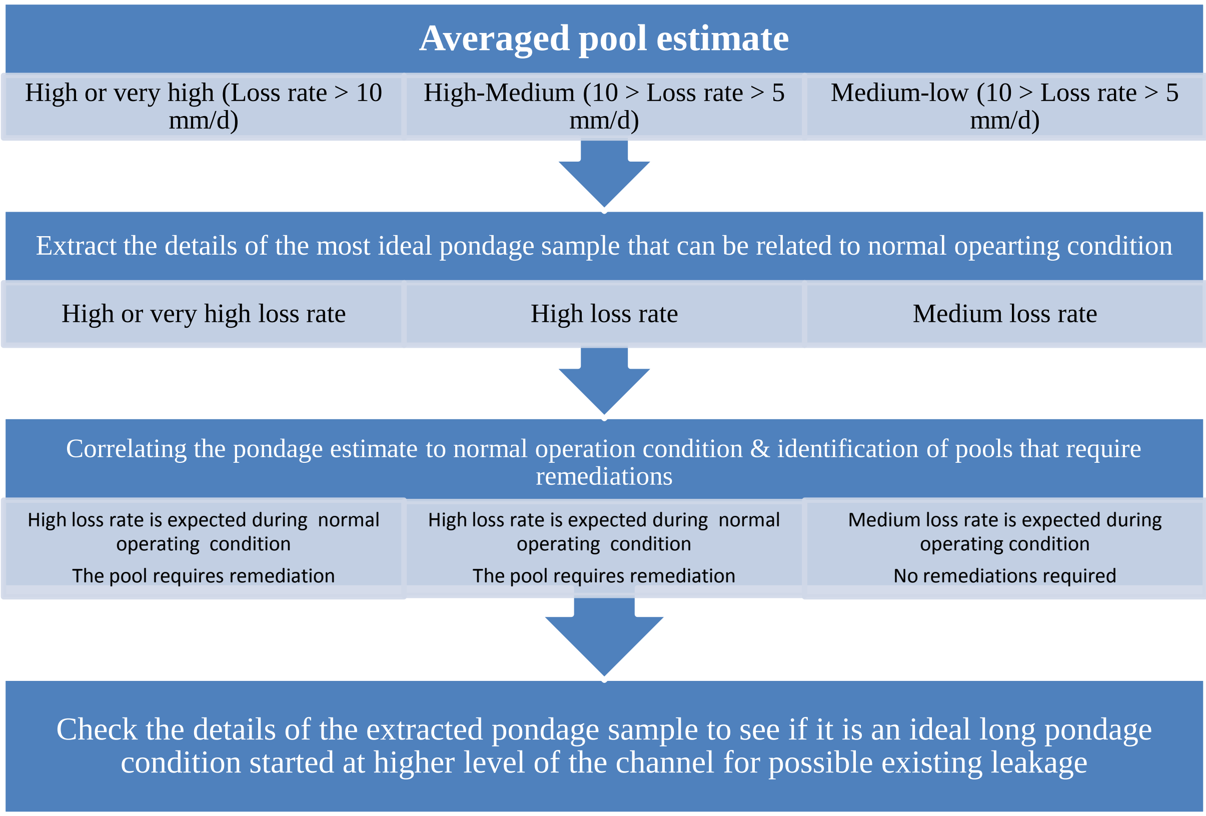


Figure 7.1 Application of the averaged pool estimate and the selected pondage rate to identify pools with high loss rates require remediation

Based on the averaged rate of pool estimate during three years as well as the higher loss rate at higher channel water levels (Appendix E), pools with high rates of water loss were classified in four different categories:

- Pools with seepage estimates greater than 20 mm/day were introduced as category 1
- Pools with seepage estimates greater than 15 but lower than 20 mm/day as category 2
- Pools with seepage estimates greater than 10 but lower than 15 mm/day as category 3
- Pools with seepage estimates lower than 10 mm/day in which a high rate has occurred at higher channel water elevation as category 4

Results of the analysis show that high seepage rates in each of the first 3 categories during each season are due to one or more high pondage based seepage rates which mainly occurred at higher water levels or in the middle of the irrigation season or both. However in some cases all pondage based seepage rates in a pool were high and approximately in the same range. It is suggested that the estimated seepage rates for categories 1 to 3 might include a leakage component especially when the higher seepage rate resulted from an ideal pondage condition. In addition, it is suggested that in other cases when a significant loss of water occurs and conditions are the same as for the other (lower) pondage samples, the loss of water might be due to unauthorized water usage.

Table 7.1 shows the list of all pools with high loss rates greater than 20 mm/day (category 1). From Table 7.1 it can be seen that the majority of pools in this priority are from the BUNDURE main channel while, TUBBO had the second highest number of pools in the 1st priority.

Except for three of the pools (BUNDURE 2, 10, TUBBO 1), high rates of water loss could be seen in both the averaged pool estimate and the higher water loss of the remaining pools over the three irrigation seasons. However, the reason for selection of the three highlighted pools was due to high rates of water loss which occurred in one season. Comparison of the two rates in each of the pools in the 1st category shows that they all had high rates of water loss indicated by both the averaged pool estimate and the higher pondage estimate.

Table 7.1 Pools with high water loss grouped as category 1

MAIN CHANNEL	POOL ID	2009				2010				2011				Full Supply el. (mm)
		Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	
BUNDURE	15	23.4	7	37.9	1677	19.7	2	22.8	1719					1776
BUNDURE	18	21.0	1	21.0	1619									1665
BUNDURE	39	29.3	6	34.6	1590	17.5	4	19.0	1602					1698
BUNDURE	42					40.9	3	56.9	1598					1708
BUNDURE	45					23.5	2	49.9	1623	26.1	1	26.1	1632	1752
COLY	9	22.1	1	22.1	1322	32.1	2	37.0	1467					1757
MAIN	6	33.5	2	33.6	1349	14.7	2	19.2	1343	16.3	1	16.3	1346	1531
MAIN	16	42.6	3	51.6	1599	17.5	3	23.3	1635	36.2	1	36.2	1589	1789
TUBBO	1					2.4	1	2.4	1261	104.6	2	104.6	1467	1717
TUBBO	5	57.7	2	62.4	1457	23.3	1	23.3	1451					1535
TUBBO	11	20.4	2	27.6	1358									1784
TUBBO	12					21.2	2	21.2	1486					1642
TUBBO	13					33.8	3	33.8	1270	39.8	2	40.8	1392	1501
BUNDURE	2	59.5	3	87.6	1647	8.8	5	11.3	1674					1770
BUNDURE	10	5.9	2	6.0	1347	4.8	1	4.8	1195	50.8	1	50.8	1499	1627
Averaged Seepage (mm/d)		**31.5**		**38.4**		**20.0**		**25.0**		**45.6**		**45.8**		
Max		**59.5**		**87.6**		**40.9**		**56.9**		**104.6**		**104.6**		
Min		**5.9**		**6.0**		**2.4**		**2.4**		**16.3**		**16.3**		

Due to the considerable effect of the high pondage estimate on the averaged pool estimate in this category, no pools with medium pool estimate were observed in Table 7.2. Considering the channel remediation works undertaken in CIA, no improvements could be seen for any of the pools that had data available for all three years. However, the data from the 2010 and 2009 seasons suggest a decline in seepage rate in BUNDURE 2, 15 and 39 pools. Analysis of pools in the category 1 suggests that these high rates of water loss might be due in part to leakage. Moreover, six of these pools were previously identified in section 6.2.6 of Chapter 6 as having possible leakage, based on their individual plots of gauge water elevations during the pondage periods. The average of all pool estimates in 2011 season was greater than in the other two years due to two high rates in the TUBBO 1 and BUNDURE 10 pools.

Similar to the 1st category, the majority of pools in the 2nd category were located on BUNDURE main channel, while YAMMA had the same number of pools highlighted with seepage estimates more than 15 but less than 20 mm/day (Figure 7.3). Results of the analysis for this group of pools showed that the majority of high seepage rates occurred at near full supply elevations.

Moreover, the effect of the higher pondage estimate on the averaged pool estimate can be seen in majority of the pools in Table 7.2. However, the comparison of the two rates highlighted two of the pools (BUNDURE 48, YAMMA 42) with a considerable number of pondage conditions during one season that had medium pool seepage estimates and high seepage rates at supply levels of the channel. The reason behind this is due great number of pondage conditions which occurred at lower channel water elevations resulting in lower seepage rates.

The data in Table 7.2 suggests that seepage rates have decreased in some pools in sequential years possibly as a result of improvements to the channels. For example, high rates of water loss were still occurring in YAMMA 13 and MAIN CANAL 22 pools while the estimated seepage rates for COLY 32, 37 and YAMMA 17 pools decreased by 84%, 81% and 88% respectively. Results of category 2 also suggest that these high rates of water loss might include a substantial leakage component. At the same time three of these pools were previously identified with possible leakage and plotted in section 6.2.6 of Chapter 6.

Table 7.2 Pools with high water loss grouped as category 2

MAIN CHANNEL	POOL ID	2009				2010				2011				Full Supply el. (mm)
		Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	
BUNDURE	22	16.8	3	25.4	1589	13.8	8	17.3	1650	20.9	5	31.2	1380	1780
BUNDURE	40	24.2	4	25.7	1561	15.4	5	16.3	1704					1726
BUNDURE	44									16.8	1	16.8	1395	1845
COLY	4					24.3	1	24.3	1591	9.8	1	9.8	1692	1770
COLY	32	40.3	1	40.3	1503	4.6	3	5.0	1440	5.1	7	6.5	1533	1571
COLY	37					27.2	1	27.2	1683	5.6	4	5.3	1679	1922
MAIN	14	16.0	1	16.0	1363									1512
MAIN	22	17.0	2	19.9	1575	26.3	3	31.2	1658	15.2	6	26.2	1625	1715
YAMMA	13	21.5	1	21.5	1447					17.3	1	17.3	1518	1630
YAMMA	42	22.0	2	23.0	1573	23.9	5	24.2	1606	8.6	11	14.4	1642	1686
YAMMA	46									18.7	2	19.7	1492	1987
ARGOON	1					24.7	1	24.7	1673	8.8	1	8.8	1683	1750
BUNDURE	48	23.3	4	96.0	1625	8.2	14	31.2	1626					1757
YAMMA	17					27.4	6	75.4	1367	7.3	12	8.9	1664	1695
Averaged Seepage (mm/d)		**22.6**		**33.5**		**19.6**		**27.7**		**12.2**		**15.0**		
Max		**40.3**		**96.0**		**27.4**		**75.4**		**20.9**		**31.2**		
Min		**16.0**		**16.0**		**4.6**		**5.0**		**5.1**		**5.3**		

Analysis of all the pools identified as the 3rd category showed that all high rates of water loss occurred at near full supply elevations in different channels (Table 7.3). Furthermore, it can be seen from this table that the majority of pools in this group are located on BUNDURE main channel.

In contrast with previous categories, a wide difference was observed between the averaged pool estimate and the higher pondage estimate for many of the pools in this category. In addition, the comparison of the two rates highlighted some of the pools with high pool estimates and very high pondage estimates (COLY 79, BUNDURE 19, 33, 41, TUBBO 10, ARGOON 16, BOONA 23 and 28) and some with medium pool estimate and high pondage estimate (COLY 1, BUNDURE 43).

The majority of the pools in Table 7.3 had high seepage rates in 2009 and 2010 prior to any evidence of improvement as a result of undertaken remediation works. However, the estimated seepage rates in 2011 showed a drop of about 60% in the majority of the pools compared with seepage estimates for 2010 and 2009.

Finally, the pools grouped as category 4 with averaged pool estimates of less than 10 mm/day and high pondage estimate greater than 10 mm/day are provided in Table 7.4. The majority of the pools in this category had similar pool and pondage estimates around and less than 10 mm/day, while some had medium pool and high pondage estimates (COLY 31, 39, 78) and some had very high rates at higher channel water levels (COLY 63, YAMMA 1).

The data in Table 7.4 indicates that the seepage rate has declined in the majority of pools included in this category. However, in the case of COLY 31, MAIN 8, TUBBO 9 and YAMMA 31 high rates of seepage still occurred in 2011 and in the case of YAMMA 1 where pondage conditions occurred at different channel water levels, no judgment about the possible seepage rate at higher channel water levels in 2011 can be made.

Table 7.3 Pools with high water loss grouped as category 3

MAIN CHANNEL	POOL ID	2009				2010				2011				Full Supply el. (mm)
		Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	
ARGOON	16	17.8	9	36.0	1662	16.1	4	20.4	1663	6.6	3	6.6	1648	1887
ARGOON	17	18.4	3	22.1	1687	15.2	5	36.3	1655	8.5	5	8.4	1593	1721
BOONA	28	6.5	3	13.9	1631	20.7	11	28.1	1691	14.4	1	14.4	1600	1820
BUNDURE	19	15.5	4	27.4	1385	13.9	5	15.4	1350	6.4	2	7.9	1428	1434
BUNDURE	33	14.3	5	19.2	1625	20.2	3	20.2	1657	9.2	13	10.3	1663	1705
BUNDURE	34	14.4	1	14.4	1385	8.3	2	8.6	1090	8.2	1	8.2	1446	1544
BUNDURE	35	13.3	1	13.3	1521	11.5	2	11.5	1613	8.2	1	8.2	1553	1670
BUNDURE	41	9.3	4	11.8	1660	13.0	10	27.4	1665					1700
COLY	1	9.0	7	15.4	1713	8.6	13	10.8	1692	13.2	13	23.4	1715	1738
COLY	6	14.2	9	24.2	1641	13.2	10	15.1	1657					1730
TUBBO	6	7.9	1	7.9	1307	7.8	2	11.9	1359	17.8	1	17.8	1427	1519
TUBBO	10	13.0	13	17.0		10.5	12	13.0		8.0	11	11.5		1786
YAMMA	8	11.7	1	11.7	1459									1576
YAMMA	29	17.9	4	34.3	1439	13.7	1	13.7	1512	8.8	5	10.3	1490	1731
BUNDURE	1	13.1	6	25.5	1670	11.9	2	11.9	1656	12.8	3	13.7	1668	1760
YAMMA	36									10.9	2	12.5	1592	1677
BUNDURE	43	19.5	1	19.5	1479	9.7	2	18.7	1571					1691
ARGOON	15	26.5	1	26.5	1559	8.3	1	8.3	1447	8.9	8	9.4	1577	1719
BOONA	16	12.7	2	16.1	1584	10.6	7	11.5	1642	7.5	2	8.6	1577	1692
BOONA	23	10.4	2	16.6	1600	11.5	5	13.0	1600					1691
COLY	79	4.8	1	4.8	1410	16.7	5	33.8	1543	5.5	9	6.2	1564	1660
Averaged (mm/d)		**13.5**		**18.9**		**12.7**		**17.3**		**9.7**		**11.1**		
Max		**26.5**		**36.0**		**20.7**		**36.3**		**17.8**		**23.4**		
Min		**4.8**		**4.8**		**7.8**		**8.3**		**5.5**		**6.2**		

Table 7.4 Pools with high water loss grouped as category 4

MAIN CHANNEL	POOL ID	2009				2010				2011				Full Supply el. (mm)
		Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Water elevation (mm)	
BOONA	20	9.1	1	9.1	1505	11.0	9	15.0	1553	7.9	6	8.4	1517	1586
BUNDURE	46	12.5	5	16.3	1487	8.0	4	10.6	1554	6.0	3	9.6	1561	1698
COLY	5	8.7	1	8.7	1522	12.1	7	14.9	1629	7.8	4	7.8	1541	1640
COLY	11	4.9	1	4.9	1173	13.4	1	13.4	1448	8.7	1	8.7	968	1565
COLY	13	16.6	3	18.2	1689	4.9	2	4.8	1692	6.3	2	8.9	1680	1818
COLY	31	9.9	3	19.4	1452	1.8	1	1.8	1452	10.2	5	25.7	1434	1567
COLY	34	11.9	4	13.3	1386	8.6	2	8.6	1423	6.6	1	6.6	1430	1450
COLY	39	9.8	4	14.6	1676	10.3	3	11.3	1597	7.5	1	7.5	1560	1744
COLY	63	15.2	8	26.4	1356	7.4	37	7.6	1383	5.8	22	5.9	1387	1676
COLY	67	11.1	2	11.1	1511					6.0	1	6.0	1493	1578
COLY	70	9.5	5	11.0	1616									1853
COLY	73	11.6	2	16.6	1390					5.0	4	5.0	1431	1580
COLY	78					9.6	6	14.2	1468					1701
MAIN	8	4.6	3	4.6	1594	3.1	6	3.6	1579	12.4	2	14.9	1635	1752
TUBBO	9	8.4	1	8.4	1396	4.5	6	6.5	1379	10.1	1	10.1	1237	1563
YAMMA	1	16.3	2	20.6	1655					2.5	1	2.5	1099	1738
YAMMA	14	9.5	2	10.6	1583	7.0	4	8.4	1585					1724
YAMMA	31	8.3	1	8.3	1598	8.8	1	8.8	1630	8.2	2	10.1	1590	1743
YAMMA	35									6.2	3	10.6	1496	1634
YAMMA	37									9.3	1	9.3	1564	1764
YAMMA	39	10.0	2	11.8	1410	5.8	1	5.8	1382	8.6	2	8.6	1403	1564
Averaged (mm/d)		**10.4**		**13.0**		**7.7**		**9.0**		**7.5**		**9.2**		
Max		**16.6**		**26.4**		**13.4**		**15.0**		**12.4**		**25.7**		
Min		**4.6**		**4.6**		**1.8**		**1.8**		**2.5**		**2.5**		

The pool estimate and higher seepage rates for all the pools on each main channel were averaged to give an approximate magnitude of seepage losses at different main channels of CIA during each irrigation season (Table 7.5).

Analysis of the main channels (Table 7.5) suggests that TUBBO main channel had the highest seepage losses, followed by the Main Canal and the ARGOON main channel. Moreover, comparison of the loss rates in different seasons indicates that seepage losses were higher during the 2009 season than in 2010 and 2011 (Table 7.5). Except for the TUBBO main channel and the MAIN CANAL, the loss rates in other main channels were lower in 2011 season compared with 2010.

Table 7.5 Averaged seepage rates for all pools and estimated operational losses in each of the main channels during 3 irrigation seasons

Main channel	2009		2010		2011		Average	Average	Ratio of
	Pool Seepage (mm/d)	Higher Seepage (mm/d)	Pool Seepage (mm/d)	Higher Seepage (mm/d)	Pool Seepage (mm/d)	Higher Seepage (mm/d)	Pool Seepage (mm/d)	Higher Seepage (mm/d)	Pool seepage/ operational condition
ARGOON	17.4	22.9	10.5	12.7	7.8	9.2	**11.9**	**14.9**	**0.8**
BOONA	7.1	10.1	7.9	11.1	6.9	7.6	**7.3**	**9.6**	**0.8**
BUNDURE	12.5	18.6	9.4	13	11.1	11.4	**11.0**	**14.3**	**0.8**
COLY	8.0	10.1	8.5	10.6	6.0	8.0	**7.5**	**9.6**	**0.8**
MAIN CANAL	14.1	15.4	8.3	9.9	14.4	16.8	**12.3**	**14.0**	**0.9**
TUBBO	17.6	22.1	10.9	12.5	30.3	30.4	**19.6**	**21.7**	**0.9**
YAMMA	9.3	13.2	7.6	9.6	7.0	8.3	**8.0**	**10.4**	**0.8**
AVERAGE	**12.3**	**16.1**	**9.0**	**11.3**	**11.9**	**13.1**	**11.1**	**13.5**	**0.8**

Assuming that the estimated loss rates at higher channel water elevations can give an estimate of the possible water loss during normal operation in each channel. The results in Table 7.5 also suggest that the averaged loss rate expected during operational condition in the majority of the channels was 20% greater than the estimated averaged pool rate during 2009-2011. While the expected loss rate in the Main Canal and TUBBO main channel is 10% greater than the estimated averaged pool rate during 2009-2011.

Considering the cross sectional dimensions of different channels across the CIA, wetted perimeter for any given pool is calculated. At the same time based on positions of upstream and downstream gates of each pool, length of any given pool can be calculated. Putting into account the length and the wetted perimeter of each pool, total annual volume of the water lost due to seepage can be calculated for each pool and up scaled for the entire scheme during each season (Table 7.6).

Table 7.6 Total annual water loss due to seepage for the entire CIA during each season

Season	Total annual seepage calculated from the analysed pools (ML)	Total length of channels covered in the analysis (Km)	Total length of channels covered in the analysis/ Total length (%)
2009	9135	225	50.8%
2010	12697	271	61.4%
2011	10666	260	58.9%

The results in Table 7.6 suggest that total annual seepage loss in different seasons were similar. While due to lower proportion of channel lengths covered in the analysis during 2009 season, the resulted annual seepage loss was the lowest among the three seasons.

A summary of previous seepage studies in compare with the total annual water loss calculated from the analysis of TCC data is illustrated in Table 7.7.

Table 7.7 Comparison of total annual water loss calculated from TCC data with previous seepage studies

Study	Area (ha), length(km)	Seepage (ML)
Seepage estimates from TCC data up scaled for all the analysed pools	252 km	10833
Van der Lely (1994)	333 farms	15000
Tiwari (1995)	1,400 hectares	12000
Pratt Water (2004)	On farm	53000
	Off farm	120000
CSIRO (2005)	channels and rice farms	38000
SKM (1997a)	all channels excluding main canal	9800
TCC	All analysed pools excluding main canal	9738
SKM (2006)	first 18km of the main canal	3900
TCC	first 18km of the main canal	No pondage was available

The results in Table 7.7 show that the annual seepage losses resulted from the analysis of TCC data were in agreement with previous studies. The total seepage losses for all the analysed pools excluding the main canal was averaged for all three seasons and showed to be in good agreement with SKM (1997a). Given that no TCC pondage data during any of the three irrigation seasons for the first 18 km of the main canal was available, no comparison was made with SKM (2006).

Overall, the comparison of the annual seepage losses from the analysis of TCC data with other seepage studies suggests that high seepage losses are occurring in the CIA.

7.3 Comparison of seepage estimates from TCC data with previous studies

A comprehensive review of seepage studies conducted in the CIA was provided in section 2.4.2 of Chapter 2. According to the review, total seepage losses as high as 10 GL/year are occurring in the CIA. The most recent and the only comprehensive seepage study in CIA was done by Allen (2006). Based on the electrical conductivity levels in the bed of the channels, Allen (2006) made a full assessment of seepage losses throughout the entire channel network and classified the high seepage (hotspot) locations in 5 different priorities (Table 2.9).

7.3.1 Seepage hot spot locations (Allen, 2006)

Using GPS positioned vertical electrical conductivity imaging along with depth recording, Allen (2006) conducted geoelectric surveys using GPS positioned vertical electrical conductivity imaging and depth recording on different channels of CIA and used the results to indentify channel seepage hot spots. The resistivity images show the presence of lower conductivity fresh water below the bed of the channel. However, the resistivity imaging technique in itself does not indicate if the seepage is actively occurring from the channel. In order to quantify the magnitude of losses, Allen (2006) placed Seepage Penetration Observation Tubes (SPOTs) in channels identified from the geoelectric imaging. The methodology applied to use the SPOTs was to equalize the inside water level with the outside and place a wire hook gauge at the inside water level. Two to three days later, the volume of water added to bring the inside water back to the hook gauge was measured. Considering the time interval, inside pipe diameter and volume of water added, the infiltration rate in mm/day was calculated.

Based on the conductivity levels in the bed of the channels, cross-referenced with the likelihood of active seepage based on surface soil features from the Google map and also the EM31 soil rice suitability survey maps of the whole irrigation area, Allen (2006) prioritized the suspect seepage hotspots into five different groups (Appendix G).

The locations identified by Allen (2006) as seepage hotspots typically cover only a small part of a channel reach whereas the pool data provides seepage rates for the entire length of that reach. The hotspot locations were identified by the name of the reach or of one of the neighboring farms. Given that the names of all gates and farm outlets in any given pool as well as name of the main channel of which the pool is part are available in the Coleambally database (Appendix F), the identified seepage hotspots in Allen (2006) study can be related to the relevant pool (Appendix G). Although the majority of the pools in the 1st priority of Allen (2006) were found, none had pondage data during the three irrigation seasons (Table 7.8).

Table 7.8 Seepage estimates for each pool containing hotspots identified as priority 1 by Allen (2006)

Site Id	Main channel	Pool Id	2009	2010	2011
			Seepage (mm/day)	Seepage (mm/day)	Seepage (mm/day)
1	MAIN CANAL	19	none available	none available	none available
3	MAIN CANAL	24	none available	none available	none available
25	COLY	40	none available	none available	none available
35					
50	YAMMA	11	none available	none available	none available
53	YAMMA	18	none available	none available	none available
65	BUNDURE	2	none available	none available	none available
66	BUNDURE	1	none available	none available	none available

Table 7.9 shows the seepage rates in the related pools for identified locations in priority 2 (20 mm/d). From Table 7.9 it can be seen that except for five locations, the remaining hotspots in the 2nd priority were linked to their related pools. TCC seepage estimates were available for all but two of the pools. Results of the comparison showed five pools with loss rates less than the 20 mm/d estimated by Allen (2006). At the same time, five of the pools (TUBBO 10, 6, YAMMA 46, BUNDURE 18 and 46) had high loss rates around 20 mm/d during 2009 and 2011 seasons. Results of the analysis showed that the high loss rates during operational conditions have decreased in TUBBO 10 and BUNURE 46. The estimated high loss rate in BUNDURE 18 occurred in 2009 and no data for this pool was available during the 2010 and 2011 seasons. At the same time, the high loss rates in the other two pools occurred during the 2011 season and require further investigation for remediation purposes. Surprisingly, the estimated loss rate for YAMMA 46 occurred at water levels 50 cm below the full supply level of the channel. Hence, it can be assumed that the loss rate that might occur during normal operation will be greater than the Allen (2006) result.

On the other hand, five of the pools (TUBBO 1, 11, BUNDURE 1, 2 and 15) had high loss rates greater than 20 mm/d during different irrigation seasons. Among which only BUNDURE 1 and 2 had lower loss rates in the next season at similar channel water elevations. TUBBO 1 was the only pool to have a very high loss rate during 2011 season and the rest of pools showed high loss rates during 2009 and 2010 but had no pondages during the 2011 season.

Results of the comparison showed that the estimated loss rates in the remaining pools were lower than that inferred by the measurements of Allen (2006).

Table 7.9 Seepage estimates for each pool containing hotspots identified as priority 3 by Allen (2006)

Site Id	Main channel	Pool ID	2009				2010				2011				Full Supply el. (mm)
			Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	
2															
4	Main canal	21													
8	TUBBO	11	20.4	2	27.6	1358									1784
9	TUBBO	11	20.4	2	27.6	1358									1784
10	TUBBO	1					2.4	1	2.4	1261	104.6	2	104.6	1467	1717
11															
13	TUBBO	6	7.9	1	7.9	1307	7.8	2	11.9	1359	17.8	1	17.8	1427	1519
14															
15	TUBBO	10	13.0	13	19.0	1687	10.5	12	13.0	1719	8.0	11	9.4	1748	1786
18	BOONA	1	6.2	1	6.2	1280									1539
20	BOONA	25	6.4	5	12.0	1631	6.3	11	16.1	1617					1804
36	YAMMA	44													
51	YAMMA	46									18.7	2	19.7	1492	1987
54	YAMMA	18													
55	YAMMA	19					7.5	1	7.5	1451	8.5	1	8.5	1685	1886
60	YAMMA	14	9.5	1	10.6	1583	7.0	4	8.4	1585					1724
64	BUNDURE	1	13.1	6	25.5	1670	11.9	2	11.9	1656	12.8	3	13.7	1668	1760
67	BUNDURE	15	23.4	7	37.9	1677	22.8	2	24.5	1616					1776
69	BUNDURE	2	59.5	3	87.6	1647	8.8	5	11.3	1674					1770
70															
74	BUNDURE	13	4.1	4	4.8	1497	2.8	1	2.8	1145					1567
75	BUNDURE	5	4.9	6	5.3	1568	3.9	5	4.8	1660					1735
77	BUNDURE	15	23.4	7	37.9	1677	22.8	2	24.5	1616					1776
78	BUNDURE	18	21.0	1	21.0	1619									1665
80	BUNDURE	34	14.4	1	14.4	1385	8.3	2	8.6	1090	8.2	1	8.2	1446	1544
84	BUNDURE	46	12.5	5	16.3	1487	8.0	4	10.6	1554	6.0	3	9.6	1561	1698
85															

Comparison of the estimated loss rates for pools linked to seepage hotspots in the 3rd priority showed that out of ten available pools with data, three of them (YAMMA 36, BUNDURE 40 and 43) had loss rates greater than the 10 mm/d as suggested by Allen (2006) (Table 7.10). The results show that the loss rates decreased slightly in BUNDURE 40 and 43 pools during 2010 compared with the 2009 season while no data was available for either of the pools during the 2011 season. The other pool had a higher loss rate during operational conditions in 2011. One of the pools (COLY 8) had a similar loss rate as suggested by Allen (2006). On the other hand, the estimated loss rates in the remaining pools were lower than 10 mm/d which might be due to possible remediation works undertaken after 2006.

Table 7.11 shows the estimated loss rates for the related pools linked to the identified locations of the 4th priority of Allen (2006). Comparison of the loss rates in this group show that two of the pools (YAMMA 39 and COLY 11) experienced loss rates greater than the 10 mm/d as suggested by Allen (2006). Both pools had data available for the three seasons. Comparison of the estimated loss rates in different seasons showed lower loss rates at similar condition in 2011 for YAMMA 39, while the only 2011 pondage sample for COLY 11 occurred at a lower channel water elevation. The estimated loss rates for the rest of the pools in Table 7.11 were less than 10 mm/d.

Finally, the pools linked to seepage hotspots identified as priority 5 with 10 mm/day seepage rate are illustrated in Table 7.12. The results of the comparison show that both pools with available data in Table 7.12 had loss rates lower than 10 mm/d. However, COLY 42 experienced loss rate around 10 mm/day at approximate supply elevation during 2009 and had lower loss rates in 2011 possibly as a result of remediation works undertaken in COLY main channel.

Table 7.10 Seepage estimates for each pool containing hotspots identified as priority 3 by Allen (2006)

Site Id	Main channel	Pool ID	2009				2010				2011				Full Supply el. (mm)
			Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	
17	COLY	50	6.7	1	6.7	1526					8.5	1	8.5	1495	1747
19															
24	COLY	8	6.1	1	6.1	1550	8.3	2	9.9	1480					1664
27	BOONA	4									4.5	2	5.5	1416	1605
37															
39	YAMMA	12													
41	ARGOON	1													
48	YAMMA	44													
52	YAMMA	43													
56	YAMMA	19					7.5	1	7.5	1451	8.5	1	8.5	1685	1886
58	YAMMA	26					7.2	1	7.2	1423	5.5	3	6.5	1437	1644
61	YAMMA	36									10.9	2	12.5	1592	1677
71	MAIN CANAL	5					2.1	4	2.1	1558					1809
79	MAIN CANAL	11	6.1	1	6.1	1239	4.1	1	4.1	1147					1554
81	BUNDURE	40	24.2	4	25.7	1561	15.4	5	16.3	1704					1726
83	BUNDURE	43	19.5	1	19.5	1479	9.7	2	18.7	1571					1691
86															

Table 7.11 Seepage estimates for each pool containing hotspots identified as priority 4 by Allen (2006)

Site Id	Main channel	Pool ID	2009				2010				2011				Full Supply el. (mm)
			Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	
6	MAIN CANAL	13													
7	MAIN CANAL	21													
16	COLY	11	4.9	1	4.9	1173	13.4	1	13.4	1448	8.7	1	8.7	968	1565
21															
23															
26															
28															
30	COLY	47													
32	COLY	51	5.8	2	6.0	1554	4.0	1	4.0	1353	5.5	1	5.5	1563	1674
38	YAMMA	49													
40	YAMMA	12													
42	COLY	48	7.9	1	7.9	1287									1621
43	ARGOON	21													
45															
47	ARGOON	22													
49	YAMMA	48													
57	YAMMA	51									2.5	1	2.5	1060	1902
59															
62															
63	YAMMA	39	10.0	2	11.8	1410	5.8	1	5.8	1382	8.6	2	8.6	1403	1564
68															
72															
73	BUNDURE	7	7.5	1	7.5	1154	1.9	1	1.9	1139					1538
76	BUNDURE	5	4.9	6	5.3	1568	3.9	5	4.8	1660					1735
82															

Table 7.12 Seepage estimates for each pool containing hotspots identified as priority 5 by Allen (2006)

Site Id	Main channel	Pool ID	2009				2010				2011				Full Supply el. (mm)
			Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	
22															
29															
31	COLY	40													
33	COLY	42	8.9	2	9.6	1721					4.0	2	3.8	1718	1860
34	COLY	64									4.6	1	4.6	1682	1750
44															
46															

7.4 Discussion and Conclusions

Analysis of all the pools based on the findings of Chapter 6 highlighted that the averaged pool estimate solely cannot identify pools with high loss rates which require remediation works. Given that higher loss rates occur at higher channel water elevations similar to operational condition, the most ideal pondage condition among all the pondage samples or simply the pondage sample that only occurred at higher channel water elevations were selected and the estimated pondage rate was used in conjunction with the averaged pool estimate to:

1) Identify any pools with either high pool or pondage seepage that require remediation, and
2) Compare the seepage results in different years to identify any improvement in channel condition due to remediation works undertaken in any channel.

Moreover, the estimated loss rates at higher channel water elevations can give an estimate of the possible water loss during normal operation in each channel. This loss rate was also used as the basis for comparing the results of this study with other seepage studies done in the CIA.

An analysis was done for all the pools and based on the averaged pool seepage rates during the three years, pools with high loss rates were identified and grouped in four different categories. Analysis of the identified pools highlighted that a leakage component can be expected in the majority of the pools in the 1st, 2nd, some of the pools in the 3rd and a small number of the pools in the 4th category. Moreover, it was shown that higher loss rates can exist in pools with medium averaged pool estimates.

It was further shown that the estimated loss rates during operational conditions are approximately 20% higher than the averaged pool estimates for most of the main channels in CIA.

The estimated loss rates at higher channel water elevations were compared with seepage inferred from EC measurements by Allen (2006), who aimed to identify locations with high potential for seepage. The related pool for each of the identified locations was linked and the seepage estimates were compared. Because no pondages occurred in any of the pools linked to locations in the 1st priority of Allen (2006), no comparison was made. However, results of the comparison for priorities 2 and 3 highlighted a number of pools with greater loss rates compared with the seepage estimates of Allen (2006). Given that all pools in these groups showed evidence of possible leakage, it can be concluded that leakage was not estimated in seepage results of Allen (2006) study. Similarly, the comparison of loss rates for the 3rd priority showed a number of pools with loss rates greater than 10 mm/d and which also showed evidence of possible leakage. The comparison for the 4th priority showed better agreement between the results and only two of the pools experienced loss rates greater than 10 mm/d. The estimated loss rates in the fifth priority also showed a good agreement with both pools having loss rates less than 10 mm/d.

In summary, results of the comparison showed a reasonable agreement with the estimates of Allen (2006) in lower priorities were no leakage was available. On the other hand, in the 2nd and the 3rd priorities where a number of pools were suspected with a possible leakage at higher channel water elevations, the estimated loss rates from the TCC data were greater compared to the estimates of Allen (2006). The difference might be due to a number of limitations in both studies.

Allen (2006) used a geophysical indicator of high potential seepage in conjunction with measurements of the seepage loss at specific points. This methodology addressed high vertical losses but might possibly have missed lateral water losses (leakage) through the channel banks. Moreover, in most locations the seepage was only occurring along a small proportion of the reach and the pondage based seepage rates from the TCC data cannot represent the seepage rate of the specified locations. In addition, pondage conditions occur randomly in different channels at different water elevations based on the system's objectives. Therefore, not all the pondage conditions have the ideal requirements such as long duration and full supply elevation.

CHAPTER 8: Conclusions and Recommendations

8.1 Review of research

Conveyance water losses are a significant concern in any irrigation scheme. The conveyance water losses refer to seepage, leakage and evaporation losses from the irrigation channels. Pondage tests are acknowledged as the best direct method for seepage and leakage measurement in irrigation channels. On the other hand, the evaporation loss can be estimated using data collected from nearby automated weather stations.

In the past, pondage testing required the construction of earthen banks to create leak-proof sections of channel where the drop in water level could be measured. However, TCC data from the existing regulating structures in automated systems during periods of gate closure, effectively allows pondage testing in each and every pool throughout a channel system.

The application of TCC data from a limited number of selected channels in Northern Victoria for the purpose of seepage and leakage estimation has previously proved to be successful. However, the application of TCC data for an entire irrigation network can lead to an evaluation of all factors affecting the estimated seepage rates during different pondage conditions as well as real time measurement of seepage and leakage losses in any given pool on different channels in the system.

This study has addressed these issues successfully in four key chapters 4, 5, 6 and 7 of this dissertation that are focused on:

- Development of a model for pondage condition detection through the entire network and analysis of TCC data for the purpose of seepage estimation
- Evaluation of all factors affecting the estimated seepage rates during different pondage conditions in any given pool
- Demonstrating the application of model results to estimate loss rates during normal channel operation
- Demonstrating the application of model results to address pools with high loss rates that require remediation

8.2 Major outcomes and key findings

The major outcomes and key findings are given in the following sections according to the issues addressed in this research study.

8.2.1 Development of a model for detection and analysis of all pondage conditions through the entire network

Under this study a novel computer model capable of automatically detecting and analysing all pondage conditions throughout the entire network has been developed. The underlying hypothesis for the computer model is that the seepage and leakage losses can be estimated and separated from combined losses during periods of shut down.

The model consists of two parts:

The first is a database consisting of all the TCC information for each gauge, pool and the automated weather station data in form of 9 tables created in Microsoft SQL server environment. In the database, the irrigation district has been divided to number of main channels and based on the locations of different gauges, resulting pools have been defined. Second, a model written in the C sharp environment has been presented to analyse the pondage samples from TCC data. The model is a robust tool for identification of all pondage conditions throughout the entire channel network, classify pondage samples based upon the set criteria, and estimate seepage rates for each gauge, pondage and pool in each irrigation season.

The model has enabled the first comprehensive analysis of TCC data for a whole system and for whole seasons. Moreover, the model has enabled an assessment to be made of the quality of the TCC data. Furthermore, the magnitude and distribution of losses have been estimated, showing that seepage losses from the CIA are significant. In addition, results of the analysis highlighted lower magnitude of losses for 2011 season in compare with 2009 and 2010 seasons. While, the magnitude of losses for 2009 and 2010 seasons were approximately equal.

8.2.2 Evaluation of all factors affecting the estimated seepage rates during different pondage conditions in any given pool

In order to evaluate the quality and accuracy of estimated seepage rates from TCC data, a detailed analysis of all pondage conditions that occurred in a number of selected pools in different channels from 2009 till 2011 was undertaken and the factors affecting the estimates of seepage rates were addressed.

It was highlighted by the results of the analysis that the initial water elevation in the channel in any given pondage condition has a direct relationship with the estimated seepage rate, with higher rates of seepage occurring at higher water elevations.

Furthermore, the variation of estimated seepage rates during any given irrigation season highlighted a seasonal affect which might be as a result of watertable levels. Consequently, lower rates are expected during months with higher watertable elevations at the beginning or towards the end of each season while, greater rates are expected in the middle of the season when the watertable elevations are lower.

Pondage duration has also been shown to be inversely related to the seepage rates estimated using linear regression. However, comparison of the estimated seepage rate at the start of longer pondage conditions compared to the averaged seepage rates has revealed that the decrease in the water elevations in the longer pondage periods might explain effect of pondage duration on the estimated seepage rate.

It has been further highlighted that the water elevation measurements during a shut down period did not commence exactly at the start and the end of pondage condition which resulted in small number of records covering a shorter duration than the actual pondage period. Therefore, the number of measured points during any given pondage condition has been introduced as another factor affecting the reliability of the estimated seepage rates.

Detailed analysis of the corrected water elevation plots has shown that a rainfall event during a pondage condition causes a rise and fall in the corrected water elevation plot and influences the estimated seepage rate. This is due to use of daily rainfall totals and a corresponding uncertainty in the timing and duration of the rainfall events. Hence, the rise and fall has been removed from the corrected water elevation plots and the seepage rate has been re estimated for the remaining part if sufficient duration and number of measured points were available.

The possible presence of noise in the water elevation data associated with the measurement devices as well as unauthorized water usage has been addressed as other factors influencing the estimation of the rate of seepage.

Results of the analysis have highlighted that high rates of water loss occurring at higher water elevations might be due in part to leakage through macro pores in the channel bank at or near the full supply level. It has been further concluded that an ideal form of water elevation plot (showing a decline in the loss rate with time or with lower water level) which indicates a leakage component can sometimes be found in longer pondage conditions with a high number of measured points at higher channel water levels.

In this case the polynomial trend line was the best model to estimate the rate of water loss while for all other pondage conditions the linear regression was the simplest and preferred approach.

8.2.3 Demonstrating the application of model results to estimate loss rates during normal channel operation

Given that the channel water elevations during normal operation condition are maintained at about the full supply level, this suggests that the loss rate estimated for pondage condition at the highest water level in each pool can be used as an estimate of the loss rate that might occur during channel operation. This loss rate can also be used as the basis for comparing the findings of this study with other seepage studies done in the CIA.

A comparison was made between the estimated loss rates and Allen, (2006) results. Results of the comparison showed a good agreement in lower loss rates. While, the estimated loss rates for cases suspected with a possible leakage showed to be greater in compare of estimates of Allen, (2006). The difference between the results might be due to missing potential lateral water losses in channel banks in Allen, (2006) study although his methodology proved to be successful in addressing high vertical losses.

8.2.4 Demonstrating the application of model results to address pools which require remediation

The estimated seepage rate for each pool can be used as a basis for rapid identification of pools which require remediation works. Furthermore, the comparison of the estimated loss rates at highest water level during each season in one pool can also be used to highlight pools that show lower loss rates as a result of remediation or pools that still require remediation.

8.3 Recommendations for further research

The estimated seepage rates for different pools suffer from two major deficiencies. Firstly, based on the fact that the pool based seepage rates are averaged based and dependent on pondage based seepage rates, not all the pools have sufficient number of pondage conditions at various water elevations which influence the estimated pool based seepage rates. Secondly, pondage conditions occur randomly in different channels at different water elevations based on the system's objectives. Therefore, not all the occurred pondage conditions in CIA have the requirements of an ideal pondage condition such as long enough duration and full supply elevation.

During the course of this PhD study it has become evident that the real time control of irrigation channels based on the analysis of TCC pondage data has the potential to bring about significant improvements in water resources management. The model has been evaluated using existing TCC data from CICL. The other areas identified for further research are:

- Better understanding of what is causing the so far unexplained fluctuations in water levels of rejected pondage samples
- Use of recording rain gauges to improve the accounting for rainfall
- Evaluation of the model with other existing TCC data and comparison the results

- Further investigation of factors affecting the estimated seepage rate in different pools
- Automating the computer model with further information including EM survey data and different soil types in order to evaluate the correlation of seepage estimates with those related values
- Automating the computer model with polynomial trend line for pondage samples suspected with leakage at higher channel water elevation
- Combining the computer model with soft computing techniques like neural networks in order to build up a predictive model

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APPENDIX A

Computer software written in C# to interrogate the database and analyse pondage samples from TCC data

```
#pragma warning disable 1591

namespace Coleambally.Common.Data {
    
    /// <summary>
    ///Represents a strongly typed in-memory cache of data.
    ///</summary>
    [global::System.Serializable()]
    [global::System.ComponentModel.DesignerCategoryAttribute("code")]
    [global::System.ComponentModel.ToolboxItem(true)]
    [global::System.Xml.Serialization.XmlSchemaProviderAttribute("GetTypedDataSetSchema")]
    [global::System.Xml.Serialization.XmlRootAttribute("AllPoolReportDS")]
    [global::System.ComponentModel.Design.HelpKeywordAttribute("vs.data.DataSet")]
    public partial class AllPoolReportDS : global::System.Data.DataSet {
        
        private ReportDTDataTable tableReportDT;
        
        private global::System.Data.SchemaSerializationMode _schemaSerializationMode = 
global::System.Data.SchemaSerializationMode.IncludeSchema;
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public AllPoolReportDS() {
            this.BeginInit();
            this.InitClass();
            global::System.ComponentModel.CollectionChangeEventHandler schemaChangedHandler = 
new global::System.ComponentModel.CollectionChangeEventHandler(this.SchemaChanged);
            base.Tables.CollectionChanged += schemaChangedHandler;
            base.Relations.CollectionChanged += schemaChangedHandler;
            this.EndInit();
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        protected AllPoolReportDS(global::System.Runtime.Serialization.SerializationInfo 
info, global::System.Runtime.Serialization.StreamingContext context) : 
                base(info, context, false) {
            if ((this.IsBinarySerialized(info, context) == true)) {
                this.InitVars(false);
                global::System.ComponentModel.CollectionChangeEventHandler 
schemaChangedHandler1 = new 
global::System.ComponentModel.CollectionChangeEventHandler(this.SchemaChanged);
                this.Tables.CollectionChanged += schemaChangedHandler1;
                this.Relations.CollectionChanged += schemaChangedHandler1;
                return;
            }
            string strSchema = ((string)(info.GetValue("XmlSchema", typeof(string))));
            if ((this.DetermineSchemaSerializationMode(info, context) == 
global::System.Data.SchemaSerializationMode.IncludeSchema)) {
                global::System.Data.DataSet ds = new global::System.Data.DataSet();
                ds.ReadXmlSchema(new global::System.Xml.XmlTextReader(new 
global::System.IO.StringReader(strSchema)));
                if ((ds.Tables["ReportDT"] != null)) {
                    base.Tables.Add(new ReportDTDataTable(ds.Tables["ReportDT"]));
                }
                this.DataSetName = ds.DataSetName;
                this.Prefix = ds.Prefix;
                this.Namespace = ds.Namespace;
                this.Locale = ds.Locale;
                this.CaseSensitive = ds.CaseSensitive;
                this.EnforceConstraints = ds.EnforceConstraints;
                this.Merge(ds, false, global::System.Data.MissingSchemaAction.Add);
```

```
                this.InitVars();
            }
            else {
                this.ReadXmlSchema(new global::System.Xml.XmlTextReader(new
global::System.IO.StringReader(strSchema)));
            }
            this.GetSerializationData(info, context);
            global::System.ComponentModel.CollectionChangeEventHandler schemaChangedHandler =
new global::System.ComponentModel.CollectionChangeEventHandler(this.SchemaChanged);
            base.Tables.CollectionChanged += schemaChangedHandler;
            this.Relations.CollectionChanged += schemaChangedHandler;
        }

        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        [global::System.ComponentModel.Browsable(false)]

[global::System.ComponentModel.DesignerSerializationVisibility(global::System.ComponentModel.
DesignerSerializationVisibility.Content)]
        public ReportDTDataTable ReportDT {
            get {
                return this.tableReportDT;
            }
        }

        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        [global::System.ComponentModel.BrowsableAttribute(true)]

[global::System.ComponentModel.DesignerSerializationVisibilityAttribute(global::System.Compon
entModel.DesignerSerializationVisibility.Visible)]
        public override global::System.Data.SchemaSerializationMode SchemaSerializationMode {
            get {
                return this._schemaSerializationMode;
            }
            set {
                this._schemaSerializationMode = value;
            }
        }

        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]

[global::System.ComponentModel.DesignerSerializationVisibilityAttribute(global::System.Compon
entModel.DesignerSerializationVisibility.Hidden)]
        public new global::System.Data.DataTableCollection Tables {
            get {
                return base.Tables;
            }
        }

        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]

[global::System.ComponentModel.DesignerSerializationVisibilityAttribute(global::System.Compon
entModel.DesignerSerializationVisibility.Hidden)]
        public new global::System.Data.DataRelationCollection Relations {
            get {
                return base.Relations;
            }
        }

        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        protected override void InitializeDerivedDataSet() {
            this.BeginInit();
            this.InitClass();
```

```
            this.EndInit();
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public override global::System.Data.DataSet Clone() {
            AllPoolReportDS cln = ((AllPoolReportDS)(base.Clone()));
            cln.InitVars();
            cln.SchemaSerializationMode = this.SchemaSerializationMode;
            return cln;
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        protected override bool ShouldSerializeTables() {
            return false;
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        protected override bool ShouldSerializeRelations() {
            return false;
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        protected override void ReadXmlSerializable(global::System.Xml.XmlReader reader) {
            if ((this.DetermineSchemaSerializationMode(reader) == 
global::System.Data.SchemaSerializationMode.IncludeSchema)) {
                this.Reset();
                global::System.Data.DataSet ds = new global::System.Data.DataSet();
                ds.ReadXml(reader);
                if ((ds.Tables["ReportDT"] != null)) {
                    base.Tables.Add(new ReportDTDataTable(ds.Tables["ReportDT"]));
                }
                this.DataSetName = ds.DataSetName;
                this.Prefix = ds.Prefix;
                this.Namespace = ds.Namespace;
                this.Locale = ds.Locale;
                this.CaseSensitive = ds.CaseSensitive;
                this.EnforceConstraints = ds.EnforceConstraints;
                this.Merge(ds, false, global::System.Data.MissingSchemaAction.Add);
                this.InitVars();
            }
            else {
                this.ReadXml(reader);
                this.InitVars();
            }
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        protected override global::System.Xml.Schema.XmlSchema GetSchemaSerializable() {
            global::System.IO.MemoryStream stream = new global::System.IO.MemoryStream();
            this.WriteXmlSchema(new global::System.Xml.XmlTextWriter(stream, null));
            stream.Position = 0;
            return global::System.Xml.Schema.XmlSchema.Read(new 
global::System.Xml.XmlTextReader(stream), null);
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        internal void InitVars() {
            this.InitVars(true);
        }
```

```
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        internal void InitVars(bool initTable) {
            this.tableReportDT = ((ReportDTDataTable)(base.Tables["ReportDT"]));
            if ((initTable == true)) {
                if ((this.tableReportDT != null)) {
                    this.tableReportDT.InitVars();
                }
            }
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        private void InitClass() {
            this.DataSetName = "AllPoolReportDS";
            this.Prefix = "";
            this.Namespace = "http://tempuri.org/AllPoolReportDS.xsd";
            this.EnforceConstraints = true;
            this.SchemaSerializationMode = 
global::System.Data.SchemaSerializationMode.IncludeSchema;
            this.tableReportDT = new ReportDTDataTable();
            base.Tables.Add(this.tableReportDT);
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        private bool ShouldSerializeReportDT() {
            return false;
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        private void SchemaChanged(object sender, 
global::System.ComponentModel.CollectionChangeEventArgs e) {
            if ((e.Action == global::System.ComponentModel.CollectionChangeAction.Remove)) {
                this.InitVars();
            }
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public static global::System.Xml.Schema.XmlSchemaComplexType 
GetTypedDataSetSchema(global::System.Xml.Schema.XmlSchemaSet xs) {
            AllPoolReportDS ds = new AllPoolReportDS();
            global::System.Xml.Schema.XmlSchemaComplexType type = new 
global::System.Xml.Schema.XmlSchemaComplexType();
            global::System.Xml.Schema.XmlSchemaSequence sequence = new 
global::System.Xml.Schema.XmlSchemaSequence();
            global::System.Xml.Schema.XmlSchemaAny any = new 
global::System.Xml.Schema.XmlSchemaAny();
            any.Namespace = ds.Namespace;
            sequence.Items.Add(any);
            type.Particle = sequence;
            global::System.Xml.Schema.XmlSchema dsSchema = ds.GetSchemaSerializable();
            if (xs.Contains(dsSchema.TargetNamespace)) {
                global::System.IO.MemoryStream s1 = new global::System.IO.MemoryStream();
                global::System.IO.MemoryStream s2 = new global::System.IO.MemoryStream();
                try {
                    global::System.Xml.Schema.XmlSchema schema = null;
                    dsSchema.Write(s1);
                    for (global::System.Collections.IEnumerator schemas = 
xs.Schemas(dsSchema.TargetNamespace).GetEnumerator(); schemas.MoveNext(); ) {
                        schema = ((global::System.Xml.Schema.XmlSchema)(schemas.Current));
                        s2.SetLength(0);
                        schema.Write(s2);
                        if ((s1.Length == s2.Length)) {
```

```
                        s1.Position = 0;
                        s2.Position = 0;
                        for (; ((s1.Position != s1.Length)
                                    && (s1.ReadByte() == s2.ReadByte())); ) {
                            ;
                        }
                        if ((s1.Position == s1.Length)) {
                            return type;
                        }
                    }
                }
            }
            finally {
                if ((s1 != null)) {
                    s1.Close();
                }
                if ((s2 != null)) {
                    s2.Close();
                }
            }
        }
        xs.Add(dsSchema);
        return type;
    }


[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public delegate void ReportDTRowChangeEventHandler(object sender,
ReportDTRowChangeEvent e);

        /// <summary>
        ///Represents the strongly named DataTable class.
        ///</summary>
        [global::System.Serializable()]
        [global::System.Xml.Serialization.XmlSchemaProviderAttribute("GetTypedTableSchema")]
        public partial class ReportDTDataTable :
global::System.Data.TypedTableBase<ReportDTRow> {

            private global::System.Data.DataColumn columnGateName;

            private global::System.Data.DataColumn columnPoolName;

            private global::System.Data.DataColumn columnStartDate;

            private global::System.Data.DataColumn columnEndDate;

            private global::System.Data.DataColumn columnSeqLevelGate1;

            private global::System.Data.DataColumn columnDesLevelGate1;

            private global::System.Data.DataColumn columnR2Gate1;

            private global::System.Data.DataColumn columnAGate1;

            private global::System.Data.DataColumn columnSeqLevelGate2;

            private global::System.Data.DataColumn columnDesLevelGate2;

            private global::System.Data.DataColumn columnR2Gate2;

            private global::System.Data.DataColumn columnAGate2;

            private global::System.Data.DataColumn columnSeqLevelGate3;

            private global::System.Data.DataColumn columnDesLevelGate3;

            private global::System.Data.DataColumn columnR2Gate3;

            private global::System.Data.DataColumn columnAGate3;

            private global::System.Data.DataColumn columnSeqLevelGate4;

            private global::System.Data.DataColumn columnDesLevelGate4;

            private global::System.Data.DataColumn columnR2Gate4;
```

```
            private global::System.Data.DataColumn columnAGate4;

            private global::System.Data.DataColumn columnSeqLevelGate5;

            private global::System.Data.DataColumn columnDesLevelGate5;

            private global::System.Data.DataColumn columnR2Gate5;

            private global::System.Data.DataColumn columnAGate5;

            private global::System.Data.DataColumn columnSeqLevelGate6;

            private global::System.Data.DataColumn columnDesLevelGate6;

            private global::System.Data.DataColumn columnR2Gate6;

            private global::System.Data.DataColumn columnAGate6;

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public ReportDTDataTable() {
                this.TableName = "ReportDT";
                this.BeginInit();
                this.InitClass();
                this.EndInit();
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            internal ReportDTDataTable(global::System.Data.DataTable table) {
                this.TableName = table.TableName;
                if ((table.CaseSensitive != table.DataSet.CaseSensitive)) {
                    this.CaseSensitive = table.CaseSensitive;
                }
                if ((table.Locale.ToString() != table.DataSet.Locale.ToString())) {
                    this.Locale = table.Locale;
                }
                if ((table.Namespace != table.DataSet.Namespace)) {
                    this.Namespace = table.Namespace;
                }
                this.Prefix = table.Prefix;
                this.MinimumCapacity = table.MinimumCapacity;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected
ReportDTDataTable(global::System.Runtime.Serialization.SerializationInfo info,
global::System.Runtime.Serialization.StreamingContext context) :
                    base(info, context) {
                this.InitVars();
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn GateNameColumn {
                get {
                    return this.columnGateName;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn PoolNameColumn {
                get {
                    return this.columnPoolName;
                }
```

```
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn StartDateColumn {
                get {
                    return this.columnStartDate;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn EndDateColumn {
                get {
                    return this.columnEndDate;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn SeqLevelGate1Column {
                get {
                    return this.columnSeqLevelGate1;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn DesLevelGate1Column {
                get {
                    return this.columnDesLevelGate1;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn R2Gate1Column {
                get {
                    return this.columnR2Gate1;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn AGate1Column {
                get {
                    return this.columnAGate1;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn SeqLevelGate2Column {
                get {
                    return this.columnSeqLevelGate2;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn DesLevelGate2Column {
```

```
                get {
                    return this.columnDesLevelGate2;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn R2Gate2Column {
                get {
                    return this.columnR2Gate2;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn AGate2Column {
                get {
                    return this.columnAGate2;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn SeqLevelGate3Column {
                get {
                    return this.columnSeqLevelGate3;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn DesLevelGate3Column {
                get {
                    return this.columnDesLevelGate3;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn R2Gate3Column {
                get {
                    return this.columnR2Gate3;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn AGate3Column {
                get {
                    return this.columnAGate3;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn SeqLevelGate4Column {
                get {
                    return this.columnSeqLevelGate4;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
```

```
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn DesLevelGate4Column {
                get {
                    return this.columnDesLevelGate4;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn R2Gate4Column {
                get {
                    return this.columnR2Gate4;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn AGate4Column {
                get {
                    return this.columnAGate4;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn SeqLevelGate5Column {
                get {
                    return this.columnSeqLevelGate5;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn DesLevelGate5Column {
                get {
                    return this.columnDesLevelGate5;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn R2Gate5Column {
                get {
                    return this.columnR2Gate5;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn AGate5Column {
                get {
                    return this.columnAGate5;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn SeqLevelGate6Column {
                get {
                    return this.columnSeqLevelGate6;
                }
```

```
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn DesLevelGate6Column {
                get {
                    return this.columnDesLevelGate6;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn R2Gate6Column {
                get {
                    return this.columnR2Gate6;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataColumn AGate6Column {
                get {
                    return this.columnAGate6;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            [global::System.ComponentModel.Browsable(false)]
            public int Count {
                get {
                    return this.Rows.Count;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public ReportDTRow this[int index] {
                get {
                    return ((ReportDTRow)(this.Rows[index]));
                }
            }


[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public event ReportDTRowChangeEventHandler ReportDTRowChanging;


[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public event ReportDTRowChangeEventHandler ReportDTRowChanged;


[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public event ReportDTRowChangeEventHandler ReportDTRowDeleting;


[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public event ReportDTRowChangeEventHandler ReportDTRowDeleted;

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
```

```
            public void AddReportDTRow(ReportDTRow row) {
                this.Rows.Add(row);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public ReportDTRow AddReportDTRow(
                        string GateName,
                        string PoolName,
                        System.DateTime StartDate,
                        string EndDate,
                        string SeqLevelGate1,
                        string DesLevelGate1,
                        string R2Gate1,
                        string AGate1,
                        string SeqLevelGate2,
                        string DesLevelGate2,
                        string R2Gate2,
                        string AGate2,
                        string SeqLevelGate3,
                        string DesLevelGate3,
                        string R2Gate3,
                        string AGate3,
                        string SeqLevelGate4,
                        string DesLevelGate4,
                        string R2Gate4,
                        string AGate4,
                        string SeqLevelGate5,
                        string DesLevelGate5,
                        string R2Gate5,
                        string AGate5,
                        string SeqLevelGate6,
                        string DesLevelGate6,
                        string R2Gate6,
                        string AGate6) {
                ReportDTRow rowReportDTRow = ((ReportDTRow)(this.NewRow()));
                object[] columnValuesArray = new object[] {
                        GateName,
                        PoolName,
                        StartDate,
                        EndDate,
                        SeqLevelGate1,
                        DesLevelGate1,
                        R2Gate1,
                        AGate1,
                        SeqLevelGate2,
                        DesLevelGate2,
                        R2Gate2,
                        AGate2,
                        SeqLevelGate3,
                        DesLevelGate3,
                        R2Gate3,
                        AGate3,
                        SeqLevelGate4,
                        DesLevelGate4,
                        R2Gate4,
                        AGate4,
                        SeqLevelGate5,
                        DesLevelGate5,
                        R2Gate5,
                        AGate5,
                        SeqLevelGate6,
                        DesLevelGate6,
                        R2Gate6,
                        AGate6};
                rowReportDTRow.ItemArray = columnValuesArray;
                this.Rows.Add(rowReportDTRow);
                return rowReportDTRow;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public override global::System.Data.DataTable Clone() {
```

```
                ReportDTDataTable cln = ((ReportDTDataTable)(base.Clone()));
                cln.InitVars();
                return cln;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected override global::System.Data.DataTable CreateInstance() {
                return new ReportDTDataTable();
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            internal void InitVars() {
                this.columnGateName = base.Columns["GateName"];
                this.columnPoolName = base.Columns["PoolName"];
                this.columnStartDate = base.Columns["StartDate"];
                this.columnEndDate = base.Columns["EndDate"];
                this.columnSeqLevelGate1 = base.Columns["SeqLevelGate1"];
                this.columnDesLevelGate1 = base.Columns["DesLevelGate1"];
                this.columnR2Gate1 = base.Columns["R2Gate1"];
                this.columnAGate1 = base.Columns["AGate1"];
                this.columnSeqLevelGate2 = base.Columns["SeqLevelGate2"];
                this.columnDesLevelGate2 = base.Columns["DesLevelGate2"];
                this.columnR2Gate2 = base.Columns["R2Gate2"];
                this.columnAGate2 = base.Columns["AGate2"];
                this.columnSeqLevelGate3 = base.Columns["SeqLevelGate3"];
                this.columnDesLevelGate3 = base.Columns["DesLevelGate3"];
                this.columnR2Gate3 = base.Columns["R2Gate3"];
                this.columnAGate3 = base.Columns["AGate3"];
                this.columnSeqLevelGate4 = base.Columns["SeqLevelGate4"];
                this.columnDesLevelGate4 = base.Columns["DesLevelGate4"];
                this.columnR2Gate4 = base.Columns["R2Gate4"];
                this.columnAGate4 = base.Columns["AGate4"];
                this.columnSeqLevelGate5 = base.Columns["SeqLevelGate5"];
                this.columnDesLevelGate5 = base.Columns["DesLevelGate5"];
                this.columnR2Gate5 = base.Columns["R2Gate5"];
                this.columnAGate5 = base.Columns["AGate5"];
                this.columnSeqLevelGate6 = base.Columns["SeqLevelGate6"];
                this.columnDesLevelGate6 = base.Columns["DesLevelGate6"];
                this.columnR2Gate6 = base.Columns["R2Gate6"];
                this.columnAGate6 = base.Columns["AGate6"];
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            private void InitClass() {
                this.columnGateName = new global::System.Data.DataColumn("GateName",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnGateName);
                this.columnPoolName = new global::System.Data.DataColumn("PoolName",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnPoolName);
                this.columnStartDate = new global::System.Data.DataColumn("StartDate",
typeof(global::System.DateTime), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnStartDate);
                this.columnEndDate = new global::System.Data.DataColumn("EndDate",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnEndDate);
                this.columnSeqLevelGate1 = new
global::System.Data.DataColumn("SeqLevelGate1", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnSeqLevelGate1);
                this.columnDesLevelGate1 = new
global::System.Data.DataColumn("DesLevelGate1", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnDesLevelGate1);
                this.columnR2Gate1 = new global::System.Data.DataColumn("R2Gate1",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnR2Gate1);
```

```
                this.columnAGate1 = new global::System.Data.DataColumn("AGate1",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnAGate1);
                this.columnSeqLevelGate2 = new
global::System.Data.DataColumn("SeqLevelGate2", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnSeqLevelGate2);
                this.columnDesLevelGate2 = new
global::System.Data.DataColumn("DesLevelGate2", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnDesLevelGate2);
                this.columnR2Gate2 = new global::System.Data.DataColumn("R2Gate2",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnR2Gate2);
                this.columnAGate2 = new global::System.Data.DataColumn("AGate2",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnAGate2);
                this.columnSeqLevelGate3 = new
global::System.Data.DataColumn("SeqLevelGate3", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnSeqLevelGate3);
                this.columnDesLevelGate3 = new
global::System.Data.DataColumn("DesLevelGate3", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnDesLevelGate3);
                this.columnR2Gate3 = new global::System.Data.DataColumn("R2Gate3",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnR2Gate3);
                this.columnAGate3 = new global::System.Data.DataColumn("AGate3",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnAGate3);
                this.columnSeqLevelGate4 = new
global::System.Data.DataColumn("SeqLevelGate4", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnSeqLevelGate4);
                this.columnDesLevelGate4 = new
global::System.Data.DataColumn("DesLevelGate4", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnDesLevelGate4);
                this.columnR2Gate4 = new global::System.Data.DataColumn("R2Gate4",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnR2Gate4);
                this.columnAGate4 = new global::System.Data.DataColumn("AGate4",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnAGate4);
                this.columnSeqLevelGate5 = new
global::System.Data.DataColumn("SeqLevelGate5", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnSeqLevelGate5);
                this.columnDesLevelGate5 = new
global::System.Data.DataColumn("DesLevelGate5", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnDesLevelGate5);
                this.columnR2Gate5 = new global::System.Data.DataColumn("R2Gate5",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnR2Gate5);
                this.columnAGate5 = new global::System.Data.DataColumn("AGate5",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnAGate5);
                this.columnSeqLevelGate6 = new
global::System.Data.DataColumn("SeqLevelGate6", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnSeqLevelGate6);
                this.columnDesLevelGate6 = new
global::System.Data.DataColumn("DesLevelGate6", typeof(string), null,
global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnDesLevelGate6);
                this.columnR2Gate6 = new global::System.Data.DataColumn("R2Gate6",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnR2Gate6);
                this.columnAGate6 = new global::System.Data.DataColumn("AGate6",
typeof(string), null, global::System.Data.MappingType.Element);
                base.Columns.Add(this.columnAGate6);
                this.columnSeqLevelGate1.Caption = "SeqLevelGate";
                this.columnDesLevelGate1.Caption = "DesLevelGate";
                this.columnR2Gate1.Caption = "R2Gate";
                this.columnAGate1.Caption = "Gate1A";
```

```
                this.columnSeqLevelGate2.Caption = "SeqLevelGate";
                this.columnDesLevelGate2.Caption = "DesLevelGate";
                this.columnR2Gate2.Caption = "R2Gate";
                this.columnAGate2.Caption = "Gate1A";
                this.columnSeqLevelGate3.Caption = "SeqLevelGate";
                this.columnDesLevelGate3.Caption = "DesLevelGate";
                this.columnR2Gate3.Caption = "R2Gate";
                this.columnAGate3.Caption = "Gate1A";
                this.columnSeqLevelGate4.Caption = "SeqLevelGate";
                this.columnDesLevelGate4.Caption = "DesLevelGate";
                this.columnR2Gate4.Caption = "R2Gate";
                this.columnAGate4.Caption = "Gate1A";
                this.columnSeqLevelGate5.Caption = "SeqLevelGate";
                this.columnDesLevelGate5.Caption = "DesLevelGate";
                this.columnR2Gate5.Caption = "R2Gate";
                this.columnAGate5.Caption = "Gate1A";
                this.columnSeqLevelGate6.Caption = "SeqLevelGate";
                this.columnDesLevelGate6.Caption = "DesLevelGate";
                this.columnR2Gate6.Caption = "R2Gate";
                this.columnAGate6.Caption = "Gate1A";
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public ReportDTRow NewReportDTRow() {
                return ((ReportDTRow)(this.NewRow()));
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected override global::System.Data.DataRow 
NewRowFromBuilder(global::System.Data.DataRowBuilder builder) {
                return new ReportDTRow(builder);
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected override global::System.Type GetRowType() {
                return typeof(ReportDTRow);
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected override void OnRowChanged(global::System.Data.DataRowChangeEventArgs 
e) {
                base.OnRowChanged(e);
                if ((this.ReportDTRowChanged != null)) {
                    this.ReportDTRowChanged(this, new 
ReportDTRowChangeEvent(((ReportDTRow)(e.Row)), e.Action));
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected override void OnRowChanging(global::System.Data.DataRowChangeEventArgs 
e) {
                base.OnRowChanging(e);
                if ((this.ReportDTRowChanging != null)) {
                    this.ReportDTRowChanging(this, new 
ReportDTRowChangeEvent(((ReportDTRow)(e.Row)), e.Action));
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
```

```
            protected override void OnRowDeleted(global::System.Data.DataRowChangeEventArgs
e) {
                base.OnRowDeleted(e);
                if ((this.ReportDTRowDeleted != null)) {
                    this.ReportDTRowDeleted(this, new
ReportDTRowChangeEvent(((ReportDTRow)(e.Row)), e.Action));
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            protected override void OnRowDeleting(global::System.Data.DataRowChangeEventArgs
e) {
                base.OnRowDeleting(e);
                if ((this.ReportDTRowDeleting != null)) {
                    this.ReportDTRowDeleting(this, new
ReportDTRowChangeEvent(((ReportDTRow)(e.Row)), e.Action));
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void RemoveReportDTRow(ReportDTRow row) {
                this.Rows.Remove(row);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public static global::System.Xml.Schema.XmlSchemaComplexType
GetTypedTableSchema(global::System.Xml.Schema.XmlSchemaSet xs) {
                global::System.Xml.Schema.XmlSchemaComplexType type = new
global::System.Xml.Schema.XmlSchemaComplexType();
                global::System.Xml.Schema.XmlSchemaSequence sequence = new
global::System.Xml.Schema.XmlSchemaSequence();
                AllPoolReportDS ds = new AllPoolReportDS();
                global::System.Xml.Schema.XmlSchemaAny any1 = new
global::System.Xml.Schema.XmlSchemaAny();
                any1.Namespace = "http://www.w3.org/2001/XMLSchema";
                any1.MinOccurs = new decimal(0);
                any1.MaxOccurs = decimal.MaxValue;
                any1.ProcessContents =
global::System.Xml.Schema.XmlSchemaContentProcessing.Lax;
                sequence.Items.Add(any1);
                global::System.Xml.Schema.XmlSchemaAny any2 = new
global::System.Xml.Schema.XmlSchemaAny();
                any2.Namespace = "urn:schemas-microsoft-com:xml-diffgram-v1";
                any2.MinOccurs = new decimal(1);
                any2.ProcessContents =
global::System.Xml.Schema.XmlSchemaContentProcessing.Lax;
                sequence.Items.Add(any2);
                global::System.Xml.Schema.XmlSchemaAttribute attribute1 = new
global::System.Xml.Schema.XmlSchemaAttribute();
                attribute1.Name = "namespace";
                attribute1.FixedValue = ds.Namespace;
                type.Attributes.Add(attribute1);
                global::System.Xml.Schema.XmlSchemaAttribute attribute2 = new
global::System.Xml.Schema.XmlSchemaAttribute();
                attribute2.Name = "tableTypeName";
                attribute2.FixedValue = "ReportDTDataTable";
                type.Attributes.Add(attribute2);
                type.Particle = sequence;
                global::System.Xml.Schema.XmlSchema dsSchema = ds.GetSchemaSerializable();
                if (xs.Contains(dsSchema.TargetNamespace)) {
                    global::System.IO.MemoryStream s1 = new global::System.IO.MemoryStream();
                    global::System.IO.MemoryStream s2 = new global::System.IO.MemoryStream();
                    try {
                        global::System.Xml.Schema.XmlSchema schema = null;
                        dsSchema.Write(s1);
                        for (global::System.Collections.IEnumerator schemas =
xs.Schemas(dsSchema.TargetNamespace).GetEnumerator(); schemas.MoveNext(); ) {
```

```
                            schema =
((global::System.Xml.Schema.XmlSchema)(schemas.Current));
                            s2.SetLength(0);
                            schema.Write(s2);
                            if ((s1.Length == s2.Length)) {
                                s1.Position = 0;
                                s2.Position = 0;
                                for (; ((s1.Position != s1.Length)
                                            && (s1.ReadByte() == s2.ReadByte())); ) {
                                    ;
                                }
                                if ((s1.Position == s1.Length)) {
                                    return type;
                                }
                            }
                        }
                    }
                    finally {
                        if ((s1 != null)) {
                            s1.Close();
                        }
                        if ((s2 != null)) {
                            s2.Close();
                        }
                    }
                }
                xs.Add(dsSchema);
                return type;
            }
        }

        /// <summary>
        ///Represents strongly named DataRow class.
        ///</summary>
        public partial class ReportDTRow : global::System.Data.DataRow {

            private ReportDTDataTable tableReportDT;

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            internal ReportDTRow(global::System.Data.DataRowBuilder rb) :
                    base(rb) {
                this.tableReportDT = ((ReportDTDataTable)(this.Table));
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string GateName {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.GateNameColumn]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'GateName\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.GateNameColumn] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string PoolName {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.PoolNameColumn]));
                    }
                    catch (global::System.InvalidCastException e) {
```

```
                        throw new global::System.Data.StrongTypingException("The value for 
column \'PoolName\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.PoolNameColumn] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public System.DateTime StartDate {
                get {
                    try {
                        return 
((global::System.DateTime)(this[this.tableReportDT.StartDateColumn]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for 
column \'StartDate\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.StartDateColumn] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string EndDate {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.EndDateColumn]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for 
column \'EndDate\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.EndDateColumn] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string SeqLevelGate1 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.SeqLevelGate1Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for 
column \'SeqLevelGate1\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.SeqLevelGate1Column] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string DesLevelGate1 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.DesLevelGate1Column]));
                    }
                    catch (global::System.InvalidCastException e) {
```

```
                        throw new global::System.Data.StrongTypingException("The value for
column \'DesLevelGate1\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.DesLevelGate1Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string R2Gate1 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.R2Gate1Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'R2Gate1\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.R2Gate1Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string AGate1 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.AGate1Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'AGate1\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.AGate1Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string SeqLevelGate2 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.SeqLevelGate2Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'SeqLevelGate2\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.SeqLevelGate2Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string DesLevelGate2 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.DesLevelGate2Column]));
                    }
                    catch (global::System.InvalidCastException e) {
```

```
                        throw new global::System.Data.StrongTypingException("The value for
column \'DesLevelGate2\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.DesLevelGate2Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string R2Gate2 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.R2Gate2Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'R2Gate2\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.R2Gate2Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string AGate2 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.AGate2Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'AGate2\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.AGate2Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string SeqLevelGate3 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.SeqLevelGate3Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'SeqLevelGate3\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.SeqLevelGate3Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string DesLevelGate3 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.DesLevelGate3Column]));
                    }
                    catch (global::System.InvalidCastException e) {
```

```
                        throw new global::System.Data.StrongTypingException("The value for
column \'DesLevelGate3\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.DesLevelGate3Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string R2Gate3 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.R2Gate3Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'R2Gate3\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.R2Gate3Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string AGate3 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.AGate3Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'AGate3\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.AGate3Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string SeqLevelGate4 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.SeqLevelGate4Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for
column \'SeqLevelGate4\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.SeqLevelGate4Column] = value;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string DesLevelGate4 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.DesLevelGate4Column]));
                    }
                    catch (global::System.InvalidCastException e) {
```

```
                throw new global::System.Data.StrongTypingException("The value for 
column \'DesLevelGate4\' in table \'ReportDT\' is DBNull.", e);
            }
        }
        set {
            this[this.tableReportDT.DesLevelGate4Column] = value;
        }
    }

    [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
    public string R2Gate4 {
        get {
            try {
                return ((string)(this[this.tableReportDT.R2Gate4Column]));
            }
            catch (global::System.InvalidCastException e) {
                throw new global::System.Data.StrongTypingException("The value for 
column \'R2Gate4\' in table \'ReportDT\' is DBNull.", e);
            }
        }
        set {
            this[this.tableReportDT.R2Gate4Column] = value;
        }
    }

    [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
    public string AGate4 {
        get {
            try {
                return ((string)(this[this.tableReportDT.AGate4Column]));
            }
            catch (global::System.InvalidCastException e) {
                throw new global::System.Data.StrongTypingException("The value for 
column \'AGate4\' in table \'ReportDT\' is DBNull.", e);
            }
        }
        set {
            this[this.tableReportDT.AGate4Column] = value;
        }
    }

    [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
    public string SeqLevelGate5 {
        get {
            try {
                return ((string)(this[this.tableReportDT.SeqLevelGate5Column]));
            }
            catch (global::System.InvalidCastException e) {
                throw new global::System.Data.StrongTypingException("The value for 
column \'SeqLevelGate5\' in table \'ReportDT\' is DBNull.", e);
            }
        }
        set {
            this[this.tableReportDT.SeqLevelGate5Column] = value;
        }
    }

    [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
    public string DesLevelGate5 {
        get {
            try {
                return ((string)(this[this.tableReportDT.DesLevelGate5Column]));
            }
            catch (global::System.InvalidCastException e) {
```

```
                        throw new global::System.Data.StrongTypingException("The value for 
column \'DesLevelGate5\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.DesLevelGate5Column] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string R2Gate5 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.R2Gate5Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for 
column \'R2Gate5\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.R2Gate5Column] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string AGate5 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.AGate5Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for 
column \'AGate5\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.AGate5Column] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string SeqLevelGate6 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.SeqLevelGate6Column]));
                    }
                    catch (global::System.InvalidCastException e) {
                        throw new global::System.Data.StrongTypingException("The value for 
column \'SeqLevelGate6\' in table \'ReportDT\' is DBNull.", e);
                    }
                }
                set {
                    this[this.tableReportDT.SeqLevelGate6Column] = value;
                }
            }
            
            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public string DesLevelGate6 {
                get {
                    try {
                        return ((string)(this[this.tableReportDT.DesLevelGate6Column]));
                    }
                    catch (global::System.InvalidCastException e) {
```

```
                    throw new global::System.Data.StrongTypingException("The value for 
column \'DesLevelGate6\' in table \'ReportDT\' is DBNull.", e);
                }
            }
            set {
                this[this.tableReportDT.DesLevelGate6Column] = value;
            }
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public string R2Gate6 {
            get {
                try {
                    return ((string)(this[this.tableReportDT.R2Gate6Column]));
                }
                catch (global::System.InvalidCastException e) {
                    throw new global::System.Data.StrongTypingException("The value for 
column \'R2Gate6\' in table \'ReportDT\' is DBNull.", e);
                }
            }
            set {
                this[this.tableReportDT.R2Gate6Column] = value;
            }
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public string AGate6 {
            get {
                try {
                    return ((string)(this[this.tableReportDT.AGate6Column]));
                }
                catch (global::System.InvalidCastException e) {
                    throw new global::System.Data.StrongTypingException("The value for 
column \'AGate6\' in table \'ReportDT\' is DBNull.", e);
                }
            }
            set {
                this[this.tableReportDT.AGate6Column] = value;
            }
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public bool IsGateNameNull() {
            return this.IsNull(this.tableReportDT.GateNameColumn);
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public void SetGateNameNull() {
            this[this.tableReportDT.GateNameColumn] = global::System.Convert.DBNull;
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public bool IsPoolNameNull() {
            return this.IsNull(this.tableReportDT.PoolNameColumn);
        }
        
        [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public void SetPoolNameNull() {
            this[this.tableReportDT.PoolNameColumn] = global::System.Convert.DBNull;
```

```
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsStartDateNull() {
                return this.IsNull(this.tableReportDT.StartDateColumn);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetStartDateNull() {
                this[this.tableReportDT.StartDateColumn] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsEndDateNull() {
                return this.IsNull(this.tableReportDT.EndDateColumn);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetEndDateNull() {
                this[this.tableReportDT.EndDateColumn] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsSeqLevelGate1Null() {
                return this.IsNull(this.tableReportDT.SeqLevelGate1Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetSeqLevelGate1Null() {
                this[this.tableReportDT.SeqLevelGate1Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsDesLevelGate1Null() {
                return this.IsNull(this.tableReportDT.DesLevelGate1Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetDesLevelGate1Null() {
                this[this.tableReportDT.DesLevelGate1Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsR2Gate1Null() {
                return this.IsNull(this.tableReportDT.R2Gate1Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
```

```
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetR2Gate1Null() {
                this[this.tableReportDT.R2Gate1Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsAGate1Null() {
                return this.IsNull(this.tableReportDT.AGate1Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetAGate1Null() {
                this[this.tableReportDT.AGate1Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsSeqLevelGate2Null() {
                return this.IsNull(this.tableReportDT.SeqLevelGate2Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetSeqLevelGate2Null() {
                this[this.tableReportDT.SeqLevelGate2Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsDesLevelGate2Null() {
                return this.IsNull(this.tableReportDT.DesLevelGate2Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetDesLevelGate2Null() {
                this[this.tableReportDT.DesLevelGate2Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsR2Gate2Null() {
                return this.IsNull(this.tableReportDT.R2Gate2Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetR2Gate2Null() {
                this[this.tableReportDT.R2Gate2Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsAGate2Null() {
                return this.IsNull(this.tableReportDT.AGate2Column);
```

```
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetAGate2Null() {
                this[this.tableReportDT.AGate2Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsSeqLevelGate3Null() {
                return this.IsNull(this.tableReportDT.SeqLevelGate3Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetSeqLevelGate3Null() {
                this[this.tableReportDT.SeqLevelGate3Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsDesLevelGate3Null() {
                return this.IsNull(this.tableReportDT.DesLevelGate3Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetDesLevelGate3Null() {
                this[this.tableReportDT.DesLevelGate3Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsR2Gate3Null() {
                return this.IsNull(this.tableReportDT.R2Gate3Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetR2Gate3Null() {
                this[this.tableReportDT.R2Gate3Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsAGate3Null() {
                return this.IsNull(this.tableReportDT.AGate3Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetAGate3Null() {
                this[this.tableReportDT.AGate3Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
```

```
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsSeqLevelGate4Null() {
                return this.IsNull(this.tableReportDT.SeqLevelGate4Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetSeqLevelGate4Null() {
                this[this.tableReportDT.SeqLevelGate4Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsDesLevelGate4Null() {
                return this.IsNull(this.tableReportDT.DesLevelGate4Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetDesLevelGate4Null() {
                this[this.tableReportDT.DesLevelGate4Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsR2Gate4Null() {
                return this.IsNull(this.tableReportDT.R2Gate4Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetR2Gate4Null() {
                this[this.tableReportDT.R2Gate4Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsAGate4Null() {
                return this.IsNull(this.tableReportDT.AGate4Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetAGate4Null() {
                this[this.tableReportDT.AGate4Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsSeqLevelGate5Null() {
                return this.IsNull(this.tableReportDT.SeqLevelGate5Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetSeqLevelGate5Null() {
                this[this.tableReportDT.SeqLevelGate5Column] = global::System.Convert.DBNull;
```

```
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsDesLevelGate5Null() {
                return this.IsNull(this.tableReportDT.DesLevelGate5Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]

            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetR2Gate6Null() {
                this[this.tableReportDT.R2Gate6Column] = global::System.Convert.DBNull;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public bool IsAGate6Null() {
                return this.IsNull(this.tableReportDT.AGate6Column);
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public void SetAGate6Null() {
                this[this.tableReportDT.AGate6Column] = global::System.Convert.DBNull;
            }
        }

        /// <summary>
        ///Row event argument class
        ///</summary>
        
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
        public class ReportDTRowChangeEvent : global::System.EventArgs {

            private ReportDTRow eventRow;

            private global::System.Data.DataRowAction eventAction;

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public ReportDTRowChangeEvent(ReportDTRow row, global::System.Data.DataRowAction
action) {
                this.eventRow = row;
                this.eventAction = action;
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public ReportDTRow Row {
                get {
                    return this.eventRow;
                }
            }

            [global::System.Diagnostics.DebuggerNonUserCodeAttribute()]
            
[global::System.CodeDom.Compiler.GeneratedCodeAttribute("System.Data.Design.TypedDataSetGener
ator", "4.0.0.0")]
            public global::System.Data.DataRowAction Action {
                get {
```

```
                    return this.eventAction;
                }
            }
        }
    }
}

#pragma warning restore 1591
```

APPENDIX B

Gate, Pool and Pool details table of all main channels in CIA

Table B.1 ARGOON Gate table

Gate Name	Main channel	Farm outlet	AWSID
174/1	ARGOON	TRUE	AWS2
174/2	ARGOON	TRUE	AWS2
175/1	ARGOON	TRUE	AWS2
175/2	ARGOON	TRUE	AWS2
176/1	ARGOON	TRUE	AWS2
178/1	ARGOON	TRUE	AWS2
178/2	ARGOON	TRUE	AWS2
179/1	ARGOON	TRUE	AWS2
179/2	ARGOON	TRUE	AWS2
180/1	ARGOON	TRUE	AWS2
182/2	ARGOON	TRUE	AWS2
183/1	ARGOON	TRUE	AWS2
184/2	ARGOON	TRUE	AWS2
193/1	ARGOON	TRUE	AWS2
193/2	ARGOON	TRUE	AWS2
194/1	ARGOON	TRUE	AWS2
194/2	ARGOON	TRUE	AWS2
195/1	ARGOON	TRUE	AWS2
196/1	ARGOON	TRUE	AWS2
197/1	ARGOON	TRUE	AWS2
198/1	ARGOON	TRUE	AWS2
2002/1	ARGOON	TRUE	AWS2
2005/1	ARGOON	TRUE	AWS2
210/1	ARGOON	TRUE	AWS2
211/1	ARGOON	TRUE	AWS2
212/1	ARGOON	TRUE	AWS2
213/1	ARGOON	TRUE	AWS2
214/1	ARGOON	TRUE	AWS2
215/1	ARGOON	TRUE	AWS2
216/1	ARGOON	TRUE	AWS2
217/1	ARGOON	TRUE	AWS2
217/2	ARGOON	TRUE	AWS2
218/1	ARGOON	TRUE	AWS2
219/1	ARGOON	TRUE	AWS2
220/1	ARGOON	TRUE	AWS2
ARGOON	ARGOON	FALSE	AWS2
ARGOON 1	ARGOON	FALSE	AWS2
ARGOON 1-1	ARGOON	FALSE	AWS2
ARGOON 1-2	ARGOON	FALSE	AWS2
ARGOON 1-3	ARGOON	FALSE	AWS2
ARGOON 1-4	ARGOON	FALSE	AWS2
ARGOON 1-5	ARGOON	FALSE	AWS2
ARGOON 2	ARGOON	FALSE	AWS2
ARGOON 3	ARGOON	FALSE	AWS2
ARGOON 3-1	ARGOON	FALSE	AWS2
ARGOON 3-2	ARGOON	FALSE	AWS2
ARGOON 3-3	ARGOON	FALSE	AWS2
ARGOON 3-4	ARGOON	FALSE	AWS2
ARGOON 3-5	ARGOON	FALSE	AWS2
ARGOON 3-6	ARGOON	FALSE	AWS2
ARGOON 3-7	ARGOON	FALSE	AWS2
ARGOON 3-8	ARGOON	FALSE	AWS2
ARGOON 3A	ARGOON	FALSE	AWS2
ARGOON-1	ARGOON	FALSE	AWS2
ARGOON-2	ARGOON	FALSE	AWS2
ARGOON-3	ARGOON	FALSE	AWS2
ARGOON-4	ARGOON	FALSE	AWS2
ARGOON-5	ARGOON	FALSE	AWS2
ESC ARGOON 1	ARGOON	FALSE	AWS2
ESC ARGOON	ARGOON	FALSE	AWS2

Table B.2 BOONA Gate table

Gate Name	Main channel	Farm outlet	AWSID
10-Jan	BOONA	TRUE	AWS1
1039/1	BOONA	TRUE	AWS1
120/1	BOONA	TRUE	AWS1
120/2	BOONA	TRUE	AWS1
141/1	BOONA	TRUE	AWS1
143/2	BOONA	TRUE	AWS1
145/1	BOONA	TRUE	AWS1
146/1	BOONA	TRUE	AWS1
150/1	BOONA	TRUE	AWS1
151/1	BOONA	TRUE	AWS1
152/1	BOONA	TRUE	AWS1
154/1	BOONA	TRUE	AWS1
155/1	BOONA	TRUE	AWS1
156/1	BOONA	TRUE	AWS1
156/3	BOONA	TRUE	AWS1
157/1	BOONA	TRUE	AWS1
158/1	BOONA	TRUE	AWS1
159/1	BOONA	TRUE	AWS1
160/1	BOONA	TRUE	AWS1
161/1	BOONA	TRUE	AWS1
162/1	BOONA	TRUE	AWS1
163/1	BOONA	TRUE	AWS1
163/2	BOONA	TRUE	AWS1
164/1	BOONA	TRUE	AWS1
165/1	BOONA	TRUE	AWS1
166/1	BOONA	TRUE	AWS1
167/1	BOONA	TRUE	AWS1
169/1	BOONA	TRUE	AWS1
2-Jan	BOONA	TRUE	AWS1
2-Feb	BOONA	TRUE	AWS1
222/1	BOONA	TRUE	AWS1
538/2	BOONA	TRUE	AWS1
642/1	BOONA	TRUE	AWS1
643/1	BOONA	TRUE	AWS1
656/1	BOONA	TRUE	AWS1
657/1	BOONA	TRUE	AWS1
665/1	BOONA	TRUE	AWS1
675/1	BOONA	TRUE	AWS1
676/1	BOONA	TRUE	AWS1
8-Jan	BOONA	TRUE	AWS1
9-Jan	BOONA	TRUE	AWS1
9-Feb	BOONA	TRUE	AWS1
BOONA 12	BOONA	FALSE	AWS1
BOONA 12-1	BOONA	FALSE	AWS1
BOONA 12-2	BOONA	FALSE	AWS1
BOONA 7	BOONA	FALSE	AWS1
BOONA 7-1	BOONA	FALSE	AWS1
BOONA 7-2	BOONA	FALSE	AWS1
BOONA 9	BOONA	FALSE	AWS1
BOONA 9-1	BOONA	FALSE	AWS1
BOONA 9A	BOONA	FALSE	AWS1
BOONA-1	BOONA	FALSE	AWS1
BOONA-10	BOONA	FALSE	AWS1
BOONA-11	BOONA	FALSE	AWS1
BOONA-12	BOONA	FALSE	AWS1
BOONA-13	BOONA	FALSE	AWS1
BOONA-14	BOONA	FALSE	AWS1
BOONA-16	BOONA	FALSE	AWS1
BOONA-17	BOONA	FALSE	AWS1
BOONA-18	BOONA	FALSE	AWS1
BOONA-19	BOONA	FALSE	AWS1
BOONA-2	BOONA	FALSE	AWS1
BOONA-20	BOONA	FALSE	AWS1
BOONA-3	BOONA	FALSE	AWS1
BOONA-4	BOONA	FALSE	AWS1
BOONA-5	BOONA	FALSE	AWS1
BOONA-6	BOONA	FALSE	AWS1
BOONA-7	BOONA	FALSE	AWS1
BOONA-8	BOONA	FALSE	AWS1
BOONA-9	BOONA	FALSE	AWS1
ESC BOONA	BOONA	FALSE	AWS1
ESC BOONA	BOONA	FALSE	AWS1
ESC BOONA	BOONA	FALSE	AWS1
ESC BOONA	BOONA	FALSE	AWS1
ESC BOONA-	BOONA	FALSE	AWS1
ESC BOONA-	BOONA	FALSE	AWS1
ESC BOONA-	BOONA	FALSE	AWS1

Table B.3 BUNDURE Gate table

Gate Name	Main	Farm outlet	AWSID
545/2	BUNDURE	TRUE	AWS2
546/1	BUNDURE	TRUE	AWS2
547/1	BUNDURE	TRUE	AWS2
547/2	BUNDURE	TRUE	AWS2
BUNDURE 1-1	BUNDURE	FALSE	AWS2
ESC BUNDURE	BUNDURE	FALSE	AWS2
31-May	BUNDURE 3	TRUE	AWS2
31/6	BUNDURE 3	TRUE	AWS2
508/3	BUNDURE 3	TRUE	AWS2
541/2	BUNDURE 3	TRUE	AWS2
545/3	BUNDURE 3	TRUE	AWS2
574/3	BUNDURE 3	TRUE	AWS2
577/3	BUNDURE 3	TRUE	AWS2
578/3	BUNDURE 3	TRUE	AWS2
59/2	BUNDURE 3	TRUE	AWS2
590/3	BUNDURE 3	TRUE	AWS2
607/2	BUNDURE 3	TRUE	AWS2
607/3	BUNDURE 3	TRUE	AWS2
608/2	BUNDURE 3	TRUE	AWS2
610/3	BUNDURE 3	TRUE	AWS2
614/2	BUNDURE 3	TRUE	AWS2
619/1	BUNDURE 3	TRUE	AWS2
619/2	BUNDURE 3	TRUE	AWS2
621/1	BUNDURE 3	TRUE	AWS2
623/1	BUNDURE 3	TRUE	AWS2
623/2	BUNDURE 3	TRUE	AWS2
624/1	BUNDURE 3	TRUE	AWS2
633/1	BUNDURE 3	TRUE	AWS2
634/1	BUNDURE 3	TRUE	AWS2
636/1	BUNDURE 3	TRUE	AWS2
640/1	BUNDURE 3	TRUE	AWS2
647/1	BUNDURE 3	TRUE	AWS2
650/1	BUNDURE 3	TRUE	AWS2
651/1	BUNDURE 3	TRUE	AWS2
664/1	BUNDURE 3	TRUE	AWS2
670/1	BUNDURE 3	TRUE	AWS2
BUNDURE 3-1	BUNDURE 3	FALSE	AWS2
BUNDURE 3-11	BUNDURE 3	FALSE	AWS2
BUNDURE 3-12	BUNDURE 3	FALSE	AWS2
BUNDURE 3-13	BUNDURE 3	FALSE	AWS2
BUNDURE 3-2	BUNDURE 3	FALSE	AWS2
BUNDURE 3-3	BUNDURE 3	FALSE	AWS2
BUNDURE 3-4	BUNDURE 3	FALSE	AWS2
BUNDURE 3-5	BUNDURE 3	FALSE	AWS2
BUNDURE 3-6	BUNDURE 3	FALSE	AWS2
BUNDURE 3-7	BUNDURE 3	FALSE	AWS2
BUNDURE 3-8	BUNDURE 3	FALSE	AWS2
BUNDURE 3-9	BUNDURE 3	FALSE	AWS2
BUNDURE 3A	BUNDURE 3	FALSE	AWS2
BUNDURE 3A-1	BUNDURE 3	FALSE	AWS2
BUNDURE 3B	BUNDURE 3	FALSE	AWS2
ESC BUNDURE	BUNDURE 3	FALSE	AWS2
ESC BUNDURE	BUNDURE 3	FALSE	AWS2
609/2	BUNDURE 5	TRUE	AWS2
610/1	BUNDURE 5	TRUE	AWS2
610/2	BUNDURE 5	TRUE	AWS2
611/1	BUNDURE 5	TRUE	AWS2
611/2	BUNDURE 5	TRUE	AWS2
612/1	BUNDURE 5	TRUE	AWS2
612/2	BUNDURE 5	TRUE	AWS2
613/1	BUNDURE 5	TRUE	AWS2
613/2	BUNDURE 5	TRUE	AWS2
614/1	BUNDURE 5	TRUE	AWS2
BUNDURE 5	BUNDURE 5	FALSE	AWS2
BUNDURE 5-1	BUNDURE 5	FALSE	AWS2
BUNDURE 5-2	BUNDURE 5	FALSE	AWS2
BUNDURE 5-3	BUNDURE 5	FALSE	AWS2
BUNDURE 5-4	BUNDURE 5	FALSE	AWS2
BUNDURE 5-5	BUNDURE 5	FALSE	AWS2
ESC BUNDURE	BUNDURE 5	FALSE	AWS2
573/1	BUNDURE 6	TRUE	AWS2
574/1	BUNDURE 6	TRUE	AWS2
BUNDURE 6	BUNDURE 6	FALSE	AWS2
BUNDURE 6-1	BUNDURE 6	FALSE	AWS2
ESC BUNDURE	BUNDURE 6	FALSE	AWS2
584/1	BUNDURE 7	TRUE	AWS2
584/2	BUNDURE 7	TRUE	AWS2
585/1	BUNDURE 7	TRUE	AWS2
587/1	BUNDURE 7	TRUE	AWS2
669/2	BUNDURE 7	TRUE	AWS2
684/1	BUNDURE 7	TRUE	AWS2
BUNDURE 7	BUNDURE 7	FALSE	AWS2
BUNDURE 7-1	BUNDURE 7	FALSE	AWS2
BUNDURE 7-2	BUNDURE 7	FALSE	AWS2
BUNDURE 7-3	BUNDURE 7	FALSE	AWS2
ESC BUNDURE	BUNDURE 7	FALSE	AWS2
578/2	BUNDURE 8	TRUE	AWS2
579/1	BUNDURE 8	TRUE	AWS2
580/1	BUNDURE 8	TRUE	AWS2
581/1	BUNDURE 8	TRUE	AWS2
582/1	BUNDURE 8	TRUE	AWS2
BUNDURE 8	BUNDURE 8	FALSE	AWS2
BUNDURE 8-1	BUNDURE 8	FALSE	AWS2
BUNDURE 8-2	BUNDURE 8	FALSE	AWS2
ESC BUNDURE	BUNDURE 8	FALSE	AWS2

Table B.4 COLY Gate table

Gate Name	Main	Farm outlet	AWSID
COLY 2 ESC	COLY 2	FALSE	AWS1
COLY 2-2	COLY 2	FALSE	AWS1
ESC COLY 2-1	COLY 2	FALSE	AWS1
3-Jan	COLY 3	TRUE	AWS1
4-Jan	COLY 3	TRUE	AWS1
5-Jan	COLY 3	TRUE	AWS1
6-Feb	COLY 3	TRUE	AWS1
8-Feb	COLY 3	TRUE	AWS1
COLY 3-2	COLY 3	FALSE	AWS1
COLY 3-3	COLY 3	FALSE	AWS1
COLY 3-4	COLY 3	FALSE	AWS1
ESC COLY 3	COLY 3	FALSE	AWS1
11-Jan	COLY 4	TRUE	AWS1
11-Feb	COLY 4	TRUE	AWS1
12-Jan	COLY 4	TRUE	AWS1
13-Jan	COLY 4	TRUE	AWS1
14-Feb	COLY 4	TRUE	AWS1
17-Jan	COLY 4	TRUE	AWS1
18-Jan	COLY 4	TRUE	AWS1
19-Jan	COLY 4	TRUE	AWS1
20-Jan	COLY 4	TRUE	AWS1
COLY 4-1	COLY 4	FALSE	AWS1
COLY 4-2	COLY 4	FALSE	AWS1
COLY 4-3	COLY 4	FALSE	AWS1
COLY 4-4	COLY 4	FALSE	AWS1
COLY 4-5	COLY 4	FALSE	AWS1
COLY 4-6	COLY 4	FALSE	AWS1
ESC COLY 4	COLY 4	FALSE	AWS1
21-Jan	COLY 5	TRUE	AWS1
22-Jan	COLY 5	TRUE	AWS1
23-Jan	COLY 5	TRUE	AWS1
23-Feb	COLY 5	TRUE	AWS1
24-Jan	COLY 5	TRUE	AWS1
24-Feb	COLY 5	TRUE	AWS1
25-Jan	COLY 5	TRUE	AWS1
COLY 5	COLY 5	FALSE	AWS1
COLY 5-1	COLY 5	FALSE	AWS1
COLY 5-2	COLY 5	FALSE	AWS1
COLY 5-3	COLY 5	FALSE	AWS1
COLY 5-4	COLY 5	FALSE	AWS1
ESC COLY 5	COLY 5	FALSE	AWS1
28-Jan	COLY 6	TRUE	AWS1
29-Jan	COLY 6	TRUE	AWS1
30-Jan	COLY 6	TRUE	AWS1
31-Jan	COLY 6	TRUE	AWS1
32/1	COLY 6	TRUE	AWS1
33/1	COLY 6	TRUE	AWS1
34/1	COLY 6	TRUE	AWS1
35/1	COLY 6	TRUE	AWS1
36/1	COLY 6	TRUE	AWS1
37/1	COLY 6	TRUE	AWS1
38/1	COLY 6	TRUE	AWS1
39/1	COLY 6	TRUE	AWS1
40/1	COLY 6	TRUE	AWS1
41/1	COLY 6	TRUE	AWS1
COLY 6	COLY 6	FALSE	AWS1
COLY 6-1	COLY 6	FALSE	AWS1
COLY 6-10	COLY 6	FALSE	AWS1
COLY 6-11	COLY 6	FALSE	AWS1
COLY 6-2	COLY 6	FALSE	AWS1
COLY 6-3	COLY 6	FALSE	AWS1
COLY 6-4	COLY 6	FALSE	AWS1
COLY 6-5	COLY 6	FALSE	AWS1
COLY 6-6	COLY 6	FALSE	AWS1
COLY 6-7	COLY 6	FALSE	AWS1
COLY 6-8	COLY 6	FALSE	AWS1
COLY 6-9	COLY 6	FALSE	AWS1
ESC 6	COLY 6	FALSE	AWS1
27-Feb	COLY 7	TRUE	AWS1
28-Mar	COLY 7	TRUE	AWS1
29/2	COLY 7	TRUE	AWS1
30/2	COLY 7	TRUE	AWS1
42/1	COLY 7	TRUE	AWS1
43/1	COLY 7	TRUE	AWS1
44/1	COLY 7	TRUE	AWS1
45/1	COLY 7	TRUE	AWS1
46/1	COLY 7	TRUE	AWS1
654/1	COLY 7	TRUE	AWS1
COLY 7	COLY 7	FALSE	AWS1
COLY 7-1	COLY 7	FALSE	AWS1
COLY 7-2	COLY 7	FALSE	AWS1
COLY 7-4	COLY 7	FALSE	AWS1
COLY 7-5	COLY 7	FALSE	AWS1
ESC COLY 7	COLY 7	FALSE	AWS1
45/2	COLY 8	TRUE	AWS1
47/1	COLY 8	TRUE	AWS1
48/1	COLY 8	TRUE	AWS1
52/1	COLY 8	TRUE	AWS1
55/1	COLY 8	TRUE	AWS1
56/1	COLY 8	TRUE	AWS1
COLY 8	COLY 8	FALSE	AWS1
COLY 8-1	COLY 8	FALSE	AWS1
COLY 8-2	COLY 8	FALSE	AWS1
COLY 8-3	COLY 8	FALSE	AWS1
COLY 8-4	COLY 8	FALSE	AWS1
COLY 8-5	COLY 8	FALSE	AWS1
COLY 8-6	COLY 8	FALSE	AWS1
ESC COLY 8	COLY 8	FALSE	AWS1
57/1	COLY 9	TRUE	AWS1
58/1	COLY 9	TRUE	AWS1
59/1	COLY 9	TRUE	AWS1
60/1	COLY 9	TRUE	AWS1
61/1	COLY 9	TRUE	AWS1
61/2	COLY 9	TRUE	AWS1
62/1	COLY 9	TRUE	AWS1
63/1	COLY 9	TRUE	AWS1
63/2	COLY 9	TRUE	AWS1
64/1	COLY 9	TRUE	AWS1
65/1	COLY 9	TRUE	AWS1
65/2	COLY 9	TRUE	AWS1
66/1	COLY 9	TRUE	AWS1
67/1	COLY 9	TRUE	AWS1
68/1	COLY 9	TRUE	AWS1
69/1	COLY 9	TRUE	AWS1

69/2	COLY 9	TRUE	AWS1
70/1	COLY 9	TRUE	AWS1
73/1	COLY 9	TRUE	AWS1
74/1	COLY 9	TRUE	AWS1
75/1	COLY 9	TRUE	AWS1
75/2	COLY 9	TRUE	AWS1
76/1	COLY 9	TRUE	AWS1
76/2	COLY 9	TRUE	AWS1
77/1	COLY 9	TRUE	AWS1
78/1	COLY 9	TRUE	AWS1
79/1	COLY 9	TRUE	AWS1
80/1	COLY 9	TRUE	AWS1
81/1	COLY 9	TRUE	AWS1
82/1	COLY 9	TRUE	AWS1
83/1	COLY 9	TRUE	AWS1
83/2	COLY 9	TRUE	AWS1
84/1	COLY 9	TRUE	AWS1
85/1	COLY 9	TRUE	AWS1
86/1	COLY 9	TRUE	AWS1
87/1	COLY 9	TRUE	AWS1
88/1	COLY 9	TRUE	AWS1
89/1	COLY 9	TRUE	AWS1
90/1	COLY 9	TRUE	AWS1
90/2	COLY 9	TRUE	AWS1
91/1	COLY 9	TRUE	AWS1
92/1	COLY 9	TRUE	AWS1
92/2	COLY 9	TRUE	AWS1
93/1	COLY 9	TRUE	AWS1
93/2	COLY 9	TRUE	AWS1
94/1	COLY 9	TRUE	AWS1
COLY 9	COLY 9	FALSE	AWS1
COLY 9-1	COLY 9	FALSE	AWS1
COLY 9-12	COLY 9	FALSE	AWS1
COLY 9-13	COLY 9	FALSE	AWS1
COLY 9-14	COLY 9	FALSE	AWS1
COLY 9-15	COLY 9	FALSE	AWS1
COLY 9-16ESC 9	COLY 9	FALSE	AWS1
COLY 9-2	COLY 9	FALSE	AWS1
COLY 9-3	COLY 9	FALSE	AWS1
COLY 9-4	COLY 9	FALSE	AWS1
COLY 9-5	COLY 9	FALSE	AWS1
COLY 9-6	COLY 9	FALSE	AWS1
COLY 9-7	COLY 9	FALSE	AWS1
COLY 9-8	COLY 9	FALSE	AWS1
COLY 9-9	COLY 9	FALSE	AWS1
COLY 9B	COLY 9	FALSE	AWS1
COLY 9B-1	COLY 9	FALSE	AWS1
COLY 9B-10	COLY 9	FALSE	AWS1
COLY 9B-2	COLY 9	FALSE	AWS1
COLY 9B-3	COLY 9	FALSE	AWS1
COLY 9B-4	COLY 9	FALSE	AWS1
COLY 9B-5	COLY 9	FALSE	AWS1
COLY 9B-7	COLY 9	FALSE	AWS1
COLY 9B-8	COLY 9	FALSE	AWS1
COLY 9C	COLY 9	FALSE	AWS1
COLY 9C-1	COLY 9	FALSE	AWS1
COLY 9C-2	COLY 9	FALSE	AWS1
COLY 9C-3 ESC	COLY 9	FALSE	AWS1
ESC 9B	COLY 9	FALSE	AWS1
100/1	COLY 10	TRUE	AWS1

101/1	COLY 10	TRUE	AWS1
102/1	COLY 10	TRUE	AWS1
102/2	COLY 10	TRUE	AWS1
102/3	COLY 10	TRUE	AWS1
103/1	COLY 10	TRUE	AWS1
104/1	COLY 10	TRUE	AWS1
105/1	COLY 10	TRUE	AWS1
107/1	COLY 10	TRUE	AWS1
662/1	COLY 10	TRUE	AWS1
96/1	COLY 10	TRUE	AWS1
96/2	COLY 10	TRUE	AWS1
97/1	COLY 10	TRUE	AWS1
97/2	COLY 10	TRUE	AWS1
98/1	COLY 10	TRUE	AWS1
98/2	COLY 10	TRUE	AWS1
99/1	COLY 10	TRUE	AWS1
COLY 10	COLY 10	FALSE	AWS1
COLY 10-1	COLY 10	FALSE	AWS1
COLY 10-3	COLY 10	FALSE	AWS1
COLY 10-4	COLY 10	FALSE	AWS1
COLY 10-5	COLY 10	FALSE	AWS1
COLY 10-6	COLY 10	FALSE	AWS1
COLY 10-7	COLY 10	FALSE	AWS1
ESC 10	COLY 10	FALSE	AWS1
108/2	COLY 11	TRUE	AWS2
110/1	COLY 11	TRUE	AWS2
111/1	COLY 11	TRUE	AWS2
112/1	COLY 11	TRUE	AWS2
113/1	COLY 11	TRUE	AWS2
114/1	COLY 11	TRUE	AWS2
118/1	COLY 11	TRUE	AWS2
118/2	COLY 11	TRUE	AWS2
119/1	COLY 11	TRUE	AWS2
170/1	COLY 11	TRUE	AWS2
171/1	COLY 11	TRUE	AWS2
172/1	COLY 11	TRUE	AWS2
COLY 11-2	COLY 11	FALSE	AWS2
COLY 11-3	COLY 11	FALSE	AWS2
COLY 11-4	COLY 11	FALSE	AWS2
COLY 11-5	COLY 11	FALSE	AWS2
COLY 11-6	COLY 11	FALSE	AWS2
COLY 11-7	COLY 11	FALSE	AWS2
COLY 11-8	COLY 11	FALSE	AWS2
COLY 11-9	COLY 11	FALSE	AWS2
ESC 11	COLY 11	FALSE	AWS2

Table B.5 MAIN CANAL Gate table

Gate Name	Main channel	Farm outlet	AWSID
14-Jan	MAIN	TRUE	AWS2
15-Jan	MAIN	TRUE	AWS2
2013/1	MAIN	TRUE	AWS2
2023/2	MAIN	TRUE	AWS2
44/3	MAIN	TRUE	AWS2
542/2	MAIN	TRUE	AWS2
544/2	MAIN	TRUE	AWS2
545/1	MAIN	TRUE	AWS2
548/1	MAIN	TRUE	AWS2
548/3	MAIN	TRUE	AWS2
549/1	MAIN	TRUE	AWS2
549/2	MAIN	TRUE	AWS2
551/1	MAIN	TRUE	AWS2
551/2	MAIN	TRUE	AWS2
551/3	MAIN	TRUE	AWS2
552/1	MAIN	TRUE	AWS2
552/2	MAIN	TRUE	AWS2
554/1	MAIN	TRUE	AWS2
554/2	MAIN	TRUE	AWS2
555/1	MAIN	TRUE	AWS2
555/2	MAIN	TRUE	AWS2
569/2	MAIN	TRUE	AWS2
572/1	MAIN	TRUE	AWS2
574/2	MAIN	TRUE	AWS2
575/1	MAIN	TRUE	AWS2
577/1	MAIN	TRUE	AWS2
578/1	MAIN	TRUE	AWS2
588/1	MAIN	TRUE	AWS2
589/2	MAIN	TRUE	AWS2
590/1	MAIN	TRUE	AWS2
591/1	MAIN	TRUE	AWS2
591/2	MAIN	TRUE	AWS2
596/2	MAIN	TRUE	AWS2
606/1	MAIN	TRUE	AWS2
606/3	MAIN	TRUE	AWS2
607/1	MAIN	TRUE	AWS2
608/1	MAIN	TRUE	AWS2
609/1	MAIN	TRUE	AWS2
615/1	MAIN	TRUE	AWS2
615/2	MAIN	TRUE	AWS2
615/3	MAIN	TRUE	AWS2
667/1	MAIN	TRUE	AWS2
669/1	MAIN	TRUE	AWS2
672/1	MAIN	TRUE	AWS2
BUNDURE 1 O/T	MAIN	FALSE	AWS2
BUNDURE MAIN O/T	MAIN	FALSE	AWS2
BUNDURE MAIN-1	MAIN	FALSE	AWS2
BUNDURE MAIN-10	MAIN	FALSE	AWS2
BUNDURE MAIN-11	MAIN	FALSE	AWS2
BUNDURE MAIN-12	MAIN	FALSE	AWS2
BUNDURE MAIN-13	MAIN	FALSE	AWS2
BUNDURE MAIN-14	MAIN	FALSE	AWS2
BUNDURE MAIN-15	MAIN	FALSE	AWS2
BUNDURE MAIN-16	MAIN	FALSE	AWS2
BUNDURE MAIN-17	MAIN	FALSE	AWS2
BUNDURE MAIN-3	MAIN	FALSE	AWS2
BUNDURE MAIN-4	MAIN	FALSE	AWS2
BUNDURE MAIN-6	MAIN	FALSE	AWS2
BUNDURE MAIN-7	MAIN	FALSE	AWS2
BUNDURE MAIN-8	MAIN	FALSE	AWS2
BUNDURE MAIN-9	MAIN	FALSE	AWS2
BUNDURE-SPUR O/T	MAIN	FALSE	AWS2
COLY 2-1	MAIN	FALSE	AWS1
COLY 3-1	MAIN	FALSE	AWS1
ESC BUNDURE MAIN-2	MAIN	FALSE	AWS2
GRANTS ESC MAIN	MAIN	FALSE	AWS1
GRANTS REGULATOR	MAIN	FALSE	AWS1
HORTICULTURE REGULATOR	MAIN	FALSE	AWS1
KOORUMBEEN	MAIN	FALSE	AWS2
MAIN CANAL ESC	MAIN	FALSE	AWS2
MAIN CANAL INLET	MAIN	FALSE	AWS1
MORUNDAH REGULATOR	MAIN	FALSE	AWS1
NO 3 REGULATOR	MAIN	FALSE	AWS1
PRICKLEY REGULATOR	MAIN	FALSE	AWS2
TOMBULLEN INLET	MAIN	FALSE	AWS1
TUBBO ESC	MAIN	FALSE	AWS1
TUBBO WELLS	MAIN	FALSE	AWS1

Table B.6 TUBBO Gate table

Gate Name	Main channel	Farm	AWSID
1-Jan	TUBBO	TRUE	AWS1
1-Feb	TUBBO	TRUE	AWS1
11-Mar	TUBBO	TRUE	AWS1
120/3	TUBBO	TRUE	AWS1
18-Mar	TUBBO	TRUE	AWS1
2-Mar	TUBBO	TRUE	AWS1
2010/1	TUBBO	TRUE	AWS1
2020/1	TUBBO	TRUE	AWS1
2026/1	TUBBO	TRUE	AWS1
2026/2	TUBBO	TRUE	AWS1
2026/3	TUBBO	TRUE	AWS1
221/1	TUBBO	TRUE	AWS1
226/1	TUBBO	TRUE	AWS1
31/4	TUBBO	TRUE	AWS1
4004/1	TUBBO	TRUE	AWS1
4005/1	TUBBO	TRUE	AWS1
5-Mar	TUBBO	TRUE	AWS1
507/2	TUBBO	TRUE	AWS1
540/2	TUBBO	TRUE	AWS1
6-Mar	TUBBO	TRUE	AWS1
639/1	TUBBO	TRUE	AWS1
661/1	TUBBO	TRUE	AWS1
663/1	TUBBO	TRUE	AWS1
673/1	TUBBO	TRUE	AWS1
7-Apr	TUBBO	TRUE	AWS1
9002/2	TUBBO	TRUE	AWS1
BOONA	TUBBO	FALSE	AWS1
ESC TUBBO	TUBBO	FALSE	AWS1
ESC TUBBO-1	TUBBO	FALSE	AWS1
KERARBURY	TUBBO	FALSE	AWS1
TUBBO 4 OT	TUBBO	FALSE	AWS1
TUBBO	TUBBO	FALSE	AWS1
TUBBO-1	TUBBO	FALSE	AWS1
TUBBO-10	TUBBO	FALSE	AWS1
TUBBO-11	TUBBO	FALSE	AWS1
TUBBO-12	TUBBO	FALSE	AWS1
TUBBO-2	TUBBO	FALSE	AWS1
TUBBO3	TUBBO	FALSE	AWS1
TUBBO-3	TUBBO	FALSE	AWS1
TUBBO-4	TUBBO	FALSE	AWS1
TUBBO-5	TUBBO	FALSE	AWS1
TUBBO-6	TUBBO	FALSE	AWS1
TUBBO-7	TUBBO	FALSE	AWS1
TUBBO-8	TUBBO	FALSE	AWS1
TUBBO-9	TUBBO	FALSE	AWS1

Table B.7 YAMMA Gate table

Gate Name	Main channel	Farm outlet	AWSID
118/3	YAMMA	TRUE	AWS2
119/2	YAMMA	TRUE	AWS2
170/2	YAMMA	TRUE	AWS2
171/2	YAMMA	TRUE	AWS2
172/2	YAMMA	TRUE	AWS2
173/1	YAMMA	TRUE	AWS2
181/1	YAMMA	TRUE	AWS2
182/1	YAMMA	TRUE	AWS2
185/1	YAMMA	TRUE	AWS2
186/3	YAMMA	TRUE	AWS2
187/1	YAMMA	TRUE	AWS2
187/2	YAMMA	TRUE	AWS2
188/1	YAMMA	TRUE	AWS2
188/2	YAMMA	TRUE	AWS2
189/1	YAMMA	TRUE	AWS2
190/1	YAMMA	TRUE	AWS2
191/1	YAMMA	TRUE	AWS2
191/2	YAMMA	TRUE	AWS2
192/1	YAMMA	TRUE	AWS2
192/2	YAMMA	TRUE	AWS2
200/1	YAMMA	TRUE	AWS2
2006/1	YAMMA	TRUE	AWS2
2007/1	YAMMA	TRUE	AWS2
2008/1	YAMMA	TRUE	AWS2
2009/1	YAMMA	TRUE	AWS2
201/1	YAMMA	TRUE	AWS2
202/1	YAMMA	TRUE	AWS2
204/1	YAMMA	TRUE	AWS2
205/1	YAMMA	TRUE	AWS2
205/2	YAMMA	TRUE	AWS2
206/1	YAMMA	TRUE	AWS2
206/2	YAMMA	TRUE	AWS2
208/1	YAMMA	TRUE	AWS2
209/1	YAMMA	TRUE	AWS2
209/3	YAMMA	TRUE	AWS2
219/3	YAMMA	TRUE	AWS2
501/1	YAMMA	TRUE	AWS2
502/1	YAMMA	TRUE	AWS2
502/2	YAMMA	TRUE	AWS2
504/1	YAMMA	TRUE	AWS2
504/2	YAMMA	TRUE	AWS2
507/1	YAMMA	TRUE	AWS2
508/1	YAMMA	TRUE	AWS2
508/2	YAMMA	TRUE	AWS2
510/1	YAMMA	TRUE	AWS2
511/1	YAMMA	TRUE	AWS2
512/1	YAMMA	TRUE	AWS2
513/1	YAMMA	TRUE	AWS2
514/1	YAMMA	TRUE	AWS2
514/2	YAMMA	TRUE	AWS2
515/1	YAMMA	TRUE	AWS2
516/1	YAMMA	TRUE	AWS2

517/1	YAMMA	TRUE	AWS2
518/1	YAMMA	TRUE	AWS2
519/1	YAMMA	TRUE	AWS2
521/1	YAMMA	TRUE	AWS2
524/1	YAMMA	TRUE	AWS2
524/2	YAMMA	TRUE	AWS2
525/1	YAMMA	TRUE	AWS2
526/1	YAMMA	TRUE	AWS2
527/1	YAMMA	TRUE	AWS2
527/2	YAMMA	TRUE	AWS2
529/1	YAMMA	TRUE	AWS2
530/1	YAMMA	TRUE	AWS2
531/1	YAMMA	TRUE	AWS2
532/1	YAMMA	TRUE	AWS2
533/1	YAMMA	TRUE	AWS2
533/2	YAMMA	TRUE	AWS2
534/1	YAMMA	TRUE	AWS2
534/2	YAMMA	TRUE	AWS2
535/1	YAMMA	TRUE	AWS2
537/1	YAMMA	TRUE	AWS2
537/2	YAMMA	TRUE	AWS2
539/1	YAMMA	TRUE	AWS2
540/1	YAMMA	TRUE	AWS2
541/1	YAMMA	TRUE	AWS2
571/1	YAMMA	TRUE	AWS2
645/1	YAMMA	TRUE	AWS2
659/1	YAMMA	TRUE	AWS2
666/1	YAMMA	TRUE	AWS2
COLY 11-1	YAMMA	FALSE	AWS2
ESC YAMMA	YAMMA	FALSE	AWS2
ESC YAMMA	YAMMA	FALSE	AWS2
ESC YAMMA	YAMMA	FALSE	AWS2
ESC YAMMA	YAMMA	FALSE	AWS2
ESC YAMMA	YAMMA	FALSE	AWS2
YAMMA	YAMMA	FALSE	AWS2
YAMMA 1-1	YAMMA	FALSE	AWS2
YAMMA 1-2	YAMMA	FALSE	AWS2
YAMMA 1-3	YAMMA	FALSE	AWS2
YAMMA 1-4	YAMMA	FALSE	AWS2
YAMMA 1-5	YAMMA	FALSE	AWS2
YAMMA 1-6	YAMMA	FALSE	AWS2
YAMMA 1-7	YAMMA	FALSE	AWS2
YAMMA 1-8	YAMMA	FALSE	AWS2
YAMMA 1A1	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1A-	YAMMA	FALSE	AWS2
YAMMA 1B	YAMMA	FALSE	AWS2
YAMMA 1B-	YAMMA	FALSE	AWS2

YAMMA 1B-	YAMMA	FALSE	AWS2
YAMMA 1B-	YAMMA	FALSE	AWS2
YAMMA 2	YAMMA	FALSE	AWS2
YAMMA 2-1	YAMMA	FALSE	AWS2
YAMMA 2-2	YAMMA	FALSE	AWS2
YAMMA 2-3	YAMMA	FALSE	AWS2
YAMMA 2-4	YAMMA	FALSE	AWS2
YAMMA 2-5	YAMMA	FALSE	AWS2
YAMMA 2-6	YAMMA	FALSE	AWS2
YAMMA 3	YAMMA	FALSE	AWS2
YAMMA 3-1	YAMMA	FALSE	AWS2
YAMMA 3-2	YAMMA	FALSE	AWS2
YAMMA 3-3	YAMMA	FALSE	AWS2
YAMMA 3-4	YAMMA	FALSE	AWS2
YAMMA 3-5	YAMMA	FALSE	AWS2
YAMMA 4	YAMMA	FALSE	AWS2
YAMMA 4-1	YAMMA	FALSE	AWS2
YAMMA 4-2	YAMMA	FALSE	AWS2
YAMMA 4-3	YAMMA	FALSE	AWS2
YAMMA 4-4	YAMMA	FALSE	AWS2
YAMMA 4-5	YAMMA	FALSE	AWS2
YAMMA 4-6	YAMMA	FALSE	AWS2
YAMMA 4-7	YAMMA	FALSE	AWS2
YAMMA-1	YAMMA	FALSE	AWS2
YAMMA1	YAMMA	FALSE	AWS2
YAMMA1A	YAMMA	FALSE	AWS2
YAMMA1A-7	YAMMA	FALSE	AWS2
YAMMA-2	YAMMA	FALSE	AWS2
YAMMA-3	YAMMA	FALSE	AWS2
YAMMA-4	YAMMA	FALSE	AWS2

Table B.8 Pool table of ARGOON main channel

Pool Name	Main channel
ARGOON 1, 1-1	ARGOON
ARGOON 1-1, 1-2	ARGOON
ARGOON 1-2, 1-3	ARGOON
ARGOON 1-3, 1-4	ARGOON
ARGOON 1-4, 1-5	ARGOON
ARGOON 1-5, ESC ARGOON 1	ARGOON
ARGOON 2, 198/1	ARGOON
ARGOON 3, ARGOON 3-1	ARGOON
ARGOON 3-1, ARGOON 3-2	ARGOON
ARGOON 3-2, ARGOON 3-3	ARGOON
ARGOON 3-3, ARGOON 3-4	ARGOON
ARGOON 3-4, ARGOON 3-5	ARGOON
ARGOON 3-5, ARGOON 3-6	ARGOON
ARGOON 3-6, ARGOON 3-8	ARGOON
ARGOON 3-8, 2005/1	ARGOON
ARGOON 3A, 220/1	ARGOON
ARGOON, ARGOON-1	ARGOON
ARGOON-1,2	ARGOON
ARGOON-2,3	ARGOON
ARGOON-3,4	ARGOON
ARGOON-4,5	ARGOON
ARGOON-5, ARGOON 3	ARGOON

Table B.9 Pool table of BOONA main channel

Pool Name	Main channel
BOONA 9-1, ESC BOONA 9	BOONA
BOONA 9A, ESC BOONA 9A	BOONA
BOONA0,1	BOONA
BOONA1,2	BOONA
BOONA10,11	BOONA
BOONA11,12	BOONA
BOONA12,12-1	BOONA
BOONA12,13	BOONA
BOONA12-1,12-2	BOONA
BOONA12-2, ESC BOONA12	BOONA
BOONA13,14	BOONA
BOONA14,16	BOONA
BOONA16,17	BOONA
BOONA17,18	BOONA
BOONA18,19	BOONA
BOONA19,20	BOONA
BOONA2,3	BOONA
BOONA20, ESC BOONA-3	BOONA
BOONA3,4	BOONA
BOONA4,5	BOONA
BOONA5,7	BOONA
BOONA7,7-1	BOONA
BOONA7,8	BOONA
BOONA7-1,7-2	BOONA
BOONA7-2, ESC BOONA7	BOONA
BOONA8,9	BOONA
BOONA9,10	BOONA
BOONA9,9-1	BOONA

Table B.10 Pool table of BUNDURE main channel

Pool Name	Main channel
BUNDURE 1 O/T, BUNDURE 1-1	BUNDURE
BUNDURE 1-1, ESC BUNDURE 1	BUNDURE
BUNDURE 3-1, BUNDURE 3-2	BUNDURE 3
BUNDURE 3-11, BUNDURE 3-12	BUNDURE 3
BUNDURE 3-12, BUNDURE 3-13	BUNDURE 3
BUNDURE 3-13, ESC BUNDURE 3	BUNDURE 3
BUNDURE 3-2, BUNDURE 3-3	BUNDURE 3
BUNDURE 3-3, BUNDURE 3-4	BUNDURE 3
BUNDURE 3-4, BUNDURE 3-5	BUNDURE 3
BUNDURE 3-5, BUNDURE 3-6	BUNDURE 3
BUNDURE 3-6, BUNDURE 3-7	BUNDURE 3
BUNDURE 3-7, BUNDURE 3-8	BUNDURE 3
BUNDURE 3-8, BUNDURE 3-9	BUNDURE 3
BUNDURE 3-9, BUNDURE 3-11	BUNDURE 3
BUNDURE 3A O/T, BUNDURE 3A-1	BUNDURE 3
BUNDURE 3A-1, ESC BUNDURE 3A	BUNDURE 3
BUNDURE 5 O/T, BUNDURE 5-1	BUNDURE 5
BUNDURE 5-1, BUNDURE 5-2	BUNDURE 5
BUNDURE 5-2, BUNDURE 5-3	BUNDURE 5
BUNDURE 5-3, BUNDURE 5-4	BUNDURE 5
BUNDURE 5-4, BUNDURE 5-5	BUNDURE 5
BUNDURE 5-5, ESC BUNDURE 5	BUNDURE 5
BUNDURE 6 O/T, BUNDURE 6-1	BUNDURE 6
BUNDURE 6-1, ESC BUNDURE 6	BUNDURE 6
BUNDURE 7 O/T, BUNDURE 7-1	BUNDURE 7
BUNDURE 7-1, BUNDURE 7-2	BUNDURE 7
BUNDURE 7-2, BUNDURE 7-3	BUNDURE 7
BUNDURE 7-3, ESC BUNDURE 7	BUNDURE 7
BUNDURE 8 O/T, BUNDURE 8-1	BUNDURE 8
BUNDURE 8-1, BUNDURE 8-2	BUNDURE 8
BUNDURE 8-2, ESC BUNDURE 8	BUNDURE 8

Table B.11 Pool table of COLY main channel

Pool Name	Main channel
COLY 2-2, COLY 2 ESC	COLY 2
COLY2-1,2-2	COLY 2
COLY3-1,3-2	COLY 3
COLY3-2,3-3	COLY 3
COLY3-3,3-4	COLY 3
COLY3-4, ESC COLY3	COLY 3
COLY 4-6, ESC COLY 4	COLY 4
COLY4-1,4-2	COLY 4
COLY4-2,4-3	COLY 4
COLY4-3,4-4	COLY 4
COLY4-4,4-5	COLY 4
COLY4-5,4-6	COLY 4
COLY5,5-1	COLY 5
COLY5-1,5-2	COLY 5
COLY5-2,5-3	COLY 5
COLY5-3,5-4	COLY 5
COLY 6-11, ESC 6	COLY 6
COLY6,6-1	COLY 6
COLY6-1,6-2	COLY 6
COLY6-10,6-11	COLY 6
COLY6-2,6-3	COLY 6
COLY6-3,6-4	COLY 6
COLY6-4,6-5	COLY 6
COLY6-5,6-6	COLY 6
COLY6-6,6-7	COLY 6
COLY6-7,6-8	COLY 6
COLY6-8,6-9	COLY 6
COLY6-9,6-10	COLY 6
COLY7,7-1	COLY 7
COLY7-1,7-2	COLY 7
COLY7-2,7-4	COLY 7
COLY7-4,7-5	COLY 7
COLY7-5, ESC COLY 7	COLY 7
COLY 8-4,8-5	COLY 8
COLY 8-5, 8-6	COLY 8
COLY8, 8-1	COLY 8
COLY8-1,8-2	COLY 8
COLY8-2,8-3	COLY 8
COLY8-3,8-4	COLY 8
COLY 9, COLY 9-2	COLY 9
COLY 9-12, 9-13	COLY 9
COLY 9-13, 9-14	COLY 9
COLY 9-14, 9-15	COLY 9
COLY 9-15, 9-16ESC 9	COLY 9
COLY 9-2,9-3	COLY 9
COLY 9-3,9-4	COLY 9
COLY 9-4,9-5	COLY 9
COLY 9-5, 9-6	COLY 9
COLY 9-6, 9-7	COLY 9
COLY 9-7, 9-8	COLY 9
COLY 9-8, 9-9	COLY 9
COLY 9-9, 9-12	COLY 9
COLY 9B, 9B-1	COLY 9
COLY 9B-1, 9B-2	COLY 9
COLY 9B-10, ESC 9B	COLY 9
COLY 9B-2, 9B-3	COLY 9
COLY 9B-3, 9B-4	COLY 9
COLY 9B-4, 9B-5	COLY 9
COLY 9B-5, 9B-7	COLY 9
COLY 9B-7, 9B-8	COLY 9
COLY 9B-8, 9B-10	COLY 9
COLY 9C, 9C-1	COLY 9
COLY 9C-1, 9C-3 ESC	COLY 9
COLY 10, 10-1	COLY 10
COLY 10-1, 10-3	COLY 10
COLY 10-3, 10-4	COLY 10
COLY 10-4, 10-5	COLY 10
COLY 10-5, 10-6	COLY 10
COLY 10-6, 10-7	COLY 10
COLY 10-7, ESC 10	COLY 10
COLY 11-1, 11-2	COLY 11
COLY 11-2, 11-3	COLY 11
COLY 11-3, 11-4	COLY 11
COLY 11-4, 11-5	COLY 11
COLY 11-5, 11-6	COLY 11
COLY 11-6, 11-7	COLY 11
COLY 11-7, 11-8	COLY 11
COLY 11-8, 11-9	COLY 11
COLY 11-9, 172/1	COLY 11

Table B.12 Pool table of MAIN CANAL

Pool Name	Main channel
BUNDURE MAIN O/T, BUNDURE MAIN-1	MAIN
BUNDURE MAIN-1, BUNDURE MAIN-3	MAIN
BUNDURE MAIN-10, BUNDURE MAIN-11	MAIN
BUNDURE MAIN-11, BUNDURE MAIN-12	MAIN
BUNDURE MAIN-12, BUNDURE MAIN-13	MAIN
BUNDURE MAIN-13, BUNDURE MAIN-14	MAIN
BUNDURE MAIN-14, BUNDURE MAIN-15	MAIN
BUNDURE MAIN-15, BUNDURE MAIN-16	MAIN
BUNDURE MAIN-16, BUNDURE MAIN-17	MAIN
BUNDURE MAIN-17, ESC BUNDURE MAIN - 2	MAIN
BUNDURE MAIN-3, BUNDURE MAIN-4	MAIN
BUNDURE MAIN-4, BUNDURE MAIN-6	MAIN
BUNDURE MAIN-6, BUNDURE MAIN-7	MAIN
BUNDURE MAIN-7, BUNDURE MAIN-8	MAIN
BUNDURE MAIN-8, BUNDURE MAIN-9	MAIN
BUNDURE MAIN-9, BUNDURE MAIN-10	MAIN
BUNDURE-SPUR O/T, 44/3	MAIN
GRANTS REG, PRICKLEY REG	MAIN
HORTICULTURE, NO. 3	MAIN
KOORUMBEEN, ESC KOORUMBEEN	MAIN
MAIN CANAL INLET, TUBBO WELLS	MAIN

MORUNDAH REG, GRANTS REG	MAIN
NO 3 REG, MORUNDAH REG	MAIN
PRICKLEY REG, BUNDURE MAIN O/T	MAIN
TUBBO WELLS, HORTICULTURE REG	MAIN

Table B.13 Pool table of TUBBO main channel

Pool Name	Main channel
TUBBO 4 OT, 2026	TUBBO
TUBBO OFFTAKE, BOONA	TUBBO
TUBBO1,2	TUBBO
TUBBO10,11	TUBBO
TUBBO11,12	TUBBO
TUBBO12,ESC TUBBO	TUBBO
TUBBO2,3	TUBBO
TUBBO3,4	TUBBO
TUBBO4,5	TUBBO
TUBBO5,6	TUBBO
TUBBO6,7	TUBBO
TUBBO7,8	TUBBO
TUBBO8,9	TUBBO
TUBBO9,10	TUBBO

Table B.14 Pool table of YAMMA main channel

Pool Name	Main channel
YAMMA 1 OFFTAKE, YAMMA 1-1	YAMMA
YAMMA 1-1, YAMMA 1-2	YAMMA
YAMMA 1-2, YAMMA 1-3	YAMMA
YAMMA 1-3, YAMMA 1-4	YAMMA
YAMMA 1-4, YAMMA 1-5	YAMMA
YAMMA 1-5, YAMMA 1-6	YAMMA
YAMMA 1-6, YAMMA 1-7	YAMMA
YAMMA 1-7, YAMMA 1-8	YAMMA
YAMMA 1-8, ESC YAMMA 1	YAMMA
YAMMA 1A-1, YAMMA 1A-2	YAMMA
YAMMA 1A-2, YAMMA 1A-3	YAMMA
YAMMA 1A-3, YAMMA 1A-4	YAMMA
YAMMA 1A-4, YAMMA 1A-5	YAMMA
YAMMA 1A-5, YAMMA 1A-6	YAMMA
YAMMA 1A-6, YAMMA 1A-7	YAMMA
YAMMA 1A-7, YAMMA1A-8	YAMMA
YAMMA 1A-8, YAMMA 1A-9	YAMMA
YAMMA 1A-9, ESC YAMMA 1A	YAMMA
YAMMA 1B, YAMMA 1B-1	YAMMA
YAMMA 1B-1, YAMMA 1B-2	YAMMA
YAMMA 1B-2, YAMMA 1B-3	YAMMA
YAMMA 1B-3, ESC YAMMA 1B	YAMMA
YAMMA 2, YAMMA 2-1	YAMMA
YAMMA 2-1, YAMMA 2-2	YAMMA
YAMMA 2-2, YAMMA 2-3	YAMMA
YAMMA 2-3, YAMMA 2-4	YAMMA
YAMMA 2-4, YAMMA 2-5	YAMMA
YAMMA 2-5, YAMMA 2-6	YAMMA
YAMMA 2-6, ESC YAMMA 2	YAMMA
YAMMA 3, YAMMA 3-1	YAMMA
YAMMA 3-1, YAMMA 3-2	YAMMA
YAMMA 3-2, YAMMA 3-3	YAMMA
YAMMA 3-3, YAMMA 3-4	YAMMA
YAMMA 3-4, YAMMA 3-5	YAMMA
YAMMA 3-5, ESC YAMMA 3	YAMMA
YAMMA 4, YAMMA 4-1	YAMMA
YAMMA 4-1, YAMMA 4-2	YAMMA
YAMMA 4-2, YAMMA 4-3	YAMMA
YAMMA 4-3, YAMMA 4-4	YAMMA
YAMMA 4-4, YAMMA 4-5	YAMMA
YAMMA 4-5, YAMMA 4-6	YAMMA
YAMMA 4-6, YAMMA 4-7	YAMMA
YAMMA 4-7, ESC YAMMA 4	YAMMA
YAMMA, YAMMA-1	YAMMA
YAMMA-1,2	YAMMA
YAMMA1A, YAMMA 1A-1	YAMMA
YAMMA-2,3	YAMMA
YAMMA-3,4	YAMMA
YAMMA-4, YAMMA 3	YAMMA

Table B.15 Pool details table of ARGOON main channel

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2547	ARGOON 1, 1-1	174/1	FALSE
2548	ARGOON 1, 1-1	176/1	FALSE
2549	ARGOON 1, 1-1	ARGOON 1	TRUE
2550	ARGOON 1, 1-1	ARGOON 1-1	FALSE
2551	ARGOON 1-1, 1-2	174/2	FALSE
2552	ARGOON 1-1, 1-2	ARGOON 1-1	TRUE
2553	ARGOON 1-1, 1-2	ARGOON 1-2	FALSE
2554	ARGOON 1-2, 1-3	175/1	FALSE
2555	ARGOON 1-2, 1-3	175/2	FALSE
2556	ARGOON 1-2, 1-3	ARGOON 1-2	TRUE
2557	ARGOON 1-2, 1-3	ARGOON 1-3	FALSE
2558	ARGOON 1-3, 1-4	178/1	FALSE
2559	ARGOON 1-3, 1-4	178/2	FALSE
2560	ARGOON 1-3, 1-4	ARGOON 1-3	TRUE
2561	ARGOON 1-3, 1-4	ARGOON 1-4	FALSE
2562	ARGOON 1-4, 1-5	179/1	FALSE
2563	ARGOON 1-4, 1-5	179/2	FALSE
2564	ARGOON 1-4, 1-5	ARGOON 1-4	TRUE
2565	ARGOON 1-4, 1-5	ARGOON 1-5	FALSE
2566	ARGOON, ARGOON-1	182/2	FALSE
2567	ARGOON, ARGOON-1	183/1	FALSE
2568	ARGOON, ARGOON-1	ARGOON	TRUE
2569	ARGOON, ARGOON-1	ARGOON-1	FALSE
2570	ARGOON-1,2	ARGOON-1	TRUE
2571	ARGOON-1,2	ARGOON-2	FALSE
2572	ARGOON-2,3	184/2	FALSE
2573	ARGOON-2,3	195/1	FALSE
2574	ARGOON-2,3	ARGOON-2	TRUE
2575	ARGOON-2,3	ARGOON-3	FALSE
2576	ARGOON-4,5	193/2	FALSE
2577	ARGOON-4,5	194/1	FALSE
2578	ARGOON-4,5	ARGOON-4	TRUE
2579	ARGOON-4,5	ARGOON-5	FALSE
2580	ARGOON-5, ARGOON 3	194/2	FALSE
2581	ARGOON-5, ARGOON 3	2002/1	FALSE
2582	ARGOON-5, ARGOON 3	219/1	FALSE
2583	ARGOON-5, ARGOON 3	ARGOON 3	FALSE
2584	ARGOON-5, ARGOON 3	ARGOON-5	TRUE
2585	ARGOON 3, ARGOON 3-1	210/1	FALSE
2586	ARGOON 3, ARGOON 3-1	ARGOON 3	TRUE
2587	ARGOON 3, ARGOON 3-1	ARGOON 3-1	FALSE
2588	ARGOON 3-1, ARGOON 3-2	218/1	FALSE
2589	ARGOON 3-1, ARGOON 3-2	ARGOON 3-1	TRUE
2590	ARGOON 3-1, ARGOON 3-2	ARGOON 3-2	FALSE
2591	ARGOON 3-1, ARGOON 3-2	ARGOON 3A	FALSE
2592	ARGOON 3A, 220/1	220/1	FALSE

2593	ARGOON 3A, 220/1	ARGOON 3A	TRUE
2594	ARGOON 3-2, ARGOON 3-3	211/1	FALSE
2595	ARGOON 3-2, ARGOON 3-3	217/1	FALSE
2596	ARGOON 3-2, ARGOON 3-3	ARGOON 3-2	TRUE
2597	ARGOON 3-2, ARGOON 3-3	ARGOON 3-3	FALSE
2598	ARGOON 3-3, ARGOON 3-4	212/1	FALSE
2599	ARGOON 3-3, ARGOON 3-4	ARGOON 3-3	TRUE
2600	ARGOON 3-3, ARGOON 3-4	ARGOON 3-4	FALSE
2601	ARGOON 3-4, ARGOON 3-5	216/1	FALSE
2602	ARGOON 3-4, ARGOON 3-5	217/2	FALSE
2603	ARGOON 3-4, ARGOON 3-5	ARGOON 3-4	TRUE
2604	ARGOON 3-4, ARGOON 3-5	ARGOON 3-5	FALSE
2605	ARGOON 3-5, ARGOON 3-6	213/1	FALSE
2606	ARGOON 3-5, ARGOON 3-6	ARGOON 3-5	TRUE
2607	ARGOON 3-5, ARGOON 3-6	ARGOON 3-6	FALSE
2608	ARGOON 3-8, 2005/1	2005/1	FALSE
2609	ARGOON 3-8, 2005/1	ARGOON 3-8	TRUE
3021	ARGOON 1-5, ESC ARGOON 1	180/1	FALSE
3022	ARGOON 1-5, ESC ARGOON 1	ARGOON 1-5	TRUE
3023	ARGOON 1-5, ESC ARGOON 1	ESC ARGOON 1	FALSE
3032	ARGOON 3-6, ARGOON 3-8	214/1	FALSE
3033	ARGOON 3-6, ARGOON 3-8	215/1	FALSE
3034	ARGOON 3-6, ARGOON 3-8	ARGOON 3-6	TRUE
3035	ARGOON 3-6, ARGOON 3-8	ARGOON 3-8	FALSE
3036	ARGOON 2, 198/1	198/1	FALSE
3037	ARGOON 2, 198/1	ARGOON 2	TRUE
3038	ARGOON-3,4	193/1	FALSE
3039	ARGOON-3,4	196/1	FALSE
3040	ARGOON-3,4	197/1	FALSE
3041	ARGOON-3,4	ARGOON 2	FALSE
3042	ARGOON-3,4	ARGOON-3	TRUE
3043	ARGOON-3,4	ARGOON-4	FALSE
3143	ARGOON-3,4	ARGOON-4	FALSE
3144	ARGOON 1-5, ESC ARGOON 1	ARGOON 1-5	TRUE

Table B.16 Pool details table of BOONA main channel

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2185	BOONA0,1	120/1	FALSE
2186	BOONA0,1	2-Jan	FALSE
2187	BOONA0,1	BOONA	TRUE
2188	BOONA0,1	BOONA-1	FALSE
2189	BOONA1,2	120/2	FALSE
2190	BOONA1,2	2-Feb	FALSE
2191	BOONA1,2	675/1	FALSE
2192	BOONA1,2	8-Jan	FALSE
2193	BOONA1,2	9-Jan	FALSE
2194	BOONA1,2	9-Feb	FALSE

2195	BOONA1,2	BOONA-1	TRUE
2196	BOONA1,2	BOONA-2	FALSE
2197	BOONA2,3	10-Jan	FALSE
2198	BOONA2,3	1039/1	FALSE
2199	BOONA2,3	BOONA-2	TRUE
2200	BOONA2,3	BOONA-3	FALSE
2201	BOONA3,4	141/1	FALSE
2202	BOONA3,4	BOONA-3	TRUE
2203	BOONA3,4	BOONA-4	FALSE
2204	BOONA3,4	ESC BOONA-1	FALSE
2205	BOONA4,5	222/1	FALSE
2206	BOONA4,5	BOONA-4	TRUE
2207	BOONA4,5	BOONA-5	FALSE
2208	BOONA5,7	643/1	FALSE
2209	BOONA5,7	BOONA-5	TRUE
2210	BOONA5,7	BOONA-7	FALSE
2211	BOONA7,8	143/2	FALSE
2212	BOONA7,8	145/1	FALSE
2213	BOONA7,8	538/2	FALSE
2214	BOONA7,8	642/1	FALSE
2215	BOONA7,8	665/1	FALSE
2216	BOONA7,8	BOONA-7	TRUE
2217	BOONA7,8	BOONA-8	FALSE
2218	BOONA8,9	BOONA 7	FALSE
2219	BOONA8,9	BOONA-8	TRUE
2220	BOONA8,9	BOONA-9	FALSE
2221	BOONA10,11	BOONA-10	TRUE
2222	BOONA10,11	BOONA-11	FALSE
2223	BOONA11,12	169/1	FALSE
2224	BOONA11,12	676/1	FALSE
2225	BOONA11,12	BOONA-11	TRUE
2226	BOONA11,12	BOONA-12	FALSE
2227	BOONA12,13	167/1	FALSE
2228	BOONA12,13	BOONA-12	TRUE
2229	BOONA12,13	BOONA-13	FALSE
2230	BOONA7,7-1	BOONA 7	TRUE
2231	BOONA7,7-1	BOONA 7-1	FALSE
2232	BOONA7-1,7-2	657/1	FALSE
2233	BOONA7-1,7-2	BOONA 7-1	TRUE
2234	BOONA7-1,7-2	BOONA 7-2	FALSE
2235	BOONA7-2, ESC BOONA7	656/1	FALSE
2236	BOONA7-2, ESC BOONA7	BOONA 7-2	TRUE
2237	BOONA7-2, ESC BOONA7	ESC BOONA 7	FALSE
2238	BOONA9,9-1	BOONA 9	TRUE
2239	BOONA9,9-1	BOONA 9-1	FALSE
2240	BOONA9,9-1	BOONA 9A	FALSE
2241	BOONA16,17	BOONA-16	TRUE
2242	BOONA16,17	BOONA-17	FALSE
2243	BOONA17,18	162/1	FALSE

2244	BOONA17,18	BOONA-17	TRUE
2245	BOONA17,18	BOONA-18	FALSE
2246	BOONA18,19	158/1	FALSE
2247	BOONA18,19	161/1	FALSE
2248	BOONA18,19	BOONA-18	TRUE
2249	BOONA18,19	BOONA-19	FALSE
2250	BOONA19,20	159/1	FALSE
2251	BOONA19,20	BOONA-19	TRUE
2252	BOONA19,20	BOONA-20	FALSE
2253	BOONA20, ESC BOONA-3	160/1	FALSE
2254	BOONA20, ESC BOONA-3	BOONA-20	TRUE
2255	BOONA20, ESC BOONA-3	ESC BOONA-3	FALSE
2256	BOONA12,12-1	156/3	FALSE
2257	BOONA12,12-1	BOONA 12	TRUE
2258	BOONA12,12-1	BOONA 12-1	FALSE
2259	BOONA12-1,12-2	154/1	FALSE
2260	BOONA12-1,12-2	BOONA 12-1	TRUE
2261	BOONA12-1,12-2	BOONA 12-2	FALSE
2262	BOONA12-2, ESC BOONA12	155/1	FALSE
2263	BOONA12-2, ESC BOONA12	BOONA 12-2	TRUE
2264	BOONA12-2, ESC BOONA12	ESC BOONA 12	FALSE
2265	BOONA16,17	157/1	FALSE
3044	BOONA13,14	152/1	FALSE
3045	BOONA13,14	164/1	FALSE
3046	BOONA13,14	166/1	FALSE
3047	BOONA13,14	BOONA-13	TRUE
3048	BOONA13,14	BOONA-14	FALSE
3049	BOONA14,16	156/1	FALSE
3050	BOONA14,16	163/1	FALSE
3051	BOONA14,16	163/2	FALSE
3052	BOONA14,16	165/1	FALSE
3053	BOONA14,16	BOONA 12	FALSE
3054	BOONA14,16	BOONA-14	TRUE
3055	BOONA14,16	BOONA-16	FALSE
3056	BOONA 9-1, ESC BOONA 9	150/1	FALSE
3057	BOONA 9-1, ESC BOONA 9	151/1	FALSE
3058	BOONA 9-1, ESC BOONA 9	BOONA 9-1	TRUE
3059	BOONA 9-1, ESC BOONA 9	ESC BOONA 9	FALSE
3060	BOONA 9A, ESC BOONA 9A	BOONA 9A	TRUE
3061	BOONA 9A, ESC BOONA 9A	ESC BOONA 9A	FALSE
3062	BOONA9,10	146/1	FALSE
3063	BOONA9,10	BOONA 9	FALSE
3064	BOONA9,10	BOONA-10	FALSE
3065	BOONA9,10	BOONA-9	TRUE
3066	BOONA9,10	ESC BOONA-2	FALSE

Table B.17 Pool details table of BUNDURE main channel

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2747	BUNDURE 1-1, ESC BUNDURE 1	547/1	FALSE
2748	BUNDURE 1-1, ESC BUNDURE 1	547/2	FALSE
2749	BUNDURE 1-1, ESC BUNDURE 1	BUNDURE 1-1	TRUE
2750	BUNDURE 1-1, ESC BUNDURE 1	ESC BUNDURE 1	FALSE
2751	BUNDURE 3-1, BUNDURE 3-2	607/3	FALSE
2752	BUNDURE 3-1, BUNDURE 3-2	BUNDURE 3-1	TRUE
2753	BUNDURE 3-1, BUNDURE 3-2	BUNDURE 3-2	FALSE
2754	BUNDURE 3-2, BUNDURE 3-3	607/2	FALSE
2755	BUNDURE 3-2, BUNDURE 3-3	664/1	FALSE
2756	BUNDURE 3-2, BUNDURE 3-3	BUNDURE 3-2	TRUE
2757	BUNDURE 3-2, BUNDURE 3-3	BUNDURE 3-3	FALSE
2758	BUNDURE 3-3, BUNDURE 3-4	31-May	FALSE
2759	BUNDURE 3-3, BUNDURE 3-4	31/6	FALSE
2760	BUNDURE 3-3, BUNDURE 3-4	545/3	FALSE
2761	BUNDURE 3-3, BUNDURE 3-4	59/2	FALSE
2762	BUNDURE 3-3, BUNDURE 3-4	BUNDURE 3-3	TRUE
2763	BUNDURE 3-3, BUNDURE 3-4	BUNDURE 3-4	FALSE
2764	BUNDURE 3-4, BUNDURE 3-5	608/2	FALSE
2765	BUNDURE 3-4, BUNDURE 3-5	619/1	FALSE
2766	BUNDURE 3-4, BUNDURE 3-5	BUNDURE 3-4	TRUE
2767	BUNDURE 3-4, BUNDURE 3-5	BUNDURE 3-5	FALSE
2768	BUNDURE 3-5, BUNDURE 3-6	508/3	FALSE
2769	BUNDURE 3-5, BUNDURE 3-6	578/3	FALSE
2770	BUNDURE 3-5, BUNDURE 3-6	590/3	FALSE
2771	BUNDURE 3-5, BUNDURE 3-6	619/2	FALSE
2772	BUNDURE 3-5, BUNDURE 3-6	621/1	FALSE
2773	BUNDURE 3-5, BUNDURE 3-6	BUNDURE 3-5	TRUE
2774	BUNDURE 3-5, BUNDURE 3-6	BUNDURE 3-6	FALSE
2775	BUNDURE 3-6, BUNDURE 3-7	623/1	FALSE
2776	BUNDURE 3-6, BUNDURE 3-7	BUNDURE 3-6	TRUE
2777	BUNDURE 3-6, BUNDURE 3-7	BUNDURE 3-7	FALSE
2778	BUNDURE 3-6, BUNDURE 3-7	BUNDURE 3A O/T	FALSE
2779	BUNDURE 3A O/T, BUNDURE 3A-1	624/1	FALSE
2780	BUNDURE 3A O/T, BUNDURE 3A-1	BUNDURE 3A O/T	TRUE
2781	BUNDURE 3A O/T, BUNDURE 3A-1	BUNDURE 3A-1	FALSE
2782	BUNDURE 3A-1, ESC BUNDURE 3A	670/1	FALSE
2783	BUNDURE 3A-1, ESC BUNDURE 3A	BUNDURE 3A-1	TRUE
2784	BUNDURE 3A-1, ESC BUNDURE 3A	ESC BUNDURE 3A	FALSE
2785	BUNDURE 3-7, BUNDURE 3-8	541/2	FALSE
2786	BUNDURE 3-7, BUNDURE 3-8	BUNDURE 3-7	TRUE
2787	BUNDURE 3-7, BUNDURE 3-8	BUNDURE 3-8	FALSE
2788	BUNDURE 3-11, BUNDURE 3-12	640/1	FALSE
2789	BUNDURE 3-11, BUNDURE 3-12	BUNDURE 3-11	TRUE
2790	BUNDURE 3-11, BUNDURE 3-12	BUNDURE 3-12	FALSE
2791	BUNDURE 3-9, BUNDURE 3-11	577/3	FALSE
2792	BUNDURE 3-9, BUNDURE 3-11	614/2	FALSE
2793	BUNDURE 3-9, BUNDURE 3-11	623/2	FALSE
2794	BUNDURE 3-9, BUNDURE 3-11	651/1	FALSE
2795	BUNDURE 3-9, BUNDURE 3-11	BUNDURE 3-11	FALSE
2796	BUNDURE 3-9, BUNDURE 3-11	BUNDURE 3-9	TRUE
2797	BUNDURE 3-9, BUNDURE 3-11	BUNDURE 3B O/T	FALSE
2798	BUNDURE 3-12, BUNDURE 3-13	633/1	FALSE

2799	BUNDURE 3-12, BUNDURE 3-13	634/1	FALSE
2800	BUNDURE 3-12, BUNDURE 3-13	647/1	FALSE
2801	BUNDURE 3-12, BUNDURE 3-13	BUNDURE 3-12	TRUE
2802	BUNDURE 3-12, BUNDURE 3-13	BUNDURE 3-13	FALSE
2803	BUNDURE 4 O/T, BUNDURE 4-1	557/1	FALSE
2804	BUNDURE 4 O/T, BUNDURE 4-1	BUNDURE 4 O/T	TRUE
2805	BUNDURE 4 O/T, BUNDURE 4-1	BUNDURE 4-1	FALSE
2806	BUNDURE 4-1, BUNDURE 4-2	557/2	FALSE
2807	BUNDURE 4-1, BUNDURE 4-2	558/1	FALSE
2808	BUNDURE 4-1, BUNDURE 4-2	BUNDURE 4-1	TRUE
2809	BUNDURE 4-1, BUNDURE 4-2	BUNDURE 4-2	FALSE
2810	BUNDURE 4-2, BUNDURE 4-3	562/1	FALSE
2811	BUNDURE 4-2, BUNDURE 4-3	BUNDURE 4-2	TRUE
2812	BUNDURE 4-2, BUNDURE 4-3	BUNDURE 4-3	FALSE
2813	BUNDURE 4-3, BUNDURE 4-4	560/1	FALSE
2814	BUNDURE 4-3, BUNDURE 4-4	BUNDURE 4-3	TRUE
2815	BUNDURE 4-3, BUNDURE 4-4	BUNDURE 4-4	FALSE
2816	BUNDURE 4-4, BUNDURE 4-5	561/1	FALSE
2817	BUNDURE 4-4, BUNDURE 4-5	563/1	FALSE
2818	BUNDURE 4-4, BUNDURE 4-5	BUNDURE 4-4	TRUE
2819	BUNDURE 4-4, BUNDURE 4-5	BUNDURE 4-5	FALSE
2820	BUNDURE 4-5, BUNDURE 4-6	564/1	FALSE
2821	BUNDURE 4-5, BUNDURE 4-6	565/1	FALSE
2822	BUNDURE 4-5, BUNDURE 4-6	BUNDURE 4-5	TRUE
2823	BUNDURE 4-5, BUNDURE 4-6	BUNDURE 4-6	FALSE
2824	BUNDURE 4-6, BUNDURE 4-7	566/1	FALSE
2825	BUNDURE 4-6, BUNDURE 4-7	567/1	FALSE
2826	BUNDURE 4-6, BUNDURE 4-7	BUNDURE 4-6	TRUE
2827	BUNDURE 4-6, BUNDURE 4-7	BUNDURE 4-7	FALSE
2828	BUNDURE 4-7, BUNDURE 4-8	566/2	FALSE
2829	BUNDURE 4-7, BUNDURE 4-8	BUNDURE 4-7	TRUE
2830	BUNDURE 4-7, BUNDURE 4-8	BUNDURE 4-8	FALSE
2831	BUNDURE 4-8, BUNDURE 4-9	568/1	FALSE
2832	BUNDURE 4-8, BUNDURE 4-9	BUNDURE 4-8	TRUE
2833	BUNDURE 4-8, BUNDURE 4-9	BUNDURE 4-9	FALSE
2834	BUNDURE 4-9, BUNDURE 4-10	597/1	FALSE
2835	BUNDURE 4-9, BUNDURE 4-10	BUNDURE 4-10	FALSE
2836	BUNDURE 4-9, BUNDURE 4-10	BUNDURE 4-9	TRUE
2837	BUNDURE 4-9, BUNDURE 4-10	BUNDURE 4B O/T	FALSE
2838	BUNDURE 4-10, BUNDURE 4-11	598/1	FALSE
2839	BUNDURE 4-10, BUNDURE 4-11	BUNDURE 4-10	TRUE
2840	BUNDURE 4-10, BUNDURE 4-11	BUNDURE 4-11	FALSE
2841	BUNDURE 4-11, BUNDURE 4-12	599/1	FALSE
2842	BUNDURE 4-11, BUNDURE 4-12	600/3	FALSE
2843	BUNDURE 4-11, BUNDURE 4-12	BUNDURE 4-11	TRUE
2844	BUNDURE 4-11, BUNDURE 4-12	BUNDURE 4-12	FALSE
2845	BUNDURE 4-12, BUNDURE 4-13	599/2	FALSE
2846	BUNDURE 4-12, BUNDURE 4-13	601/1	FALSE
2847	BUNDURE 4-12, BUNDURE 4-13	BUNDURE 4-12	TRUE
2848	BUNDURE 4-12, BUNDURE 4-13	BUNDURE 4-13	FALSE
2849	BUNDURE 4B O/T, BUNDURE 4B-1	571/2	FALSE
2850	BUNDURE 4B O/T, BUNDURE 4B-1	BUNDURE 4B O/T	TRUE
2851	BUNDURE 4B O/T, BUNDURE 4B-1	BUNDURE 4B-1	FALSE
2852	BUNDURE 4B-1, ESC BUNDURE 4B	600/1	FALSE

2853	BUNDURE 4B-1, ESC BUNDURE 4B	BUNDURE 4B-1	TRUE
2854	BUNDURE 4B-1, ESC BUNDURE 4B	ESC BUNDURE 4B	FALSE
2855	BUNDURE 4-13, ESC BUNDURE 4	596/1	FALSE
2856	BUNDURE 4-13, ESC BUNDURE 4	BUNDURE 4-13	TRUE
2857	BUNDURE 5 O/T, BUNDURE 5-1	609/2	FALSE
2858	BUNDURE 5 O/T, BUNDURE 5-1	BUNDURE 5 O/T	TRUE
2859	BUNDURE 5 O/T, BUNDURE 5-1	BUNDURE 5-1	FALSE
2860	BUNDURE 5-1, BUNDURE 5-2	610/1	FALSE
2861	BUNDURE 5-1, BUNDURE 5-2	BUNDURE 5-1	TRUE
2862	BUNDURE 5-1, BUNDURE 5-2	BUNDURE 5-2	FALSE
2863	BUNDURE 5-2, BUNDURE 5-3	610/2	FALSE
2864	BUNDURE 5-2, BUNDURE 5-3	611/1	FALSE
2865	BUNDURE 5-2, BUNDURE 5-3	BUNDURE 5-2	TRUE
2866	BUNDURE 5-2, BUNDURE 5-3	BUNDURE 5-3	FALSE
2867	BUNDURE 5-3, BUNDURE 5-4	611/2	FALSE
2868	BUNDURE 5-3, BUNDURE 5-4	612/1	FALSE
2869	BUNDURE 5-3, BUNDURE 5-4	612/2	FALSE
2870	BUNDURE 5-3, BUNDURE 5-4	BUNDURE 5-3	TRUE
2871	BUNDURE 5-3, BUNDURE 5-4	BUNDURE 5-4	FALSE
2872	BUNDURE 5-4, BUNDURE 5-5	613/1	FALSE
2873	BUNDURE 5-4, BUNDURE 5-5	BUNDURE 5-4	TRUE
2874	BUNDURE 5-4, BUNDURE 5-5	BUNDURE 5-5	FALSE
2875	BUNDURE 5-5, ESC BUNDURE 5	613/2	FALSE
2876	BUNDURE 5-5, ESC BUNDURE 5	614/1	FALSE
2877	BUNDURE 5-5, ESC BUNDURE 5	BUNDURE 5-5	TRUE
2878	BUNDURE 5-5, ESC BUNDURE 5	ESC BUNDURE 5	FALSE
2879	BUNDURE 6 O/T, BUNDURE 6-1	573/1	FALSE
2880	BUNDURE 6 O/T, BUNDURE 6-1	BUNDURE 6 O/T	TRUE
2881	BUNDURE 6 O/T, BUNDURE 6-1	BUNDURE 6-1	FALSE
2882	BUNDURE 6-1, ESC BUNDURE 6	574/1	FALSE
2883	BUNDURE 6-1, ESC BUNDURE 6	BUNDURE 6-1	TRUE
2884	BUNDURE 7 O/T, BUNDURE 7-1	669/2	FALSE
2885	BUNDURE 7 O/T, BUNDURE 7-1	584/1	FALSE
2886	BUNDURE 7 O/T, BUNDURE 7-1	BUNDURE 7 O/T	TRUE
2887	BUNDURE 7 O/T, BUNDURE 7-1	BUNDURE 7-1	FALSE
2888	BUNDURE 7-1, BUNDURE 7-2	584/2	FALSE
2889	BUNDURE 7-1, BUNDURE 7-2	585/1	FALSE
2890	BUNDURE 7-1, BUNDURE 7-2	BUNDURE 7-1	TRUE
2891	BUNDURE 7-1, BUNDURE 7-2	BUNDURE 7-2	FALSE
2892	BUNDURE 7-2, BUNDURE 7-3	BUNDURE 7-2	TRUE
2893	BUNDURE 7-2, BUNDURE 7-3	BUNDURE 7-3	FALSE
2894	BUNDURE 7-3, ESC BUNDURE 7	587/1	FALSE
2895	BUNDURE 7-3, ESC BUNDURE 7	BUNDURE 7-3	TRUE
2896	BUNDURE 8 O/T, BUNDURE 8-1	578/2	FALSE
2897	BUNDURE 8 O/T, BUNDURE 8-1	579/1	FALSE
2898	BUNDURE 8 O/T, BUNDURE 8-1	BUNDURE 8 O/T	TRUE
2899	BUNDURE 8 O/T, BUNDURE 8-1	BUNDURE 8-1	FALSE
2900	BUNDURE 8-1, BUNDURE 8-2	580/1	FALSE
2901	BUNDURE 8-1, BUNDURE 8-2	BUNDURE 8-1	TRUE
2902	BUNDURE 8-1, BUNDURE 8-2	BUNDURE 8-2	FALSE
2903	BUNDURE 8-2, ESC BUNDURE 8	581/1	FALSE
2904	BUNDURE 8-2, ESC BUNDURE 8	582/1	FALSE
2905	BUNDURE 8-2, ESC BUNDURE 8	BUNDURE 8-2	TRUE
2906	BUNDURE 8-2, ESC BUNDURE 8	ESC BUNDURE 8	FALSE

3067	BUNDURE 1 O/T, BUNDURE 1-1	545/2	FALSE
3068	BUNDURE 1 O/T, BUNDURE 1-1	546/1	FALSE
3069	BUNDURE 1 O/T, BUNDURE 1-1	BUNDURE 1 O/T	TRUE
3070	BUNDURE 1 O/T, BUNDURE 1-1	BUNDURE 1-1	FALSE
3071	BUNDURE 3-13, ESC BUNDURE 3	574/3	FALSE
3072	BUNDURE 3-13, ESC BUNDURE 3	610/3	FALSE
3073	BUNDURE 3-13, ESC BUNDURE 3	636/1	FALSE
3074	BUNDURE 3-13, ESC BUNDURE 3	BUNDURE 3-13	TRUE
3075	BUNDURE 3-8, BUNDURE 3-9	650/1	FALSE
3076	BUNDURE 3-8, BUNDURE 3-9	BUNDURE 3-8	TRUE
3077	BUNDURE 3-8, BUNDURE 3-9	BUNDURE 3-9	FALSE

Table B.18 Pool details table of COLY main channel

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2266	COLY2-1,2-2	COLY 2-1	TRUE
2267	COLY2-1,2-2	COLY 2-2	FALSE
2268	COLY3-1,3-2	5-Jan	FALSE
2269	COLY3-1,3-2	COLY 3-1	TRUE
2270	COLY3-1,3-2	COLY 3-2	FALSE
2271	COLY3-2,3-3	4-Jan	FALSE
2272	COLY3-2,3-3	6-Feb	FALSE
2273	COLY3-2,3-3	COLY 3-2	TRUE
2274	COLY3-2,3-3	COLY 3-3	FALSE
2275	COLY3-3,3-4	3-Jan	FALSE
2276	COLY3-3,3-4	COLY 3-3	TRUE
2277	COLY3-3,3-4	COLY 3-4	FALSE
2278	COLY3-4, ESC COLY3	8-Feb	FALSE
2279	COLY3-4, ESC COLY3	COLY 3-4	TRUE
2280	COLY3-4, ESC COLY3	ESC COLY 3	FALSE
2281	COLY4-1,4-2	14-Feb	FALSE
2282	COLY4-1,4-2	COLY 4-1	TRUE
2283	COLY4-1,4-2	COLY 4-2	FALSE
2284	COLY4-2,4-3	13-Jan	FALSE
2285	COLY4-2,4-3	17-Jan	FALSE
2286	COLY4-2,4-3	COLY 4-2	TRUE
2287	COLY4-2,4-3	COLY 4-3	FALSE
2288	COLY4-5,4-6	11-Jan	FALSE
2289	COLY4-5,4-6	11-Feb	FALSE
2290	COLY4-5,4-6	COLY 4-5	TRUE
2291	COLY4-5,4-6	COLY 4-6	FALSE
2292	COLY4-4,4-5	19-Jan	FALSE
2293	COLY4-4,4-5	COLY 4-4	TRUE
2294	COLY4-4,4-5	COLY 4-5	FALSE
2295	COLY5,5-1	25-Jan	FALSE
2296	COLY5,5-1	COLY 5	TRUE
2297	COLY5,5-1	COLY 5-1	FALSE
2298	COLY5-1,5-2	24-Jan	FALSE
2299	COLY5-1,5-2	24-Feb	FALSE
2300	COLY5-1,5-2	COLY 5-1	TRUE
2301	COLY5-1,5-2	COLY 5-2	FALSE
2302	COLY5-2,5-3	23-Jan	FALSE
2303	COLY5-2,5-3	COLY 5-2	TRUE

2304	COLY5-2,5-3	COLY 5-3	FALSE
2305	COLY5-3,5-4	21-Jan	FALSE
2306	COLY5-3,5-4	22-Jan	FALSE
2307	COLY5-3,5-4	23-Feb	FALSE
2308	COLY5-3,5-4	COLY 5-3	TRUE
2309	COLY5-3,5-4	COLY 5-4	FALSE
2310	COLY4-3,4-4	12-Jan	FALSE
2311	COLY4-3,4-4	18-Jan	FALSE
2312	COLY4-3,4-4	COLY 4-3	TRUE
2313	COLY4-3,4-4	COLY 4-4	FALSE
2314	COLY6,6-1	COLY 6	TRUE
2315	COLY6,6-1	COLY 6-1	FALSE
2316	COLY6-1,6-2	28-Jan	FALSE
2317	COLY6-1,6-2	COLY 6-1	TRUE
2318	COLY6-1,6-2	COLY 6-2	FALSE
2319	COLY6-2,6-3	29-Jan	FALSE
2320	COLY6-2,6-3	COLY 6-2	TRUE
2321	COLY6-2,6-3	COLY 6-3	FALSE
2322	COLY6-3,6-4	30-Jan	FALSE
2323	COLY6-3,6-4	COLY 6-3	TRUE
2324	COLY6-3,6-4	COLY 6-4	FALSE
2325	COLY6-4,6-5	31-Jan	FALSE
2326	COLY6-4,6-5	COLY 6-4	TRUE
2327	COLY6-4,6-5	COLY 6-5	FALSE
2328	COLY6-5,6-6	32/1	FALSE
2329	COLY6-5,6-6	COLY 6-5	TRUE
2330	COLY6-5,6-6	COLY 6-6	FALSE
2331	COLY6-6,6-7	33/1	FALSE
2332	COLY6-6,6-7	COLY 6-6	TRUE
2333	COLY6-6,6-7	COLY 6-7	FALSE
2334	COLY6-7,6-8	34/1	FALSE
2335	COLY6-7,6-8	COLY 6-7	TRUE
2336	COLY6-7,6-8	COLY 6-8	FALSE
2337	COLY6-8,6-9	35/1	FALSE
2338	COLY6-8,6-9	41/1	FALSE
2339	COLY6-8,6-9	COLY 6-8	TRUE
2340	COLY6-8,6-9	COLY 6-9	FALSE
2341	COLY6-9,6-10	36/1	FALSE
2342	COLY6-9,6-10	40/1	FALSE
2343	COLY6-9,6-10	COLY 6-10	FALSE
2344	COLY6-9,6-10	COLY 6-9	TRUE
2345	COLY6-10,6-11	37/1	FALSE
2346	COLY6-10,6-11	39/1	FALSE
2347	COLY6-10,6-11	COLY 6-10	TRUE
2348	COLY6-10,6-11	COLY 6-11	FALSE
2349	COLY7,7-1	27-Feb	FALSE
2350	COLY7,7-1	46/1	FALSE
2351	COLY7,7-1	COLY 7	TRUE
2352	COLY7,7-1	COLY 7-1	FALSE
2353	COLY7-1,7-2	28-Mar	FALSE
2354	COLY7-1,7-2	COLY 7-1	TRUE
2355	COLY7-1,7-2	COLY 7-2	FALSE
2356	COLY7-2,7-4	29/2	FALSE
2357	COLY7-2,7-4	30/2	FALSE

2358	COLY7-2,7-4	44/1	FALSE
2359	COLY7-2,7-4	45/1	FALSE
2360	COLY7-2,7-4	COLY 7-2	TRUE
2361	COLY7-2,7-4	COLY 7-4	FALSE
2362	COLY7-4,7-5	43/1	FALSE
2363	COLY7-4,7-5	654/1	FALSE
2364	COLY7-4,7-5	COLY 7-4	TRUE
2365	COLY7-4,7-5	COLY 7-5	FALSE
2366	COLY7-5, ESC COLY 7	42/1	FALSE
2367	COLY7-5, ESC COLY 7	COLY 7-5	TRUE
2368	COLY7-5, ESC COLY 7	ESC COLY 7	FALSE
2369	COLY8, 8-1	56/1	FALSE
2370	COLY8, 8-1	COLY 8	TRUE
2371	COLY8, 8-1	COLY 8-1	FALSE
2372	COLY8-1,8-2	55/1	FALSE
2373	COLY8-1,8-2	COLY 8-1	TRUE
2374	COLY8-1,8-2	COLY 8-2	FALSE
2375	COLY8-2,8-3	45/2	FALSE
2376	COLY8-2,8-3	48/1	FALSE
2377	COLY8-2,8-3	COLY 8-2	TRUE
2378	COLY8-2,8-3	COLY 8-3	FALSE
2379	COLY8-3,8-4	COLY 8-3	TRUE
2380	COLY8-3,8-4	COLY 8-4	FALSE
2381	COLY 8-4,8-5	52/1	FALSE
2382	COLY 8-4,8-5	COLY 8-4	TRUE
2383	COLY 8-4,8-5	COLY 8-5	FALSE
2384	COLY 8-5, 8-6	COLY 8-5	TRUE
2385	COLY 8-5, 8-6	COLY 8-6	FALSE
2386	COLY 9-2,9-3	94/1	FALSE
2387	COLY 9-2,9-3	COLY 9-2	TRUE
2388	COLY 9-2,9-3	COLY 9-3	FALSE
2389	COLY 9-3,9-4	59/1	FALSE
2390	COLY 9-3,9-4	60/1	FALSE
2391	COLY 9-3,9-4	COLY 9-3	TRUE
2392	COLY 9-3,9-4	COLY 9-4	FALSE
2393	COLY 9-4,9-5	61/1	FALSE
2394	COLY 9-4,9-5	93/1	FALSE
2395	COLY 9-4,9-5	COLY 9-4	TRUE
2396	COLY 9-4,9-5	COLY 9-5	FALSE
2397	COLY 9-5, 9-6	61/2	FALSE
2398	COLY 9-5, 9-6	62/1	FALSE
2399	COLY 9-5, 9-6	92/1	FALSE
2400	COLY 9-5, 9-6	92/2	FALSE
2401	COLY 9-5, 9-6	93/2	FALSE
2402	COLY 9-5, 9-6	COLY 9-5	TRUE
2403	COLY 9-5, 9-6	COLY 9-6	FALSE
2404	COLY 9-5, 9-6	COLY 9B	FALSE
2405	COLY 9-6, 9-7	91/1	FALSE
2406	COLY 9-6, 9-7	COLY 9-6	TRUE
2407	COLY 9-6, 9-7	COLY 9-7	FALSE
2408	COLY 9-7, 9-8	90/1	FALSE
2409	COLY 9-7, 9-8	90/2	FALSE
2410	COLY 9-7, 9-8	COLY 9-7	TRUE
2411	COLY 9-7, 9-8	COLY 9-8	FALSE

2412	COLY 9B, 9B-1	63/1	FALSE
2413	COLY 9B, 9B-1	63/2	FALSE
2414	COLY 9B, 9B-1	COLY 9B	TRUE
2415	COLY 9B, 9B-1	COLY 9B-1	FALSE
2416	COLY 9B-1, 9B-2	64/1	FALSE
2417	COLY 9B-1, 9B-2	COLY 9B-1	TRUE
2418	COLY 9B-1, 9B-2	COLY 9B-2	FALSE
2419	COLY 9B-2, 9B-3	65/1	FALSE
2420	COLY 9B-2, 9B-3	COLY 9B-2	TRUE
2421	COLY 9B-2, 9B-3	COLY 9B-3	FALSE
2422	COLY 9B-3, 9B-4	65/2	FALSE
2423	COLY 9B-3, 9B-4	66/1	FALSE
2424	COLY 9B-3, 9B-4	67/1	FALSE
2425	COLY 9B-3, 9B-4	COLY 9B-3	TRUE
2426	COLY 9B-3, 9B-4	COLY 9B-4	FALSE
2427	COLY 9B-4, 9B-5	68/1	FALSE
2428	COLY 9B-4, 9B-5	COLY 9B-4	TRUE
2429	COLY 9B-4, 9B-5	COLY 9B-5	FALSE
2430	COLY 9B-5, 9B-7	69/1	FALSE
2431	COLY 9B-5, 9B-7	76/1	FALSE
2432	COLY 9B-5, 9B-7	76/2	FALSE
2433	COLY 9B-5, 9B-7	77/1	FALSE
2434	COLY 9B-5, 9B-7	COLY 9B-5	TRUE
2435	COLY 9B-5, 9B-7	COLY 9B-7	FALSE
2436	COLY 9-8, 9-9	89/1	FALSE
2437	COLY 9-8, 9-9	COLY 9-8	TRUE
2438	COLY 9-8, 9-9	COLY 9-9	FALSE
2439	COLY 9B-8, 9B-10	70/1	FALSE
2440	COLY 9B-8, 9B-10	74/1	FALSE
2441	COLY 9B-8, 9B-10	75/2	FALSE
2442	COLY 9B-8, 9B-10	COLY 9B-10	FALSE
2443	COLY 9B-8, 9B-10	COLY 9B-8	TRUE
2444	COLY 9B-10, ESC 9B	73/1	FALSE
2445	COLY 9B-10, ESC 9B	COLY 9B-10	TRUE
2446	COLY 9B-10, ESC 9B	ESC 9B	FALSE
2447	COLY 9-9, 9-12	78/1	FALSE
2448	COLY 9-9, 9-12	88/1	FALSE
2449	COLY 9-9, 9-12	COLY 9-12	FALSE
2450	COLY 9-9, 9-12	COLY 9-9	TRUE
2451	COLY 9-9, 9-12	COLY 9C	FALSE
2452	COLY 9-12, 9-13	79/1	FALSE
2453	COLY 9-12, 9-13	COLY 9-12	TRUE
2454	COLY 9-12, 9-13	COLY 9-13	FALSE
2455	COLY 9-13, 9-14	80/1	FALSE
2456	COLY 9-13, 9-14	83/1	FALSE
2457	COLY 9-13, 9-14	COLY 9-13	TRUE
2458	COLY 9-13, 9-14	COLY 9-14	FALSE
2459	COLY 9-14, 9-15	81/1	FALSE
2460	COLY 9-14, 9-15	COLY 9-14	TRUE
2461	COLY 9-14, 9-15	COLY 9-15	FALSE
2462	COLY 9C, 9C-1	86/1	FALSE
2463	COLY 9C, 9C-1	87/1	FALSE
2464	COLY 9C, 9C-1	COLY 9C	TRUE
2465	COLY 9C, 9C-1	COLY 9C-1	FALSE

2466	COLY 9C-1, 9C-3 ESC	83/2	FALSE
2467	COLY 9C-1, 9C-3 ESC	85/1	FALSE
2468	COLY 9C-1, 9C-3 ESC	COLY 9C-1	TRUE
2469	COLY 9C-1, 9C-3 ESC	COLY 9C-3 ESC	FALSE
2470	COLY 9-15, 9-16ESC 9	82/1	FALSE
2471	COLY 9-15, 9-16ESC 9	COLY 9-15	TRUE
2472	COLY 9-15, 9-16ESC 9	COLY 9-16ESC 9	FALSE
2473	COLY 10, 10-1	96/1	FALSE
2474	COLY 10, 10-1	96/2	FALSE
2475	COLY 10, 10-1	97/1	FALSE
2476	COLY 10, 10-1	COLY 10	TRUE
2477	COLY 10, 10-1	COLY 10-1	FALSE
2478	COLY 10-1, 10-3	100/1	FALSE
2479	COLY 10-1, 10-3	97/2	FALSE
2480	COLY 10-1, 10-3	98/1	FALSE
2481	COLY 10-1, 10-3	98/2	FALSE
2482	COLY 10-1, 10-3	99/1	FALSE
2483	COLY 10-1, 10-3	COLY 10-1	TRUE
2484	COLY 10-1, 10-3	COLY 10-3	FALSE
2485	COLY 10-3, 10-4	101/1	FALSE
2486	COLY 10-3, 10-4	102/1	FALSE
2487	COLY 10-3, 10-4	102/2	FALSE
2488	COLY 10-3, 10-4	COLY 10-3	TRUE
2489	COLY 10-3, 10-4	COLY 10-4	FALSE
2490	COLY 10-4, 10-5	102/3	FALSE
2491	COLY 10-4, 10-5	103/1	FALSE
2492	COLY 10-4, 10-5	COLY 10-4	TRUE
2493	COLY 10-4, 10-5	COLY 10-5	FALSE
2494	COLY 10-5, 10-6	COLY 10-5	TRUE
2495	COLY 10-5, 10-6	COLY 10-6	FALSE
2496	COLY 10-6, 10-7	104/1	FALSE
2497	COLY 10-6, 10-7	105/1	FALSE
2498	COLY 10-6, 10-7	662/1	FALSE
2499	COLY 10-6, 10-7	COLY 10-6	TRUE
2500	COLY 10-6, 10-7	COLY 10-7	FALSE
2501	COLY 10-7, ESC 10	107/1	FALSE
2502	COLY 10-7, ESC 10	COLY 10-7	TRUE
2503	COLY 10-7, ESC 10	ESC 10	FALSE
2504	COLY 11-1, 11-2	114/1	FALSE
2505	COLY 11-1, 11-2	COLY 11-1	TRUE
2506	COLY 11-1, 11-2	COLY 11-2	FALSE
2507	COLY 11-2, 11-3	118/1	FALSE
2508	COLY 11-2, 11-3	COLY 11-2	TRUE
2509	COLY 11-2, 11-3	COLY 11-3	FALSE
2510	COLY 11-3, 11-4	113/1	FALSE
2511	COLY 11-3, 11-4	118/2	FALSE
2512	COLY 11-3, 11-4	COLY 11-3	TRUE
2513	COLY 11-3, 11-4	COLY 11-4	FALSE
2514	COLY 11-4, 11-5	112/1	FALSE
2515	COLY 11-4, 11-5	119/1	FALSE
2516	COLY 11-4, 11-5	COLY 11-4	TRUE
2517	COLY 11-4, 11-5	COLY 11-5	FALSE
2518	COLY 11-5, 11-6	170/1	FALSE
2519	COLY 11-5, 11-6	COLY 11-5	TRUE

2520	COLY 11-5, 11-6	COLY 11-6	FALSE
2521	COLY 11-6, 11-7	111/1	FALSE
2522	COLY 11-6, 11-7	COLY 11-6	TRUE
2523	COLY 11-6, 11-7	COLY 11-7	FALSE
2524	COLY 11-7, 11-8	110/1	FALSE
2525	COLY 11-7, 11-8	171/1	FALSE
2526	COLY 11-7, 11-8	COLY 11-7	TRUE
2527	COLY 11-7, 11-8	COLY 11-8	FALSE
2528	COLY 11-8, 11-9	108/2	FALSE
2529	COLY 11-8, 11-9	COLY 11-8	TRUE
2530	COLY 11-8, 11-9	COLY 11-9	FALSE
2531	COLY 11-8, 11-9	ESC 11	FALSE
2532	COLY 11-9, 172/1	172/1	FALSE
2533	COLY 11-9, 172/1	COLY 11-9	TRUE
3002	COLY 2-2, COLY 2 ESC	COLY 2 ESC	FALSE
3003	COLY 2-2, COLY 2 ESC	COLY 2-2	TRUE
3004	COLY 4-6, ESC COLY 4	20-Jan	FALSE
3005	COLY 4-6, ESC COLY 4	COLY 4-6	TRUE
3006	COLY 4-6, ESC COLY 4	ESC COLY 4	FALSE
3007	COLY 6-11, ESC 6	38/1	FALSE
3008	COLY 6-11, ESC 6	COLY 6-11	TRUE
3009	COLY 6-11, ESC 6	ESC 6	FALSE
3080	COLY 9B-7, 9B-8	COLY 9B-7	TRUE
3081	COLY 9B-7, 9B-8	COLY 9B-8	FALSE
3078	COLY 9B-7, 9B-8	69/2	FALSE
3079	COLY 9B-7, 9B-8	75/1	FALSE
3126	COLY 9, COLY 9-2	57/1	FALSE
3127	COLY 9, COLY 9-2	58/1	FALSE
3128	COLY 9, COLY 9-2	COLY 9	TRUE
3129	COLY 9, COLY 9-2	COLY 9-2	FALSE

Table B.19 Pool details table of MAIN CANAL

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2907	MAIN CANAL INLET, TUBBO WELLS	MAIN CANAL INLET	TRUE
2908	MAIN CANAL INLET, TUBBO WELLS	TOMBULLEN INLET	FALSE
2909	MAIN CANAL INLET, TUBBO WELLS	TUBBO WELLS	FALSE
2910	BUNDURE MAIN-16, BUNDURE MAIN-17	BUNDURE MAIN-16	TRUE
2911	BUNDURE MAIN-16, BUNDURE MAIN-17	BUNDURE MAIN-17	FALSE
2912	BUNDURE MAIN-15, BUNDURE MAIN-16	BUNDURE MAIN-15	TRUE
2913	BUNDURE MAIN-15, BUNDURE MAIN-16	BUNDURE MAIN-16	FALSE
2914	BUNDURE MAIN-14, BUNDURE MAIN-15	BUNDURE MAIN-14	TRUE
2915	BUNDURE MAIN-14, BUNDURE MAIN-15	BUNDURE MAIN-15	FALSE
2916	BUNDURE MAIN-13, BUNDURE MAIN-14	590/1	FALSE
2917	BUNDURE MAIN-13, BUNDURE MAIN-14	591/2	FALSE
2918	BUNDURE MAIN-13, BUNDURE MAIN-14	BUNDURE MAIN-13	TRUE
2919	BUNDURE MAIN-13, BUNDURE MAIN-14	BUNDURE MAIN-14	FALSE
2920	BUNDURE MAIN-12, BUNDURE MAIN-13	589/2	FALSE
2921	BUNDURE MAIN-12, BUNDURE MAIN-13	591/1	FALSE
2922	BUNDURE MAIN-12, BUNDURE MAIN-13	BUNDURE MAIN-12	TRUE
2923	BUNDURE MAIN-12, BUNDURE MAIN-13	BUNDURE MAIN-13	FALSE
2924	BUNDURE MAIN-11, BUNDURE MAIN-12	588/1	FALSE
2925	BUNDURE MAIN-11, BUNDURE MAIN-12	BUNDURE MAIN-11	TRUE

2926	BUNDURE MAIN-11, BUNDURE MAIN-12	BUNDURE MAIN-12	FALSE
2927	BUNDURE MAIN-10, BUNDURE MAIN-11	577/1	FALSE
2928	BUNDURE MAIN-10, BUNDURE MAIN-11	578/1	FALSE
2929	BUNDURE MAIN-10, BUNDURE MAIN-11	BUNDURE 8 O/T	FALSE
2930	BUNDURE MAIN-10, BUNDURE MAIN-11	BUNDURE MAIN-10	TRUE
2931	BUNDURE MAIN-10, BUNDURE MAIN-11	BUNDURE MAIN-11	FALSE
2932	BUNDURE MAIN-9, BUNDURE MAIN-10	669/1	FALSE
2933	BUNDURE MAIN-9, BUNDURE MAIN-10	BUNDURE 7 O/T	FALSE
2934	BUNDURE MAIN-9, BUNDURE MAIN-10	BUNDURE MAIN-10	FALSE
2935	BUNDURE MAIN-9, BUNDURE MAIN-10	BUNDURE MAIN-9	TRUE
2936	BUNDURE MAIN-8, BUNDURE MAIN-9	574/2	FALSE
2937	BUNDURE MAIN-8, BUNDURE MAIN-9	575/1	FALSE
2938	BUNDURE MAIN-8, BUNDURE MAIN-9	BUNDURE MAIN-8	TRUE
2939	BUNDURE MAIN-8, BUNDURE MAIN-9	BUNDURE MAIN-9	FALSE
2940	BUNDURE MAIN-7, BUNDURE MAIN-8	555/2	FALSE
2941	BUNDURE MAIN-7, BUNDURE MAIN-8	572/1	FALSE
2942	BUNDURE MAIN-7, BUNDURE MAIN-8	609/1	FALSE
2943	BUNDURE MAIN-7, BUNDURE MAIN-8	BUNDURE 5 O/T	FALSE
2944	BUNDURE MAIN-7, BUNDURE MAIN-8	BUNDURE 6 O/T	FALSE
2945	BUNDURE MAIN-7, BUNDURE MAIN-8	BUNDURE MAIN-7	TRUE
2946	BUNDURE MAIN-7, BUNDURE MAIN-8	BUNDURE MAIN-8	FALSE
2947	BUNDURE MAIN-6, BUNDURE MAIN-7	554/2	FALSE
2948	BUNDURE MAIN-6, BUNDURE MAIN-7	555/1	FALSE
2949	BUNDURE MAIN-6, BUNDURE MAIN-7	607/1	FALSE
2950	BUNDURE MAIN-6, BUNDURE MAIN-7	608/1	FALSE
2951	BUNDURE MAIN-6, BUNDURE MAIN-7	BUNDURE MAIN-6	TRUE
2952	BUNDURE MAIN-6, BUNDURE MAIN-7	BUNDURE MAIN-7	FALSE
2953	BUNDURE MAIN-4, BUNDURE MAIN-6	552/1	FALSE
2954	BUNDURE MAIN-4, BUNDURE MAIN-6	554/1	FALSE
2955	BUNDURE MAIN-4, BUNDURE MAIN-6	606/3	FALSE
2956	BUNDURE MAIN-4, BUNDURE MAIN-6	BUNDURE - ESC O/T	FALSE
2957	BUNDURE MAIN-4, BUNDURE MAIN-6	BUNDURE MAIN-4	TRUE
2958	BUNDURE MAIN-4, BUNDURE MAIN-6	BUNDURE MAIN-6	FALSE
2959	BUNDURE MAIN-1, BUNDURE MAIN-3	549/1	FALSE
2960	BUNDURE MAIN-1, BUNDURE MAIN-3	549/2	FALSE
2961	BUNDURE MAIN-1, BUNDURE MAIN-3	551/1	FALSE
2962	BUNDURE MAIN-1, BUNDURE MAIN-3	615/2	FALSE
2963	BUNDURE MAIN-1, BUNDURE MAIN-3	672/1	FALSE
2964	BUNDURE MAIN-1, BUNDURE MAIN-3	BUNDURE MAIN-1	TRUE
2965	BUNDURE MAIN-1, BUNDURE MAIN-3	BUNDURE MAIN-3	FALSE
2966	PRICKLEY REG, BUNDURE MAIN O/T	BUNDURE MAIN O/T	FALSE
2967	PRICKLEY REG, BUNDURE MAIN O/T	COLY 11-1	FALSE
2968	PRICKLEY REG, BUNDURE MAIN O/T	KOORUMBEEN	FALSE
2969	PRICKLEY REG, BUNDURE MAIN O/T	MAIN CANAL ESC	FALSE
2970	PRICKLEY REG, BUNDURE MAIN O/T	PRICKLEY REGULATOR	TRUE
2971	PRICKLEY REG, BUNDURE MAIN O/T	YAMMA	FALSE
2972	MORUNDAH REG, GRANTS REG	COLY 7	FALSE
2973	MORUNDAH REG, GRANTS REG	COLY 8	FALSE
2974	MORUNDAH REG, GRANTS REG	GRANTS REGULATOR	FALSE
2975	MORUNDAH REG, GRANTS REG	MORUNDAH REGULATOR	TRUE
2976	NO 3 REG, MORUNDAH REG	15-Jan	FALSE
2977	NO 3 REG, MORUNDAH REG	2023/2	FALSE
2978	NO 3 REG, MORUNDAH REG	COLY 4-1	FALSE
2979	NO 3 REG, MORUNDAH REG	COLY 5	FALSE

2980	NO 3 REG, MORUNDAH REG	COLY 6	FALSE
2981	NO 3 REG, MORUNDAH REG	MORUNDAH REGULATOR	FALSE
2982	NO 3 REG, MORUNDAH REG	NO 3 REGULATOR	TRUE
2983	BUNDURE MAIN-3, BUNDURE MAIN-4	548/3	FALSE
2984	BUNDURE MAIN-3, BUNDURE MAIN-4	551/2	FALSE
2985	BUNDURE MAIN-3, BUNDURE MAIN-4	551/3	FALSE
2986	BUNDURE MAIN-3, BUNDURE MAIN-4	606/1	FALSE
2987	BUNDURE MAIN-3, BUNDURE MAIN-4	615/1	FALSE
2988	BUNDURE MAIN-3, BUNDURE MAIN-4	615/3	FALSE
2989	BUNDURE MAIN-3, BUNDURE MAIN-4	BUNDURE 3-1	FALSE
2990	BUNDURE MAIN-3, BUNDURE MAIN-4	BUNDURE MAIN-3	TRUE
2991	BUNDURE MAIN-3, BUNDURE MAIN-4	BUNDURE MAIN-4	FALSE
2992	GRANTS REG, PRICKLEY REG	COLY 10	FALSE
2993	GRANTS REG, PRICKLEY REG	COLY 9	FALSE
2994	GRANTS REG, PRICKLEY REG	GRANTS REGULATOR	TRUE
2995	GRANTS REG, PRICKLEY REG	PRICKLEY REGULATOR	FALSE
3013	HORTICULTURE, NO. 3	14-Jan	FALSE
3014	HORTICULTURE, NO. 3	COLY 3-1	FALSE
3015	HORTICULTURE, NO. 3	HORTICULTURE REGULATOR	TRUE
3016	HORTICULTURE, NO. 3	NO 3 REGULATOR	FALSE
3017	TUBBO WELLS, HORTICULTURE REG	COLY 2-1	FALSE
3018	TUBBO WELLS, HORTICULTURE REG	HORTICULTURE REGULATOR	FALSE
3019	TUBBO WELLS, HORTICULTURE REG	TUBBO OFFTAKE	FALSE
3020	TUBBO WELLS, HORTICULTURE REG	TUBBO WELLS	TRUE
3107	BUNDURE MAIN O/T, BUNDURE MAIN-1	542/2	FALSE
3108	BUNDURE MAIN O/T, BUNDURE MAIN-1	545/1	FALSE
3109	BUNDURE MAIN O/T, BUNDURE MAIN-1	548/1	FALSE
3110	BUNDURE MAIN O/T, BUNDURE MAIN-1	BUNDURE 1 O/T	FALSE
3111	BUNDURE MAIN O/T, BUNDURE MAIN-1	BUNDURE MAIN O/T	TRUE
3112	BUNDURE MAIN O/T, BUNDURE MAIN-1	BUNDURE MAIN-1	FALSE
3113	BUNDURE MAIN O/T, BUNDURE MAIN-1	BUNDURE-SPUR O/T	FALSE
3114	BUNDURE MAIN-17, ESC BUNDURE MAIN -	596/2	FALSE
3115	BUNDURE MAIN-17, ESC BUNDURE MAIN -	BUNDURE MAIN-17	TRUE
3116	KOORUMBEEN, ESC KOORUMBEEN	2013/1	FALSE
3117	KOORUMBEEN, ESC KOORUMBEEN	544/2	FALSE
3118	KOORUMBEEN, ESC KOORUMBEEN	KOORUMBEEN	TRUE
3119	BUNDURE-SPUR O/T, 44/3	44/3	FALSE
3120	BUNDURE-SPUR O/T, 44/3	667/1	FALSE
3121	BUNDURE-SPUR O/T, 44/3	BUNDURE-SPUR O/T	TRUE
3122	BUNDURE-ESC O/T, ESC BUNDURE MAIN1	556/1	FALSE
3123	BUNDURE-ESC O/T, ESC BUNDURE MAIN1	BUNDURE - ESC O/T	TRUE
3124	BUNDURE-ESC O/T, ESC BUNDURE MAIN1	BUNDURE 4 O/T	FALSE
3125	BUNDURE-ESC O/T, ESC BUNDURE MAIN1	ESC BUNDURE MAIN-1	FALSE

Table B.20 Pool details table of TUBBO main channel

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2149	TUBBO1,2	5-Mar	FALSE
2150	TUBBO1,2	TUBBO-1	TRUE
2151	TUBBO1,2	TUBBO-2	FALSE
2152	TUBBO3,4	120/3	FALSE
2153	TUBBO3,4	639/1	FALSE
2154	TUBBO3,4	TUBBO-3	TRUE

2155	TUBBO3,4	TUBBO-4	FALSE
2156	TUBBO4,5	11-Mar	FALSE
2157	TUBBO4,5	TUBBO-4	TRUE
2158	TUBBO4,5	TUBBO-5	FALSE
2159	TUBBO6,7	221/1	FALSE
2160	TUBBO6,7	4005/1	FALSE
2161	TUBBO6,7	7-Apr	FALSE
2162	TUBBO6,7	TUBBO-6	TRUE
2163	TUBBO6,7	TUBBO-7	FALSE
2164	TUBBO8,9	226/1	FALSE
2165	TUBBO8,9	31/4	FALSE
2166	TUBBO8,9	TUBBO-8	TRUE
2167	TUBBO8,9	TUBBO-9	FALSE
2168	TUBBO9,10	4004/1	FALSE
2169	TUBBO9,10	6-Mar	FALSE
2170	TUBBO9,10	661/1	FALSE
2171	TUBBO9,10	663/1	FALSE
2172	TUBBO9,10	TUBBO-10	FALSE
2173	TUBBO9,10	TUBBO-9	TRUE
2174	TUBBO10,11	507/2	FALSE
2175	TUBBO10,11	673/1	FALSE
2176	TUBBO10,11	TUBBO-10	TRUE
2177	TUBBO10,11	TUBBO-11	FALSE
2178	TUBBO11,12	2020/1	FALSE
2179	TUBBO11,12	540/2	FALSE
2180	TUBBO11,12	TUBBO-11	TRUE
2181	TUBBO11,12	TUBBO-12	FALSE
2182	TUBBO12,ESC TUBBO	2010/1	FALSE
2183	TUBBO12,ESC TUBBO	ESC TUBBO	FALSE
2184	TUBBO12,ESC TUBBO	TUBBO-12	TRUE
3010	TUBBO7,8	TUBBO 4 OT	FALSE
3011	TUBBO7,8	TUBBO-7	TRUE
3012	TUBBO7,8	TUBBO-8	FALSE
3082	TUBBO5,6	ESC TUBBO-1	FALSE
3083	TUBBO5,6	TUBBO3	FALSE
3084	TUBBO5,6	TUBBO-5	TRUE
3085	TUBBO5,6	TUBBO-6	FALSE
3086	TUBBO2,3	18-Mar	FALSE
3087	TUBBO2,3	KERARBURY	FALSE
3088	TUBBO2,3	TUBBO-2	TRUE
3089	TUBBO2,3	TUBBO-3	FALSE
3130	TUBBO 4 OT, 2026	2026/1	FALSE
3131	TUBBO 4 OT, 2026	2026/2	FALSE
3132	TUBBO 4 OT, 2026	2026/3	FALSE
3133	TUBBO 4 OT, 2026	TUBBO 4 OT	TRUE
3134	TUBBO OFFTAKE, BOONA	1-Jan	FALSE
3135	TUBBO OFFTAKE, BOONA	1-Feb	FALSE
3136	TUBBO OFFTAKE, BOONA	2-Mar	FALSE
3137	TUBBO OFFTAKE, BOONA	BOONA	FALSE
3138	TUBBO OFFTAKE, BOONA	TUBBO OFFTAKE	TRUE
3139	TUBBO OFFTAKE, BOONA	TUBBO-1	FALSE

Table B.21 Pool details table of YAMMA main channel

Pool Details ID	Pool Name	Gate Name	Is Up Stream
2534	YAMMA-1,2	170/2	FALSE
2535	YAMMA-1,2	YAMMA-1	TRUE
2536	YAMMA-1,2	YAMMA-2	FALSE
2537	YAMMA-2,3	171/2	FALSE
2538	YAMMA-2,3	YAMMA-2	TRUE
2539	YAMMA-2,3	YAMMA-3	FALSE
2540	YAMMA-3,4	172/2	FALSE
2541	YAMMA-3,4	173/1	FALSE
2542	YAMMA-3,4	181/1	FALSE
2543	YAMMA-3,4	ARGOON	FALSE
2544	YAMMA-3,4	ARGOON 1	FALSE
2545	YAMMA-3,4	YAMMA-3	TRUE
2546	YAMMA-3,4	YAMMA-4	FALSE
2610	YAMMA-4, YAMMA 3	182/1	FALSE
2611	YAMMA-4, YAMMA 3	187/1	FALSE
2612	YAMMA-4, YAMMA 3	187/2	FALSE
2613	YAMMA-4, YAMMA 3	188/1	FALSE
2614	YAMMA-4, YAMMA 3	188/2	FALSE
2615	YAMMA-4, YAMMA 3	YAMMA 2	FALSE
2616	YAMMA-4, YAMMA 3	YAMMA 3	FALSE
2617	YAMMA-4, YAMMA 3	YAMMA 4	FALSE
2618	YAMMA-4, YAMMA 3	YAMMA-4	TRUE
2619	YAMMA 2, YAMMA 2-1	189/1	FALSE
2620	YAMMA 2, YAMMA 2-1	YAMMA 2	TRUE
2621	YAMMA 2, YAMMA 2-1	YAMMA 2-1	FALSE
2622	YAMMA 2-1, YAMMA 2-2	185/1	FALSE
2623	YAMMA 2-1, YAMMA 2-2	186/3	FALSE
2624	YAMMA 2-1, YAMMA 2-2	190/1	FALSE
2625	YAMMA 2-1, YAMMA 2-2	YAMMA 2-1	TRUE
2626	YAMMA 2-1, YAMMA 2-2	YAMMA 2-2	FALSE
2627	YAMMA 2-2, YAMMA 2-3	206/1	FALSE
2628	YAMMA 2-2, YAMMA 2-3	YAMMA 2-2	TRUE
2629	YAMMA 2-2, YAMMA 2-3	YAMMA 2-3	FALSE
2630	YAMMA 2-3, YAMMA 2-4	200/1	FALSE
2631	YAMMA 2-3, YAMMA 2-4	206/2	FALSE
2632	YAMMA 2-3, YAMMA 2-4	YAMMA 2-3	TRUE
2633	YAMMA 2-3, YAMMA 2-4	YAMMA 2-4	FALSE
2634	YAMMA 2-4, YAMMA 2-5	201/1	FALSE
2635	YAMMA 2-4, YAMMA 2-5	202/1	FALSE
2636	YAMMA 2-4, YAMMA 2-5	205/1	FALSE
2637	YAMMA 2-4, YAMMA 2-5	YAMMA 2-4	TRUE
2638	YAMMA 2-4, YAMMA 2-5	YAMMA 2-5	FALSE
2639	YAMMA 2-5, YAMMA 2-6	204/1	FALSE
2640	YAMMA 2-5, YAMMA 2-6	205/2	FALSE
2641	YAMMA 2-5, YAMMA 2-6	YAMMA 2-5	TRUE
2642	YAMMA 2-5, YAMMA 2-6	YAMMA 2-6	FALSE
2643	YAMMA 3, YAMMA 3-1	191/1	FALSE
2644	YAMMA 3, YAMMA 3-1	YAMMA 3	TRUE
2645	YAMMA 3, YAMMA 3-1	YAMMA 3-1	FALSE
2646	YAMMA 3-1, YAMMA 3-2	191/2	FALSE
2647	YAMMA 3-1, YAMMA 3-2	YAMMA 3-1	TRUE
2648	YAMMA 3-1, YAMMA 3-2	YAMMA 3-2	FALSE

2649	YAMMA 3-2, YAMMA 3-3	192/1	FALSE
2650	YAMMA 3-2, YAMMA 3-3	YAMMA 3-2	TRUE
2651	YAMMA 3-2, YAMMA 3-3	YAMMA 3-3	FALSE
2652	YAMMA 3-3, YAMMA 3-4	192/2	FALSE
2653	YAMMA 3-3, YAMMA 3-4	209/1	FALSE
2654	YAMMA 3-3, YAMMA 3-4	YAMMA 3-3	TRUE
2655	YAMMA 3-3, YAMMA 3-4	YAMMA 3-4	FALSE
2656	YAMMA 3-4, YAMMA 3-5	208/1	FALSE
2657	YAMMA 3-4, YAMMA 3-5	YAMMA 3-4	TRUE
2658	YAMMA 3-4, YAMMA 3-5	YAMMA 3-5	FALSE
2659	YAMMA 3-5, ESC YAMMA 3	2006/1	FALSE
2660	YAMMA 3-5, ESC YAMMA 3	ESC YAMMA 3	FALSE
2661	YAMMA 3-5, ESC YAMMA 3	YAMMA 3-5	TRUE
2662	YAMMA 4, YAMMA 4-1	659/1	FALSE
2663	YAMMA 4, YAMMA 4-1	YAMMA 4	TRUE
2664	YAMMA 4, YAMMA 4-1	YAMMA 4-1	FALSE
2665	YAMMA 4-1, YAMMA 4-2	515/1	FALSE
2666	YAMMA 4-1, YAMMA 4-2	YAMMA 4-1	TRUE
2667	YAMMA 4-1, YAMMA 4-2	YAMMA 4-2	FALSE
2668	YAMMA 4-2, YAMMA 4-3	516/1	FALSE
2669	YAMMA 4-2, YAMMA 4-3	YAMMA 4-2	TRUE
2670	YAMMA 4-2, YAMMA 4-3	YAMMA 4-3	FALSE
2671	YAMMA 4-3, YAMMA 4-4	517/1	FALSE
2672	YAMMA 4-3, YAMMA 4-4	YAMMA 4-3	TRUE
2673	YAMMA 4-3, YAMMA 4-4	YAMMA 4-4	FALSE
2674	YAMMA 4-4, YAMMA 4-5	518/1	FALSE
2675	YAMMA 4-4, YAMMA 4-5	519/1	FALSE
2676	YAMMA 4-4, YAMMA 4-5	YAMMA 4-4	TRUE
2677	YAMMA 4-4, YAMMA 4-5	YAMMA 4-5	FALSE
2678	YAMMA 4-5, YAMMA 4-6	521/1	FALSE
2679	YAMMA 4-5, YAMMA 4-6	YAMMA 4-5	TRUE
2680	YAMMA 4-5, YAMMA 4-6	YAMMA 4-6	FALSE
2681	YAMMA 4-7, ESC YAMMA 4	2008/1	FALSE
2682	YAMMA 4-7, ESC YAMMA 4	YAMMA 4-7	TRUE
2683	YAMMA 1A-1, YAMMA 1A-2	YAMMA 1A-1	TRUE
2684	YAMMA 1A-1, YAMMA 1A-2	YAMMA 1A-2	FALSE
2685	YAMMA 1A-2, YAMMA 1A-3	YAMMA 1A-2	TRUE
2686	YAMMA 1A-2, YAMMA 1A-3	YAMMA 1A-3	FALSE
2687	YAMMA 1A-3, YAMMA 1A-4	504/1	FALSE
2688	YAMMA 1A-3, YAMMA 1A-4	504/2	FALSE
2689	YAMMA 1A-3, YAMMA 1A-4	YAMMA 1A-3	TRUE
2690	YAMMA 1A-3, YAMMA 1A-4	YAMMA 1A-4	FALSE
2691	YAMMA 1A-4, YAMMA 1A-5	507/1	FALSE
2692	YAMMA 1A-4, YAMMA 1A-5	YAMMA 1A-4	TRUE
2693	YAMMA 1A-4, YAMMA 1A-5	YAMMA 1A-5	FALSE
2694	YAMMA 1A-5, YAMMA 1A-6	508/1	FALSE
2695	YAMMA 1A-5, YAMMA 1A-6	YAMMA 1A-5	TRUE
2696	YAMMA 1A-5, YAMMA 1A-6	YAMMA 1A-6	FALSE
2697	YAMMA 1A-8, YAMMA 1A-9	513/1	FALSE
2698	YAMMA 1A-8, YAMMA 1A-9	666/1	FALSE
2699	YAMMA 1A-8, YAMMA 1A-9	YAMMA 1A-8	TRUE
2700	YAMMA 1A-8, YAMMA 1A-9	YAMMA 1A-9	FALSE
2701	YAMMA 1A-9, ESC YAMMA 1A	514/1	FALSE
2702	YAMMA 1A-9, ESC YAMMA 1A	514/2	FALSE

2703	YAMMA 1A-9, ESC YAMMA 1A	ESC YAMMA 1A	FALSE
2704	YAMMA 1A-9, ESC YAMMA 1A	YAMMA 1A-9	TRUE
2705	YAMMA 1B, YAMMA 1B-1	535/1	FALSE
2706	YAMMA 1B, YAMMA 1B-1	YAMMA 1B	TRUE
2707	YAMMA 1B, YAMMA 1B-1	YAMMA 1B-1	FALSE
2708	YAMMA 1B-1, YAMMA 1B-2	537/1	FALSE
2709	YAMMA 1B-1, YAMMA 1B-2	537/2	FALSE
2710	YAMMA 1B-1, YAMMA 1B-2	YAMMA 1B-1	TRUE
2711	YAMMA 1B-1, YAMMA 1B-2	YAMMA 1B-2	FALSE
2712	YAMMA 1B-2, YAMMA 1B-3	539/1	FALSE
2713	YAMMA 1B-2, YAMMA 1B-3	540/1	FALSE
2714	YAMMA 1B-2, YAMMA 1B-3	YAMMA 1B-2	TRUE
2715	YAMMA 1B-2, YAMMA 1B-3	YAMMA 1B-3	FALSE
2716	YAMMA 1B-3, ESC YAMMA 1B	541/1	FALSE
2717	YAMMA 1B-3, ESC YAMMA 1B	ESC YAMMA 1B	FALSE
2718	YAMMA 1B-3, ESC YAMMA 1B	YAMMA 1B-3	TRUE
2719	YAMMA 1-1, YAMMA 1-2	524/1	FALSE
2720	YAMMA 1-1, YAMMA 1-2	YAMMA 1-1	TRUE
2721	YAMMA 1-1, YAMMA 1-2	YAMMA 1-2	FALSE
2722	YAMMA 1-2, YAMMA 1-3	525/1	FALSE
2723	YAMMA 1-2, YAMMA 1-3	YAMMA 1-2	TRUE
2724	YAMMA 1-2, YAMMA 1-3	YAMMA 1-3	FALSE
2725	YAMMA 1-3, YAMMA 1-4	526/1	FALSE
2726	YAMMA 1-3, YAMMA 1-4	527/1	FALSE
2727	YAMMA 1-3, YAMMA 1-4	YAMMA 1-3	TRUE
2728	YAMMA 1-3, YAMMA 1-4	YAMMA 1-4	FALSE
2729	YAMMA 1-4, YAMMA 1-5	527/2	FALSE
2730	YAMMA 1-4, YAMMA 1-5	YAMMA 1-4	TRUE
2731	YAMMA 1-4, YAMMA 1-5	YAMMA 1-5	FALSE
2732	YAMMA 1-5, YAMMA 1-6	529/1	FALSE
2733	YAMMA 1-5, YAMMA 1-6	530/1	FALSE
2734	YAMMA 1-5, YAMMA 1-6	YAMMA 1-5	TRUE
2735	YAMMA 1-5, YAMMA 1-6	YAMMA 1-6	FALSE
2736	YAMMA 1-6, YAMMA 1-7	531/1	FALSE
2737	YAMMA 1-6, YAMMA 1-7	532/1	FALSE
2738	YAMMA 1-6, YAMMA 1-7	YAMMA 1-6	TRUE
2739	YAMMA 1-6, YAMMA 1-7	YAMMA 1-7	FALSE
2740	YAMMA 1-7, YAMMA 1-8	533/1	FALSE
2741	YAMMA 1-7, YAMMA 1-8	YAMMA 1-7	TRUE
2742	YAMMA 1-7, YAMMA 1-8	YAMMA 1-8	FALSE
2743	YAMMA 1-8, ESC YAMMA 1	533/2	FALSE
2744	YAMMA 1-8, ESC YAMMA 1	534/1	FALSE
2745	YAMMA 1-8, ESC YAMMA 1	534/2	FALSE
2746	YAMMA 1-8, ESC YAMMA 1	YAMMA 1-8	TRUE
2996	YAMMA, YAMMA-1	118/3	FALSE
2997	YAMMA, YAMMA-1	119/2	FALSE
2998	YAMMA, YAMMA-1	501/1	FALSE
2999	YAMMA, YAMMA-1	YAMMA	TRUE
3000	YAMMA, YAMMA-1	YAMMA1	FALSE
3001	YAMMA, YAMMA-1	YAMMA-1	FALSE
3024	YAMMA 1A-7, YAMMA1A-8	511/1	FALSE
3025	YAMMA 1A-7, YAMMA1A-8	512/1	FALSE
3026	YAMMA 1A-7, YAMMA1A-8	YAMMA 1A-8	FALSE
3027	YAMMA 1A-7, YAMMA1A-8	YAMMA1A-7	TRUE

3028	YAMMA1A, YAMMA 1A-1	502/1	FALSE
3029	YAMMA1A, YAMMA 1A-1	502/2	FALSE
3030	YAMMA1A, YAMMA 1A-1	YAMMA 1A-1	FALSE
3031	YAMMA1A, YAMMA 1A-1	YAMMA1A	TRUE
3092	YAMMA 4-6, YAMMA 4-7	571/1	FALSE
3093	YAMMA 4-6, YAMMA 4-7	YAMMA 4-6	TRUE
3094	YAMMA 4-6, YAMMA 4-7	YAMMA 4-7	FALSE
3095	YAMMA 1 OFFTAKE, YAMMA 1-1	645/1	FALSE
3096	YAMMA 1 OFFTAKE, YAMMA 1-1	YAMMA 1-1	FALSE
3097	YAMMA 1 OFFTAKE, YAMMA 1-1	YAMMA 1B	FALSE
3098	YAMMA 1 OFFTAKE, YAMMA 1-1	YAMMA1	TRUE
3099	YAMMA 1 OFFTAKE, YAMMA 1-1	YAMMA1A	FALSE
3100	YAMMA 2-6, ESC YAMMA 2	209/3	FALSE
3101	YAMMA 2-6, ESC YAMMA 2	219/3	FALSE
3102	YAMMA 2-6, ESC YAMMA 2	YAMMA 2-6	TRUE
3103	YAMMA 1A-6, YAMMA 1A-7	508/2	FALSE
3104	YAMMA 1A-6, YAMMA 1A-7	510/1	FALSE
3105	YAMMA 1A-6, YAMMA 1A-7	YAMMA 1A-6	TRUE
3106	YAMMA 1A-6, YAMMA 1A-7	YAMMA1A-7	FALSE
3090	YAMMA 4-6, YAMMA 4-7	2007/1	FALSE
3091	YAMMA 4-6, YAMMA 4-7	2009/1	FALSE

APPENDIX C

Detailed results of all pondage conditions on different main channels during 2009/10 season

Table C.1 Detailed results of all gauges on ARGOON main channel during 2009/10 season

Pool ID	Start	End	Gate 1					Gate 2					Gate 3					Priority	Seepage (mm/hr)
			NMP	SDR	TDR	R^2	Seepage	NMP	SDR	TDR	R^2	Seepage	NMP	SDR	TDR	R^2	Seepage		
2	7/03/2010	9/03/2010	13	0.67	0.67	0.61	-0.98	16	0.60	0.67	0.69	-1.20						4	-1.09
3	28/05/2010	30/05/2010	3	0.50	0.50	0.38	-0.19	4	0.33	0.33	0.70	-0.22	2	1.00	1.00	1.00	-0.29	3	-0.29
4	28/05/2010	30/05/2010	2	1.00	1.00	1.00	-0.86	2	1.00	1.00	1.00	-0.66	4	1.00	1.00	1.00	-0.50	1	-0.67
5	28/05/2010	30/05/2010	3	0.50	0.50	0.58	-0.19	3	1.00	1.00	0.99	-0.28	5	1.00	1.00	0.90	-0.31	1	-0.29
15	17/04/2010	19/04/2010	8	1.00	1.00	1.00	-1.09	8	1.00	1.00	1.00	-1.09	6	1.00	1.00	1.00	-1.13	1	-1.10
16	6/08/2009	12/08/2009	41	0.15	0.90	0.97	-0.80											2	-0.80
16	8/09/2009	28/09/2009	47	0.63	0.89	1.00	-0.43											2	-0.43
16	28/09/2009	9/10/2009	15	0.93	0.93	1.00	-0.62											2	-0.62
16	12/02/2010	19/02/2010	9	0.50	0.88	0.92	-0.97											2	-0.97
16	26/02/2010	1/03/2010	8	0.71	0.71	0.86	-0.68											2	-0.68
16	5/03/2010	8/03/2010	18	0.29	0.65	0.99	-1.33											2	-1.33
16	8/03/2010	11/03/2010	14	0.38	0.69	1.00	-0.85											2	-0.85
16	30/03/2010	12/04/2010	17	0.81	0.88	0.98	-0.39											2	-0.39
16	17/04/2010	23/04/2010	8	1.00	1.00	0.98	-1.51											2	-1.51
17	29/01/2010	15/02/2010	133	0.26	0.64	0.93	-0.92											2	-0.92
17	19/02/2010	11/03/2010	64	0.44	0.84	0.86	-0.80											2	-0.80
17	29/05/2010	28/06/2010	62	0.38	0.79	0.85	-0.38											2	-0.38

Table C.2 Details of Pondage conditions in different pools of ARGOON main channel during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage(mm/hr)	LOC	NO Points	Max EL	Supply EL
2	7/03/2010	51	-0.98	UPS	-1.20		4	-1.09	0.65	15	1655	1671
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage(mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply EL**
3	28/05/2010	50	-0.19	-0.22	UPS	-0.29	3	-0.29	0.69	2	1497	1707
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage(mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply EL**
4	28/05/2010	50	-0.86	-0.66	UPS	-0.50	1	-0.67	1.00	3	1607	1710
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage(mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply EL**
5	28/05/2010	62	-0.19	-0.28	UPS	-0.31	1	-0.29	0.95	4	1615	1742
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage(mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply EL**
15	17/04/2010	53	-1.09	-1.09	UPS	-1.13	1	-1.10	1.00	7	1559	1719
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage(mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply EL**
16	6/08/2009	164	-0.80	UPS			2	-0.80	0.97	41	1636	1772
16	8/09/2009	476	-0.43	UPS			2	-0.43	1.00	47	1594	1772
16	28/09/2009	263	-0.62	UPS			2	-0.62	1.00	15	1527	1772
16	12/02/2010	176	-0.97	UPS			2	-0.97	0.92	9	1598	1772
16	26/02/2010	71	-0.68	UPS			2	-0.68	0.86	8	1661	1772
16	5/03/2010	80	-1.33	UPS			2	-1.33	0.99	18	1645	1772
16	8/03/2010	51	-0.85	UPS			2	-0.85	1.00	14	1592	1772
16	30/03/2010	313	-0.39	UPS			2	-0.39	0.98	17	1635	1772
16	17/04/2010	151	-1.51	UPS			2	-1.51	0.98	8	1662	1772
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage(mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply EL**
17	29/01/2010	417	-0.92	UPS			2	-0.92	0.93	133	1687	1727
17	19/02/2010	478	-0.80	UPS			2	-0.80	0.86	64	1676	1727
17	29/05/2010	733	-0.38	UPS			2	-0.38	0.85	62	1595	1727

Table C.3 Details of Pondage conditions in different pools of BOONA main channel during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	NO Points	Max EL	Supply
25	26/03/2010	61	-0.94	-0.99	UPS	N.A	1	-0.96	0.98	9	1604	1661
25	29/03/2010	118	-0.23	-0.22	UPS	N.A	1	-0.22	0.94	9	1550	1661
25	3/04/2010	58	-0.18	-0.17	UPS	N.A	1	-0.18	0.96	4	1545	1661
25	5/04/2010	137	-0.08	-0.07	UPS	N.A	1	-0.08	0.75	8	1532	1661
25	26/05/2010	58	-0.19	-0.19	UPS	N.A	1	-0.19	0.98	53	1633	1661
Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	NO Points	Max EL	Supply
26	6/09/2009	57	UPS	-0.17			2	-0.17	1.00	3	1630	1689
26	9/09/2009	53	UPS	-0.08			2	-0.08	1.00	3	1622	1689
26	23/09/2009	57	UPS	-0.04			5	-0.04	0.50	3	1626	1689
26	4/10/2009	57	UPS	-0.29			2	-0.29	0.96	3	1644	1689
26	26/11/2009	50	UPS	-0.97			2	-0.97	1.00	2	1635	1689
26	24/12/2009	64	UPS	-0.34			2	-0.34	0.96	4	1633	1689
26	4/03/2010	289	UPS	-0.34			2	-0.34	0.78	13	1691	1689
26	5/04/2010	104	UPS	-0.22			2	-0.22	0.99	5	1633	1689
26	11/04/2010	60	UPS	-0.22			2	-0.22	0.99	3	1636	1689
26	14/04/2010	62	UPS	-0.21			2	-0.21	0.98	3	1626	1689
26	24/04/2010	80	UPS	-0.39			2	-0.39	0.98	4	1645	1689
26	2/05/2010	83	UPS	-0.28			2	-0.28	0.87	4	1644	1689
26	6/05/2010	53	UPS	-0.20			2	-0.20	1.00	2	1636	1689
26	10/05/2010	54	UPS	-0.21			2	-0.21	0.90	3	1634	1689
26	14/05/2010	70	UPS	-0.25			2	-0.25	1.00	3	1628	1689
26	17/05/2010	71	UPS	-0.24			2	-0.24	0.98	3	1626	1689
26	20/05/2010	70	UPS	-0.19			2	-0.19	0.96	4	1626	1689
26	23/05/2010	333	UPS	-0.14			2	-0.14	0.92	16	1646	1689
26	6/06/2010	124	UPS	-0.12			2	-0.12	0.93	5	1625	1689
26	11/06/2010	66	UPS	-0.18			2	-0.18	0.98	4	1624	1689
26	14/06/2010	99	UPS	-0.05			2	-0.05	0.82	4	1621	1689
26	18/06/2010	99	UPS	-0.11			2	-0.11	0.99	4	1620	1689
26	23/06/2010	155	UPS	-0.12			2	-0.12	0.77	8	1626	1689

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	NO Points	Max EL	Supply
1	18/05/2010	253	-0.26	-0.25	UPS	-0.08	3	-0.26	0.81	48	1280	1539
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
5	11/05/2010	48	-0.28	UPS	-0.46		1	-0.37	0.94	5	1667	1774
5	28/05/2010	78	-0.24	UPS	-0.18		1	-0.21	0.99	4	1629	1774
5	11/06/2010	418	-0.14	UPS	-0.14		1	-0.14	0.97	27	1617	1774
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
7	7/09/2009	48	N.A	UPS	-0.63		2	-0.63	0.97	6	1502	1509
7	24/05/2010	262	N.A	UPS	-0.23		2	-0.23	0.89	19	1510	1509
7	9/06/2010	52	N.A	UPS	-0.28		2	-0.28	0.99	3	1481	1509
7	11/06/2010	434	N.A	UPS	-0.17		2	-0.17	0.99	28	1479	1509
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
8	7/09/2009	52	-0.15	UPS	N.A		5	-0.15	0.54	4	1576	1747
8	24/12/2009	69	-0.36	UPS	N.A		2	-0.36	0.91	6	1586	1747
8	5/02/2010	48	-0.91	UPS	N.A		5	-0.91	0.90	5	1584	1747
8	6/03/2010	114	-0.52	UPS	N.A		5	-0.52	0.87	11	1602	1747
8	28/03/2010	49	-0.09	UPS	N.A		2	-0.09	1.00	2	1577	1747
8	9/04/2010	48	-0.54	UPS	N.A		2	-0.54	1.00	2	1576	1747
8	13/04/2010	51	-0.08	UPS	N.A		2	-0.08	1.00	2	1574	1747
8	16/04/2010	60	-0.04	UPS	N.A		2	-0.04	0.99	3	1577	1747
8	24/04/2010	69	-0.24	UPS	N.A		2	-0.24	0.87	4	1580	1747
8	1/05/2010	60	-0.11	UPS	N.A		2	-0.11	0.92	5	1582	1747
8	3/05/2010	53	-0.34	UPS	N.A		2	-0.34	0.93	3	1582	1747
8	7/05/2010	72	-0.06	UPS	N.A		5	-0.06	0.58	4	1580	1747
8	17/05/2010	74	-0.09	UPS	N.A		2	-0.09	0.90	4	1575	1747
8	22/05/2010	311	-0.17	UPS	N.A		2	-0.17	0.72	22	1616	1747
8	4/06/2010	51	-0.22	UPS	N.A		2	-0.22	0.99	3	1580	1747
8	6/06/2010	53	-0.19	UPS	N.A		2	-0.19	1.00	2	1578	1747
8	9/06/2010	486	-0.15	UPS	N.A		2	-0.15	0.98	35	1582	1747
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
16	14/11/2009	58	-0.26	UPS	-0.51		3	-0.51	0.55	115	1585	1676

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	NO Points	Max EL	Supply
16	25/05/2010	79	-0.64	UPS	-0.70		1	-0.67	0.95	8	1584	1676
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
20	6/03/2010	106	UPS	-0.38			5	-0.38	0.75	14	1505	1612
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
22	28/05/2010	756	-0.22	UPS	-0.21		1	-0.21	0.99	58	1552	1738
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
23	9/03/2010	33	-0.69	UPS	N.A		2	-0.69	0.95	4	1600	1637
23	28/05/2010	766	-0.43	UPS	N.A		5	-0.43	0.74	510	1574	1637
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**NO Points**	**Max EL**	**Supply**
28	4/08/2009	572	UPS	-0.07	-0.07		4	-0.07	0.94	40	1408	1774
28	9/09/2009	53	UPS	-0.60	-0.57		1	-0.58	0.93	5	1631	1774
28	4/10/2009	57	UPS	-0.16	-0.16		1	-0.16	0.85	4	1614	1774

Table C.4 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 1) during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply
1	15/03/2010	53	-0.96	-1.06	UPS	-1.07	1	-1.03	1.00	6	1663	1677
1	4/04/2010	75	-1.06	-1.06	UPS	-1.07	1	-1.06	1.00	7	1670	1677
1	7/04/2010	235	-0.76	-0.75	UPS	-0.74	1	-0.75	0.99	18	1582	1677
1	17/04/2010	187	-0.63	-0.64	UPS	-0.64	1	-0.64	0.98	12	1371	1677
1	26/04/2010	76	-1.92	-1.94	UPS	-1.95	1	-1.94	1.00	8	1642	1677
1	30/04/2010	675	-0.21	-0.21	UPS	-0.26	1	-0.23	0.82	86	1536	1677
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
2	9/09/2009	148	-0.22	-0.69	UPS	N.A	1	-0.46	0.73	16	1547	1770

Table C.5 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 3) during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	Priority	S	LOC	No.	Max	Supply
3	21/06/2010	174	-0.34	UPS	-0.36					1	-0.35	0.98	12	1199	1509
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
4	11/11/2009	289	-0.16	UPS	-0.20					1	-0.18	0.83	33	1286	1487

4	28/11/2009	335	-0.29	UPS	-0.38					3	-0.33	0.68	34	1263	1487
4	15/12/2009	143	-0.21	UPS	-0.20					1	-0.21	0.87	12	1315	1487
4	26/01/2010	75	-0.20	UPS	-0.15					1	-0.17	0.75	6	1155	1487
4	15/06/2010	317	-0.21	UPS	-0.21					1	-0.21	0.99	21	1274	1487
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
5	11/11/2009	143	-0.23	-0.21	-0.20	UPS	-0.23			1	-0.22	0.99	7	1568	1735
5	18/11/2009	125	-0.28	-0.26	-0.23	UPS	-0.22			1	-0.27	0.86	7	1457	1735
5	28/11/2009	351	-0.24	-0.23	-0.23	UPS	-0.24			1	-0.23	0.98	18	1463	1735
5	15/12/2009	146	-0.21	-0.22	-0.24	UPS	-0.21			1	-0.22	0.96	8	1461	1735
5	22/01/2010	660	-0.06	-0.17	0.14	UPS	-0.16			3	-0.17	0.55	35	1342	1735
5	16/06/2010	291	-0.18	-0.17	-0.18	UPS	-0.16			1	-0.18	0.94	16	1558	1735
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
6	28/10/2009	288	-1.05	-1.05	-0.88	UPS				1	-1.05	0.77	16	1612	1708
6	10/11/2009	167	-1.01	-1.02	-1.62	UPS				1	-1.01	0.80	9	1645	1708
6	18/11/2009	130	-1.07	-1.08	-0.41	UPS				1	-1.07	0.74	7	1641	1708
6	28/11/2009	368	-0.96	-0.97	-0.91	UPS				1	-0.95	0.96	32	1605	1708
6	15/12/2009	154	-0.34	-0.33	-0.25	UPS				1	-0.33	0.95	9		1708
6	22/01/2010	76	-0.43	-0.47	-0.41	UPS				1	-0.44	0.93	6		1708
6	26/01/2010	604	-0.22	-0.22	0.01	UPS				3	-0.22	0.63	42		1708
6	24/05/2010	49	-0.17	-0.08	-0.40	UPS				1	-0.21	0.99	3		1708
6	28/05/2010	50	-0.71	-0.62	-0.68	UPS				1	-0.67	1.00	2		1708
6	16/06/2010	288	-0.24	-0.25	-0.24	UPS				1	-0.25	0.97	20		1708
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
7	26/06/2010	65	-0.24	-0.38	UPS	-0.09				1	-0.31	1.00	4	1154	1538
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
8	23/06/2010	54	-0.10	-0.15	-0.05	N.A	UPS	0.02		3	-0.13	0.48	3	1109	1567
8	26/06/2010	64	-0.34	-0.29	-0.19	N.A	UPS	-0.14		1	-0.25	0.72	4	1101	1567
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
9	9/06/2010	171	-0.14	0.06	UPS	-0.16				3	-0.15	0.61	10	1014	1499
9	22/06/2010	151	-0.15	-0.12	UPS	-0.18				1	-0.15	0.86	8	1252	1499
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**

10	9/06/2010	237	-0.25	-0.25	-0.25	-0.25	-0.25	UPS	-0.26	1	-0.25	0.99	14	1347	1627
10	22/06/2010	49	-0.22	-0.14	-0.27	-0.22	-0.23	UPS	-0.26	1	-0.22	0.94	4	1270	1627
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
11	9/06/2010	461	-0.50	UPS	-0.50	-0.51				1	-0.50	1.00	38	1546	1576
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
12	11/06/2010	425	-0.15	UPS	-0.10					1	-0.12	0.91	25	1311	1582
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
13	24/09/2009	144	N.A	UPS	-0.18					2	-0.18	0.80	17	1270	1567
13	11/11/2009	290	N.A	UPS	-0.20					2	-0.20	0.98	28	1497	1567
13	28/11/2009	314	N.A	UPS	-0.17					2	-0.17	0.97	34	1152	1567
13	11/06/2010	440	N.A	UPS	-0.13					2	-0.13	0.98	27	1223	1567
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
14	11/11/2009	289	-0.23	-0.23	-0.23	-0.26	-0.23	UPS	-0.24	1	-0.24	0.97	15	1594	1764
14	28/11/2009	318	-0.19	-0.22	-0.19	-0.20	-0.21	UPS	-0.22	1	-0.20	0.99	17	1531	1764
14	15/12/2009	140	-0.23	-0.22	-0.20	N.A	-0.23	UPS	-0.22	1	-0.22	0.94	9	1501	1764
14	26/01/2010	30	-0.28	N.A	0.23	N.A	-0.30	UPS	N.A	3	-0.29	0.54	3	1194	1764
14	15/06/2010	321	-0.16	-0.15	-0.16	-0.13	-0.17	UPS	-0.17	1	-0.16	0.94	18	1397	1764
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
15	12/09/2009	636	-0.49	UPS	-0.61					1	-0.55	0.87	77	1520	1833
15	14/10/2009	208	-1.13	UPS	-1.13					1	-1.13	1.00	40	1621	1833
15	31/10/2009	58	-1.58	UPS	-1.59					1	-1.58	1.00	15	1667	1833
15	5/11/2009	76	-1.59	UPS	-1.57					1	-1.58	1.00	18	1677	1833
15	7/03/2010	37	-1.52	UPS	-1.18					4	-1.35	0.65	8	1683	1833
15	28/05/2010	52	-0.86	UPS	-0.93					1	-0.90	0.97	6	1674	1833
15	8/06/2010	489	-0.98	UPS	-0.99					1	-0.99	1.00	72	1644	1833

Table C.6 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 4) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply
18	9/06/2010	456	-0.87	-0.88	UPS	-0.88	1	-0.87	0.98	65	1619	1797
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**

19	5/10/2009	56	N.A	UPS	-0.34		2	-0.34	0.99	3	1365	1404
19	15/03/2010	68	N.A	UPS	-1.14		2	-1.14	1.00	4	1385	1404
19	13/05/2010	67	N.A	UPS	-0.29		2	-0.29	1.00	3	1304	1404
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
20	17/10/2009	128	-0.05	-0.14	UPS	-0.05	3	-0.10	0.50	8	1485	1652
20	13/05/2010	63	0.06	-0.01	UPS	-0.12	3	-0.12	0.27	3	1481	1652
20	9/06/2010	114	-0.08	-0.04	UPS	N.A	3	-0.08	0.64	6		
20	19/06/2010	78	-0.06	-0.10	UPS	-0.06	1	-0.07	0.93	4	1456	1652
20	25/06/2010	68	-0.26	-0.17	UPS	0.14	3	-0.22	0.52	4	1456	1652
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
21	6/10/2009	103	0.18	-0.23	UPS	-0.22	3	-0.23	0.66	8	1480	1544
21	17/10/2009	415	-4.52	-0.20	UPS	-0.40	3	-0.20	0.68	26	1481	1544
21	13/05/2010	48	-0.14	-0.16	UPS	-0.41	1	-0.15	0.98	3	1501	1544
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
22	5/10/2009	130	-1.06	UPS			2	-1.06	0.97	23		1733
22	16/10/2009	437	-0.55	UPS			2	-0.55	0.95	55		
22	13/05/2010	48	-0.64	UPS			2	-0.64	0.97	4		
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
23	20/06/2010	199	N.A	UPS	-0.07		2	-0.07	0.87	5	1560	1720
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
26	7/03/2010	59	-0.33	-0.61	UPS	-0.65	1	-0.33	0.80	7	1531	1597
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
31	17/11/2009	188	-33.63	UPS	-0.22		3	-0.22	0.61	19	1339	1428
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
33	7/09/2009	288	-0.44	UPS	N.A		2	-0.44	0.97	33		
33	5/10/2009	150	-0.80	UPS	N.A		2	-0.80	0.99	22		
33	12/10/2009	68	-0.38	UPS	N.A		2	-0.38	0.96	5		
33	30/10/2009	165	-0.58	UPS	N.A		2	-0.58	0.99	22		
33	17/11/2009	187	-0.67	UPS	N.A		2	-0.67	0.89	28		

Table C.7 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 5) during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply
34	20/11/2009	138	N.A	UPS	-0.60		2	-0.60	0.99	7	1385	1562
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
35	20/11/2009	138	-0.56	UPS	-0.55		1	-0.55	0.98	7	1521	1662
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
36	26/09/2009	79	0.03	-0.11	UPS	-0.27	3	-0.27	0.36	4	1414	1695
36	20/11/2009	440	-0.21	-0.21	UPS	-0.21	1	-0.21	0.98	25	1577	1695
36	9/12/2009 9:03	145	-0.29	-0.24	UPS	-0.17	3	-0.27	0.67	8	1246	1695
36	19/01/2010	78	-0.20	-0.32	UPS	-0.07	3	-0.20	0.68	5	1407	1695
36	5/02/2010	447	-0.20	-0.19	UPS	-0.20	1	-0.20	0.98	25	1512	1695
36	8/03/2010	52	-0.41	-0.45	UPS	-0.21	1	-0.36	0.99	3	1486	1695
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
39	1/09/2009	62	-1.12	-0.96	UPS	N.A	1	-1.04	0.99	6	1516	1723
39	26/09/2009	190	-0.92	-0.92	UPS	N.A	1	-0.92	1.00	17	1567	1723
39	5/10/2009	69	-1.63	-1.64	UPS	N.A	1	-1.64	1.00	8	1561	1723
39	12/11/2009	143	-1.50	-1.40	UPS	N.A	1	-1.45	1.00	17	1590	1723
39	19/01/2010	107	-1.09	-1.13	UPS	N.A	1	-1.11	0.99	13		
39	10/03/2010	83	-1.29	-1.22	UPS	N.A	1	-1.26	0.97	10		

Table C.8 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 6) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply el.
40	18/09/2009	409	-0.82	UPS	-0.83	1	-0.82	0.99	59	1534	1726
40	15/10/2009	123	-1.32	UPS	-1.30	1	-1.31	1.00	25	1554	1726
40	24/10/2009	618	-0.06	UPS	-0.71	3	-0.71	0.43	83	1528	1726
40	22/11/2009	354	-1.11	UPS	-1.04	1	-1.08	0.98	215	1561	1726
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
41	18/09/2009	427	-0.49	UPS		2	-0.49	0.89	64	1660	1700
41	15/10/2009	123	-0.96	UPS		2	-0.96	0.99	24	1649	1700

41	16/03/2010	283	-0.36	UPS		2	-0.36	0.98	32	1641	1700
41	28/03/2010	210	-0.26	UPS		2	-0.26	0.98	19	1471	1700

Table C.9 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 7) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply
43	28/05/2010	748	N.A	-0.47	UPS	-0.52	1	-0.49	0.80	55	1479	1691

Table C.10 Details of Pondage conditions in different pools of BUNDURE main channel (BUNDURE 8) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply
46	27/11/2009	228	N.A	N.A	UPS	-0.68	2	-0.68	0.98	32	1487	1670
46	12/02/2010	83	N.A	N.A	UPS	-0.48	2	-0.48	0.99	9	1487	1670
46	3/03/2010	160	N.A	N.A	UPS	-0.66	2	-0.66	0.93	27	1487	1670
46	22/03/2010	239	N.A	N.A	UPS	-0.53	2	-0.53	0.96	30	1426	1670
46	7/04/2010	683	N.A	N.A	UPS	-0.37	2	-0.37	0.88	63	1479	1670
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
47	25/03/2010	192	-1.56	UPS	-1.50		1	-1.53	0.77	11	1467	1613
47	8/04/2010 2:28	702	-0.08	UPS	-0.08		1	-0.08	0.90	34	1460	1613
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
48	11/09/2009	76	-1.12	N.A	UPS	N.A	2	-1.12	0.99	16	1456	1757
48	28/11/2009	258	-0.60	N.A	UPS	N.A	2	-0.60	0.98	35	1554	1757
48	3/03/2010	44	-3.98	N.A	UPS	N.A	2	-3.98	0.99	20	1625	1757
48	25/03/2010	202	-0.19	N.A	UPS	N.A	5	-0.19	0.69	27	1243	1757
49	8/04/2010 2:28	707	-0.24	N.A	UPS	N.A	5	-0.24	0.79	60	1332	1757

Table C.11 Details of Pondage conditions in different pools of COLY main channel (COLY 2) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply el.
1	5/08/2009 10:47	60	-0.22	UPS	2	-0.22	0.90	6	1679	1738

1	26/08/2009 9:59	53	-0.47	UPS	2	-0.47	0.96	5	1681	1738
1	16/09/2009 19:50	73	-0.26	UPS	2	-0.26	0.90	6	1682	1738
1	5/03/2010 15:01	140	-0.64	UPS	5	-0.64	0.86	18	1713	1738
1	13/05/2010 21:00	57	-0.23	UPS	2	-0.23	0.99	4	1673	1738
1	20/05/2010 13:32	55	-0.17	UPS	2	-0.17	1.00	3	1671	1738
1	24/05/2010 8:11	184	-0.19	UPS	2	-0.19	0.84	12	1678	1738
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
2	13/05/2010 21:42	56	UPS	-0.24	2	-0.24	0.99	5	1625	1796
2	20/05/2010 13:38	55	UPS	-0.18	2	-0.18	0.83	4	1614	1796

Table C.12 Details of Pondage conditions in different pools of COLY main channel (COLY 3) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply el.
5	24/05/2010	103	-0.32	UPS	-0.40	1	-0.36	0.96	99	1522	1688
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
6	12/12/2009	55	-0.87	UPS	N.A	2	-0.87	0.99	9	1608	1730
6	24/12/2009	76	-0.86	UPS	N.A	2	-0.86	0.99	10	1610	1730
6	13/01/2010	60	-0.95	UPS	N.A	2	-0.95	0.99	13	1612	1730
6	22/01/2010	69	-0.88	UPS	N.A	2	-0.88	0.99	12	1618	1730
6	30/01/2010	50	-0.96	UPS	N.A	2	-0.96	0.96	11	1623	1730
6	20/02/2010	78	-1.01	UPS	N.A	2	-1.01	0.99	13	1641	1730
6	13/04/2010	552	-0.50	UPS	N.A	2	-0.50	0.99	60	1540	1730
6	7/05/2010	69	-0.48	UPS	N.A	2	-0.48	0.96	7	1522	1730
6	23/05/2010	131	-0.37	UPS	N.A	2	-0.37	0.98	74	1512	1730

Table C.13 Details of Pondage conditions in different pools of COLY main channel (COLY 4) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply
7	9/02/2010	110	-0.27	UPS	N.A		2	-0.27	0.96	8	1412	1720
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**

8	1/04/2010	66	-0.19	UPS	-0.32		1	-0.25	0.89	6	1550	1664
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
9	31/05/2010	687	-0.09	-0.43	UPS	-0.51	3	-0.47	0.63	64	1322	1626
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
10	1/04/2010	186	-0.15	-0.15	UPS	-0.15	1	-0.15	0.99	69	1395	1644
10	15/05/2010	332	-0.18	-0.19	UPS	-0.18	1	-0.18	0.96	76	1493	1644
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
11	1/04/2010	280	0.07	UPS	-0.21		3	-0.21	0.49	82	1173	1635
11	15/05/2010	332	0.00	UPS	-0.07		4	-0.07	0.53	66	973	1635

Table C.14 Details of Pondage conditions in different pools of COLY main channel (COLY 5) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply
13	24/12/2009	71	-0.52	UPS	-0.59			1	-0.56	0.93	7	1671	1636
13	4/02/2010	77	-0.79	UPS	-0.76			1	-0.77	0.92	10	1689	1636
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
14	24/12/2009	69	-0.16	-0.21	UPS	-0.35		3	-0.35	0.55	3	1271	1528
14	6/03/2010	103	-0.42	-0.41	UPS	-0.56		3	-0.49	0.64	9	1310	1528
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
15	24/12/2009	69	-0.19	UPS	-0.44			1	-0.32	0.75	6	1503	1569
15	5/03/2010	135	-0.34	UPS	-0.45			4	-0.40	0.65	17	1561	1569
15	28/03/2010	48	-0.24	UPS	-0.08			3	-0.24	0.48	5	1500	1569
15	23/04/2010	68	-0.25	UPS	-0.34			1	-0.34	0.94	5	1498	1569
15	19/05/2010	49	N.A	UPS	-0.21			2	-0.21	1.00	2	1500	1569
15	23/05/2010	329	-0.19	UPS	-0.19			1	-0.19	0.97	22	1515	1569
15	6/06/2010	75	-0.18	UPS	-0.21			1	-0.19	0.95	5	1437	1569
15	9/06/2010	66	-0.19	UPS	-0.19			1	-0.19	0.98	5	1402	1569
15	12/06/2010	49	-0.08	UPS	-0.23			3	-0.23	0.59	4	1370	1569
15	20/06/2010	69	-0.17	UPS	-0.16			1	-0.16	0.96	5	1265	1569
15	23/06/2010	109	-0.07	UPS	-0.14			4	-0.10	0.63	6	1231	1569
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**

16	26/11/2009	88	-0.47	-0.38	-0.07	UPS	N.A	3	-0.42	0.55	7		1667
16	24/12/2009	77	-0.32	-0.09	-0.15	UPS	N.A	3	-0.32	0.47	6		1667
16	6/03/2010	124	-0.45	-0.45	-0.48	UPS	N.A	1	-0.46	0.76	13	1555	1667
16	15/03/2010	84	-0.21	-0.23	-0.23	UPS	N.A	1	-0.22	0.93	7	1525	1667
16	28/03/2010	54	-0.22	-0.21	-0.18	UPS	N.A	1	-0.20	0.96	4		1667
16	6/04/2010	74	-0.22	-0.23	-0.16	UPS	N.A	1	-0.21	0.97	4		1667
16	9/04/2010	56	-0.43	-0.21	-0.16	UPS	N.A	1	-0.27	0.74	3		1667
16	23/04/2010	94	-0.21	-0.26	-0.19	UPS	N.A	1	-0.20	0.88	7		1667
16	19/05/2010	56	-0.11	N.A	-0.12	UPS	N.A	1	-0.11	0.98	3		1667
16	23/05/2010	331	-0.12	-0.10	-0.10	UPS	N.A	1	-0.11	0.89	23		1667
16	6/06/2010	75	-0.14	-0.18	-0.17	UPS	N.A	1	-0.16	0.94	4		1667
16	9/06/2010	66	-0.13	-0.10	-0.05	UPS	N.A	1	-0.09	0.99	4		1667
16	12/06/2010	49	-0.15	-0.09	-0.14	UPS	N.A	1	-0.12	1.00	2		1667
16	14/06/2010	58	0.00	0.02	-0.16	UPS	N.A	3	-0.08	0.66	3		1667
16	17/06/2010	88	-0.13	-0.10	0.02	UPS	N.A	3	-0.12	0.64	5		1667
16	20/06/2010	69	-0.14	-0.09	-0.12	UPS	N.A	1	-0.13	0.99	4		1667
16	23/06/2010	109	-0.13	-0.16	-0.09	UPS	N.A	3	-0.16	0.63	6		1667

Table C.15 Details of Pondage conditions in different pools of COLY main channel (COLY 6) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply el.
17	11/02/2010	183	-0.14	UPS	N.A		2	-0.14	0.91	11	1598	1750
17	11/03/2010	156	-0.15	UPS	N.A		5	-0.15	0.68	11	1603	1750
17	23/04/2010	96	-0.23	UPS	N.A		2	-0.23	0.90	5	1614	1750
17	24/05/2010	306	-0.12	UPS	N.A		2	-0.12	0.94	18	1610	1750
17	17/06/2010	119	-0.11	UPS	N.A		2	-0.11	0.94	7	1613	1750
17	25/06/2010	69	-0.25	UPS	N.A		2	-0.25	0.96	5	1607	1750
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
20	20/11/2009	453	-0.15	-0.15	UPS	3.44	3	-0.15	0.63	46	1284	1680

20	24/12/2009	62	-0.24	-0.36	UPS	-0.43	1	-0.34	0.78	5	1466	1680
20	4/05/2010	86	-0.23	-0.24	UPS	-0.10	1	-0.19	0.90	5	1466	1680
20	24/05/2010	306	-0.14	-0.14	UPS	-0.16	1	-0.15	0.96	18	1474	1680
20	17/06/2010	119	-0.12	-0.08	UPS	-0.10	1	-0.11	0.96	7	1368	1680
20	25/06/2010	69	-0.16	-0.08	UPS	-0.17	3	-0.16	0.69	4	1340	1680
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
23	30/05/2010	717	-0.09	UPS	-0.09		1	-0.09	0.92	48	1351	1594
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
24	24/05/2010	62	-0.29	UPS	-0.46		1	-0.46	0.70	6	1421	1687
24	28/05/2010	52	-0.07	UPS	-0.09		1	-0.09	0.72	2	1392	1687
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
25	24/05/2010	62	-0.41	UPS	-0.48		1	-0.45	0.83	4	1456	1536
25	28/05/2010	52	-0.41	UPS	-0.19		1	-0.30	0.97	3	1450	1536
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
26	24/05/2010	164	-0.21	UPS	-0.23		1	-0.22	0.88	11	1494	1564
Pool ID	**Start**	**Du.(hr)**	**Gate1-5**	**Gate2-5**	**Gate3-5**	**Gate4-5**	**Priority**	**Seepage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
27	4/10/2009	54	-0.26	-0.23	UPS	-0.23	1	-0.24	0.84	5	1527	1669
27	24/04/2010	57	-0.26	-0.38	UPS	-0.31	1	-0.32	0.85	4	1531	1669
27	24/05/2010	179	-0.22	-0.22	UPS	-0.23	1	-0.22	0.90	12	1535	1669
Pool ID	**Start**	**Du.(hr)**	**Gate1-5**	**Gate2-5**	**Gate3-5**	**Gate4-5**	**Priority**	**Seepage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
28	24/04/2010	107	-0.17	-0.15	-0.27	UPS	1	-0.16	0.73	7	1371	1524
28	4/05/2010	77	-0.22	-0.29	-0.20	UPS	1	-0.24	0.74	5	1368	1524
28	20/05/2010	63	-0.07	-0.15	-0.16	UPS	3	-0.07	0.40	4	1357	1524
28	23/05/2010	358	-0.12	-0.13	-0.11	UPS	1	-0.12	0.89	39	1379	1524
28	7/06/2010	102	-0.13	-0.13	-0.13	UPS	3	-0.13	0.68	6	1356	1524
28	11/06/2010	84	-0.09	-0.08	-0.14	UPS	3	-0.09	0.58	5	1358	1524
28	17/06/2010	115	-0.11	-0.10	-0.07	UPS	3	-0.10	0.61	7	1360	1524
28	22/06/2010	73	-0.07	-0.14	0.00	UPS	3	-0.11	0.54	5	1359	1524

Table C.16 Details of Pondage conditions in different pools of COLY main channel (COLY 7) during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply
29	7/03/2010	57	-0.75	-0.85	UPS	-1.09			1	-0.92	0.76	5	1667	1655
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
30	4/02/2010	55	-0.64	UPS	-0.41				4	-0.52	0.58	6	1606	1652
30	24/04/2010	53	-0.29	UPS	0.12				3	-0.29	0.76	3	1613	1652
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
31	22/11/2009	89	-0.13	-0.19	-0.10	-0.11	UPS	-0.08	3	-0.16	0.64	6	1442	1671
31	21/02/2010	91	-0.28	-0.25	-0.22	-0.33	UPS	-0.22	1	-0.26	0.88	7	1450	1671
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
32	11/05/2010	67	-1.68	N.A	UPS	-1.68			1	-1.68	0.99	10	1503	1521
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
33	23/04/2010	79	-0.20	UPS	N.A				2	-0.20	0.91	4	1575	1672
33	11/05/2010	429	-0.08	UPS	N.A				2	-0.08	0.93	81		

Table C.17 Details of Pondage conditions in different pools of COLY main channel (COLY 8) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	Priority	S pondage (mm/hr)	LOC	No. Points	Max el.	Supply
34	4/03/2010 21:14	180	-0.57	UPS	-0.54	1	-0.56	0.76	24	1386	1538
34	15/03/2010 8:58	71	-0.47	UPS	-0.47	1	-0.47	0.99	8	1333	1538
34	24/05/2010 18:22	63	-0.42	UPS	-0.58	1	-0.50	0.85	3	1311	1538
34	28/05/2010 21:48	64	-0.34	UPS	-0.23	1	-0.29	0.84	5	1315	1538
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
35	9/09/2009 14:19	57	UPS	-0.25		2	-0.25	0.92	3	1558	1627
35	24/05/2010 18:16	278	UPS	-0.15		2	-0.15	0.93	18	1412	1627
35	9/06/2010 7:27	290	UPS	-0.12		2	-0.12	0.83	19	1257	1627
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**Priority**	**S pondage (mm/hr)**	**LOC**	**No. Points**	**Max el.**	**Supply**
39	5/03/2010 10:12	143	UPS	-0.62		2	-0.62	0.82	7	1676	1706
39	15/03/2010 9:13	55	UPS	-0.40		2	-0.40	1.00	4	1608	1706
39	24/05/2010 18:22	63	UPS	-0.29		5	-0.29	0.67	5	1610	1706

39	28/05/2010 21:48	64	UPS	-0.24		2	-0.24	0.94	5	1607	1706

Table C.18 Details of Pondage conditions in different pools of COLY main channel (COLY 9) during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
42	9/10/2009	116	-0.39	-0.42	UPS	-0.39					1	-0.40	0.89	14	1721	1860
42	27/10/2009	73	-0.34	-0.29	UPS	-0.33					1	-0.32	0.88	10	1714	1860
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
43	10/10/2009	214	-0.11	UPS	-0.13						1	-0.12	0.75	17	1645	1676
43	27/10/2009	244	-0.16	UPS	-0.17						1	-0.16	0.92	24	1694	1676
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
44	24/09/2009	176	-0.40	UPS	N.A						5	-0.40	0.60	41		1690
44	10/10/2009	214	-0.43	UPS	N.A						2	-0.43	0.76	34	1425	1690
44	6/05/2010	458	-0.19	UPS	N.A						2	-0.19	0.89	34		1690
44	7/06/2010	510	-0.10	UPS	N.A						2	-0.10	0.76	25		1690
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
45	25/05/2010	67	-0.27	UPS	-0.27						1	-0.27	1.00	60	1591	1664
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
46	25/05/2010	68	-0.36	0.02	UPS	-0.36					3	-0.36	0.67	50	1600	1686
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
48	31/05/2010	203	-0.31	-0.16	-0.41	-0.34	-0.30	UPS	-0.32	-0.32	1	-0.33	0.75	12	1287	1621
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
49	25/05/2010	74	-0.21	UPS	-0.30						3	-0.30	0.57	58	1599	1729
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
50	25/05/2010	68	-0.29	-0.27	UPS	-0.28					1	-0.28	0.84	36	1526	1747
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
51	20/08/2009	93	-0.21	UPS	-0.20						1	-0.21	0.74	10	1356	1674
51	31/05/2010	666	-0.25	UPS	-0.25						1	-0.25	1.00	33	1554	1674
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
53	31/05/2010	192	-0.39	-0.43	UPS	-0.39					1	-0.40	1.00	9	1497	1724
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply

54	3/04/2010	42	-0.39	UPS	-0.29						1	-0.34	0.98	4	1538	1562
54	5/04/2010	54	-0.26	UPS	-0.27						1	-0.26	0.96	4	1458	1562
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**S8(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
55	19/09/2009	417	-0.13	UPS	N.A						5	-0.13	0.52	865	1399	
55	9/02/2010	86	-0.64	UPS	N.A						2	-0.64	0.98	9	1481	
55	18/02/2010	111	-0.98	UPS	N.A						2	-0.98	0.96	18	1591	
55	23/02/2010	235	-0.23	UPS	N.A						5	-0.23	0.86	27	1451	
55	1/04/2010	285	-0.55	UPS	N.A						5	-0.55	0.99	527	1459	
55	16/04/2010	101	-0.71	UPS	N.A						2	-0.71	0.99	14	1536	
55	30/04/2010	417	-0.44	UPS	N.A						2	-0.44	0.98	38	1457	
55	1/06/2010	142	-0.40	UPS	N.A						2	-0.40	0.99	12	1444	
55	13/06/2010	236	-0.48	UPS	N.A						2	-0.48	0.86	26	1451	
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**S8(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
56	31/03/2010	68	-0.26	UPS	-0.22						1	-0.24	0.82	7	1461	1507
56	3/04/2010	48	-0.33	UPS	-0.11						3	-0.33	0.65	4	1453	1507
56	5/04/2010	95	-0.30	UPS	-0.13						4	-0.21	0.71	8	1453	1507
56	10/04/2010	59	-0.42	UPS	-0.36						1	-0.39	0.98	4	1452	1507
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**S8(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
57	5/06/2010	439	0.01	-0.07	0.04	UPS	-0.05				3	-0.05	0.32	25	1217	1605
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**S8(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
59	22/04/2010	79	0.05	-0.08	-0.16	-0.12	UPS	-0.16			3	-0.14	0.38	6	1702	1913
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**S8(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
60	23/04/2010	68	-0.32	-0.34	UPS	-0.21					1	-0.29	0.89	6	1692	1789
60	30/05/2010	114	-0.23	-0.12	UPS	-0.12					3	-0.18	0.60	5	1696	1789
60	12/06/2010	55	-0.47	-0.43	UPS	-0.42					1	-0.44	0.99	4	1693	1789
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**S8(mm/hr)**	**Priority**	**S**	**LOC**	**No.**	**Max**	**Supply**
61	1/04/2010	285	-0.06	-0.18	-0.18	-0.18	UPS				1	-0.18	0.74	17	1723	1883
61	30/04/2010	117	0.37	-0.16	-0.18	-0.17	UPS				3	-0.17	0.66	7	1724	1883
61	1/06/2010	99	N.A	-0.05	N.A	-0.04	UPS				1	-0.04	0.88	5	1719	1883
61	13/06/2010	93	-4.07	-0.18	-0.11	-0.19	UPS				1	-1.14	0.95	4	1726	1883
61	17/06/2010	117	N.A	-0.13	N.A	-0.13	UPS				1	-0.13	0.94	7	1709	1883

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
62	6/04/2010	60	-1.02	-0.24	UPS	-0.26					1	-0.25	0.88	4	1402	1745
62	12/04/2010	174	0.13	0.01	UPS	-0.32					3	-0.32	0.32	8	1282	1745
62	28/05/2010	67	N.A	-0.31	UPS	N.A					2	-0.31	1.00	2		
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	S8(mm/hr)	Priority	S	LOC	No.	Max	Supply
63	2/11/2009	54	N.A	-1.55	UPS	-0.66					1	-1.10	0.77	8	1356	1935
63	13/11/2009	49	N.A	-0.82	UPS	0.24					3	-0.82	0.47	8	1322	1935
63	18/12/2009	93	N.A	-0.70	UPS	-0.17					1	-0.44	1.00	8	1524	1935
63	4/03/2010	133	N.A	-0.82	UPS	N.A					2	-0.82	0.79	12	1315	1935
63	15/03/2010	103	N.A	-0.57	UPS	-0.58					1	-0.58	0.99	8	1619	1935
63	6/04/2010	60	N.A	-0.38	UPS	N.A					2	-0.38	0.92	6		1935
63	12/04/2010	174	N.A	-0.42	UPS	-0.39					1	-0.41	1.00	10	1400	1935
63	22/04/2010	89	N.A	-0.38	UPS	-1.03					1	-0.70	0.97	5	1501	1935

Table C.19 Details of Pondage conditions in different pools of COLY main channel (COLY 10) during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	Priority	S pondage	LOC	No.	Max	Supply
67	6/05/2010	72	-0.47	-0.47	UPS	-0.45		1	-0.46	1.00	5	1511	1511
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	Priority	S pondage	LOC	No.	Max	Supply
68	24/05/2010	67	UPS	-0.49				2	-0.49	0.92	6	1568	1680
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	Priority	S pondage	LOC	No.	Max	Supply
69	20/05/2010	56	-0.34	-0.32	-0.27	UPS	-0.30	1	-0.31	0.98	3	1356	1499
69	24/05/2010	67	-0.40	-0.38	-0.42	UPS	-0.50	1	-0.42	0.91	4	1335	1499

Table C.20 Details of Pondage conditions in different pools of COLY main channel (COLY 11) during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply el.
71	2/06/2010	349	N.A	UPS	-0.09		2	-0.09	0.90	17	913	1680
Pool ID	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	Priority	S pondage	LOC	No. Points	Max el.	Supply el.

72	23/04/2010	55	-0.24	UPS	-0.33		1	-0.29	0.75	3	1600	1687
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
73	22/08/2009	50	N.A	N.A	UPS	-0.31	2	-0.31	0.96	6	1383	1591
73	23/04/2010	55	N.A	N.A	UPS	-0.69	2	-0.69	0.97	5	1390	1591
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
74	26/11/2009	64	N.A	N.A	UPS	-0.48	2	-0.48	0.74	7	1595	1642
74	15/02/2010	82	N.A	N.A	UPS	-0.37	2	-0.37	0.95	7	1564	1642
75	23/04/2010	56	N.A	N.A	UPS	-0.40	2	-0.40	0.93	3	1570	1642
75	26/05/2010	193	N.A	N.A	UPS	-0.27	2	-0.27	0.99	12	1556	1642
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
75	23/04/2010	53	-0.52	UPS	-0.34		1	-0.43	0.97	3	1392	1511
75	23/05/2010	255	-0.19	UPS	-0.23		1	-0.21	0.91	16	1413	1511
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
76	23/04/2010	59	-0.51	UPS	-0.23		1	-0.37	0.89	3	1527	1572
76	23/05/2010	309	-0.12	UPS	-0.14		1	-0.13	0.88	18	1549	1572
76	12/06/2010	111	-0.06	UPS	-0.06		1	-0.06	0.84	6	1071	1572
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
77	24/05/2010	64	-0.28	N.A	UPS	-0.42	1	-0.35	0.77	4	1463	1761
77	28/05/2010	65	-0.23	N.A	UPS	-0.38	4	-0.31	0.52	4	1453	1761
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
78	24/05/2010	64	-0.45	UPS	-0.56	N.A	1	-0.50	0.92	3	1465	1701
78	28/05/2010	65	-0.49	UPS	-0.36	N.A	1	-0.43	0.98	3	1463	1701
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply el.**
79	14/05/2010	341	-0.20	UPS			5	-0.20	0.70	76	1410	1623

Table C.21 Details of Pondage conditions in different pools of MAIN CANAL during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	S7(mm/hr)	Priority	S pondage	LOC	No.	Max	Supply
3	24/09/20	56	0.00	N.A	-0.42	UPS	-0.46			4	-0.44	0.55	14	1516	1621
3	4/10/200	82	-0.37	N.A	-0.36	UPS	-0.33			1	-0.35	0.93	7	1515	1621
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**

4	14/05/20	65	-0.12	UPS	-0.12					1	-0.12	0.95	4	1424	1608
4	28/05/20	103	-0.26	UPS	-0.32					1	-0.29	0.89	6	1424	1608
4	26/06/20	56	-0.14	UPS	-0.04					1	-0.09	1.00	3	1414	1608
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
6	23/09/20	334	N.A	-1.42	UPS	-1.39				1	-1.41	0.80	77	1349	1489
6	14/10/20	208	N.A	-1.37	UPS	-1.40				1	-1.38	0.88	44	1170	1489
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
7	23/09/20	370	UPS	-0.08						5	-0.08	0.86	36	1594	1783
7	12/10/20	264	UPS	-0.06						5	-0.06	0.68	26	1582	1783
7	24/05/20	232	UPS	-0.24						2	-0.24	0.81	18	1635	1783
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
8	26/09/20	333	UPS	-0.19						2	-0.19	0.97	36	1582	1753
8	10/10/20	299	UPS	-0.19						2	-0.19	0.94	33	1577	1753
8	24/05/20	230	UPS	-0.19						2	-0.19	0.95	14	1594	1753
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
9	26/09/20	656	UPS	-0.09						5	-0.09	0.89	73	1528	1747
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
16	11/09/20	95	-2.15	UPS						2	-2.15	0.99	28		
16	24/05/20	70	-0.60	UPS						2	-0.60	0.87	7		
16	28/05/20	52	-0.11	UPS						2	-0.11	1.00	2		
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
11	17/06/20	275	-0.26	-0.23	-0.26	-0.25	UPS	-0.27		1	-0.25	0.97	19	1239	1554
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
14	3/10/200	100	N.A	-0.66	UPS	-0.68				1	-0.67	0.85	23	1363	1590
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
15	4/10/200	81	N.A	-0.27	-0.31	UPS				3	-0.31	0.62	10	1265	1622
Pool	**Start**	**Du.(hr)**	**S1(mm/hr)**	**S2(mm/hr)**	**S3(mm/hr)**	**S4(mm/hr)**	**S5(mm/hr)**	**S6(mm/hr)**	**S7(mm/hr)**	**Priority**	**S pondage**	**LOC**	**No.**	**Max**	**Supply**
22	27/05/20	118	-0.84	-0.83	UPS					1	-0.84	0.99	10		
22	1/06/201	653	-0.80	-0.57	UPS					1	-0.68	0.93	56		

Table C.22 Details of Pondage conditions in different pools of TUBBO main channel during 2009/10 season

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
10	4/11/2009	57	-0.23	-0.69	-0.64	UPS			1	-0.66	0.80	7	1641	
10	10/12/2009	70	-0.68	-0.65	-0.71	UPS			1	-0.68	0.99	8	1662	
10	23/12/2009	24	-0.83	-0.60	N.A	UPS			1	-0.72	0.94	4	1664	
10	24/12/2009	65	-0.70	-0.63	-0.63	UPS			1	-0.65	0.94	8		
10	3/01/2010	77	-0.72	-0.69	-0.74	UPS			1	-0.72	0.99	8		
10	11/01/2010	85	-0.82	-0.76	-0.80	UPS			1	-0.79	0.99	10	1687	
10	18/01/2010	61	-0.61	-0.60	-0.64	UPS			1	-0.62	0.98	7		
10	25/01/2010	93	-0.71	-0.69	-0.71	UPS			1	-0.70	1.00	11		
10	3/02/2010	128	-0.71	-0.70	-0.68	UPS			1	-0.70	0.97	14		
10	16/02/2010	78	-0.73	-0.64	-0.72	UPS			1	-0.70	0.99	11		
10	26/02/2010	121	-0.62	-0.63	-0.65	UPS			1	-0.63	0.96	14		
10	16/03/2010	85	-0.62	-0.60	-0.64	UPS			1	-0.62	1.00	8		
10	21/05/2010	189	-0.38	-0.37	-0.37	UPS			1	-0.38	0.99	93		
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
11	22/05/2010	91	-0.82	-1.20	-1.22	-1.08	UPS	-1.11	1	-1.15	0.96	12	1358	1340
11	27/05/2010	91	-0.65	-0.51	-0.51	-0.51	UPS	-0.49	1	-0.51	0.87	7	1248	1340
11	10/06/2010	69	0.04	-0.15	0.07	0.06	UPS	-0.20	3	-0.17	0.39	4	1154	1340
11	18/06/2010	49	0.02	0.00	0.05	0.05	UPS	-0.14	3	-0.14	0.20	2	1154	1340
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
2	23/10/2009	140	-0.25	-0.32	UPS	-0.23			1	-0.27	0.87	10	1555	1732
2	2/11/2009	434	-0.18	-0.18	UPS	-0.20			1	-0.19	0.94	32	1513	1732
2	26/11/2009	433	-0.31	-0.32	UPS	-0.33			1	-0.32	0.96	30	1627	1732
2	18/12/2009	78	-0.19	-0.23	UPS	-0.14			1	-0.19	0.85	5	1365	1732
2	23/12/2009	163	-0.26	-0.26	UPS	-0.26			1	-0.26	0.86	12	1375	1732
2	2/01/2010	74	-0.54	-0.47	UPS	-0.31			1	-0.44	0.99	5	1539	1732
2	11/01/2010	55	-0.75	-0.64	UPS	-0.76			1	-0.72	0.99	5	1598	1732
2	20/01/2010	97	-0.90	-0.89	UPS	-0.95			1	-0.91	0.99	10	1668	1732
2	28/01/2010	136	-0.41	-0.47	UPS	-0.40			1	-0.43	0.95	11	1583	1732
2	27/05/2010	36	-0.25	-0.25	UPS	-0.25			1	-0.25	0.98	45	1622	1732

Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
4	19/05/2010	176	-0.25	N.A	UPS				2	-0.25	0.89	14	1544	
4	28/05/2010	762	-0.31	N.A	UPS				2	-0.31	0.99	64	1619	
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
5	12/10/2009	87	N.A	-2.55	UPS	-2.67			1	-2.61	0.99	19	1451	1492
5	16/10/2009	136	N.A	-2.23	UPS	-2.25			1	-2.24	0.99	24	1277	1492
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
6	24/05/2010	68	0.08	-0.02	UPS	-0.33			3	-0.33	1.00	2	1307	1503
Pool	Start	Du.(hr)	S1(mm/hr)	S2(mm/hr)	S3(mm/hr)	S4(mm/hr)	S5(mm/hr)	S6(mm/hr)	Priority	S pondage	LOC	No.	Max el.	Supply
9	25/06/2010	59	-0.08	-0.36	-0.43	UPS	-0.53		1	-0.35	0.87	3	1396	1564

Table C.23 Details of Pondage conditions in different pools of YAMMA main channel during 2009/10 season

Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply
1	6/04/201	50	-0.87	UPS	-0.86			1	-0.87	1.00	5	1655	1738
1	24/05/20	192	-0.61	UPS	-0.61			1	-0.61	0.98	13	1651	1738
Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply
3	23/09/20	50	-0.29	0.09	UPS	-0.23		3	-0.26	0.48	5	1517	1704
3	5/04/201	59	-0.55	-0.48	UPS	-0.48		1	-0.50	0.96	5	1533	1704
3	25/05/20	164	-0.23	-0.20	UPS	-0.21		1	-0.22	0.82	10	1514	1704
Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply
4	5/04/201	57	-0.18	UPS	-0.18			1	-0.18	0.84	4	1595	1705
4	25/05/20	89	-0.20	UPS	-0.20			1	-0.20	0.72	7	1607	1705
4	28/05/20	69	-0.28	UPS	-0.14			1	-0.21	0.95	4	1599	1705
Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply
5	28/05/20	69	-0.45	N.A	UPS	-0.40		1	-0.19	0.84	7	1334	1633
Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply
6	28/05/20	288	N.A	N.A	UPS	-0.53		2	-0.53	0.99	28	1518	1691
Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply
7	19/05/20	501	N.A	UPS	-0.08			2	-0.08	0.81	33	1443	1631
Pool ID	Start	Du.(hr)	S1(mm/hr	S2(mm/hr	S3(mm/hr	S4(mm/hr)	S5(mm/hr	Priority	S pondage	LOC	No. Points	Max el.	Supply

8	19/05/20	502	-0.51	-0.44	-0.51	UPS		1	-0.49	0.98	29		
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
13	30/09/20	138	N.A	UPS	-0.90			2	-0.90	0.97	21	1447	1571
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
14	28/05/20	61	-0.49	-0.56	UPS	-0.59		1	-0.53	0.99	3		
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
15	17/05/20	44	-0.20	-0.22	-0.14	UPS		1	-0.17	0.96	4	1465	1522
15	28/05/20	88	-0.31	-0.34	-0.33	UPS		1	-0.33	0.93	5	1467	1522
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
16	29/08/20	122	N.A	-0.09	UPS	-0.09		1	-0.09	0.80	10	1631	1920
16	10/10/20	146	N.A	-0.22	UPS	-0.23		1	-0.23	0.83	15	1661	1920
16	22/01/20	62	N.A	-0.65	UPS	-0.63		1	-0.64	0.86	10	1580	1920
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
20	23/04/20	201	-0.50	-0.54	UPS	-0.57		1	-0.54	0.98	12	1568	1621
20	21/05/20	451	-0.34	-0.35	UPS	-0.35		1	-0.35	0.99	25	1458	1621
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
21	21/04/20	487	-0.39	N.A	UPS			2	-0.39	0.97	48	1575	
21	12/05/20	661	-0.43	N.A	UPS			2	-0.43	0.95	63	1540	
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
22	28/05/20	64	-0.44	UPS	-0.49			1	-0.46	0.94	3	1547	1700
22	7/06/201	515	-0.09	UPS	0.02			3	-0.09	0.49	25	1246	1700
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
23	28/05/20	64	N.A	-0.26	-0.46	UPS	-0.43	1	-0.39	0.94	4	1658	1827
23	10/06/20	443	N.A	-0.11	-0.12	UPS	-0.11	1	-0.11	0.87	29	1524	1827
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
24	26/11/20	48	N.A	UPS	-0.67			2	-0.67	0.96	6	1490	1651
24	6/03/201	57	N.A	UPS	-0.95			5	-0.95	0.69	9	1503	1651
24	28/05/20	62	N.A	UPS	-0.46			2	-0.46	0.81	5	1483	1651
24	10/06/20	457	N.A	UPS	-0.20			2	-0.20	0.99	34	1368	1651
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
25	26/11/20	48	N.A	N.A	UPS	-0.76		2	-0.76	0.95	6	1486	1528

25	6/03/201	64	N.A	N.A	UPS	-0.78		2	-0.78	0.80	8	1490	1528
25	28/05/20	62	N.A	N.A	UPS	-0.47		2	-0.47	0.80	5	1478	1528
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
26	26/11/20	53	N.A	-0.66	-0.56	UPS	-0.55	1	-0.59	0.76	7	1435	1645
26	28/05/20	65	N.A	-0.65	-0.66	UPS	-0.56	1	-0.62	0.93	5	1413	1645
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
27	26/11/20	53	N.A	-0.80	UPS	-0.78		1	-0.79	0.85	8	1614	1739
27	7/03/201	87	N.A	-0.57	UPS	-0.48		3	-0.52	0.68	12	1628	1739
27	18/05/20	488	N.A	-0.27	UPS	-0.27		1	-0.27	0.99	37	1575	1739
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
28	26/11/20	97	N.A	-0.52	UPS			2	-0.52	0.85	5		
28	27/01/20	71	N.A	-0.33	UPS			2	-0.33	0.99	3		
28	4/03/201	151	N.A	-0.31	UPS			5	-0.31	0.60	12		
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
29	23/09/20	294	-0.62	UPS	-0.60			1	-0.61	0.98	46	1462	1463
29	7/10/200	180	-0.57	UPS	-0.57			1	-0.57	0.98	27	1490	1463
29	24/05/20	100	-1.47	UPS	-1.40			1	-1.43	0.93	16	1439	1463
29	28/05/20	55	-0.90	UPS	-0.87			1	-0.89	0.94	5	1342	1463
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
30	23/09/20	296	-0.39	UPS	-0.40			1	-0.40	0.91	37	1466	1732
30	7/10/200	180	-0.16	UPS	-0.27			1	-0.21	0.90	23	1391	1732
30	24/05/20	93	-0.40	UPS	-0.33			1	-0.36	0.76	8	1555	1732
30	28/05/20	52	-0.49	UPS	-0.90			1	-0.70	0.99	3	1539	1732
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
31	24/05/20	93	-0.32	UPS	-0.35			1	-0.35	0.82	7	1598	1743
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
32	25/09/20	573	N.A	N.A	UPS	-0.40		2	-0.40	0.99	84	1418	1571
32	24/05/20	248	N.A	N.A	UPS	-0.19		2	-0.19	0.83	17	1398	1571
32	25/06/20	82	N.A	N.A	UPS	-0.24		5	-0.24	0.54	8	1122	1571
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
33	25/09/20	587	N.A	UPS	-0.13			5	-0.13	0.95	55	1503	1831

33	22/10/20	148	N.A	UPS	-0.13			2	-0.13	0.85	12	1443	1831
33	27/11/20	2	N.A	UPS	-62.56			2	-62.56	0.98	4	1681	1831
33	29/11/20	146	N.A	UPS	-0.14			2	-0.14	0.91	12	1686	1831
33	19/12/20	58	N.A	UPS	-0.35			5	-0.35	0.98	5	1653	1831
33	7/02/201	81	N.A	UPS	-0.35			5	-0.35	0.61	10	1688	1831
33	14/02/20	68	N.A	UPS	-0.19			2	-0.19	0.98	5	1657	1831
33	1/03/201	165	N.A	UPS	-0.16			5	-0.16	0.63	20	1683	1831
33	15/03/20	61	N.A	UPS	-0.84			2	-0.84	0.99	10	1689	1831
33	28/05/20	70	N.A	UPS	-0.39			2	-0.39	0.93	3	1653	1831
33	25/06/20	66	N.A	UPS	-0.22			2	-0.22	0.87	3	1636	1831
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
34	27/11/20	287	-0.03	N.A	UPS			5	-0.03	0.57	342		1705
34	24/05/20	81	-0.36	N.A	UPS			2	-0.36	0.82	5	1601	1705
34	28/05/20	70	-0.26	N.A	UPS			2	-0.26	0.99	3	1602	1705
34	25/06/20	66	-0.39	N.A	UPS			2	-0.39	0.95	5	1612	1705
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
39	7/03/201	76	-0.53	N.A	UPS	-0.49		1	-0.49	0.74	9	1410	1564
39	17/03/20	71	-0.31	N.A	UPS	-0.30		1	-0.30	0.99	5	1397	1564
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
40	4/03/201	49	-0.29	UPS	-0.44			1	-0.29	0.74	2	1533	1780
40	29/03/20	55	0.00	UPS	-0.49			3	0.00	0.68	2	1573	1780
40	23/04/20	57	-0.44	UPS	-0.15			3	-0.44	0.53	3	1586	1780
Pool ID	**Start**	**Du.(hr)**	**S1(mm/hr**	**S2(mm/hr**	**S3(mm/hr**	**S4(mm/hr)**	**S5(mm/hr**	**Priority**	**S pondage**	**LOC**	**No. Points**	**Max el.**	**Supply**
42	7/09/200	60	-0.38	UPS				2	-0.38	0.99	7	1628	1686
42	18/01/20	273	-0.96	UPS				5	-0.96	0.71	121	1573	1686

APPENDIX D

Detailed results of pools highlighted in Chapter 6

Table D.1 Detailed results of BOONA 9-1gauge in BOONA 9, 9-1 pool illustrated in Figure 6.1

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BOONA 9-1	15/10/2010 4:23	1563	1625.91	453.00	1563.00
BOONA 9-1	15/10/2010 6:06	1568	1625.92	453.00	1568.01
BOONA 9-1	15/10/2010 6:38	1573	1625.92	453.00	1573.01
BOONA 9-1	15/10/2010 7:38	1583	1625.93	453.00	1583.02
BOONA 9-1	15/10/2010 8:25	1593	1625.94	453.00	1593.03
BOONA 9-1	15/10/2010 9:06	1603	1625.95	453.00	1603.04
BOONA 9-1	15/10/2010 9:52	1613	1625.97	453.00	1613.06
BOONA 9-1	15/10/2010 10:53	1623	1625.98	537.81	1538.27
BOONA 9-1	16/10/2010 1:42	1618	1626.79	537.81	1534.07
BOONA 9-1	16/10/2010 4:24	1613	1626.83	537.81	1529.12
BOONA 9-1	16/10/2010 9:42	1603	1627.44	537.81	1519.73
BOONA 9-1	16/10/2010 15:57	1593	1628.90	549.81	1499.19
BOONA 9-1	16/10/2010 23:06	1583	1629.57	549.81	1489.85
BOONA 9-1	16/10/2010 23:51	1582	1629.57	549.81	1488.86
BOONA 9-1	17/10/2010 5:53	1573	1629.59	549.81	1479.88
BOONA 9-1	17/10/2010 11:22	1563	1630.16	550.01	1470.24
BOONA 9-1	17/10/2010 17:49	1553	1631.62	550.01	1461.71
BOONA 9A	15/10/2010 7:26	1632	1625.93	453.00	1632.00
BOONA 9A	16/10/2010 3:02	1669	1626.80	537.81	1585.08
BOONA 9A	17/10/2010 1:11	1634	1629.58	549.81	1540.85

Table D.2 Detailed results of farm outlet 220/1 in ARGOON 3A, 220/1pool illustrated in Figure 6.2

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
220/1	5/02/2011 6:10	1606	2410.42	793.02	1606.00
220/1	5/02/2011 8:59	1614	2410.44	793.02	1614.02
220/1	5/02/2011 9:19	1625	2410.46	793.02	1625.04
220/1	5/02/2011 10:32	1635	2410.47	848.82	1579.25
220/1	5/02/2011 15:27	1645	2411.33	848.82	1590.11
220/1	5/02/2011 18:19	1655	2411.45	848.82	1600.24
220/1	6/02/2011 4:33	1650	2411.54	848.82	1595.32
220/1	6/02/2011 6:41	1645	2411.56	848.82	1590.34
220/1	6/02/2011 12:38	1635	2412.41	903.02	1526.99
220/1	6/02/2011 18:13	1625	2415.15	903.02	1519.73
220/1	6/02/2011 23:22	1615	2415.82	903.02	1510.40
220/1	7/02/2011 2:56	1610	2415.92	903.02	1505.50
220/1	7/02/2011 6:33	1605	2415.93	903.02	1500.51

Table D.3 Detailed results of BOONA 7-1 gauge in BOONA 7, 7-1 pool illustrated in Figure 6.3

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BOONA 7-1	13/11/2010 19:03	1462	1728.44	579.81	1462.00
BOONA 7-1	13/11/2010 20:09	1472	1728.47	579.81	1472.03
BOONA 7-1	13/11/2010 23:12	1482	1728.48	579.81	1482.04
BOONA 7-1	14/11/2010 3:35	1482	1728.50	579.81	1482.06
BOONA 7-1	15/11/2010 1:54	1476	1729.98	627.01	1430.34
BOONA 7-1	15/11/2010 12:02	1472	1731.27	627.21	1427.42
BOONA 7-1	16/11/2010 0:13	1466	1734.79	627.21	1424.95

Table D.4 Detailed results of 27/2 farm outlet in COLY 7, 7-1 pool illustrated in Figure 6.4

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
27-Feb	7/03/2010 16:57	1639	1150.95	145.00	1639.00
27-Feb	7/03/2010 17:02	1649	1150.95	145.00	1649.00
27-Feb	7/03/2010 17:08	1659	1150.98	145.00	1659.03
27-Feb	8/03/2010 0:26	1667	1151.18	145.00	1667.23
27-Feb	8/03/2010 20:13	1656	1154.95	175.80	1629.20
27-Feb	9/03/2010 6:45	1649	1155.47	175.80	1622.71
27-Feb	9/03/2010 16:00	1645	1156.79	175.80	1620.04

Table D.5 Detailed results of 2005/1 farm outlet in ARGOON 3-8, 2005/1 pool illustrated in Figure 6.5

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2005/1	17/04/2010 9:08	1662	1453.99	170.20	1662.00
2005/1	18/04/2010 5:44	1608	1457.85	170.20	1611.86
2005/1	19/04/2010 2:18	1560	1461.58	170.20	1567.59
2005/1	19/04/2010 22:54	1528	1465.34	170.20	1539.35
2005/1	20/04/2010 19:28	1502	1468.17	170.20	1516.18
2005/1	21/04/2010 16:04	1474	1470.85	183.80	1477.26
2005/1	22/04/2010 12:38	1453	1472.69	184.40	1457.50
2005/1	23/04/2010 9:13	1434	1474.66	184.60	1440.27

Table D.6 Detailed results of 2005/1 farm outlet in ARGOON 3-8, 2005/1 pool illustrated in Figure 6.6

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2005/1	13/02/2010 8:01	1598	1104.22	82.60	1598.00
2005/1	14/02/2010 3:24	1554	1107.58	82.60	1557.36
2005/1	14/02/2010 8:30	1546	1107.67	82.60	1549.45
2005/1	14/02/2010 9:51	1544	1107.79	84.20	1545.97
2005/1	14/02/2010 11:10	1527	1108.16	84.20	1529.34
2005/1	14/02/2010 22:47	1524	1112.50	84.20	1530.68
2005/1	16/02/2010 3:20	1491	1118.74	84.40	1503.72
2005/1	16/02/2010 22:43	1468	1125.30	84.40	1487.28
2005/1	19/02/2010 0:01	1418	1140.52	84.40	1452.50

Table D.7 Detailed results of TUBBO-9 gauge in TUBBO 8, 9 pool illustrated in Figure 6.7

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-9	15/10/2010 7:05	1292	1625.92	453.00	1292.00
TUBBO-9	15/10/2010 7:25	1302	1625.93	453.00	1302.00
TUBBO-9	15/10/2010 7:46	1312	1625.93	453.00	1312.01
TUBBO-9	15/10/2010 8:27	1322	1625.94	453.00	1322.02
TUBBO-9	15/10/2010 8:56	1332	1625.95	453.00	1332.02
TUBBO-9	15/10/2010 9:20	1342	1625.95	453.00	1342.03
TUBBO-9	15/10/2010 9:54	1350	1625.97	453.00	1350.04
TUBBO-9	15/10/2010 10:16	1353	1625.97	537.81	1268.24
TUBBO-9	15/10/2010 13:32	1363	1626.15	537.81	1278.42
TUBBO-9	16/10/2010 5:30	1354	1626.84	537.81	1270.12
TUBBO-9	16/10/2010 6:09	1353	1626.86	537.81	1269.13
TUBBO-9	16/10/2010 12:04	1343	1627.87	549.81	1248.15
TUBBO-9	16/10/2010 19:11	1333	1629.51	549.81	1239.78
TUBBO-9	17/10/2010 1:18	1323	1629.58	549.81	1229.85
TUBBO-9	17/10/2010 3:39	1319	1629.59	549.81	1225.86
TUBBO-9	17/10/2010 7:20	1313	1629.60	549.81	1219.87
TUBBO-9	17/10/2010 12:51	1303	1630.52	550.01	1210.59
TUBBO-9	17/10/2010 19:11	1293	1631.75	550.01	1201.83
TUBBO-9	18/10/2010 1:46	1283	1631.81	550.01	1191.88
TUBBO-9	18/10/2010 8:16	1272	1631.88	550.01	1180.96

Table D.8 Detailed results of BUNDURE 8-1 gauge in BUNDURE 8-OT/ 8-1 illustrated in Figure 6.8

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 8-1	28/02/2012 9:53	1534.14	3857.61	1313.18	1534.14
BUNDURE 8-1	28/02/2012 15:56	1538.46	3858.55	1326.78	1525.80
BUNDURE 8-1	29/02/2012 15:41	1529.60	3859.79	1329.18	1515.78
BUNDURE 8-1	1/03/2012 15:26	1536.13	3861.22	1344.38	1508.53
BUNDURE 8-1	2/03/2012 15:11	1533.25	3862.96	1351.38	1500.40
BUNDURE 8-1	3/03/2012 14:39	1549.56	3865.05	1352.58	1517.60
BUNDURE 8-1	4/03/2012 14:41	1561.01	3866.77	1402.97	1480.39
BUNDURE 8-1	5/03/2012 14:26	1547.12	3870.83	1403.17	1470.35
BUNDURE 8-1	6/03/2012 6:10	1534.54	3873.05	1403.17	1459.99
BUNDURE 8-1	6/03/2012 14:11	1527.39	3874.94	1403.17	1454.72
BUNDURE 8-1	7/03/2012 1:45	1519.54	3877.46	1403.17	1449.40
BUNDURE 8-1	7/03/2012 13:56	1515.80	3879.92	1403.17	1448.12

Table D.9 Detailed results of 640/1 farm outlet during the shorter pondage condition illustrated in Figure 6.9

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
640/1	30/10/2010 18:00	1305	1861.34	538.01	1305.00
640/1	30/10/2010 22:44	1312	1861.41	538.01	1312.08
640/1	31/10/2010 21:03	1307	1863.95	570.21	1277.41
640/1	1/11/2010 19:22	1297	1867.21	571.81	1269.07
640/1	1/11/2010 23:37	1296	1867.30	571.81	1268.16

Table D.10 Detailed results of 640/1 farm outlet during the longer pondage condition illustrated in Figure 6.9

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
640/1	30/06/2010 4:20	1507	1593.05	253.00	1507.00
640/1	1/07/2010 1:19	1502	1593.05	253.00	1502.00
640/1	1/07/2010 22:18	1497	1594.17	253.00	1498.11
640/1	2/07/2010 19:17	1493	1594.81	253.00	1494.75
640/1	3/07/2010 16:16	1487	1595.97	253.40	1489.52
640/1	4/07/2010 13:15	1482	1596.74	253.40	1485.29
640/1	5/07/2010 10:14	1481	1597.21	253.60	1484.56
640/1	6/07/2010 7:13	1477	1597.83	253.60	1481.18
640/1	7/07/2010 4:12	1475	1598.98	253.60	1480.33
640/1	8/07/2010 1:11	1469	1600.28	253.80	1475.43

640/1	8/07/2010 22:10	1465	1601.38	253.80	1472.53
640/1	9/07/2010 19:09	1460	1602.92	253.80	1469.07
640/1	10/07/2010 16:08	1457	1603.97	254.00	1466.92
640/1	11/07/2010 13:07	1457	1604.84	260.00	1461.79
640/1	12/07/2010 10:06	1455	1605.76	260.00	1460.70
640/1	13/07/2010 7:05	1453	1607.18	260.00	1460.13
640/1	14/07/2010 4:04	1472	1607.75	260.00	1479.70
640/1	15/07/2010 1:03	1473	1608.79	281.20	1460.53
640/1	15/07/2010 22:02	1470	1610.09	284.40	1455.64
640/1	16/07/2010 19:01	1465	1611.36	284.40	1451.91
640/1	17/07/2010 16:00	1461	1612.34	284.60	1448.68
640/1	18/07/2010 12:59	1457	1613.04	284.60	1445.39
640/1	19/07/2010 9:58	1456	1613.69	286.80	1442.83
640/1	20/07/2010 6:57	1453	1614.62	286.80	1440.77
640/1	21/07/2010 3:56	1449	1615.95	287.00	1437.90
640/1	22/07/2010 0:55	1445	1617.20	287.00	1435.15
640/1	22/07/2010 21:54	1440	1618.65	287.00	1431.59
640/1	23/07/2010 18:53	1435	1620.19	287.00	1428.14
640/1	24/07/2010 15:52	1431	1621.36	287.20	1425.11
640/1	25/07/2010 12:51	1428	1621.76	287.20	1422.51
640/1	26/07/2010 9:50	1424	1621.99	287.40	1418.54
640/1	27/07/2010 6:49	1422	1622.72	287.40	1417.27
640/1	28/07/2010 3:48	1418	1624.26	287.80	1414.40
640/1	29/07/2010 0:47	1428	1624.82	287.80	1424.97
640/1	29/07/2010 21:46	1427	1625.43	291.00	1421.38
640/1	30/07/2010 18:45	1424	1626.23	291.80	1418.37
640/1	31/07/2010 15:44	1418	1627.29	292.00	1413.24
640/1	1/08/2010 12:43	1415	1628.08	292.40	1410.63
640/1	2/08/2010 9:42	1413	1628.96	295.20	1406.71
640/1	3/08/2010 19:44	1406	1635.95	295.20	1406.70
640/1	4/08/2010 16:43	1402	1636.86	295.20	1403.61
640/1	5/08/2010 13:42	1396	1637.83	295.20	1398.58
640/1	6/08/2010 10:41	1393	1638.73	295.20	1396.48
640/1	7/08/2010 7:40	1393	1640.07	295.20	1397.82
640/1	8/08/2010 4:39	1389	1641.72	295.20	1395.46
640/1	9/08/2010 1:38	1386	1643.38	295.20	1394.12
640/1	9/08/2010 19:49	1381	1645.60	295.20	1391.35
640/1	10/08/2010 16:50	1398	1646.84	298.20	1406.59
640/1	11/08/2010 13:51	1401	1647.39	306.60	1401.74
640/1	12/08/2010 10:52	1397	1648.17	308.80	1396.32
640/1	13/08/2010 7:53	1398	1649.45	308.80	1398.60
640/1	14/08/2010 4:54	1395	1651.17	309.00	1397.12
640/1	15/08/2010 1:55	1391	1653.09	309.00	1395.04
640/1	15/08/2010 22:56	1391	1654.20	309.20	1395.94

Table D.11 Detailed results of BUNDURE 7-1 gauge during the shorter pondage condition illustrated in Figure 6.10

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 7-1	5/11/2010 18:59	1598	1883.18	572.01	1598.00
BUNDURE 7-1	5/11/2010 21:52	1588	1883.36	572.01	1588.17
BUNDURE 7-1	6/11/2010 0:15	1578	1883.40	572.01	1578.21
BUNDURE 7-1	6/11/2010 3:19	1568	1883.44	572.01	1568.25
BUNDURE 7-1	6/11/2010 7:07	1558	1883.44	572.01	1558.26
BUNDURE 7-1	6/11/2010 8:19	1553	1883.54	572.01	1553.36
BUNDURE 7-1	6/11/2010 10:53	1548	1884.35	572.01	1549.17
BUNDURE 7-1	6/11/2010 13:49	1538	1885.91	572.01	1540.73
BUNDURE 7-1	6/11/2010 17:18	1528	1887.62	572.01	1532.44
BUNDURE 7-1	6/11/2010 21:09	1518	1888.11	572.01	1522.93
BUNDURE 7-1	7/11/2010 0:32	1508	1888.18	572.01	1513.00
BUNDURE 7-1	7/11/2010 5:10	1498	1888.21	572.01	1503.03
BUNDURE 7-1	7/11/2010 6:38	1494	1888.22	572.01	1499.04
BUNDURE 7-1	7/11/2010 9:57	1488	1888.64	572.01	1493.46
BUNDURE 7-1	7/11/2010 18:35	1467	1893.36	572.01	1477.17
BUNDURE 7-1	7/11/2010 22:49	1457	1893.61	572.01	1467.42
BUNDURE 7-1	8/11/2010 3:41	1447	1893.67	572.01	1457.49
BUNDURE 7-1	8/11/2010 4:57	1445	1893.68	572.01	1455.50

Table D.12 Detailed results of BUNDURE 7-1 gauge during the longer pondage condition illustrated in Figure 6.10

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 7-1	26/08/2010 2:49	1279	1671.58	319.40	1279.00
BUNDURE 7-1	26/08/2010 14:54	1269	1672.39	321.60	1267.61
BUNDURE 7-1	26/08/2010 20:29	1259	1672.75	321.60	1257.97
BUNDURE 7-1	26/08/2010 21:32	1258	1672.76	321.60	1256.98
BUNDURE 7-1	27/08/2010 5:28	1249	1672.82	321.60	1248.04
BUNDURE 7-1	27/08/2010 9:47	1239	1673.00	322.20	1237.62
BUNDURE 7-1	27/08/2010 17:28	1229	1674.55	322.20	1229.17
BUNDURE 7-1	27/08/2010 19:09	1229	1674.59	322.20	1229.21
BUNDURE 7-1	28/08/2010 0:03	1219	1674.60	322.20	1219.22
BUNDURE 7-1	28/08/2010 7:21	1209	1674.60	322.20	1209.22
BUNDURE 7-1	28/08/2010 11:02	1199	1675.05	322.40	1199.47
BUNDURE 7-1	28/08/2010 16:46	1193	1676.41	322.40	1194.83
BUNDURE 7-1	28/08/2010 20:29	1189	1676.51	322.40	1190.93
BUNDURE 7-1	29/08/2010 4:06	1179	1676.51	322.40	1180.93
BUNDURE 7-1	29/08/2010 9:21	1169	1676.64	322.40	1171.06
BUNDURE 7-1	29/08/2010 14:23	1161	1678.03	322.40	1164.45
BUNDURE 7-1	29/08/2010 16:22	1159	1678.35	322.40	1162.77

BUNDURE 7-1	30/08/2010 2:17	1149	1678.48	322.40	1152.90
BUNDURE 7-1	30/08/2010 8:37	1139	1678.51	322.40	1142.93
BUNDURE 7-1	30/08/2010 12:00	1134	1679.27	322.40	1138.69
BUNDURE 7-1	30/08/2010 17:00	1129	1680.50	322.40	1134.92
BUNDURE 7-1	31/08/2010 0:59	1119	1680.57	322.40	1124.99
BUNDURE 7-1	31/08/2010 8:20	1109	1680.61	322.40	1115.02
BUNDURE 7-1	31/08/2010 9:37	1110	1680.73	322.40	1116.15
BUNDURE 7-1	31/08/2010 19:03	1099	1682.90	322.40	1107.32
BUNDURE 7-1	1/09/2010 2:18	1091	1682.97	322.40	1099.39
BUNDURE 7-1	2/09/2010 0:13	1091	1684.26	322.40	1100.68

Table D.13 Detailed results of BUNDURE 5-5 gauge during the shorter pondage condition illustrated in Figure 6.11

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 5-5	5/02/2011 10:48	1617	2410.48	848.82	1617.00
BUNDURE 5-5	5/02/2011 11:54	1627	2410.54	848.82	1627.06
BUNDURE 5-5	5/02/2011 12:30	1629	2410.59	848.82	1629.11
BUNDURE 5-5	5/02/2011 15:39	1637	2411.33	848.82	1637.85
BUNDURE 5-5	5/02/2011 17:29	1647	2411.43	848.82	1647.95
BUNDURE 5-5	5/02/2011 23:43	1657	2411.51	848.82	1658.03
BUNDURE 5-5	6/02/2011 10:53	1651	2411.97	903.02	1598.29
BUNDURE 5-5	6/02/2011 13:26	1647	2412.91	903.02	1595.23
BUNDURE 5-5	6/02/2011 22:31	1637	2415.79	903.02	1588.11
BUNDURE 5-5	7/02/2011 8:43	1627	2416.08	903.02	1578.40
BUNDURE 5-5	7/02/2011 9:16	1626	2416.16	903.02	1577.48
BUNDURE 5-5	7/02/2011 19:32	1617	2421.20	903.02	1573.52

Table D.14 Detailed results of BUNDURE 5-5 gauge during the longer pondage condition illustrated in Figure 6.11

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 5-5	17/07/2010 12:14	1246	1611.93	284.60	1246.00
BUNDURE 5-5	17/07/2010 23:32	1248	1612.43	284.60	1248.50
BUNDURE 5-5	18/07/2010 20:31	1244	1613.64	284.60	1245.71
BUNDURE 5-5	19/07/2010 17:30	1241	1614.62	286.80	1241.49
BUNDURE 5-5	20/07/2010 11:52	1236	1615.07	287.00	1236.74
BUNDURE 5-5	20/07/2010 14:29	1233	1615.63	287.00	1234.30
BUNDURE 5-5	21/07/2010 11:28	1231	1616.27	287.00	1232.95
BUNDURE 5-5	22/07/2010 8:27	1230	1617.20	287.00	1232.87
BUNDURE 5-5	22/07/2010 12:11	1226	1617.63	287.00	1229.31
BUNDURE 5-5	23/07/2010 5:26	1226	1618.65	287.00	1230.32
BUNDURE 5-5	24/07/2010 2:25	1222	1620.19	287.00	1227.87

BUNDURE 5-5	24/07/2010 11:09	1216	1620.35	287.20	1221.82
BUNDURE 5-5	24/07/2010 23:24	1218	1621.51	287.20	1224.98
BUNDURE 5-5	25/07/2010 20:23	1214	1621.94	287.20	1221.41
BUNDURE 5-5	26/07/2010 14:53	1206	1622.49	287.40	1213.76
BUNDURE 5-5	26/07/2010 17:22	1206	1622.72	287.40	1214.00
BUNDURE 5-5	27/07/2010 14:21	1199	1623.79	287.80	1207.67
BUNDURE 5-5	28/07/2010 11:20	1204	1624.45	287.80	1213.32
BUNDURE 5-5	29/07/2010 8:19	1206	1624.84	287.80	1215.71
BUNDURE 5-5	30/07/2010 5:18	1204	1625.45	291.00	1211.13
BUNDURE 5-5	31/07/2010 2:17	1202	1626.23	291.80	1209.10
BUNDURE 5-5	31/07/2010 12:38	1196	1626.59	292.00	1203.27
BUNDURE 5-5	31/07/2010 23:16	1198	1627.54	292.00	1206.21
BUNDURE 5-5	1/08/2010 10:00	1206	1627.79	292.40	1214.06
BUNDURE 5-5	1/08/2010 12:32	1196	1628.08	292.40	1204.35
BUNDURE 5-5	1/08/2010 20:15	1196	1628.77	292.40	1205.04
BUNDURE 5-5	2/08/2010 7:25	1186	1628.85	292.40	1195.13
BUNDURE 5-5	2/08/2010 11:19	1176	1629.28	295.20	1182.75
BUNDURE 5-5	4/08/2010 3:16	1181	1635.97	295.20	1194.44
BUNDURE 5-5	5/08/2010 0:15	1177	1637.02	295.20	1191.49
BUNDURE 5-5	5/08/2010 21:14	1173	1638.46	295.20	1188.93
BUNDURE 5-5	6/08/2010 9:36	1166	1638.52	295.20	1181.99
BUNDURE 5-5	6/08/2010 18:13	1165	1640.07	295.20	1182.54
BUNDURE 5-5	7/08/2010 15:12	1159	1641.50	295.20	1177.97
BUNDURE 5-5	8/08/2010 12:09	1156	1642.40	295.20	1175.88
BUNDURE 5-5	9/08/2010 9:10	1153	1643.47	295.20	1173.95
BUNDURE 5-5	10/08/2010 3:23	1148	1645.65	295.20	1171.13
BUNDURE 5-5	10/08/2010 15:44	1167	1646.77	298.20	1188.24
BUNDURE 5-5	11/08/2010 0:24	1161	1647.00	298.20	1182.47
BUNDURE 5-5	11/08/2010 12:16	1177	1647.26	306.60	1190.33
BUNDURE 5-5	11/08/2010 15:02	1167	1647.48	306.60	1180.55
BUNDURE 5-5	11/08/2010 21:25	1160	1647.70	306.60	1173.77
BUNDURE 5-5	12/08/2010 0:18	1147	1647.75	306.60	1160.82
BUNDURE 5-5	12/08/2010 2:05	1157	1647.77	306.60	1170.84
BUNDURE 5-5	12/08/2010 12:14	1147	1648.46	308.80	1159.33
BUNDURE 5-5	12/08/2010 18:05	1157	1649.42	308.80	1170.30
BUNDURE 5-5	13/08/2010 15:27	1153	1650.85	309.00	1167.53
BUNDURE 5-5	14/08/2010 12:28	1160	1651.95	309.00	1175.62
BUNDURE 5-5	15/08/2010 9:29	1159	1653.22	309.20	1175.69
BUNDURE 5-5	15/08/2010 11:55	1167	1653.60	309.20	1184.07
BUNDURE 5-5	15/08/2010 14:36	1157	1653.79	309.20	1174.26
BUNDURE 5-5	16/08/2010 6:30	1153	1654.22	309.20	1170.70
BUNDURE 5-5	16/08/2010 12:45	1147	1654.74	312.20	1162.21
BUNDURE 5-5	17/08/2010 4:22	1146	1655.58	312.20	1162.06
BUNDURE 5-5	17/08/2010 14:02	1137	1656.80	312.40	1154.08
BUNDURE 5-5	18/08/2010 4:03	1141	1657.49	312.40	1158.76

BUNDURE 5-5	18/08/2010 13:06	1147	1657.81	312.40	1165.08
BUNDURE 5-5	19/08/2010 0:44	1157	1658.25	312.40	1175.52
BUNDURE 5-5	19/08/2010 1:20	1147	1658.27	312.40	1165.54
BUNDURE 5-5	19/08/2010 4:31	1144	1658.29	312.40	1162.56
BUNDURE 5-5	19/08/2010 15:10	1137	1659.86	317.60	1151.93
BUNDURE 5-5	20/08/2010 1:52	1137	1660.49	317.60	1152.56
BUNDURE 5-5	20/08/2010 23:13	1134	1662.40	317.80	1151.27
BUNDURE 5-5	21/08/2010 11:21	1127	1662.84	317.80	1144.71
BUNDURE 5-5	21/08/2010 20:34	1126	1664.30	317.80	1145.18
BUNDURE 5-5	22/08/2010 17:55	1122	1666.39	317.80	1143.26
BUNDURE 5-5	23/08/2010 11:22	1117	1666.92	317.80	1138.79
BUNDURE 5-5	23/08/2010 15:15	1118	1667.40	317.80	1140.27
BUNDURE 5-5	24/08/2010 22:15	1127	1669.41	318.00	1151.08
BUNDURE 5-5	24/08/2010 22:30	1117	1669.41	318.00	1141.08
BUNDURE 5-5	25/08/2010 4:42	1115	1669.46	318.00	1139.13
BUNDURE 5-5	26/08/2010 2:19	1115	1671.58	319.40	1139.85
BUNDURE 5-5	26/08/2010 16:07	1107	1672.54	321.60	1130.62
BUNDURE 5-5	26/08/2010 23:56	1109	1672.78	321.60	1132.85
BUNDURE 5-5	27/08/2010 21:33	1100	1674.60	322.20	1125.07
BUNDURE 5-5	28/08/2010 8:37	1097	1674.63	322.40	1121.90
BUNDURE 5-5	28/08/2010 19:10	1093	1676.49	322.40	1119.77
BUNDURE 5-5	29/08/2010 16:47	1091	1678.39	322.40	1119.67
BUNDURE 5-5	30/08/2010 14:24	1091	1680.03	322.40	1121.30
BUNDURE 5-5	31/08/2010 12:01	1091	1681.39	322.40	1122.66

Table D.15 Detailed results of TUBBO-8 gauge in early August illustrated in Figure 6.12

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-8	5/08/2010 14:00	910	1471.99	324.80	910.00
TUBBO-8	6/08/2010 0:56	907	1472.62	324.80	907.62
TUBBO-8	6/08/2010 7:13	900	1472.65	324.80	900.66
TUBBO-8	6/08/2010 11:20	890	1472.98	325.40	890.39
TUBBO-8	6/08/2010 21:55	886	1474.16	325.40	887.57
TUBBO-8	7/08/2010 1:20	880	1474.16	325.40	881.57
TUBBO-8	7/08/2010 9:51	870	1474.27	325.60	871.47
TUBBO-8	7/08/2010 18:54	863	1475.53	325.60	865.74
TUBBO-8	7/08/2010 23:42	860	1475.53	325.60	862.74

Table D.16 Detailed results of TUBBO-8 gauge in mid October illustrated in Figure 6.12

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-8	15/10/2010 7:01	1432	1625.92	453.00	1432.00
TUBBO-8	15/10/2010 7:33	1442	1625.93	453.00	1442.00
TUBBO-8	15/10/2010 8:00	1452	1625.93	453.00	1452.01
TUBBO-8	15/10/2010 8:35	1463	1625.94	453.00	1463.02
TUBBO-8	15/10/2010 9:01	1473	1625.95	453.00	1473.02
TUBBO-8	15/10/2010 9:30	1483	1625.95	453.00	1483.03
TUBBO-8	15/10/2010 9:56	1486	1625.97	453.00	1486.04
TUBBO-8	15/10/2010 14:40	1473	1626.31	537.81	1388.59
TUBBO-8	15/10/2010 14:44	1462	1626.31	537.81	1377.59
TUBBO-8	15/10/2010 14:58	1472	1626.31	537.81	1387.59
TUBBO-8	15/10/2010 23:56	1462	1626.74	537.81	1378.01
TUBBO-8	16/10/2010 5:32	1457	1626.84	537.81	1373.12
TUBBO-8	16/10/2010 8:18	1452	1626.91	537.81	1368.19
TUBBO-8	16/10/2010 14:22	1441	1628.53	549.81	1346.80
TUBBO-8	17/10/2010 3:41	1438	1629.59	549.81	1344.86
TUBBO-8	17/10/2010 12:46	1431	1630.52	550.01	1338.59
TUBBO-8	18/10/2010 1:50	1425	1631.81	550.01	1333.88
TUBBO-8	18/10/2010 8:21	1421	1631.88	550.01	1329.96

Table D.17 Detailed results of 221/1 gauge in early July illustrated in Figure 6.13

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
221/1	2/07/2010 21:03	1525	1431.95	276.80	1525.00
221/1	3/07/2010 18:02	1520	1432.99	283.20	1514.64
221/1	4/07/2010 15:01	1516	1433.76	283.20	1511.41

Table D.18 Detailed results of 221/1 gauge in mid Oct illustrated in Figure 6.13

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
221/1	14/10/2010 23:58	1443	1625.89	453.00	1443.00
221/1	15/10/2010 19:34	1523	1626.67	537.81	1438.98
221/1	16/10/2010 17:43	1524	1629.30	549.81	1430.61
221/1	17/10/2010 15:52	1525	1631.29	550.01	1433.40

Table D.19 Detailed results of 221/1 gauge in late June illustrated in Figure 6.13

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
221/1	25/06/2011 16:01	1450	2367.87	1010.42	1450.00
221/1	26/06/2011 14:36	1447	2368.90	1010.62	1447.83
221/1	27/06/2011 13:11	1445	2369.83	1010.82	1446.56

Table D.20 Detailed results of BUNDURE 3A-1 gauge towards the end of 2009/10 season illustrated in Figure 6.14

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 3A-1	8/06/2010 19:34	1644	1567.54	242.40	1644.00
BUNDURE 3A-1	9/06/2010 4:29	1634	1567.58	242.40	1634.04
BUNDURE 3A-1	9/06/2010 4:51	1634	1567.58	242.40	1634.05
BUNDURE 3A-1	9/06/2010 14:13	1624	1567.96	243.40	1623.42
BUNDURE 3A-1	10/06/2010 0:47	1614	1568.31	243.40	1613.77
BUNDURE 3A-1	10/06/2010 1:28	1613	1568.31	243.40	1612.77
BUNDURE 3A-1	10/06/2010 8:48	1604	1568.36	243.40	1603.82
BUNDURE 3A-1	10/06/2010 19:49	1594	1569.65	243.40	1595.11
BUNDURE 3A-1	10/06/2010 22:27	1591	1569.66	243.40	1592.13
BUNDURE 3A-1	11/06/2010 5:10	1584	1569.69	243.40	1585.15
BUNDURE 3A-1	11/06/2010 13:18	1574	1570.21	243.40	1575.67
BUNDURE 3A-1	11/06/2010 19:26	1569	1570.76	243.40	1571.22
BUNDURE 3A-1	12/06/2010 0:42	1564	1570.82	243.40	1566.28
BUNDURE 3A-1	12/06/2010 9:03	1554	1570.90	243.40	1556.36
BUNDURE 3A-1	12/06/2010 16:25	1546	1572.24	243.40	1549.70
BUNDURE 3A-1	12/06/2010 19:24	1544	1572.37	243.40	1547.83
BUNDURE 3A-1	13/06/2010 5:03	1533	1572.38	243.40	1536.84
BUNDURE 3A-1	13/06/2010 13:07	1523	1572.97	243.40	1527.43
BUNDURE 3A-1	13/06/2010 13:24	1524	1573.08	243.40	1528.54
BUNDURE 3A-1	14/06/2010 1:09	1513	1573.70	243.40	1518.16
BUNDURE 3A-1	14/06/2010 9:17	1503	1573.75	243.40	1508.21
BUNDURE 3A-1	14/06/2010 10:23	1504	1573.86	243.40	1509.32
BUNDURE 3A-1	14/06/2010 20:42	1493	1575.01	243.40	1499.47
BUNDURE 3A-1	15/06/2010 6:47	1483	1575.01	243.40	1489.47
BUNDURE 3A-1	15/06/2010 7:22	1483	1575.01	243.40	1489.47
BUNDURE 3A-1	15/06/2010 13:41	1472	1575.87	243.40	1479.33
BUNDURE 3A-1	16/06/2010 4:21	1463	1576.33	243.40	1470.79
BUNDURE 3A-1	16/06/2010 12:05	1452	1576.71	243.40	1460.18
BUNDURE 3A-1	16/06/2010 23:40	1442	1577.91	243.40	1451.37
BUNDURE 3A-1	17/06/2010 1:20	1441	1577.97	243.40	1450.44
BUNDURE 3A-1	17/06/2010 8:25	1432	1578.26	243.40	1441.72
BUNDURE 3A-1	17/06/2010 10:33	1422	1578.49	244.40	1430.96

BUNDURE 3A-1	17/06/2010 12:50	1412	1579.19	244.40	1421.65
BUNDURE 3A-1	17/06/2010 13:31	1422	1579.35	244.40	1431.82
BUNDURE 3A-1	17/06/2010 22:19	1424	1579.84	244.40	1434.30
BUNDURE 3A-1	18/06/2010 8:43	1412	1579.88	244.80	1421.94
BUNDURE 3A-1	18/06/2010 19:18	1404	1581.14	244.80	1415.20
BUNDURE 3A-1	18/06/2010 21:14	1402	1581.14	244.80	1413.20
BUNDURE 3A-1	19/06/2010 5:14	1392	1581.25	244.80	1403.31
BUNDURE 3A-1	19/06/2010 12:51	1382	1581.78	244.80	1393.85
BUNDURE 3A-1	19/06/2010 16:17	1378	1582.15	244.80	1390.21
BUNDURE 3A-1	20/06/2010 5:23	1372	1582.22	244.80	1384.29
BUNDURE 3A-1	20/06/2010 11:50	1362	1582.57	244.80	1374.63
BUNDURE 3A-1	20/06/2010 13:16	1359	1582.84	244.80	1371.90
BUNDURE 3A-1	20/06/2010 19:02	1352	1583.20	244.80	1365.26
BUNDURE 3A-1	21/06/2010 1:58	1342	1583.20	244.80	1355.27
BUNDURE 3A-1	21/06/2010 7:58	1331	1583.20	244.80	1344.27
BUNDURE 3A-1	21/06/2010 10:15	1328	1583.29	245.20	1340.95
BUNDURE 3A-1	21/06/2010 12:55	1321	1583.59	245.20	1334.26
BUNDURE 3A-1	21/06/2010 20:24	1311	1584.00	245.20	1324.67
BUNDURE 3A-1	22/06/2010 2:20	1301	1584.00	245.20	1314.67
BUNDURE 3A-1	22/06/2010 7:14	1295	1584.00	245.20	1308.67
BUNDURE 3A-1	22/06/2010 8:36	1291	1584.00	245.20	1304.67
BUNDURE 3A-1	22/06/2010 15:52	1281	1584.69	245.20	1295.35
BUNDURE 3A-1	23/06/2010 4:13	1273	1584.85	245.20	1287.52
BUNDURE 3A-1	23/06/2010 6:10	1271	1584.86	245.20	1285.52
BUNDURE 3A-1	23/06/2010 14:14	1261	1585.85	245.20	1276.51
BUNDURE 3A-1	24/06/2010 1:12	1254	1586.40	245.20	1270.06
BUNDURE 3A-1	24/06/2010 3:54	1251	1586.44	245.20	1267.10
BUNDURE 3A-1	24/06/2010 12:24	1241	1587.10	245.40	1257.56
BUNDURE 3A-1	24/06/2010 22:11	1235	1588.22	245.40	1252.68
BUNDURE 3A-1	25/06/2010 3:08	1231	1588.30	245.40	1248.77
BUNDURE 3A-1	25/06/2010 11:53	1221	1588.69	245.40	1239.15
BUNDURE 3A-1	25/06/2010 19:10	1229	1588.99	245.40	1247.45
BUNDURE 3A-1	26/06/2010 10:59	1211	1589.32	252.80	1222.38
BUNDURE 3A-1	26/06/2010 16:09	1209	1590.22	252.80	1221.28
BUNDURE 3A-1	27/06/2010 7:31	1200	1590.36	252.80	1212.43
BUNDURE 3A-1	27/06/2010 13:08	1191	1590.93	253.00	1203.80
BUNDURE 3A-1	28/06/2010 3:37	1179	1591.59	253.00	1192.45
BUNDURE 3A-1	28/06/2010 10:07	1177	1591.67	253.00	1190.53

Table D.21 Detailed results of BUNDURE 3A-1 gauge in the middle of 2009/10 season illustrated in Figure 6.14

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BUNDURE 3A-1	14/10/2009 22:25	1621	233.10	0.00	1621.00
BUNDURE 3A-1	15/10/2009 1:52	1616	233.23	0.00	1616.13
BUNDURE 3A-1	15/10/2009 6:02	1611	233.28	0.00	1611.18
BUNDURE 3A-1	15/10/2009 10:32	1601	233.60	0.00	1601.49
BUNDURE 3A-1	15/10/2009 16:40	1591	235.48	0.00	1593.38
BUNDURE 3A-1	15/10/2009 22:15	1590	236.09	0.00	1592.99
BUNDURE 3A-1	16/10/2009 5:35	1581	236.18	0.00	1584.08
BUNDURE 3A-1	16/10/2009 10:24	1571	236.64	0.00	1574.54
BUNDURE 3A-1	16/10/2009 17:14	1563	238.79	0.00	1568.68
BUNDURE 3A-1	16/10/2009 18:09	1561	238.92	0.00	1566.82
BUNDURE 3A-1	17/10/2009 3:44	1551	239.35	0.00	1557.25
BUNDURE 3A-1	17/10/2009 9:32	1541	239.59	0.00	1547.48
BUNDURE 3A-1	17/10/2009 12:13	1537	240.68	0.00	1544.57
BUNDURE 3A-1	17/10/2009 16:25	1531	242.78	0.00	1540.68
BUNDURE 3A-1	18/10/2009 1:24	1521	244.20	0.00	1532.10
BUNDURE 3A-1	18/10/2009 7:12	1513	244.21	0.00	1524.11
BUNDURE 3A-1	18/10/2009 7:56	1510	244.24	0.00	1521.14
BUNDURE 3A-1	18/10/2009 13:28	1500	246.16	0.00	1513.06
BUNDURE 3A-1	18/10/2009 22:57	1490	248.94	0.00	1505.84
BUNDURE 3A-1	19/10/2009 2:11	1487	249.03	0.00	1502.93
BUNDURE 3A-1	19/10/2009 7:11	1480	249.05	0.00	1495.94
BUNDURE 3A-1	19/10/2009 11:45	1470	250.27	0.00	1487.17
BUNDURE 3A-1	19/10/2009 21:54	1460	253.75	0.00	1480.64
BUNDURE 3A-1	20/10/2009 1:40	1456	253.75	0.00	1476.65
BUNDURE 3A-1	20/10/2009 6:48	1450	253.77	0.00	1470.67
BUNDURE 3A-1	20/10/2009 10:57	1440	254.83	0.00	1461.73
BUNDURE 3A-1	20/10/2009 18:05	1430	259.55	0.00	1456.45
BUNDURE 3A-1	20/10/2009 20:37	1429	260.15	0.00	1456.05
BUNDURE 3A-1	21/10/2009 5:34	1420	260.40	0.00	1447.30
BUNDURE 3A-1	21/10/2009 10:14	1410	261.19	0.00	1438.09
BUNDURE 3A-1	21/10/2009 15:34	1400	264.47	0.00	1431.37
BUNDURE 3A-1	21/10/2009 15:46	1399	264.80	0.00	1430.70
BUNDURE 3A-1	22/10/2009 2:25	1391	267.05	0.00	1424.95
BUNDURE 3A-1	22/10/2009 3:32	1389	267.08	0.00	1422.97
BUNDURE 3A-1	22/10/2009 9:36	1379	267.40	0.00	1413.30
BUNDURE 3A-1	22/10/2009 15:50	1369	270.94	0.00	1406.83
BUNDURE 3A-1	22/10/2009 21:09	1367	272.79	0.00	1406.68
BUNDURE 3A-1	23/10/2009 3:14	1359	272.98	0.00	1398.88
BUNDURE 3A-1	23/10/2009 9:05	1349	273.22	0.00	1389.12

Table D.22 Detailed results of 2005/1 farm outlet in late August of 2010/11 season illustrated in Figure 6.15

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2005/1	21/08/2010 2:28	1663	1662.40	317.80	1663.00
2005/1	21/08/2010 23:49	1654	1664.30	317.80	1655.91
2005/1	22/08/2010 21:10	1632	1666.43	317.80	1636.03
2005/1	23/08/2010 18:32	1606	1667.51	317.80	1611.11
2005/1	25/08/2010 7:58	1564	1669.47	318.00	1570.88
2005/1	26/08/2010 5:35	1544	1671.59	319.40	1551.59
2005/1	27/08/2010 3:12	1524	1672.81	321.60	1530.61
2005/1	28/08/2010 0:49	1509	1674.60	322.20	1516.81
2005/1	28/08/2010 22:26	1490	1676.51	322.40	1499.52
2005/1	29/08/2010 20:03	1473	1678.48	322.40	1484.48
2005/1	30/08/2010 17:40	1455	1680.55	322.40	1468.56
2005/1	31/08/2010 1:05	1452	1680.57	322.40	1465.57
2005/1	31/08/2010 1:50	1451	1680.57	322.40	1464.57
2005/1	31/08/2010 2:20	1451	1680.57	322.40	1464.57
2005/1	31/08/2010 2:50	1450	1680.57	322.40	1463.57
2005/1	31/08/2010 15:17	1437	1682.34	322.40	1452.35

Table D.23 Detailed results of 2005/1 farm outlet in early Sep of 2010/11 season illustrated in Figure 6.15

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2005/1	7/09/2010 16:56	1660	1695.81	354.00	1660.00
2005/1	7/09/2010 17:42	1659	1695.87	354.00	1659.06
2005/1	8/09/2010 9:06	1649	1696.01	354.20	1649.00
2005/1	9/09/2010 2:06	1640	1698.56	354.20	1642.55
2005/1	10/09/2010 0:03	1637	1699.93	354.20	1640.91
2005/1	10/09/2010 22:00	1627	1701.95	369.20	1617.93
2005/1	11/09/2010 19:57	1615	1704.55	369.40	1608.34
2005/1	12/09/2010 17:54	1602	1706.57	369.40	1597.36
2005/1	13/09/2010 15:51	1590	1709.03	369.80	1587.41
2005/1	13/09/2010 20:05	1589	1709.24	369.80	1586.62
2005/1	15/09/2010 2:42	1591	1709.96	370.00	1589.15
2005/1	15/09/2010 5:26	1589	1709.98	370.00	1587.17
2005/1	16/09/2010 0:39	1578	1712.21	393.20	1555.20
2005/1	16/09/2010 22:36	1566	1713.80	393.20	1544.79
2005/1	17/09/2010 20:33	1554	1716.44	393.20	1535.43
2005/1	18/09/2010 18:30	1542	1718.59	393.20	1525.58
2005/1	19/09/2010 16:27	1528	1720.95	393.20	1513.94
2005/1	20/09/2010 14:24	1516	1723.16	393.20	1504.15
2005/1	22/09/2010 2:32	1500	1726.68	393.20	1491.66

2005/1	23/09/2010 0:15	1488	1729.42	414.40	1461.21
2005/1	23/09/2010 22:46	1476	1732.40	414.60	1451.98
2005/1	24/09/2010 20:54	1464	1735.48	414.60	1443.07
2005/1	25/09/2010 19:00	1449	1738.95	414.60	1431.54
2005/1	26/09/2010 17:07	1435	1742.28	414.60	1420.86
2005/1	27/09/2010 8:54	1428	1742.62	414.60	1414.21
2005/1	28/09/2010 1:37	1421	1745.73	414.60	1410.31
2005/1	29/09/2010 4:34	1406	1748.78	414.60	1398.37

Table D.24 Detailed results of 596/1 farm outlet in early Oct of 2009/10 season illustrated in Figure 6.16

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
596/1	5/10/2009 13:24	1589	192.34	0.00	1589.00
596/1	5/10/2009 18:11	1579	194.35	0.00	1581.01
596/1	5/10/2009 23:38	1573	194.86	0.00	1575.53
596/1	6/10/2009 1:42	1569	194.87	0.00	1571.53
596/1	6/10/2009 7:49	1559	194.90	0.00	1561.56
596/1	6/10/2009 12:15	1549	195.94	0.00	1552.60
596/1	6/10/2009 16:32	1539	197.59	0.00	1544.25
596/1	6/10/2009 18:37	1538	198.27	0.00	1543.93
596/1	7/10/2009 1:10	1528	198.56	0.00	1534.22
596/1	7/10/2009 8:02	1518	198.63	0.00	1524.29
596/1	7/10/2009 13:03	1508	200.03	0.00	1515.69
596/1	7/10/2009 13:36	1508	200.27	0.00	1515.93
596/1	7/10/2009 21:48	1498	203.08	0.00	1508.75
596/1	8/10/2009 8:06	1488	203.29	0.00	1498.96
596/1	8/10/2009 8:35	1487	203.31	0.00	1497.98
596/1	8/10/2009 15:12	1478	205.69	0.00	1491.35
596/1	9/10/2009 3:34	1470	207.41	0.00	1485.07
596/1	9/10/2009 5:34	1468	207.41	0.00	1483.08
596/1	9/10/2009 12:45	1458	209.01	0.00	1474.67
596/1	9/10/2009 22:33	1452	211.75	0.00	1471.41
596/1	10/10/2009 2:21	1448	211.83	0.00	1467.49
596/1	10/10/2009 12:20	1438	213.34	0.00	1459.00
596/1	10/10/2009 17:32	1432	215.80	0.00	1455.46

Table D.25 Detailed results of 596/1 farm outlet in mid Oct of 2009/10 season illustrated in Figure 6.16

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
596/1	16/10/2009 15:52	1599	238.30	0.00	1599.00
596/1	16/10/2009 18:24	1597	239.05	0.00	1597.75
596/1	17/10/2009 2:37	1589	239.35	0.00	1590.05
596/1	17/10/2009 9:22	1579	239.59	0.00	1580.29
596/1	17/10/2009 13:23	1573	241.21	0.00	1575.91
596/1	17/10/2009 16:21	1569	242.78	0.00	1573.48
596/1	18/10/2009 4:52	1559	244.21	0.00	1564.91
596/1	18/10/2009 8:22	1554	244.27	0.00	1559.97
596/1	18/10/2009 11:32	1549	245.12	0.00	1555.82
596/1	18/10/2009 21:29	1539	248.89	0.00	1549.59
596/1	19/10/2009 3:21	1532	249.04	0.00	1542.74
596/1	19/10/2009 6:53	1529	249.05	0.00	1539.75
596/1	19/10/2009 11:58	1519	250.27	0.00	1530.97
596/1	19/10/2009 23:00	1509	253.75	0.00	1524.45
596/1	20/10/2009 2:50	1505	253.75	0.00	1520.45
596/1	20/10/2009 8:50	1499	253.99	0.00	1514.69
596/1	20/10/2009 14:20	1488	257.28	0.00	1506.98
596/1	20/10/2009 21:47	1482	260.21	0.00	1503.91
596/1	21/10/2009 1:31	1478	260.33	0.00	1500.03
596/1	21/10/2009 9:04	1468	260.75	0.00	1490.45
596/1	21/10/2009 15:25	1458	264.47	0.00	1484.17
596/1	22/10/2009 3:35	1451	267.08	0.00	1479.78
596/1	22/10/2009 7:09	1448	267.13	0.00	1476.83
596/1	22/10/2009 13:32	1438	269.28	0.00	1468.98
596/1	22/10/2009 22:19	1435	272.84	0.00	1469.54
596/1	23/10/2009 7:33	1428	273.03	0.00	1462.73
596/1	23/10/2009 14:27	1418	276.15	0.00	1455.85
596/1	23/10/2009 17:16	1417	278.19	0.00	1456.89
596/1	24/10/2009 9:24	1408	279.69	0.00	1449.39
596/1	24/10/2009 12:13	1404	281.11	0.00	1446.81
596/1	25/10/2009 3:38	1398	285.12	0.00	1444.81
596/1	25/10/2009 7:10	1397	285.28	0.00	1443.98
596/1	25/10/2009 13:46	1388	287.88	0.00	1437.57
596/1	26/10/2009 2:07	1382	291.01	0.00	1434.71
596/1	26/10/2009 8:05	1378	291.30	0.00	1431.00
596/1	26/10/2009 21:04	1372	297.05	0.00	1430.75
596/1	27/10/2009 2:50	1368	297.42	0.00	1427.12
596/1	27/10/2009 15:22	1358	301.02	0.00	1420.72
596/1	27/10/2009 16:01	1357	301.31	0.00	1420.00
596/1	28/10/2009 9:33	1348	303.51	0.00	1413.21
596/1	28/10/2009 10:58	1346	303.96	0.00	1411.66

596/1	29/10/2009 5:55	1339	308.93	0.00	1409.63
596/1	29/10/2009 7:20	1338	309.05	0.00	1408.75
596/1	29/10/2009 13:56	1328	311.83	0.00	1401.53
596/1	30/10/2009 1:47	1325	315.09	0.00	1401.79
596/1	30/10/2009 10:39	1318	316.30	0.00	1396.00
596/1	30/10/2009 20:46	1311	320.30	0.00	1393.00
596/1	31/10/2009 1:32	1308	320.47	0.00	1390.17
596/1	31/10/2009 9:55	1298	321.15	0.00	1380.85
596/1	31/10/2009 15:45	1299	324.69	0.00	1385.39
596/1	31/10/2009 23:30	1288	325.84	0.00	1375.54
596/1	1/11/2009 8:50	1277	326.31	0.00	1365.01
596/1	1/11/2009 10:44	1277	327.37	0.00	1366.06
596/1	2/11/2009 5:43	1277	333.80	0.00	1372.50
596/1	3/11/2009 0:42	1277	341.48	3.40	1376.78

Table D.26 Detailed results of BOONA-7 gauge in BOONA 8, 9 pool illustrated in Figure 6.19

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
BOONA 7	7/02/2011 14:50	1682	2022.07	885.42	1682.00
BOONA 7	8/02/2011 12:33	1671	2025.47	885.42	1674.40
BOONA 7	8/02/2011 13:15	1661	2025.97	885.42	1664.90
BOONA 7	8/02/2011 14:05	1651	2026.52	885.42	1655.44
BOONA 7	8/02/2011 15:14	1641	2027.06	885.42	1645.99
BOONA 7	8/02/2011 16:58	1631	2027.81	885.42	1636.74
BOONA 7	8/02/2011 19:25	1621	2028.66	885.42	1627.59
BOONA 7	9/02/2011 0:06	1611	2028.77	885.42	1617.69
BOONA 7	9/02/2011 4:14	1601	2028.77	885.42	1607.69
BOONA 7	9/02/2011 5:24	1599	2028.77	885.42	1605.69

Table D.27 Detailed results of COLY 5-1 gauge in COLY 5, 5-1 pool illustrated in Figure 6.20

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
COLY 5-1	29/11/2010 9:27	1545	1775.65	668.81	1545.00
COLY 5-1	29/11/2010 9:45	1535	1775.70	668.81	1535.05
COLY 5-1	29/11/2010 10:01	1524	1775.70	669.41	1523.45
COLY 5-1	29/11/2010 10:18	1514	1775.75	669.41	1513.51
COLY 5-1	29/11/2010 10:36	1504	1775.75	669.41	1503.51
COLY 5-1	29/11/2010 10:56	1494	1775.87	669.41	1493.62
COLY 5-1	29/11/2010 11:17	1484	1775.98	669.41	1483.74
COLY 5-1	29/11/2010 11:44	1474	1776.07	669.41	1473.82
COLY 5-1	29/11/2010 12:16	1464	1776.15	669.41	1463.90

COLY 5-1	29/11/2010 12:59	1454	1776.28	669.41	1454.04
COLY 5-1	29/11/2010 14:03	1443	1776.55	669.41	1443.31
COLY 5-1	29/11/2010 15:31	1433	1777.05	669.41	1433.80
COLY 5-1	29/11/2010 17:32	1423	1777.36	669.41	1424.11
COLY 5-1	29/11/2010 20:20	1413	1777.68	669.41	1414.43
COLY 5-1	29/11/2010 23:40	1403	1777.78	669.41	1404.53
COLY 5-1	30/11/2010 1:53	1397	1777.86	669.41	1398.61
COLY 5-1	30/11/2010 3:42	1393	1777.93	669.41	1394.68
COLY 5-1	30/11/2010 14:16	1382	1778.95	672.01	1382.10
COLY 5-1	1/12/2010 0:12	1382	1779.63	672.01	1382.79
COLY 5-1	1/12/2010 8:32	1381	1779.77	672.01	1381.93

Table D.28 Detailed results of 2008/1 farm outlet in YAMMA 4-7, ESC YAMMA 4 pool illustrated in Figure 6.21

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2008/1	18/01/2010 23:23	1573	914.36	61.00	1573.00
2008/1	19/01/2010 3:38	1567	914.57	61.00	1567.21
2008/1	19/01/2010 8:11	1557	914.78	61.00	1557.42
2008/1	19/01/2010 12:22	1547	916.56	61.00	1549.20
2008/1	19/01/2010 18:12	1537	920.38	61.00	1543.02
2008/1	20/01/2010 5:33	1527	921.81	61.00	1534.45
2008/1	20/01/2010 9:36	1517	922.22	61.00	1524.86
2008/1	20/01/2010 13:41	1512	924.99	61.00	1522.63
2008/1	20/01/2010 15:05	1507	926.31	61.00	1518.95
2008/1	21/01/2010 4:24	1499	930.39	61.00	1515.03
2008/1	21/01/2010 6:00	1497	930.42	61.00	1513.06
2008/1	21/01/2010 10:11	1487	931.21	61.00	1503.85
2008/1	21/01/2010 16:22	1477	935.56	61.00	1498.20
2008/1	22/01/2010 3:56	1467	938.65	61.00	1491.29
2008/1	22/01/2010 4:47	1466	938.75	61.00	1490.39
2008/1	22/01/2010 10:32	1457	940.75	61.00	1483.39
2008/1	22/01/2010 15:27	1446	946.65	61.00	1478.29
2008/1	23/01/2010 1:05	1436	951.81	61.00	1473.45
2008/1	23/01/2010 3:51	1434	952.32	61.00	1471.96
2008/1	23/01/2010 9:56	1426	953.43	61.00	1465.07
2008/1	23/01/2010 15:46	1416	957.99	61.00	1459.63
2008/1	23/01/2010 23:04	1413	961.18	61.00	1459.82
2008/1	24/01/2010 7:55	1406	961.51	61.00	1453.15
2008/1	24/01/2010 14:04	1396	964.35	61.00	1445.99
2008/1	24/01/2010 18:17	1391	967.42	61.00	1444.06
2008/1	25/01/2010 5:44	1386	968.60	61.00	1440.24
2008/1	25/01/2010 11:18	1343	969.91	61.00	1398.55
2008/1	25/01/2010 11:18	1320	969.91	61.00	1375.55

2008/1	25/01/2010 11:18	1337	969.91	61.00	1392.55
2008/1	25/01/2010 11:19	1349	969.91	61.00	1404.55
2008/1	25/01/2010 11:19	1363	969.91	61.00	1418.55
2008/1	25/01/2010 11:20	1374	969.91	61.00	1429.55
2008/1	25/01/2010 11:21	1342	969.91	61.00	1397.55
2008/1	25/01/2010 11:21	1319	969.91	61.00	1374.55
2008/1	25/01/2010 11:21	1349	969.91	61.00	1404.55
2008/1	25/01/2010 11:22	1363	969.91	61.00	1418.55
2008/1	25/01/2010 11:22	1334	969.91	61.00	1389.55
2008/1	25/01/2010 11:23	1347	969.91	61.00	1402.55
2008/1	25/01/2010 11:23	1362	969.91	61.00	1417.55
2008/1	25/01/2010 11:24	1336	969.91	61.00	1391.55
2008/1	25/01/2010 11:24	1315	969.91	61.00	1370.55
2008/1	25/01/2010 11:25	1300	969.91	61.00	1355.55
2008/1	25/01/2010 11:25	1323	969.91	61.00	1378.55
2008/1	25/01/2010 11:25	1305	969.91	61.00	1360.55
2008/1	25/01/2010 11:26	1327	969.91	61.00	1382.55
2008/1	25/01/2010 11:26	1319	969.91	61.00	1374.55
2008/1	25/01/2010 11:26	1302	969.91	61.00	1357.55
2008/1	25/01/2010 11:26	1325	969.91	61.00	1380.55
2008/1	25/01/2010 11:27	1307	969.91	61.00	1362.55
2008/1	25/01/2010 11:27	1328	969.91	61.00	1383.55
2008/1	25/01/2010 11:27	1343	969.91	61.00	1398.55
2008/1	25/01/2010 11:28	1353	969.91	61.00	1408.55
2008/1	25/01/2010 11:28	1332	969.91	61.00	1387.55
2008/1	25/01/2010 11:28	1346	969.91	61.00	1401.55
2008/1	25/01/2010 11:29	1328	969.91	61.00	1383.55
2008/1	25/01/2010 11:30	1309	969.91	61.00	1364.55
2008/1	25/01/2010 11:31	1296	969.91	61.00	1351.55
2008/1	25/01/2010 11:31	1280	969.91	61.00	1335.55
2008/1	25/01/2010 13:30	1280	971.38	61.00	1337.02
2008/1	25/01/2010 21:01	1300	975.86	61.00	1361.50
2008/1	25/01/2010 21:02	1289	975.86	61.00	1350.50
2008/1	25/01/2010 21:04	1275	975.86	61.00	1336.50
2008/1	25/01/2010 21:04	1301	975.86	61.00	1362.50
2008/1	25/01/2010 21:05	1289	975.86	61.00	1350.50
2008/1	25/01/2010 21:06	1307	975.86	61.00	1368.50
2008/1	25/01/2010 21:07	1294	975.86	61.00	1355.50
2008/1	25/01/2010 21:07	1277	975.86	61.00	1338.50
2008/1	25/01/2010 21:08	1302	975.86	61.00	1363.50
2008/1	25/01/2010 21:08	1290	975.86	61.00	1351.50
2008/1	25/01/2010 21:09	1308	975.86	61.00	1369.50
2008/1	25/01/2010 21:09	1294	975.86	61.00	1355.50
2008/1	25/01/2010 21:10	1310	975.86	61.00	1371.50
2008/1	25/01/2010 21:11	1295	975.86	61.00	1356.50

2008/1	25/01/2010 21:11	1318	975.86	61.00	1379.50
2008/1	25/01/2010 21:11	1301	975.86	61.00	1362.50
2008/1	25/01/2010 21:11	1289	975.86	61.00	1350.50
2008/1	25/01/2010 21:12	1313	975.86	61.00	1374.50
2008/1	25/01/2010 21:12	1330	975.86	61.00	1391.50
2008/1	25/01/2010 21:12	1310	975.86	61.00	1371.50
2008/1	25/01/2010 21:13	1328	975.86	61.00	1389.50
2008/1	25/01/2010 21:13	1340	975.86	61.00	1401.50
2008/1	25/01/2010 21:13	1317	975.86	61.00	1378.50
2008/1	25/01/2010 21:14	1300	975.86	61.00	1361.50
2008/1	25/01/2010 21:14	1321	975.86	61.00	1382.50
2008/1	25/01/2010 21:14	1303	975.86	61.00	1364.50
2008/1	25/01/2010 21:15	1291	975.86	61.00	1352.50
2008/1	25/01/2010 21:15	1315	975.86	61.00	1376.50
2008/1	25/01/2010 21:16	1331	975.91	61.00	1392.55
2008/1	25/01/2010 21:16	1343	975.91	61.00	1404.55
2008/1	25/01/2010 21:17	1357	975.91	61.00	1418.55
2008/1	25/01/2010 21:18	1334	975.91	61.00	1395.55
2008/1	25/01/2010 21:19	1312	975.91	61.00	1373.55
2008/1	25/01/2010 21:19	1330	975.91	61.00	1391.55
2008/1	25/01/2010 21:19	1309	975.91	61.00	1370.55
2008/1	25/01/2010 21:19	1295	975.91	61.00	1356.55
2008/1	25/01/2010 21:20	1310	975.91	61.00	1371.55
2008/1	25/01/2010 21:20	1328	975.91	61.00	1389.55
2008/1	25/01/2010 21:20	1341	975.91	61.00	1402.55
2008/1	25/01/2010 21:21	1355	975.91	61.00	1416.55
2008/1	25/01/2010 21:22	1366	975.91	61.00	1427.55
2008/1	25/01/2010 21:24	1337	975.91	61.00	1398.55
2008/1	25/01/2010 21:25	1354	975.91	61.00	1415.55
2008/1	25/01/2010 21:26	1364	975.91	61.00	1425.55
2008/1	25/01/2010 21:28	1337	975.91	61.00	1398.55
2008/1	25/01/2010 21:28	1354	975.91	61.00	1415.55
2008/1	25/01/2010 21:29	1364	975.91	61.00	1425.55
2008/1	26/01/2010 8:43	1360	976.34	61.00	1421.98
2008/1	26/01/2010 9:28	1328	976.70	61.00	1390.34
2008/1	26/01/2010 9:29	1307	976.70	61.00	1369.34
2008/1	26/01/2010 9:29	1322	976.70	61.00	1384.34
2008/1	26/01/2010 9:30	1333	976.70	61.00	1395.34
2008/1	26/01/2010 9:31	1346	976.70	61.00	1408.34
2008/1	27/01/2010 3:56	1339	984.78	61.00	1409.42
2008/1	27/01/2010 7:18	1336	984.98	61.00	1406.62
2008/1	27/01/2010 21:01	1324	993.00	61.00	1402.64
2008/1	27/01/2010 21:46	1308	993.17	61.00	1386.81
2008/1	27/01/2010 21:47	1318	993.17	61.00	1396.81
2008/1	28/01/2010 5:44	1312	993.77	61.00	1391.41

2008/1	28/01/2010 7:52	1308	993.82	61.00	1387.46
2008/1	29/01/2010 0:12	1303	1001.48	61.00	1390.12
2008/1	29/01/2010 19:35	1303	1009.43	61.00	1398.07

Table D.29 Detailed results of 182/1 farm outlet in YAMMA 1, 2 pool illustrated in Figure 6.22

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
182/1	12/06/2010 9:53	1656	1570.98	243.40	1656.00
182/1	12/06/2010 16:59	1662	1572.29	243.40	1663.30
182/1	13/06/2010 6:52	1670	1572.38	243.40	1671.40
182/1	13/06/2010 9:01	1672	1572.39	243.40	1673.41
182/1	14/06/2010 2:42	1682	1573.70	243.40	1684.72
182/1	14/06/2010 3:51	1682	1573.70	243.40	1684.72
182/1	14/06/2010 18:17	1692	1575.01	243.40	1696.03
182/1	15/06/2010 0:50	1694	1575.01	243.40	1698.03
182/1	15/06/2010 14:50	1702	1576.08	243.40	1707.09
182/1	15/06/2010 21:49	1706	1576.33	243.40	1711.34
182/1	16/06/2010 9:06	1712	1576.35	243.40	1717.37
182/1	16/06/2010 18:48	1713	1577.74	243.40	1719.76
182/1	17/06/2010 12:20	1702	1579.03	244.40	1709.04
182/1	17/06/2010 14:14	1712	1579.43	244.40	1719.44
182/1	17/06/2010 15:47	1711	1579.64	244.40	1718.65
182/1	18/06/2010 12:46	1715	1580.46	244.80	1723.08
182/1	19/06/2010 9:40	1702	1581.37	244.80	1710.99
182/1	20/06/2010 6:44	1697	1582.22	244.80	1706.84
182/1	20/06/2010 11:30	1692	1582.48	244.80	1702.10
182/1	21/06/2010 3:43	1686	1583.20	244.80	1696.82
182/1	21/06/2010 7:36	1682	1583.20	244.80	1692.82
182/1	22/06/2010 0:42	1675	1584.00	245.20	1686.22
182/1	22/06/2010 5:34	1672	1584.00	245.20	1683.22
182/1	22/06/2010 21:41	1665	1584.78	245.20	1677.00
182/1	23/06/2010 3:50	1662	1584.85	245.20	1674.07
182/1	23/06/2010 18:40	1653	1586.29	245.20	1666.51
182/1	23/06/2010 23:09	1652	1586.36	245.20	1665.58

Table D.30 Detailed results of 2020/1 farm outlet in TUBBO 10, 11 pool illustrated in Figure 6.23

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2020/1	16/04/2010 22:00	1519	1302.54	204.80	1519.00
2020/1	17/04/2010 18:35	1522	1305.69	204.80	1525.16
2020/1	18/04/2010 12:27	1525	1307.18	204.80	1529.64
2020/1	18/04/2010 15:10	1525	1308.46	204.80	1530.92
2020/1	19/04/2010 11:45	1527	1310.47	204.80	1534.93
2020/1	20/04/2010 8:21	1530	1312.57	204.80	1540.03
2020/1	20/04/2010 15:13	1535	1314.61	204.80	1547.07
2020/1	21/04/2010 4:55	1533	1315.14	204.80	1545.60
2020/1	22/04/2010 1:30	1536	1317.97	204.80	1551.43
2020/1	22/04/2010 22:05	1538	1320.96	205.00	1556.23
2020/1	23/04/2010 18:40	1538	1324.50	205.00	1559.76
2020/1	24/04/2010 4:04	1545	1324.90	205.00	1567.17
2020/1	24/04/2010 15:15	1549	1325.37	209.20	1567.43
2020/1	25/04/2010 11:50	1553	1326.32	215.00	1566.58
2020/1	25/04/2010 22:52	1555	1327.78	215.00	1570.05
2020/1	26/04/2010 8:25	1556	1327.80	215.00	1571.07
2020/1	27/04/2010 5:00	1558	1329.89	215.20	1574.95
2020/1	28/04/2010 1:35	1560	1332.10	215.20	1579.16
2020/1	29/04/2010 18:45	1564	1334.53	215.20	1585.59
2020/1	29/04/2010 22:01	1565	1334.63	215.20	1586.69
2020/1	30/04/2010 15:20	1566	1336.50	215.20	1589.56
2020/1	1/05/2010 11:55	1569	1337.64	215.20	1593.70
2020/1	2/05/2010 8:30	1573	1339.18	215.20	1599.25
2020/1	3/05/2010 0:18	1575	1341.38	215.20	1603.44
2020/1	3/05/2010 5:05	1576	1341.38	215.20	1604.44
2020/1	4/05/2010 1:40	1578	1344.03	215.20	1609.09

Table D.31 Detailed results of YAMMA-2 gauge in YAMMA-1, 2 pool illustrated in Figure 6.24

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
YAMMA-2	4/08/2009 19:37	1054	1.42	0.00	1054.00
YAMMA-2	5/08/2009 11:42	1054	1.90	0.00	1054.48
YAMMA-2	6/08/2009 3:47	1054	3.38	0.00	1055.96
YAMMA-2	6/08/2009 19:52	1054	5.93	0.00	1058.52
YAMMA-2	7/08/2009 11:57	1054	6.83	0.00	1059.42
YAMMA-2	8/08/2009 4:02	1054	8.67	0.00	1061.25

YAMMA-2	8/08/2009 20:07	1054	10.45	0.00	1063.03
YAMMA-2	9/08/2009 12:12	1054	10.95	0.00	1063.53
YAMMA-2	10/08/2009 4:17	1054	12.23	0.00	1064.81
YAMMA-2	10/08/2009 20:22	1054	14.44	0.00	1067.02
YAMMA-2	11/08/2009 12:27	1054	15.62	0.00	1068.20
YAMMA-2	12/08/2009 4:32	1054	17.24	0.00	1069.82
YAMMA-2	12/08/2009 20:37	1054	18.88	0.00	1071.47
YAMMA-2	13/08/2009 12:42	1054	19.43	0.00	1072.01
YAMMA-2	14/08/2009 4:47	1054	20.43	0.00	1073.01
YAMMA-2	14/08/2009 20:52	1054	21.76	0.00	1074.34
YAMMA-2	15/08/2009 12:57	1054	22.81	0.00	1075.39
YAMMA-2	16/08/2009 5:02	1054	25.05	0.00	1077.63
YAMMA-2	16/08/2009 21:07	1054	27.16	0.00	1079.75
YAMMA-2	17/08/2009 13:12	1054	28.32	0.00	1080.91
YAMMA-2	18/08/2009 5:17	1054	29.63	0.00	1082.22
YAMMA-2	18/08/2009 21:22	1054	31.85	0.00	1084.43

Table D.32 Detailed results of BUNDURE 7-2 gauge in BUNDURE 7-1, 7-2 pool illustrated in Figure 6.25, 26, 27

Gate name	Date	Measured el. (mm)	Estimated evaporation	Accumulative rainfall(mm)	Corrected el. (mm)	Seepage (mm/hr)
BUNDURE 7-2	28/05/2010	1479	1552.60	222.40	1479.00	1.69
BUNDURE 7-2	29/05/2010 6:22	1471	1552.67	222.40	1471.07	1.66
BUNDURE 7-2	29/05/2010 9:21	1469	1552.72	239.20	1452.32	1.64
BUNDURE 7-2	29/05/2010	1459	1553.41	239.20	1443.01	1.62
BUNDURE 7-2	29/05/2010	1449	1553.49	239.20	1433.09	1.60
BUNDURE 7-2	30/05/2010 3:20	1439	1553.49	239.20	1423.09	1.57
BUNDURE 7-2	30/05/2010 9:00	1429	1553.51	241.60	1410.71	1.55
BUNDURE 7-2	30/05/2010	1419	1554.02	241.60	1401.22	1.52
BUNDURE 7-2	30/05/2010	1409	1554.36	241.60	1391.56	1.50
BUNDURE 7-2	31/05/2010 0:19	1406	1554.41	241.60	1388.61	1.49
BUNDURE 7-2	31/05/2010 5:31	1399	1554.49	241.60	1381.69	1.47
BUNDURE 7-2	31/05/2010	1389	1555.02	242.00	1371.82	1.45
BUNDURE 7-2	31/05/2010	1379	1556.31	242.00	1363.11	1.41
BUNDURE 7-2	31/05/2010	1377	1556.31	242.00	1361.11	1.40
BUNDURE 7-2	1/06/2010 2:54	1369	1556.31	242.00	1353.11	1.38
BUNDURE 7-2	1/06/2010 9:47	1359	1556.42	242.00	1343.22	1.35
BUNDURE 7-2	1/06/2010 15:59	1349	1557.56	242.00	1334.36	1.33
BUNDURE 7-2	1/06/2010 18:18	1347	1557.63	242.00	1332.44	1.32
BUNDURE 7-2	2/06/2010 0:43	1339	1557.64	242.00	1324.44	1.29
BUNDURE 7-2	2/06/2010 8:18	1329	1557.64	242.00	1314.44	1.26
BUNDURE 7-2	2/06/2010 13:38	1319	1558.50	242.00	1305.30	1.24
BUNDURE 7-2	2/06/2010 15:16	1317	1558.82	242.00	1303.62	1.24
BUNDURE 7-2	2/06/2010 23:56	1309	1559.03	242.00	1295.83	1.20
BUNDURE 7-2	3/06/2010 7:53	1299	1559.03	242.00	1285.83	1.17
BUNDURE 7-2	3/06/2010 12:15	1290	1559.65	242.20	1277.25	1.15
BUNDURE 7-2	3/06/2010 13:00	1289	1559.78	242.20	1276.38	1.15
BUNDURE 7-2	3/06/2010 22:34	1279	1560.68	242.20	1267.28	1.11

BUNDURE 7-2	4/06/2010 7:23	1269	1560.69	242.20	1257.29	1.08
BUNDURE 7-2	4/06/2010 9:14	1266	1560.74	242.20	1254.34	1.07
BUNDURE 7-2	4/06/2010 12:11	1259	1561.25	242.20	1247.85	1.06
BUNDURE 7-2	4/06/2010 22:50	1249	1562.28	242.20	1238.88	1.01
BUNDURE 7-2	5/06/2010 6:13	1241	1562.28	242.20	1230.88	0.98
BUNDURE 7-2	5/06/2010 7:56	1239	1562.29	242.20	1228.89	0.98
BUNDURE 7-2	5/06/2010 12:53	1229	1562.81	242.20	1219.41	0.96
BUNDURE 7-2	5/06/2010 21:55	1219	1563.58	242.20	1210.18	0.92
BUNDURE 7-2	6/06/2010 3:12	1214	1563.64	242.20	1205.24	0.90
BUNDURE 7-2	6/06/2010 8:31	1209	1563.69	242.20	1200.29	0.88
BUNDURE 7-2	6/06/2010 15:19	1199	1564.95	242.20	1191.55	0.85
BUNDURE 7-2	7/06/2010 0:11	1196	1565.24	242.20	1188.84	0.82
BUNDURE 7-2	7/06/2010 9:18	1189	1565.28	242.20	1181.88	0.78
BUNDURE 7-2	8/06/2010 2:01	1182	1566.46	242.20	1176.06	0.71
BUNDURE 7-2	8/06/2010 8:29	1179	1566.46	242.20	1173.06	0.69
BUNDURE 7-2	9/06/2010 0:39	1172	1567.55	242.40	1166.95	0.62
BUNDURE 7-2	9/06/2010 7:41	1169	1567.63	242.40	1164.03	0.59
BUNDURE 7-2	9/06/2010 21:38	1164	1568.29	243.40	1158.69	0.54
BUNDURE 7-2	10/06/2010 8:36	1159	1568.33	243.40	1153.73	0.50
BUNDURE 7-2	10/06/2010	1153	1569.63	243.40	1149.03	0.46
BUNDURE 7-2	11/06/2010 7:10	1149	1569.70	243.40	1145.10	0.40
BUNDURE 7-2	11/06/2010	1143	1570.54	243.40	1139.94	0.37
BUNDURE 7-2	12/06/2010 7:42	1139	1570.87	243.40	1136.27	0.31
BUNDURE 7-2	12/06/2010	1133	1571.42	243.40	1130.82	0.29
BUNDURE 7-2	13/06/2010 5:18	1129	1572.38	243.40	1127.78	0.22
BUNDURE 7-2	13/06/2010 9:34	1124	1572.40	243.40	1122.81	0.20
BUNDURE 7-2	13/06/2010	1119	1573.18	243.40	1118.58	0.19
BUNDURE 7-2	14/06/2010	1109	1574.47	243.40	1109.87	0.09
BUNDURE 7-2	15/06/2010 3:33	1108	1575.01	243.40	1109.41	0.04
BUNDURE 7-2	15/06/2010	1099	1575.75	243.40	1101.15	0.00
BUNDURE 7-2	16/06/2010 0:31	1100	1576.33	243.40	1102.73	-0.05
BUNDURE 7-2	16/06/2010	1091	1577.83	243.40	1095.23	-0.13
BUNDURE 7-2	17/06/2010	1091	1579.81	244.40	1096.22	-0.22
BUNDURE 7-2	18/06/2010	1091	1580.96	244.80	1096.96	-0.30
BUNDURE 7-2	19/06/2010	1091	1581.72	244.80	1097.72	-0.38
BUNDURE 7-2	20/06/2010 9:26	1091	1582.25	244.80	1098.25	-0.47
BUNDURE 7-2	21/06/2010 6:25	1091	1583.20	244.80	1099.20	-0.55
BUNDURE 7-2	22/06/2010 3:24	1091	1584.00	245.20	1099.60	-0.64
BUNDURE 7-2	23/06/2010 0:23	1091	1584.81	245.20	1100.41	-0.72
BUNDURE 7-2	23/06/2010	1091	1586.34	245.20	1101.94	-0.80
BUNDURE 7-2	24/06/2010	1091	1588.14	245.40	1103.54	-0.89
BUNDURE 7-2	25/06/2010	1091	1588.93	245.40	1104.33	-0.97
BUNDURE 7-2	26/06/2010	1091	1589.58	252.80	1097.58	-1.06
BUNDURE 7-2	27/06/2010 9:18	1091	1590.40	253.00	1098.20	-1.14
BUNDURE 7-2	28/06/2010 6:17	1091	1591.59	253.00	1099.39	-1.22

Table D.33 Detailed results of TUBBO-2 gauge in TUBBO-1, 2 pool illustrated in Figure 6.28

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-2	22/03/2012 10:49	1467.437	3470.78	1403.38	1467.44
TUBBO-2	22/03/2012 10:49	1467.437	3470.78	1403.38	1467.44
TUBBO-2	22/03/2012 12:01	1452.046	3471.05	1403.38	1452.31
TUBBO-2	22/03/2012 12:01	1452.046	3471.05	1403.38	1452.31
TUBBO-2	22/03/2012 13:11	1436.634	3471.38	1403.38	1437.23
TUBBO-2	22/03/2012 13:11	1436.634	3471.38	1403.38	1437.23
TUBBO-2	22/03/2012 14:23	1421.462	3471.93	1403.38	1422.62
TUBBO-2	22/03/2012 14:23	1421.462	3471.93	1403.38	1422.62
TUBBO-2	22/03/2012 15:49	1406.314	3472.49	1403.38	1408.02
TUBBO-2	22/03/2012 15:49	1406.314	3472.49	1403.38	1408.02
TUBBO-2	22/03/2012 17:08	1391.173	3472.80	1403.38	1393.19
TUBBO-2	22/03/2012 17:08	1391.173	3472.80	1403.38	1393.19
TUBBO-2	22/03/2012 18:34	1376.081	3473.12	1403.38	1378.42
TUBBO-2	22/03/2012 18:34	1376.081	3473.12	1403.38	1378.42
TUBBO-2	22/03/2012 20:04	1361.069	3473.22	1403.38	1363.52
TUBBO-2	22/03/2012 20:04	1361.069	3473.22	1403.38	1363.52
TUBBO-2	22/03/2012 21:32	1346.066	3473.24	1403.38	1348.53
TUBBO-2	22/03/2012 21:32	1346.066	3473.24	1403.38	1348.53
TUBBO-2	22/03/2012 23:04	1331.036	3473.24	1403.38	1333.50
TUBBO-2	22/03/2012 23:04	1331.036	3473.24	1403.38	1333.50
TUBBO-2	23/03/2012 0:40	1316.029	3473.24	1403.38	1318.49
TUBBO-2	23/03/2012 0:40	1316.029	3473.24	1403.38	1318.49
TUBBO-2	23/03/2012 2:15	1301.026	3473.24	1403.38	1303.49
TUBBO-2	23/03/2012 2:15	1301.026	3473.24	1403.38	1303.49
TUBBO-2	23/03/2012 3:54	1285.985	3473.24	1403.38	1288.45
TUBBO-2	23/03/2012 3:54	1285.985	3473.24	1403.38	1288.45
TUBBO-2	23/03/2012 5:28	1270.917	3473.24	1403.38	1273.38
TUBBO-2	23/03/2012 5:28	1270.917	3473.24	1403.38	1273.38
TUBBO-2	23/03/2012 7:22	1255.865	3473.25	1403.38	1258.34
TUBBO-2	23/03/2012 7:22	1255.865	3473.25	1403.38	1258.34
TUBBO-2	23/03/2012 8:27	1244.539	3473.26	1403.38	1247.03
TUBBO-2	23/03/2012 8:27	1244.539	3473.26	1403.38	1247.03
TUBBO-2	23/03/2012 8:37	1240.771	3473.26	1403.38	1243.26
TUBBO-2	23/03/2012 8:37	1240.771	3473.26	1403.38	1243.26
TUBBO-2	23/03/2012 10:37	1225.763	3473.40	1403.38	1228.39
TUBBO-2	23/03/2012 10:37	1225.763	3473.40	1403.38	1228.39
TUBBO-2	23/03/2012 11:23	1220.711	3473.58	1403.38	1223.51
TUBBO-2	23/03/2012 11:23	1220.711	3473.58	1403.38	1223.51
TUBBO-2	23/03/2012 11:58	1210.257	3473.68	1403.38	1213.16
TUBBO-2	23/03/2012 11:58	1210.257	3473.68	1403.38	1213.16
TUBBO-2	23/03/2012 14:00	1195.247	3474.09	1403.38	1198.56

TUBBO-2	23/03/2012 14:00	1195.247	3474.09	1403.38	1198.56
TUBBO-2	23/03/2012 16:44	1180.201	3474.61	1403.38	1184.03
TUBBO-2	23/03/2012 16:44	1180.201	3474.61	1403.38	1184.03
TUBBO-2	23/03/2012 19:49	1165.077	3474.97	1403.38	1169.26
TUBBO-2	23/03/2012 19:49	1165.077	3474.97	1403.38	1169.26
TUBBO-2	23/03/2012 22:24	1150.065	3474.98	1403.38	1154.27
TUBBO-2	23/03/2012 22:24	1150.065	3474.98	1403.38	1154.27
TUBBO-2	24/03/2012 1:24	1135.018	3474.99	1403.38	1139.23
TUBBO-2	24/03/2012 1:24	1135.018	3474.99	1403.38	1139.23
TUBBO-2	24/03/2012 4:41	1120.009	3475.00	1403.38	1124.23
TUBBO-2	24/03/2012 4:41	1120.009	3475.00	1403.38	1124.23
TUBBO-2	24/03/2012 7:59	1105.001	3475.01	1403.38	1109.23
TUBBO-2	24/03/2012 7:59	1105.001	3475.01	1403.38	1109.23
TUBBO-2	24/03/2012 10:46	1089.541	3475.30	1403.38	1094.06
TUBBO-2	24/03/2012 10:46	1089.541	3475.30	1403.38	1094.06
TUBBO-2	24/03/2012 14:19	1074.429	3476.08	1403.38	1079.73
TUBBO-2	24/03/2012 14:19	1074.429	3476.08	1403.38	1079.73
TUBBO-2	24/03/2012 22:28	1059.397	3476.85	1403.38	1065.47
TUBBO-2	24/03/2012 22:28	1059.397	3476.85	1403.38	1065.47
TUBBO-2	25/03/2012 7:57	1044.347	3476.85	1403.38	1050.42
TUBBO-2	25/03/2012 7:57	1044.347	3476.85	1403.38	1050.42
TUBBO-2	25/03/2012 14:11	1029.166	3478.19	1403.38	1036.57
TUBBO-2	25/03/2012 14:11	1029.166	3478.19	1403.38	1036.57
TUBBO-2	26/03/2012 0:26	1014.126	3479.73	1403.38	1023.08
TUBBO-2	26/03/2012 0:26	1014.126	3479.73	1403.38	1023.08
TUBBO-2	26/03/2012 4:11	999.1128	3479.73	1403.38	1008.07
TUBBO-2	26/03/2012 4:11	999.1128	3479.73	1403.38	1008.07

Table D.34 Detailed results of 591/2 farm outlet in BUNDURE MAIN 13, 14 pool illustrated in Figure 6.29, 30, 31

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)	Seepage (mm/hr)
591/2	23/09/2009 18:27	1544	152.6940193	0	1544	3.4686
591/2	23/09/2009 21:44	1534	152.8073293	0	1534.11	3.423951
591/2	23/09/2009 23:46	1524	152.8432943	0	1524.15	3.396289
591/2	24/09/2009 1:59	1514	152.8700374	0	1514.18	3.366151
591/2	24/09/2009 4:28	1504	152.8883214	0	1504.19	3.332369
591/2	24/09/2009 6:57	1494	152.8993545	0	1494.21	3.2986
591/2	24/09/2009 7:32	1491	152.9049114	0	1491.21	3.290671
591/2	24/09/2009 8:34	1488	152.9970914	0	1488.3	3.276609
591/2	24/09/2009 8:39	1487	153.0981602	0	1487.4	3.27548
591/2	24/09/2009 8:54	1484	153.0981602	0	1484.4	3.27208
591/2	24/09/2009 11:36	1474	154.0572514	0	1475.36	3.23536
591/2	24/09/2009 14:21	1464	155.0672752	0	1466.37	3.19796
591/2	24/09/2009 17:22	1454	156.0702913	0	1457.38	3.156929

591/2	24/09/2009 20:17	1444	156.2400469	0	1447.55	3.117271
591/2	24/09/2009 22:52	1434	156.2585223	0	1437.56	3.082129
591/2	25/09/2009 1:58	1424	156.2612373	0	1427.57	3.039969
591/2	25/09/2009 2:31	1422	156.2612373	0	1425.57	3.032489
591/2	25/09/2009 5:09	1414	156.2667164	0	1417.57	2.99668
591/2	25/09/2009 8:40	1404	156.6122564	0	1407.92	2.948849
591/2	25/09/2009 11:12	1394	157.7802292	0	1399.09	2.9144
591/2	25/09/2009 14:03	1384	159.2621917	0	1390.57	2.87564
591/2	25/09/2009 16:46	1373	160.4155478	0	1380.72	2.838689
591/2	25/09/2009 20:09	1362	161.1882239	0	1370.49	2.79268
591/2	25/09/2009 20:11	1351	161.1882239	0	1359.49	2.792231
591/2	25/09/2009 20:14	1341	161.1882239	0	1349.49	2.791551
591/2	25/09/2009 20:21	1352	161.1882239	0	1360.49	2.78996
591/2	25/09/2009 20:25	1363	161.1882239	0	1371.49	2.789049
591/2	25/09/2009 21:30	1362	161.2360873	0	1370.54	2.77432
591/2	26/09/2009 0:33	1353	161.2941176	0	1361.6	2.73284
591/2	26/09/2009 3:00	1343	161.3346271	0	1351.64	2.69952
591/2	26/09/2009 7:09	1333	161.4526571	0	1341.76	2.64308
591/2	26/09/2009 9:30	1322	161.6887771	0	1330.99	2.61112
591/2	26/09/2009 12:34	1312	162.2901786	0	1321.6	2.569409
591/2	26/09/2009 12:49	1323	162.3964636	0	1332.7	2.566009
591/2	26/09/2009 13:52	1312	162.6754295	0	1321.98	2.551729
591/2	26/09/2009 14:43	1302	162.9466036	0	1312.25	2.540169
591/2	26/09/2009 14:53	1313	162.9466036	0	1323.25	2.537911
591/2	26/09/2009 16:17	1303	163.2144443	0	1313.52	2.518871
591/2	26/09/2009 16:29	1304	163.2144443	0	1314.52	2.516151
591/2	26/09/2009 20:33	1293	163.5658366	0	1303.87	2.46084
591/2	27/09/2009 1:29	1282	163.6613683	0	1292.97	2.393751
591/2	27/09/2009 5:49	1272	163.6970008	0	1283	2.334809
591/2	27/09/2009 8:13	1262	163.8130018	0	1273.12	2.302169
591/2	27/09/2009 10:09	1252	164.2177131	0	1263.52	2.27588
591/2	27/09/2009 11:28	1255	164.4825466	0	1266.79	2.257969
591/2	27/09/2009 14:31	1242	165.40876	0	1254.71	2.216489
591/2	27/09/2009 17:09	1231	166.2234647	0	1244.53	2.18068
591/2	27/09/2009 17:48	1242	166.3235597	0	1255.63	2.17184
591/2	27/09/2009 22:08	1232	166.5950674	0	1245.9	2.112911
591/2	28/09/2009 3:34	1221	166.6782574	0	1234.98	2.039009
591/2	28/09/2009 6:27	1215	166.6956874	0	1229	1.9998
591/2	28/09/2009 7:14	1211	166.7219274	0	1225.03	1.989151
591/2	28/09/2009 12:05	1201	167.8215044	0	1216.13	1.923191
591/2	28/09/2009 18:20	1191	169.9778078	0	1208.28	1.838191
591/2	29/09/2009 0:34	1181	170.0707649	0	1198.38	1.753409
591/2	29/09/2009 1:26	1180	170.0707649	0	1197.38	1.741631
591/2	29/09/2009 6:10	1171	170.0707649	0	1188.38	1.677249
591/2	29/09/2009 10:16	1161	170.7139119	0	1179.02	1.621489

591/2	29/09/2009 16:54	1151	173.2228137	0	1171.53	1.53128
591/2	29/09/2009 23:11	1141	173.4055767	0	1161.71	1.445831
591/2	30/09/2009 6:05	1131	173.4311079	0	1151.74	1.351991
591/2	30/09/2009 11:19	1121	174.8327853	0	1143.14	1.280809
591/2	30/09/2009 18:12	1114	178.0766433	0	1139.38	1.1872
591/2	30/09/2009 21:10	1111	178.2489729	0	1136.55	1.146849
591/2	1/10/2009 10:32	1101	179.3567376	0	1127.66	0.965071
591/2	1/10/2009 13:11	1096	180.8945526	0	1124.2	0.929031
591/2	2/10/2009 6:06	1091	184.000634	0	1122.31	0.69896
591/2	2/10/2009 8:10	1089	184.132339	0	1120.44	0.670849
591/2	2/10/2009 16:16	1081	186.7322443	0	1115.04	0.560689
591/2	3/10/2009 3:09	1082	186.9692585	0	1116.28	0.41268
591/2	3/10/2009 22:08	1080	188.1992323	0	1115.51	0.154511
591/2	4/10/2009 13:58	1071	189.6364388	0	1107.94	-0.06083
591/2	4/10/2009 18:07	1072	190.3382616	0	1109.64	-0.11727
591/2	5/10/2009 12:01	1061	191.6831813	0	1099.99	-0.36071
591/2	5/10/2009 13:06	1061	192.1094013	0	1100.42	-0.37544
591/2	6/10/2009 8:05	1051	194.8992029	0	1093.21	-0.63361
591/2	6/10/2009 16:42	1040	197.590378	0	1084.9	-0.7508
591/2	6/10/2009 17:38	1050	197.988738	0	1095.29	-0.76349
591/2	7/10/2009 3:04	1042	198.5838758	0	1087.89	-0.89179
591/2	7/10/2009 7:27	1040	198.6088796	0	1085.91	-0.9514

Table D.35 Detailed results of TUBBO-11 gauge in TUBBO-10, 11 pool during the 3rd pondage condition illustrated in Figure 6.32

Gate name	Date	Measured el. (mm)	Estimated evaporation	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-11	27/11/2009 12:52	1617	515.78	27.00	1597.37
TUBBO-11	27/11/2009 18:52	1614	518.89	27.00	1597.48
TUBBO-11	28/11/2009 1:48	1607	519.56	27.00	1591.14
TUBBO-11	28/11/2009 13:36	1597	522.22	27.00	1583.81
TUBBO-11	28/11/2009 20:59	1587	525.87	27.00	1577.46
TUBBO-11	29/11/2009 9:02	1587	526.38	27.00	1577.97
TUBBO-11	30/11/2009 4:07	1579	529.94	28.80	1571.73
TUBBO-11	30/11/2009 6:56	1577	530.04	28.80	1569.83
TUBBO-11	30/11/2009 20:54	1567	534.89	29.60	1563.88
TUBBO-11	30/11/2009 23:12	1567	534.96	29.60	1563.94
TUBBO-11	1/12/2009 12:47	1557	537.12	29.60	1556.11
TUBBO-11	1/12/2009 18:17	1554	540.32	29.60	1556.31
TUBBO-11	2/12/2009 8:36	1546	541.52	29.60	1549.51
TUBBO-11	2/12/2009 13:23	1541	543.72	29.60	1546.71
TUBBO-11	2/12/2009 19:45	1536	546.73	29.60	1544.72
TUBBO-11	3/12/2009 12:28	1526	551.80	29.60	1539.79
TUBBO-11	3/12/2009 20:41	1516	556.95	29.60	1534.93
TUBBO-11	4/12/2009 14:29	1506	561.73	29.60	1529.72
TUBBO-11	4/12/2009 15:58	1505	562.91	29.60	1529.90

TUBBO-11	5/12/2009 9:24	1496	566.17	29.60	1524.16
TUBBO-11	5/12/2009 11:03	1495	566.78	29.60	1523.77
TUBBO-11	6/12/2009 6:06	1486	572.56	29.60	1520.54
TUBBO-11	7/12/2009 1:06	1476	578.50	29.60	1516.48
TUBBO-11	7/12/2009 13:55	1466	581.66	29.60	1509.65
TUBBO-11	7/12/2009 20:18	1465	585.54	29.60	1512.53
TUBBO-11	8/12/2009 11:29	1455	587.34	29.60	1504.33
TUBBO-11	8/12/2009 15:23	1451	589.58	29.60	1502.57
TUBBO-11	9/12/2009 10:28	1455	590.75	36.00	1501.34
TUBBO-11	10/12/2009 5:33	1448	594.57	36.00	1498.15
TUBBO-11	10/12/2009 9:43	1445	595.29	36.20	1495.68
TUBBO-11	10/12/2009 15:12	1435	597.97	36.20	1488.36
TUBBO-11	11/12/2009 0:38	1436	600.39	36.20	1491.77
TUBBO-11	11/12/2009 15:29	1425	604.15	36.20	1484.54
TUBBO-11	11/12/2009 19:43	1427	606.40	36.20	1488.78
TUBBO-11	12/12/2009 14:48	1419	610.01	36.20	1484.40
TUBBO-11	12/12/2009 16:54	1415	611.30	36.20	1481.69
TUBBO-11	13/12/2009 9:53	1414	614.07	36.20	1483.45
TUBBO-11	13/12/2009 17:10	1405	618.46	36.20	1478.85
TUBBO-11	14/12/2009 4:58	1404	620.50	36.20	1479.89
TUBBO-11	14/12/2009 9:26	1402	620.84	36.20	1478.23

Table D.36 Detailed results of TUBBO-11 gauge in TUBBO-10, 11 pool during the last pondage condition illustrated in Figure 6.32

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-11	27/05/2010 18:23	1622	1389.709	246.7991	1622
TUBBO-11	28/05/2010 5:43	1618	1389.74	246.7991	1618.031
TUBBO-11	28/05/2010 15:23	1617	1390.468	246.9991	1617.559
TUBBO-11	29/05/2010 12:21	1621	1391.027	259.1991	1609.918
TUBBO-11	30/05/2010 9:20	1615	1391.521	261.5991	1602.012
TUBBO-11	31/05/2010 6:20	1608	1392.275	261.5991	1595.766
TUBBO-11	31/05/2010 7:24	1608	1392.292	261.5991	1595.782
TUBBO-11	1/06/2010 3:18	1600	1394.002	262.1992	1588.892
TUBBO-11	1/06/2010 9:43	1597	1394.11	262.3992	1585.801
TUBBO-11	2/06/2010 0:17	1592	1395.354	262.3992	1582.045
TUBBO-11	2/06/2010 10:13	1587	1395.495	262.3992	1577.186
TUBBO-11	2/06/2010 21:16	1584	1396.789	262.3992	1575.48
TUBBO-11	3/06/2010 15:21	1577	1398.165	262.3992	1569.855
TUBBO-11	3/06/2010 18:15	1577	1398.488	262.3992	1570.179
TUBBO-11	4/06/2010 15:14	1568	1399.936	262.3992	1562.627
TUBBO-11	4/06/2010 15:53	1567	1400.034	262.3992	1561.725
TUBBO-11	5/06/2010 12:13	1559	1400.687	262.5992	1554.178
TUBBO-11	5/06/2010 14:01	1557	1401.008	262.5992	1552.499
TUBBO-11	6/06/2010 9:12	1553	1401.78	262.5992	1549.271
TUBBO-11	7/06/2010 6:11	1548	1403.332	262.5992	1545.823

TUBBO-11	7/06/2010 8:03	1547	1403.335	262.5992	1544.825
TUBBO-11	8/06/2010 8:01	1539	1404.525	262.7992	1537.816
TUBBO-11	8/06/2010 10:11	1537	1404.642	262.7992	1535.933
TUBBO-11	9/06/2010 6:39	1532	1405.753	262.7992	1532.044
TUBBO-11	9/06/2010 14:31	1527	1406.045	264.3993	1525.736
TUBBO-11	10/06/2010 3:38	1527	1406.472	264.3993	1526.162
TUBBO-11	11/06/2010 0:37	1522	1407.777	265.5993	1521.268
TUBBO-11	11/06/2010 8:25	1517	1407.843	265.5993	1516.334
TUBBO-11	11/06/2010 21:36	1515	1408.898	265.7993	1515.189
TUBBO-11	12/06/2010 12:24	1507	1409.521	265.7993	1507.811
TUBBO-11	12/06/2010 18:35	1507	1410.543	265.7993	1508.834
TUBBO-11	13/06/2010 15:34	1500	1411.543	265.7993	1502.834
TUBBO-11	14/06/2010 8:32	1497	1411.693	265.7993	1499.984
TUBBO-11	14/06/2010 12:33	1495	1412.126	265.7993	1498.417
TUBBO-11	15/06/2010 9:32	1490	1412.858	265.7993	1494.148
TUBBO-11	15/06/2010 13:12	1487	1413.475	265.7993	1491.766
TUBBO-11	16/06/2010 6:31	1485	1414	265.7993	1490.291
TUBBO-11	17/06/2010 3:08	1477	1415.779	265.7993	1484.07
TUBBO-11	17/06/2010 11:52	1467	1416.534	266.9994	1473.624
TUBBO-11	17/06/2010 13:30	1455	1417.007	266.9994	1462.097
TUBBO-11	17/06/2010 13:48	1465	1417.109	266.9994	1472.199
TUBBO-11	17/06/2010 16:38	1475	1417.555	266.9994	1482.645
TUBBO-11	18/06/2010 0:29	1475	1417.712	266.9994	1482.802
TUBBO-11	18/06/2010 21:28	1470	1419.021	266.9994	1479.112
TUBBO-11	19/06/2010 6:11	1465	1419.134	266.9994	1474.224
TUBBO-11	19/06/2010 18:27	1463	1420.139	266.9994	1473.23
TUBBO-11	20/06/2010 15:26	1457	1420.913	267.5994	1467.404
TUBBO-11	21/06/2010 8:28	1455	1421.066	267.5994	1465.557
TUBBO-11	21/06/2010 12:25	1454	1421.33	267.7994	1464.62
TUBBO-11	22/06/2010 9:24	1451	1421.82	267.7994	1462.11
TUBBO-11	22/06/2010 12:58	1445	1422.045	267.7994	1456.336
TUBBO-11	23/06/2010 6:23	1445	1422.654	267.7994	1456.945
TUBBO-11	24/06/2010 2:39	1435	1424.018	267.7994	1448.308
TUBBO-11	24/06/2010 3:22	1440	1424.025	267.7994	1453.315
TUBBO-11	25/06/2010 0:21	1437	1425.633	267.9994	1451.724
TUBBO-11	25/06/2010 21:20	1439	1426.276	267.9994	1454.367
TUBBO-11	26/06/2010 18:19	1434	1427.613	276.3997	1442.303
TUBBO-11	27/06/2010 15:18	1427	1428.648	276.5997	1436.138
TUBBO-11	28/06/2010 9:29	1425	1428.873	276.5997	1434.364
TUBBO-11	28/06/2010 12:17	1422	1429.229	276.5997	1431.719

Table D.37 Detailed results of TUBBO-11 gauge in TUBBO-10, 11 pool during the 8th pondage condition illustrated in Figure 6.32

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
TUBBO-11	20/01/2010 10:18	1668	870.49	61.40	1668.00
TUBBO-11	20/01/2010 12:43	1658	871.98	61.40	1659.49
TUBBO-11	20/01/2010 14:05	1658	873.07	61.40	1660.58
TUBBO-11	20/01/2010 17:01	1648	875.32	61.40	1652.83
TUBBO-11	21/01/2010 4:48	1638	877.72	61.40	1645.23
TUBBO-11	21/01/2010 11:39	1628	878.82	61.40	1636.33
TUBBO-11	21/01/2010 17:21	1618	882.64	61.40	1630.15
TUBBO-11	22/01/2010 4:24	1607	885.08	61.40	1621.59
TUBBO-11	22/01/2010 5:11	1609	885.20	61.40	1623.71
TUBBO-11	22/01/2010 11:28	1597	887.36	61.40	1613.87
TUBBO-11	22/01/2010 15:33	1587	892.64	61.40	1609.16
TUBBO-11	23/01/2010 1:30	1577	895.12	61.40	1601.64
TUBBO-11	23/01/2010 4:15	1570	895.64	61.40	1595.15
TUBBO-11	23/01/2010 7:41	1567	896.08	61.40	1592.60
TUBBO-11	23/01/2010 15:25	1557	900.04	61.40	1586.55
TUBBO-11	23/01/2010 23:28	1553	903.70	61.40	1586.21
TUBBO-11	24/01/2010 6:57	1547	903.88	61.40	1580.40

Table D.38 Detailed results of 2026/1 farm outlet in TUBBO 4OT, 2026 pool during the 7th pondage condition illustrated in Figure 6.33

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2026/1	21/12/2011 19:49	1739.07	3006.76	1187.40	1739.07
2026/1	22/12/2011 11:47	1729.92	3008.32	1187.40	1731.48
2026/1	22/12/2011 11:49	1731.48	3008.56	1187.40	1733.29
2026/1	22/12/2011 14:51	1727.07	3009.87	1187.40	1730.19
2026/1	22/12/2011 19:33	1724.17	3011.53	1187.40	1728.94

Table D.39 Detailed results of 2026/1 farm outlet in TUBBO 4OT, 2026 pool during the 9th pondage condition illustrated in Figure 6.33

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2026/1	18/03/2012 11:47	1748.52	3457.85	1403.38	1748.52
2026/1	19/03/2012 11:32	1730.69	3461.51	1403.38	1734.35
2026/1	20/03/2012 3:27	1715.13	3464.61	1403.38	1721.88
2026/1	21/03/2012 3:12	1699.52	3467.89	1403.38	1709.56
2026/1	22/03/2012 2:57	1683.76	3470.42	1403.38	1696.32

2026/1	23/03/2012 2:43	1668.78	3473.24	1403.38	1684.17
2026/1	24/03/2012 2:27	1653.97	3474.99	1403.38	1671.12
2026/1	25/03/2012 2:12	1642.09	3476.85	1403.38	1661.09
2026/1	26/03/2012 4:44	1628.53	3479.73	1403.38	1650.41
2026/1	27/03/2012 4:29	1616.09	3482.91	1403.38	1641.15
2026/1	28/03/2012 4:14	1604.06	3484.87	1403.38	1631.08
2026/1	29/03/2012 3:59	1592.52	3487.97	1403.38	1622.64
2026/1	30/03/2012 3:44	1581.48	3490.52	1403.38	1614.15
2026/1	31/03/2012 3:29	1569.74	3493.50	1403.38	1605.39
2026/1	1/04/2012 2:14	1558.16	3496.26	1403.38	1596.57
2026/1	2/04/2012 1:59	1548.78	3498.36	1403.38	1589.29
2026/1	3/04/2012 1:44	1537.40	3501.20	1403.58	1580.55
2026/1	4/04/2012 1:29	1525.52	3504.19	1403.58	1571.66
2026/1	5/04/2012 1:14	1514.37	3506.92	1403.58	1563.24
2026/1	6/04/2012 0:08	1503.97	3509.62	1403.58	1555.53
2026/1	6/04/2012 23:53	1490.81	3512.66	1403.58	1545.42
2026/1	7/04/2012 23:38	1479.58	3515.06	1403.58	1536.59
2026/1	8/04/2012 23:23	1467.91	3518.15	1403.58	1528.01
2026/1	9/04/2012 23:08	1456.20	3521.14	1403.58	1519.29
2026/1	10/04/2012 22:53	1444.38	3524.43	1403.58	1510.75
2026/1	11/04/2012 22:38	1434.75	3526.91	1403.58	1503.61
2026/1	12/04/2012 22:23	1423.91	3529.51	1403.58	1495.36
2026/1	13/04/2012 22:08	1414.11	3532.15	1403.58	1488.21
2026/1	14/04/2012 21:53	1405.92	3533.67	1403.58	1481.53

Table D.40 Detailed results of 2026/1 farm outlet in TUBBO 4OT, 2026 pool during the 1st pondage condition illustrated in Figure 6.33

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2026/1	20/08/2011 21:40	1753.24	2470.67	1074.02	1753.24
2026/1	21/08/2011 20:32	1741.85	2472.57	1074.02	1743.76
2026/1	22/08/2011 19:24	1732.51	2474.48	1074.02	1736.33
2026/1	24/08/2011 2:47	1720.08	2476.61	1074.02	1726.02
2026/1	25/08/2011 1:45	1712.20	2478.69	1074.02	1720.22
2026/1	26/08/2011 4:41	1702.01	2483.90	1074.02	1715.24
2026/1	27/08/2011 3:55	1693.24	2486.09	1074.02	1708.66
2026/1	28/08/2011 3:09	1685.00	2488.27	1074.02	1702.60
2026/1	29/08/2011 2:23	1677.02	2490.17	1074.02	1696.53
2026/1	30/08/2011 1:37	1669.46	2492.29	1074.02	1691.08
2026/1	31/08/2011 0:51	1661.13	2494.56	1074.02	1685.02

2026/1	1/09/2011 0:05	1653.74	2496.96	1074.02	1680.03

Table D.41 Detailed results of 2026/1 farm outlet in TUBBO 4OT, 2026 pool during the 10th pondage condition illustrated in Figure 6.34

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2026/1	16/04/2012 22:02	1530.23	3539.12	1403.58	1530.23
2026/1	17/04/2012 21:51	1519.86	3541.95	1403.58	1522.69
2026/1	18/04/2012 21:40	1509.74	3544.50	1403.58	1515.13
2026/1	19/04/2012 21:29	1505.90	3545.84	1406.38	1509.83
2026/1	20/04/2012 21:05	1497.36	3547.88	1407.98	1501.73
2026/1	21/04/2012 20:54	1487.46	3550.17	1407.98	1494.12
2026/1	22/04/2012 20:43	1479.02	3552.36	1409.18	1486.66
2026/1	23/04/2012 22:09	1468.67	3555.13	1409.18	1479.08
2026/1	24/04/2012 21:58	1458.31	3557.05	1409.38	1470.44
2026/1	25/04/2012 21:48	1446.44	3558.84	1410.18	1459.57
2026/1	26/04/2012 21:38	1438.63	3560.51	1410.18	1453.42
2026/1	27/04/2012 21:28	1429.80	3562.74	1410.38	1446.63
2026/1	28/04/2012 21:18	1419.73	3565.08	1410.38	1438.90
2026/1	29/04/2012 21:08	1411.71	3567.75	1410.38	1433.55
2026/1	30/04/2012 20:58	1401.01	3569.65	1410.38	1424.74
2026/1	1/05/2012 20:48	1391.37	3572.17	1410.38	1417.63
2026/1	2/05/2012 20:38	1384.16	3574.10	1410.38	1412.34
2026/1	4/05/2012 2:56	1373.78	3576.17	1410.38	1404.04
2026/1	5/05/2012 2:47	1334.46	3578.13	1410.38	1366.68
2026/1	6/05/2012 2:39	1330.93	3580.20	1410.38	1365.22
2026/1	7/05/2012 2:31	1335.87	3582.21	1410.38	1372.16
2026/1	8/05/2012 2:23	1331.58	3583.83	1411.18	1368.70
2026/1	9/05/2012 2:15	1327.19	3586.47	1411.18	1366.95

Table D.42 Detailed results of 2026/1 farm outlet in TUBBO 4OT, 2026 pool during the last pondage condition illustrated in Figure 6.34

Gate name	Date	Measured el. (mm)	Estimated evaporation (mm)	Accumulative rainfall(mm)	Corrected el. (mm)
2026/1	22/05/2012 0:32	1598.03	3612.02	1411.18	1598.03
2026/1	23/05/2012 0:23	1587.74	3614.00	1411.18	1589.73
2026/1	24/05/2012 0:16	1577.42	3616.68	1411.18	1582.08
2026/1	25/05/2012 0:08	1570.96	3617.37	1411.18	1576.32
2026/1	25/05/2012 23:59	1565.25	3618.03	1414.78	1567.67
2026/1	26/05/2012 23:51	1557.59	3618.71	1416.38	1559.09
2026/1	27/05/2012 23:43	1548.34	3620.15	1416.58	1551.08
2026/1	29/05/2012 0:03	1539.03	3621.61	1416.58	1543.22
2026/1	29/05/2012 23:58	1529.82	3623.19	1416.58	1535.59
2026/1	30/05/2012 23:51	1520.68	3624.66	1416.58	1527.92
2026/1	31/05/2012 23:46	1511.46	3626.26	1416.58	1520.30
2026/1	1/06/2012 23:39	1503.06	3627.67	1416.58	1513.32
2026/1	2/06/2012 23:33	1494.41	3629.01	1416.58	1506.00
2026/1	3/06/2012 23:28	1486.61	3630.15	1416.58	1499.34
2026/1	4/06/2012 23:22	1474.96	3631.84	1416.58	1489.39
2026/1	5/06/2012 23:16	1471.43	3633.03	1420.40	1483.22
2026/1	6/06/2012 23:10	1463.87	3634.72	1420.40	1477.35
2026/1	7/06/2012 23:03	1455.29	3636.16	1420.60	1470.02
2026/1	8/06/2012 22:57	1447.05	3637.57	1420.60	1463.18
2026/1	9/06/2012 22:51	1438.64	3638.95	1420.60	1456.15
2026/1	10/06/2012 22:45	1430.65	3640.36	1420.60	1449.57
2026/1	11/06/2012 22:39	1422.23	3642.04	1420.60	1442.83

APPENDIX E

Analysis of all averaged pool estimate seepage rates in different main channels

Table E.1 Analysis of pool based seepage rates in ARGOON main channel

POOL ID	2009 Pool Seepage (mm/d)	2009 No of Pondage	2009 Higher Seepage (mm/d)	2009 Elevation (mm)	2010 Pool Seepage (mm/d)	2010 No of Pondage	2010 Higher Seepage (mm/d)	2010 Elevation (mm)	2011 Pool Seepage (mm/d)	2011 No of Pondage	2011 Higher Seepage (mm/d)	2011 Elevation (mm)	Full Supply el. (mm)
1					-24.7	1	-24.7	1673	-8.8	1	-8.8	1683	1750
2					-8.7	1	-8.7	1557	-7.5	1	-7.5	1603	1702
3									-8.7	3	-9.4	1650	1708
4									-4.9	2	-4.9	1682	1710
5	-7.0	1	-7.0	1615					-7.4	1	-7.4	1681	1742
7					-5.4	11	-5.5	1685	-4.4	6	-4.8	1689	1700
8					-10.1	1	-10.1	1330					1619
10					-7.4	1	-7.4	1479					1650
11					-7.6	2	-10.1	1314					1441
12					-16.5	1	-16.5	1623					1677
14									-5.9	3			
15	-26.5	1	-26.5	1559	-8.3	1	-8.3	1447	-8.9	8	-9.4	1577	1719
16	-17.8	9	-36.0	1662	-16.1	4	-20.4	1663	-6.6	3	-6.6	1648	1887
17	-18.4	3	-22.1	1687	-15.2	5	-36.3	1655	-8.5	5	-8.4	1593	1721
18					-8.2	1	-8.2	1216					1723
19					-5.7	1	-5.7	1496	-14.1	2	-24.5	1554	1655
20					-3.2	1	-3.2	1144					1526
Averaged Seepage (mm/d)	**-17.4**		**-22.9**		**-10.5**		**-12.7**		**-7.8**		**-9.2**		
Max	**-26.5**		**-36.0**		**-24.7**		**-36.3**		**-8.9**		**-24.5**		
Min	**-7.0**		**-7.0**		**-3.2**		**-3.2**		**-4.4**		**-4.8**		

Table E.2 Analysis of pool based seepage rates in BOONA main channel

POOL ID	2009				2010				2011				Full Supply el. (mm)
	pool seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	pool seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	pool seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	
1	-6.2	1	-6.2	1280									1539
3					-3.0	1	-3.0	1470	-3.9	2	-5.8	1484	1615
4									-4.5	2	-5.5	1416	1605
5	-4.3	3	-8.9	1667	-5.5	7	-9.8	1650	-4.8	7	-5.2	1689	1774
6					-4.7	1	-4.7	1299	-4.3	1	-4.3	1698	1766
7	-5.9	4	-5.5	1510	-4.4	8	-8.2	1588	-6.7	3	-8.9	1593	1670
8	-5.7	18	-8.6	1586	-5.3	16	-11.3	1592					1592
9									-6.9	1	-6.9	1587	1685
10									-5.5	1	-5.5	1513	1628
11									-9.0	2	-11.0	1662	1734
13					-7.6	3	-13.0	1598	-7.3	1	-7.3	1632	1803
14									-7.5	2	-7.5	1658	1710
16	-12.7	2	-16.1	1584	-10.6	7	-11.5	1642	-7.5	2	-8.6	1577	1692
20	-9.1	1	-9.1	1505	-11.0	9	-15.0	1553	-7.9	6	-8.4	1517	1586
21					-7.0	1	-7.0	1151					1820
22	-5.1	1	-5.1	1552	-8.1	9	-12.0	1719	-8.1	7	-8.6	1703	1740
23	-10.4	2	-16.6	1600	-11.5	5	-13.0	1600					1691
24					-8.8	1	-8.8	1182					1351
25	-6.4	5	-12.0	1631	-6.3	11	-16.1	1617					1804
26	-5.2	25	-9.4	1645	-3.4	42	-5.8	1625	-4.8	12	-6.2	1658	1690
28	-6.5	3	-13.9	1631	-20.7	11	-28.1	1691	-14.4	1	-14.4	1600	1820
Averaged Seepage (mm/d)	**-7.1**		**-10.1**		**-7.9**		**-11.1**		**-6.9**		**-7.6**		
Max	**-12.7**		**-16.6**		**-20.7**		**-28.1**		**-14.4**		**-14.4**		
Min	**-4.3**		**-5.1**		**-3.0**		**-3.0**		**-3.9**		**-4.3**		

Table E.3 Analysis of pool based seepage rates in BUNDURE main channel

POOL ID	2009				2010				2011				Full Supply el. (mm)
	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	
1	-13.1	6	-25.5	1670	-11.9	2	-11.9	1656	-12.8	3	-13.7	1668	1760
2	-59.5	3	-87.6	1647	-8.8	5	-11.3	1674					1770
3	-8.4	1	-8.4	1199	-3.1	1	-3.1	1129					1509
4	-5.5	5	-5.3	1315	-5.3	7	-8.6	1305					1487
5	-4.9	6	-5.3	1568	-3.9	5	-4.8	1660					1735
6	-14.6	10	-25.2	1645	-5.8	7	-10.6	1625	-7.4	3	-9.4	1620	1708
7	-7.5	1	-7.5	1154	-1.9	1	-1.9	1139					1538
8	-5.0	2	-6.0	1101									1567
9	-3.6	2	-3.6	1252	-2.8	1	-2.8	1222	-11.5	1	-11.5	1384	1499
10	-5.9	2	-6.0	1347	-4.8	1	-4.8	1195	-50.8	1	-50.8	1499	1627
11	-12.1	1	-12.1	1546	-8.3	1	-8.3	1276					1576
12	-3.0	1	-3.0	1311	-1.9	1	-1.9	1246	-6.4	1	-6.4	1510	1582
13	-4.1	4	-4.8	1497	-2.8	1	-2.8	1145					1567
14	-4.9	5	-5.8	1594	-3.1	2	-6.5	1588					1764
15	-23.4	7	-37.9	1677	-22.8	2	-24.5	1616					1776
16					-7.1	10	-15.8	1593					1645
17													
18	-21.0	1	-21.0	1619									1665
19	-15.5	4	-27.4	1385	-13.9	5	-15.4	1350	-6.4	2	7.9	1428	1434
20	-2.4	6	-2.6	1485	-2.1	2	-2.2	1573	-3.7	2	-4.6	1521	1653
21	-4.7	3	-4.8	1481	-5.8	9	-5.5	1522	-3.2	4	-5.3	1494	1658
22	-16.8	3	-25.4	1589	-13.8	8	-17.3	1650	-20.9	5	-31.2	1380	1780
23	-1.7	1	-1.7	1560	-5.3	1	-5.3	1527					1720
24									-3.5	1	-3.5		1620
25													
26	-8.1	1	-8.1	1501	-8.7	2	-8.9	1517	-3.8	1	-3.8	1505	1597
27													
28													

29									-3.8	1	-3.8	1540	1750
30													
31	-5.3	1	-5.3	1339	-5.0	2	-8.9	1334					1620
32					-9.9	1	-9.9	1331					1663
33	-14.3	5	-19.2	1625	-20.2	3	-20.2	1657	-9.2	13	-10.3	1663	1705
34	-14.4	1	-14.4	1385	-8.3	2	-8.6	1090	-8.2	1	-8.2	1446	1544
35	-13.3	1	-13.3	1521	-11.5	2	-11.5	1613	-8.2	1	-8.2	1553	1670
36	-5.2	6	-5.3	1577					-4.1	1	-4.1	1638	1695
37													
38					-2.7	1	-2.7	1248	-8.9	2	-8.9	1643	1724
39	-29.3	6	-34.6	1590	-17.5	4	-19.0	1602					1698
40	-24.2	4	-25.7	1561	-15.4	5	-16.3	1704					1726
41	-9.3	4	-11.8	1660	-13.0	10	-27.4	1665					1700
42					-40.9	3	-56.9	1598					1708
43	-19.5	1	-19.5	1479	-9.7	2	-18.7	1571					1691
44									-16.8	1	-16.8	1395	1845
45					-23.5	2	-49.9	1623	-26.1	1	-26.1	1632	1752
46	-12.5	5	-16.3	1487	-8.0	4	-10.6	1554	-6.0	3	-9.6	1561	1698
47	-9.2	2	-36.7	1467	-1.5	6	-1.4	1539					1613
48	-23.3	4	-96.0	1625	-8.2	14	-31.2	1626					1757
Averaged (mm/d)	**-12.5**		**-18.6**		**-9.4**		**-13.0**		**-11.1**		**-11.4**		
Max	**-59.5**		**-96.0**		**-40.9**		**-56.9**		**-50.8**		**-50.8**		
Min	**-1.7**		**-1.7**		**-1.5**		**-1.4**		**-3.2**		**7.9**		

Table E.4 Analysis of pool based seepage rates in COLY main channel

POOL	2009				2010				2011				Full
ID	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Supply el. (mm)
1	-9.0	7	-15.4	1713	-8.6	13	-10.8	1692	-13.2	13	-23.4	1715	1738
2	-5.2	2	-5.8	1625	-7.0	11	-17.0	1771	-7.4	6	-31.4	1772	1796
3					-7.1	1	-7.1	1666	-9.9	2	-9.9	1692	1709
4					-24.3	1	-24.3	1591	-9.8	1	-9.8	1692	1770
5	-8.7	1	-8.7	1522	-12.1	7	-14.9	1629	-7.8	4	-7.4	1541	1640
6	-14.2	9	-24.2	1641	-13.2	10	-15.1	1657					1730
7					-13.7	10	-19.9	1565	-10.1	23	-31.9	1630	1729
8	-6.1	1	-6.1	1550	-8.3	2	-9.9	1480					1664
9	-22.1	1	-22.1	1322	-32.1	2	-37.0	1467					1757
10	-4.0	2	-4.3	1493	-2.9	3	-5.0	1396	-4.0	4	-5.0	1465	1644
11	-4.9	1	-4.9	1173	-13.4	1	-13.4	1448	-8.7	1	-8.7	968	1565
12					-5.6	2	-6.0	1711	-3.5	6	-4.1	1717	1769
13	-16.6	3	-18.2	1689	-4.9	2	-4.8	1692	-6.3	2	-8.9	1680	1818
14	-11.0	2	-11.8	1310	-9.6	6	-10.6	1417	-6.8	2	-7.2	1348	1528
15	-5.8	11	-9.4	1561	-7.0	11	-9.1	1599	-3.8	4	-4.8	1538	1658
16	-4.9	17	-11.3	1555	-8.2	28	-13.9	1517	-6.1	21	-18.7	1636	1667
17	-3.6	7	-5.5	1614	-4.8	13	-7.2	1642					1750
18													
19									-3.6	1	-3.6	1450	1650
20	-3.9	8	-4.6	1466	-4.7	14	-4.6	1634	-3.1	7	-3.1	1610	1680
21													
22					-9.3	1	-9.3	1546	-3.6	1	-3.6	1542	1752
23	-2.4	2	-2.2	1351	-1.9	2	-1.9	1262	-12.4	2	-12.2	1562	1660
24	-8.8	2	-11.0	1421					-7.5	1	-7.5	1650	1687
25	-9.0	2	-10.6	1456					-2.3	1	-2.3	1456	1700

26	-5.3	1	-5.3	1494					-3.4	1	-3.4	1473	1691
27	-5.9	3	-7.7	1531					-5.4	3	-5.8	1521	1624
28	-3.0	8	-2.9	1379	-3.4	8	-7.5	1368	-2.6	5	-4.3	1356	1524
29					-7.5	3	-7.5	1662	-7.6	2	-8.4	1671	1856
30	-7.7	2	-12.2	1606	-2.7	2	-3.3	1623					1839
31	-9.9	3	-19.4	1452	-1.8	1	-1.8	1452	-10.2	5	-25.7	1434	1567
32	-40.3	1	-40.3	1503	-4.6	3	-5.0	1440	-5.1	7	-6.5	1533	1571
33	-2.1	2	-4.8	1575	-3.5	10	-9.6	1600					1672
34	-11.9	4	-13.3	1386	-8.6	2	-8.6	1423	-6.6	1	-6.6	1430	1450
35	-3.5	3	-6.0	1558	-10.0	6	-10.6	1616	-4.8	1	-4.8	1522	1631
36					-10.2	1	-10.2	1516	-9.0	3	-13.0	1607	1814
37					-27.2	1	-27.2	1683	-5.6	4	-5.3	1679	1922
38					-6.0	3	-9.4	1553	-3.2	1	-3.2	1564	1696
39	-9.8	4	-14.6	1676	-10.3	3	-11.3	1597	-7.5	1	-7.5	1560	1744
40													
41									-3.0	1	-3.0	1690	1770
42	-8.9	2	-9.6	1721					-4.0	2	-3.8	1718	1860
43	-3.5	2	-3.8	1694					-2.2	6			1750
44	-6.9	4	-10.1	1425	-4.2	1	-4.2	1482					1690
45	-6.6	1	-6.6	1591									1720
46	-8.6	1	-8.6	1600									1720
47													
48	-7.9	1	-7.9	1287									1621
49	-7.3	1	-7.3	1599	-2.5	1	-2.5	1309	-6.8	1	-6.8	1681	1729
50	-6.7	1	-6.7	1526					-8.5	1	-8.5	1495	1747
51	-5.8	2	-6.0	1554	-4.0	1	-4.0	1353	-5.5	1	-5.5	1563	1674
52													
53	-9.7	1	-9.7	1497									1720
54	-7.1	2	-8.2	1538									
55	-8.9	9	-10.6	1457									1700
56	-6.6	4	-9.4	1452					-11.2	1	-11.2	1403	1550
57	-1.2	1	-1.2	1217					-0.2	1			1650
58									-8.7	1	-8.7	1585	1650
59	-3.3	1	-3.3	1702					-9.0	1			1920

60	-7.5	3	-10.6	1693					-1.1	1			1800
61	-6.7	5	-27.4	1726	-5.3	2	-6.6	1689					1883
62	-6.9	3	-6.9	1402	-3.1	5	-4.6	1695	-5.0	4	-7.4	1701	1745
63	-15.2	8	-26.4	1356	-7.4	37	-7.4	1383	-5.8	22	-5.9	1387	1676
64									-4.6	1	-4.6	1682	1750
65									-8.9	1	-8.9	1637	1896
66									-3.7	1	-3.7	1558	1720
67	-11.1	2	-11.1	1511					-6.0	1	-6.0	1493	1578
68									-6.2	1	-6.2	1606	1680
69	-8.9	2	-10.1	1335					-5.1	2	-5.1	1428	1500
70	-9.5	5	-11.0	1616									1853
71	-2.1	1	-2.1	913					-7.6	5	-7.2	1694	1750
72	-6.9	1	-6.9	1600	-5.5	2	-6.7	1661	-5.3	3	-5.0	1661	1687
73	-11.6	2	-16.6	1390					-5.0	4	-5.0	1431	1580
74	-8.4	4	-11.3	1570					-6.0	4	-6.0	1619	1650
75	-6.0	2	-5.3	1413	-7.5	5	-10.6	1409	-4.6	3	-4.6	1449	1711
76	-3.5	3	-3.4	1549	-6.6	6	-12.0	1667	-4.6	5	-4.6	1576	1722
77	-8.0	2	-8.4	1463	-7.5	1	-7.5	1479	-3.8	3	-2.4	1468	1624
78					-9.6	6	-14.2	1468					1701
79	-4.8	1	-4.8	1410	-16.7	5	-33.8	1543	-5.5	9	-6.2	1564	1660
Averaged Seepage (mm/d)	**-8.0**		**-10.1**		**-8.5**		**-10.6**		**-6.0**		**-8.0**		
Max	**-40.3**		**-40.3**		**-32.1**		**-37.0**		**-13.2**		**-31.9**		
Min	**-1.2**		**-1.2**		**-1.8**		**-1.8**		**-0.2**		**-2.3**		

Table E.5 Analysis of pool based seepage rates in MAIN CANAL

POOL	2009				2010				2011				Full
ID	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Supply el. (mm)
1													
2													
3	-9.6	2	-10.6	1515	-9.2	2	-9.8	1565					1650
4	-2.5	2	-2.8	1424	-2.7	10	-2.9	1482	-4.0	1	-4.0	1457	1608
5					-2.1	4	-2.1	1558					1809
6	-33.5	2	-33.6	1349	-14.7	2	-19.2	1343	-16.3	1	-16.3	1346	1531
7					-1.4	2	-1.0	1630					1783
8	-4.6	3	-4.6	1594	-3.1	6	-3.6	1579	-12.4	2	-14.9	1635	1753
9	-2.1	1	-2.1	1528	-1.4	1	-1.4	1433	-2.4	2	-3.1	1550	1747
10													
11	-6.1	1	-6.1	1239	-4.1	1	-4.1	1147					1554
12													
13													
14	-16.0	1	-16.0	1363									1512
15	-7.3	1	-7.3	1265									1622
16	-42.6	3	-51.6	1599	-17.5	3	-23.3	1635	-36.2	1	-36.2	1589	1789
17													
18													
19													
20													
21													
22	-17.0	2	-19.9	1575	-26.3	3	-31.2	1658	-15.2	6	-26.2	1625	1715
23													
24													
Averaged (mm/d)	**-14.1**		**-15.4**		**-8.3**		**-9.9**		**-14.4**		**-16.8**		
Max	**-42.6**		**-51.6**		**-26.3**		**-31.2**		**-36.2**		**-36.2**		
Min	**-2.1**		**-2.1**		**-1.4**		**-1.0**		**-2.4**		**-3.1**		

Table E.6 Analysis of pool based seepage rates in TUBBO main channel

POOL	2009				2010				2011				Full
ID	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Supply el. (mm)
1					-2.4	1	-2.4	1261	-104.6	2	-104.6	1467	1717
2	-8.3	11	-21.8	1668	-5.1	3	-9.6	1582					1732
3					-1.5	3	-1.7	1653					1850
4	-7.2	2	-7.7	1619	-7.4	5	-10.8	1614					1721
5	-57.7	2	-62.4	1457	-23.3	1	-23.3	1451					1535
6	-7.9	1	-7.9	1307	-7.8	2	-11.9	1359	-17.8	1	-17.8	1427	1519
7					-2.5	3	-3.6	1346	-1.8	1	-0.1	1287	1469
8													
9	-8.4	1	-8.4	1396	-4.5	6	-6.5	1379	-10.1	1	-10.1	1237	1563
10	-13.0	13	-19.0	1687	-10.5	12	-13.0	1719	-8.0	11	-9.4	1748	1786
11	-20.4	2	-27.6	1358									
12					-21.2	2	-21.2	1486					1642
13					-33.8	3	-33.8	1270	-39.8	2	-40.8	1392	1501
14													
Averaged Seepage (mm/d)	**-17.6**		**-22.1**		**-10.9**		**-12.5**		**-30.3**		**-30.4**		
Max	**-57.7**		**-62.4**		**-33.8**		**-33.8**		**-104.6**		**-104.6**		
Min	**-7.2**		**-7.7**		**-1.5**		**-1.7**		**-1.8**		**-0.1**		

Table E.7 Analysis of pool based seepage rates in YAMMA main channel

POOL	2009				2010				2011				Full
ID	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Pool Seepage (mm/d)	No of Pondage	Higher Seepage (mm/d)	Elevation (mm)	Supply el. (mm)
1	-16.3	2	-20.6	1655					-2.5	1	-2.5	1099	1738
2					-6.3	1	-6.3	1553	-3.3	1	-0.1	1092	1676
3	-7.6	3	-12.0	1533					-3.1	1	-3.1	1094	1705
4	-4.7	3	-4.7	1607	-4.5	1	-4.5	1616	-2.5	1	-2.5	1590	1705
5	-4.6	1	-4.6	1317	-6.9	3	-8.9	1436	-2.9	1	-2.9	861	1633
6					-6.8	2	-7.2	1551	-3.8	2	-11.5	1541	1691
7	-2.0	1	-2.0	1443	-4.5	1	-4.5	1337					1631
8	-11.7	1	-11.7	1459									
9													
10									-30.7	1	-30.7	1447	1507
11													
12													
13	-21.5	1	-21.5	1447					-17.3	1	-17.3	1518	1630
14	-9.5	1	-10.6	1583	-7.0	4	-8.4	1585					1724
15	-6.2	2	-7.4	1467	-5.2	8	-5.8	1488					1522
16	-7.5	3	-14.9	1580	-8.4	6	-10.6	1676	-3.6	6	-5.0	1644	1920
17					-27.4	6	-75.4	1367	-7.3	12	-8.9	1664	1695
18													
19					-7.5	1	-7.5	1451	-8.5	1	-8.5	1685	1886
20	-9.8	2	-13.0	1568	-11.0	3	-11.0	1503	-2.8	1	-2.8	1089	1621
21	-9.9	2	-10.3	1540	-5.1	2	-5.1	1539					1690
22	-3.8	3	-11.0	1547	-2.2	1	-2.2	1234	-5.1	4	-7.0	1635	1700
23	-4.4	2	-9.1	1658	-2.7	1	-2.7	1448	-6.1	3	-7.0	1689	1827
24	-8.9	4	-16.1	1490	-4.5	4	-4.1	1373	-5.3	2	-5.8	1509	1651
25									-5.1	2	-5.8	1504	1565

26					-7.2	1	-7.2	1423	-5.5	3	-6.5	1437	1644
27	-9.1	3	-19.0	1614	-8.8	6	-12.2	1633	-8.6	4	-8.9	1617	1739
28	-9.1	3	-12.5	1663	-7.4	12	-6.5	1638	-3.8	7	-6.2	1591	1690
29	-17.9	4	-34.3	1439	-13.7	1	-13.7	1512	-8.8	5	-10.3	1490	1731
30	-8.3	4	-16.6	1540	-8.8	1	-8.8	1563	-6.5	2	-6.7	1550	1732
31	-8.3	1	-8.3	1598	-8.8	1	-8.8	1630	-8.2	2	-10.1	1590	1743
32					-5.7	3	-7.7	1541					1640
33	-5.5	11	-19.2	1689	-3.0	8	-3.4	1685	-3.1	3	-4.1	1648	1831
34	-8.3	3	-9.4	1612	-6.6	15	-8.6	1649					1705
35									-6.2	3	-10.6	1496	1634
36									-10.9	2	-12.5	1592	1677
37									-9.3	1	-9.3	1564	1764
38					-3.3	2	-0.1	1484	-5.4	2	-5.5	1502	1535
39	-10.0	2	-11.8	1410	-5.8	1	-5.8	1382	-8.6	2	-8.6	1403	1564
40	-7.0	1	-7.0	1533	-4.9	2	-5.0	1645	-6.7	8	-13.2	1534	1780
41					-3.8	1	-3.8	1475	-5.8	4	-9.4	1485	1656
42	-22.0	2	-23.0	1573	-23.9	5	-24.2	1606	-8.6	11	-14.4	1642	1686
43													
44													
45													
46									-18.7	2	-19.7	1492	1987
47													
48													
49													
50									-1.9	1	-1.9	938	1760
51									-2.5	1	-2.5	1060	1902
Averaged (mm/d)	**-9.3**		**-13.2**		**-7.6**		**-9.6**		**-7.0**		**-8.3**		
Max	**-22.0**		**-34.3**		**-27.4**		**-75.4**		**-30.7**		**-30.7**		
Min	**-2.0**		**-2.0**		**-2.2**		**-0.1**		**-1.9**		**-0.1**		

APPENDIX F

List of gates and farm outlets in different pools of CIA

Table F.1 List of gates and farm outlets in different pools of ARGOON main channel

ARGOON main channel		
Pool name	**Gates & farm outlets**	**ID**
ARGOON 1, 1-1	174/1|176/1|ARGOON 1|ARGOON 1-1|	1
ARGOON 1-1, 1-2	174/2|ARGOON 1-1|ARGOON 1-2|	2
ARGOON 1-2, 1-3	175/1|175/2|ARGOON 1-2|ARGOON 1-3|	3
ARGOON 1-3, 1-4	178/1|178/2|ARGOON 1-3|ARGOON 1-4|	4
ARGOON 1-4, 1-5	179/1|179/2|ARGOON 1-4|ARGOON 1-5|	5
ARGOON 1-5, ESC ARGOON 1	180/1|ARGOON 1-5|ESC ARGOON 1|	6
ARGOON 2, 198/1	ARGOON 2 |198/1	7
ARGOON 3, 4	193/1|196/1|ARGOON 2|ARGOON-3|ARGOON-4|197/1|	8
ARGOON 3, 3-1	210/1|ARGOON 3|ARGOON 3-1|	9
ARGOON 3-1, 3-2	218/1|ARGOON 3-1|ARGOON 3-2|ARGOON 3A|	10
ARGOON 3-2, 3-3	211/1|217/1|ARGOON 3-2|ARGOON 3-3|	11
ARGOON 3-3, 3-4	212/1|ARGOON 3-3|ARGOON 3-4|	12
ARGOON 3-4, 3-5	216/1|217/2|ARGOON 3-4|ARGOON 3-5|	13
ARGOON 3-5, 3-6	213/1|ARGOON 3-5|ARGOON 3-6|	14
ARGOON 3-6, 3-8	214/1|215/1|ARGOON 3-6|ARGOON 3-8|	15
ARGOON 3-8, 2005/1	2005/1|ARGOON 3-8|	16
ARGOON 3A, 220/1	220/1|ARGOON 3A|	17
ARGOON, -1	182/2|183/1|ARGOON|ARGOON-1|	18
ARGOON-1,2	ARGOON-1|ARGOON-2|	19
ARGOON-2,3	184/2|195/1|ARGOON-2|ARGOON-3|	20
ARGOON-4,5	193/2|194/1|ARGOON-4|ARGOON-5|	21
ARGOON-5, 3	219/1|194/2|2002/1|ARGOON 3|ARGOON-5|	22

Table F.2 List of gates and farm outlets in different pools of BOONA main channel

BOONA main channel		
Pool name	**Gates & farm outlets**	**ID**
BOONA0,1	120/1|2/1|BOONA|BOONA-1|	1
BOONA1,2	120/2|2/2|675/1|8/1|9/1|9/2|BOONA-1|BOONA-2|	2
BOONA10,11	BOONA-10|BOONA-11|	3
BOONA11,12	169/1|676/1|BOONA-11|BOONA-12|	4
BOONA12,12-1	156/3|BOONA 12|BOONA 12-1|	5
BOONA12,13	167/1|BOONA-12|BOONA-13|	6
BOONA12-1,12-2	154/1|BOONA 12-1|BOONA 12-2|	7
BOONA12-2, ESC 12	155/1|BOONA 12-2|ESC BOONA 12|	8
BOONA13,14	152/1|164/1|BOONA-13|BOONA-14|166/1|	9
BOONA14,16	156/1|163/1|163/2|165/1|BOONA 12|BOONA-14|BOONA-16|	10
BOONA16,17	BOONA-16|BOONA-17|157/1|	11
BOONA17,18	162/1|BOONA-17|BOONA-18|	12
BOONA18,19	158/1|161/1|BOONA-18|BOONA-19|	13
BOONA19,20	159/1|BOONA-19|BOONA-20|	14
BOONA2,3	10/1|1039/1|BOONA-2|BOONA-3|	15
BOONA20, ESC 3	160/1|BOONA-20|ESC BOONA-3|	16
BOONA3,4	141/1|BOONA-3|BOONA-4|ESC BOONA-1|	17
BOONA4,5	222/1|BOONA-4|BOONA-5|	18
BOONA5,7	643/1|BOONA-5|BOONA-7|	19
BOONA7,7-1	BOONA 7|BOONA 7-1|	20
BOONA7,8	143/2|145/1|538/2|642/1|665/1|BOONA-7|BOONA-8|	21
BOONA7-1,7-2	657/1|BOONA 7-1|BOONA 7-2|	22
BOONA7-2, ESC 7	656/1|BOONA 7-2|ESC BOONA 7|	23
BOONA8,9	BOONA 7|BOONA-8|BOONA-9|	24
BOONA 9-1, ESC 9	BOONA 9-1|ESC BOONA 9|150/1|151/1|	25
BOONA 9A, ESC 9A	BOONA 9A|ESC BOONA 9A|	26
BOONA9,10	BOONA 9|BOONA-10|BOONA-9|ESC BOONA-2|146/1|	27
BOONA9,9-1	BOONA 9|BOONA 9-1|BOONA 9A|	28

Table F.3 List of gates and farm outlets in different pools of BUNDURE main channel

BUNDURE main channel		
Pool name	**Gates & farm outlets**	**ID**
BUNDURE 1 O/T, 1-1	545/2|BUNDURE 1 O/T|BUNDURE 1-1|546/1|	1
BUNDURE 1-1, ESC 1	547/1|547/2|BUNDURE 1-1|ESC BUNDURE 1|	2
BUNDURE 3-1, 3-2	607/3|BUNDURE 3-1|BUNDURE 3-2|	3
BUNDURE 3-11, 3-12	640/1|BUNDURE 3-11|BUNDURE 3-12|	4
BUNDURE 3-12, 3-13	633/1|634/1|647/1|BUNDURE 3-12|BUNDURE 3-13|	5
BUNDURE 3-13, ESC 3	574/3|610/3|636/1|BUNDURE 3-13|	6
BUNDURE 3-2, 3-3	607/2|664/1|BUNDURE 3-2|BUNDURE 3-3|	7
BUNDURE 3-3, 3-4	31/5|31/6|545/3|59/2|BUNDURE 3-3|BUNDURE 3-4|	8
BUNDURE 3-4, 3-5	608/2|619/1|BUNDURE 3-4|BUNDURE 3-5|	9
BUNDURE 3-5, 3-6	508/3|578/3|590/3|619/2|621/1|BUNDURE 3-5|BUNDURE 3-6|	10
BUNDURE 3-6, 3-7	623/1|BUNDURE 3-6|BUNDURE 3-7|BUNDURE 3A O/T|	11
BUNDURE 3-7, 3-8	541/2|BUNDURE 3-7|BUNDURE 3-8|	12
BUNDURE 3-8, 3-9	BUNDURE 3-8|BUNDURE 3-9|650/1|	13
BUNDURE 3-9, 3-11	577/3|614/2|623/2|651/1|BUNDURE 3-11|BUNDURE 3-9|BUNDURE 3B O/T|	14
BUNDURE 3A O/T, 3A-1	624/1|BUNDURE 3A O/T|BUNDURE 3A-1|	15
BUNDURE 3A-1, ESC 3A	670/1|BUNDURE 3A-1|ESC BUNDURE 3A|	16
BUNDURE 4 O/T, 4-1	557/1|BUNDURE 4 O/T|BUNDURE 4-1|	17
BUNDURE 4-1, 4-2	557/2|558/1|BUNDURE 4-1|BUNDURE 4-2|	18
BUNDURE 4-10, 4-11	598/1|BUNDURE 4-10|BUNDURE 4-11|	19
BUNDURE 4-11, 4-12	599/1|600/3|BUNDURE 4-11|BUNDURE 4-12|	20
BUNDURE 4-12, 4-13	599/2|601/1|BUNDURE 4-12|BUNDURE 4-13|	21
BUNDURE 4-13, ESC 4	596/1|BUNDURE 4-13|	22
BUNDURE 4-2, 4-3	562/1|BUNDURE 4-2|BUNDURE 4-3|	23
BUNDURE 4-3, 4-4	560/1|BUNDURE 4-3|BUNDURE 4-4|	24
BUNDURE 4-4, 4-5	561/1|563/1|BUNDURE 4-4|BUNDURE 4-5|	25
BUNDURE 4-5, 4-6	564/1|565/1|BUNDURE 4-5|BUNDURE 4-6|	26
BUNDURE 4-6, 4-7	566/1|567/1|BUNDURE 4-6|BUNDURE 4-7|	27
BUNDURE 4-7, 4-8	566/2|BUNDURE 4-7|BUNDURE 4-8|	28
BUNDURE 4-8, 4-9	568/1|BUNDURE 4-8|BUNDURE 4-9|	29
BUNDURE 4-9, 4-10	597/1|BUNDURE 4-10|BUNDURE 4-9|BUNDURE 4B O/T|	30
BUNDURE 4B O/T, 4B-1	571/2|BUNDURE 4B O/T|BUNDURE 4B-1|	31
BUNDURE-ESC O/T, ESC 1	BUNDURE-ESC O/T|ESC BUNDURE MAIN-1|556/1|BUNDURE 4 O/T|	32
BUNDURE 4B-1, ESC 4B	600/1|BUNDURE 4B-1|ESC BUNDURE 4B|	33
BUNDURE 5 O/T, 5-1	609/2|BUNDURE 5 O/T|BUNDURE 5-1|	34
BUNDURE 5-1, 5-2	610/1|BUNDURE 5-1|BUNDURE 5-2|	35
BUNDURE 5-2, 5-3	610/2|611/1|BUNDURE 5-2|BUNDURE 5-3|	36
BUNDURE 5-3, 5-4	611/2|612/1|612/2|BUNDURE 5-3|BUNDURE 5-4|	37

BUNDURE 5-4, 5-5	613/1|BUNDURE 5-4|BUNDURE 5-5|	38
BUNDURE 5-5, ESC 5	613/2|614/1|BUNDURE 5-5|ESC BUNDURE 5|	39
BUNDURE 6 O/T, 6-1	573/1|BUNDURE 6 O/T|BUNDURE 6-1|	40
BUNDURE 6-1, ESC 6	574/1|BUNDURE 6-1|	41
BUNDURE 7 O/T, 7-1	669/2|584/1|BUNDURE 7 O/T|BUNDURE 7-1|	42
BUNDURE 7-1, 7-2	584/2|585/1|BUNDURE 7-1|BUNDURE 7-2|	43
BUNDURE 7-2, 7-3	BUNDURE 7-2|BUNDURE 7-3|	44
BUNDURE 7-3, ESC 7	587/1|BUNDURE 7-3|	45
BUNDURE 8 O/T, 8-1	578/2|579/1|BUNDURE 8 O/T|BUNDURE 8-1|	46
BUNDURE 8-1, 8-2	580/1|BUNDURE 8-1|BUNDURE 8-2|	47
BUNDURE 8-2, ESC 8	581/1|582/1|BUNDURE 8-2|ESC BUNDURE 8|	48

Table F.4 List of gates and farm outlets in different pools of COLY main channel

COLY main channel		
Pool name	**Gates & farm outlets**	**ID**
COLY 2-2, COLY 2 ESC	COLY 2 ESC|COLY 2-2|	1
COLY2-1,2-2	COLY 2-1|COLY 2-2|	2
COLY3-1,3-2	5/1|COLY 3-1|COLY 3-2|	3
COLY3-2,3-3	4/1|6/2|COLY 3-2|COLY 3-3|	4
COLY3-3,3-4	3/1|COLY 3-3|COLY 3-4|	5
COLY3-4, ESC 3	8/2|COLY 3-4|ESC COLY 3|	6
COLY 4-6, ESC COLY 4	20/1|COLY 4-6|ESC COLY 4|	7
COLY4-1,4-2	14/2|COLY 4-1|COLY 4-2|	8
COLY4-2,4-3	13/1|17/1|COLY 4-2|COLY 4-3|	9
COLY4-3,4-4	12/1|18/1|COLY 4-3|COLY 4-4|	10
COLY4-4,4-5	19/1|COLY 4-4|COLY 4-5|	11
COLY4-5,4-6	11/1|11/2|COLY 4-5|COLY 4-6|	12
COLY5,5-1	25/1|COLY 5|COLY 5-1|	13
COLY5-1,5-2	24/1|24/2|COLY 5-1|COLY 5-2|	14
COLY5-2,5-3	23/1|COLY 5-2|COLY 5-3|	15
COLY5-3,5-4	21/1|22/1|23/2|COLY 5-3|COLY 5-4|	16
COLY 6-11, ESC 6	38/1|COLY 6-11|ESC 6|	17
COLY6,6-1	COLY 6|COLY 6-1|	18
COLY6-1,6-2	28/1|COLY 6-1|COLY 6-2|	19
COLY6-10,6-11	37/1|39/1|COLY 6-10|COLY 6-11|	20
COLY6-2,6-3	29/1|COLY 6-2|COLY 6-3|	21
COLY6-3,6-4	30/1|COLY 6-3|COLY 6-4|	22
COLY6-4,6-5	31/1|COLY 6-4|COLY 6-5|	23
COLY6-5,6-6	32/1|COLY 6-5|COLY 6-6|	24
COLY6-6,6-7	33/1|COLY 6-6|COLY 6-7|	25

COLY6-7,6-8	34/1|COLY 6-7|COLY 6-8|	26
COLY6-8,6-9	35/1|41/1|COLY 6-8|COLY 6-9|	27
COLY6-9,6-10	36/1|40/1|COLY 6-10|COLY 6-9|	28
COLY7,7-1	27/2|46/1|COLY 7|COLY 7-1|	29
COLY7-1,7-2	28/3|COLY 7-1|COLY 7-2|	30
COLY7-2,7-4	29/2|30/2|44/1|45/1|COLY 7-2|COLY 7-4|	31
COLY7-4,7-5	43/1|654/1|COLY 7-4|COLY 7-5|	32
COLY7-5, ESC COLY 7	42/1|COLY 7-5|ESC COLY 7|	33
COLY 8-4,8-5	52/1|COLY 8-4|COLY 8-5|	34
COLY 8-5, 8-6	COLY 8-5|COLY 8-6|	35
COLY8, 8-1	56/1|COLY 8|COLY 8-1|47/1|	36
COLY8-1,8-2	55/1 |COLY 8-1|COLY 8-2|	37
COLY8-2,8-3	45/2|48/1|COLY 8-2|COLY 8-3|	38
COLY8-3,8-4	COLY 8-3|COLY 8-4|	39
COLY 9,9-2	57/1|58/1|COLY 9|COLY 9-2|	40
COLY 9-12, 9-13	79/1|COLY 9-12|COLY 9-13|	41
COLY 9-13, 9-14	80/1|83/1|COLY 9-13|COLY 9-14|	42
COLY 9-14, 9-15	81/1|COLY 9-14|COLY 9-15|	43
COLY 9-15, 9-16ESC 9	82/1|COLY 9-15|COLY 9-16ESC 9|	44
COLY 9-2,9-3	94/1|COLY 9-2|COLY 9-3|	45
COLY 9-3,9-4	59/1|60/1|COLY 9-3|COLY 9-4|	46
COLY 9-4,9-5	61/1|93/1|COLY 9-4|COLY 9-5|	47
COLY 9-5, 9-6	61/2|62/1|92/2|92/1|93/2|COLY 9-5|COLY 9-6|COLY 9B|	48
COLY 9-6, 9-7	91/1|COLY 9-6|COLY 9-7|	49
COLY 9-7, 9-8	90/1|90/2|COLY 9-7|COLY 9-8|	50
COLY 9-8, 9-9	89/1|COLY 9-8|COLY 9-9|	51
COLY 9-9, 9-12	78/1|88/1|COLY 9-12|COLY 9-9|COLY 9C|	52
COLY 9B, 9B-1	63/1|63/2|COLY 9B|COLY 9B-1|	53
COLY 9B-1, 9B-2	64/1|COLY 9B-1|COLY 9B-2|	54
COLY 9B-10, ESC 9B	73/1|COLY 9B-10|ESC 9B|	55
COLY 9B-2, 9B-3	65/1|COLY 9B-2|COLY 9B-3|	56
COLY 9B-3, 9B-4	65/2|66/1|67/1|COLY 9B-3|COLY 9B-4|	57
COLY 9B-4, 9B-5	68/1|COLY 9B-4|COLY 9B-5|	58
COLY 9B-5, 9B-7	69/1|76/1|76/2|77/1|COLY 9B-5|COLY 9B-7|	59
COLY 9B-7, 9B-8	75/1|COLY 9B-7|COLY 9B-8|69/2|	60
COLY 9B-8, 9B-10	70/1|74/1|75/2|COLY 9B-10|COLY 9B-8|	61
COLY 9C, 9C-1	86/1|87/1|COLY 9C|COLY 9C-1|	62
COLY 9C-1, 9C-3 ESC	83/2|85/1|COLY 9C-1|COLY 9C-3 ESC|	63
COLY 10, 10-1	96/1|96/2|97/1|COLY 10|COLY 10-1|	64
COLY 10-1, 10-3	100/1|97/2|98/1|98/2|99/1|COLY 10-1|COLY 10-3|	65
COLY 10-3, 10-4	101/1|102/1|102/2|COLY 10-3|COLY 10-4|	66
COLY 10-4, 10-5	102/3|103/1|COLY 10-4|COLY 10-5|	67
COLY 10-5, 10-6	COLY 10-5|COLY 10-6|	68
COLY 10-6, 10-7	104/1|105/1|662/1|COLY 10-6|COLY 10-7|	69

COLY 10-7, ESC 10	107/1|COLY 10-7|ESC 10|	70
COLY 11-1, 11-2	114/1|COLY 11-1|COLY 11-2|	71
COLY 11-2, 11-3	118/1|COLY 11-2|COLY 11-3|	72
COLY 11-3, 11-4	113/1|118/2|COLY 11-3|COLY 11-4|	73
COLY 11-4, 11-5	112/1|119/1|COLY 11-4|COLY 11-5|	74
COLY 11-5, 11-6	170/1|COLY 11-5|COLY 11-6|	75
COLY 11-6, 11-7	111/1|COLY 11-6|COLY 11-7|	76
COLY 11-7, 11-8	110/1|171/1|COLY 11-7|COLY 11-8|	77
COLY 11-8, 11-9	108/2|COLY 11-8|COLY 11-9|ESC 11|	78
COLY 11-9, 172/1	172/1|COLY 11-9|	79

Table F.5 List of gates and farm outlets in different pools of MAIN CANAL

Main CANAL		
Pool name	**Gates & farm outlets**	**ID**
BUNDURE MAIN O/T, 1	542/2|545/1|548/1|BUNDURE MAIN O/T|BUNDURE MAIN-1|BUNDURE 1 O/T|BUNDURE-SPUR O/T	1
BUNDURE MAIN-1, 3	549/2|549/1|551/1|615/2|672/1|BUNDURE MAIN-3|BUNDURE MAIN-1|	2
BUNDURE MAIN-10, 11	577/1|578/1|BUNDURE 8 O/T|BUNDURE MAIN-10|BUNDURE MAIN-11|	3
BUNDURE MAIN-11, 12	588/1|BUNDURE MAIN-11|BUNDURE MAIN-12|	4
BUNDURE MAIN-12, 13	589/2|591/1|BUNDURE MAIN-12|BUNDURE MAIN-13|	5
BUNDURE MAIN-13, 14	590/1|591/2|BUNDURE MAIN-13|BUNDURE MAIN-14|	6
BUNDURE MAIN-14, 15	BUNDURE MAIN-14|BUNDURE MAIN-15|	7
BUNDURE MAIN-15, 16	BUNDURE MAIN-15|BUNDURE MAIN-16|	8
BUNDURE MAIN-16, 17	BUNDURE MAIN-16|BUNDURE MAIN-17|	9
BUNDURE MAIN-3, 4	548/3|551/2|551/3|606/1|615/1|615/3|BUNDURE 3-1|BUNDURE MAIN-3|BUNDURE MAIN-4|	10
BUNDURE MAIN-4, 6	552/1|554/1|606/3|BUNDURE - ESC O/T|BUNDURE MAIN-4|BUNDURE MAIN-6|	11
BUNDURE MAIN-6, 7	554/2|555/1|607/1|608/1|BUNDURE MAIN-6|BUNDURE MAIN-7|	12
BUNDURE MAIN-7, 8	555/2|572/1|609/1|BUNDURE 5 O/T|BUNDURE 6 O/T|BUNDURE MAIN-7|BUNDURE MAIN-8|	13
BUNDURE MAIN-8, 9	574/2|575/1|BUNDURE MAIN-8|BUNDURE MAIN-9|	14
BUNDURE MAIN-9, 10	669/1|BUNDURE 7 O/T|BUNDURE MAIN-10|BUNDURE MAIN-9|	15
BUNDURE MAIN-17, ESC 2	596/2|BUNDURE MAIN-17	16
GRANTS REG, PRICKLEY REG	COLY 10|COLY9|GRANTS REGULATOR|PRICKLEY REGULATOR|	17
HORTICULTURE, NO. 3	14/1|COLY 3-1|HORTICULTURE REGULATOR|NO 3 REGULATOR|	18
MAIN CANAL INLET, TUBBO WELLS	MAIN CANAL INLET|TUBBO WELLS|TUMBULLEN INLET|TUBBO ESC|	19
MORUNDAH REG, GRANTS REG	COLY7|COLY8|GRANTS REGULATOR|MORUNDAH REGULATOR|	20
NO 3 REG, MORUNDAH REG	15/1|2023/2|COLY 4-1|COLY 5|COLY 6|MORUNDAH REGULATOR|NO 3 REGULATOR|	21
KOORUMBEEN, ESC KOORUMBEEN	KOORUMBEEN|544/2|2013/1|ESC KOORUMBEEN|	22
PRICKLEY REG, BUNDURE MAIN O/T	BUNDURE MAIN O/T|COLY 11-1|KOORUMBEEN|MAIN CANAL ESC|PRICKLEY REGULATOR|YAMMA|	23
TUBBO WELLS, HORTICULTURE REG	TUBBO WELLS|HORTICULTURE REGULATOR|COLY 2-1|TUBBO OFFTAKE|	24

Table F.6 List of gates and farm outlets in different pools of TUBBO main channel

TUBBO main Channel		
Pool name	**Gates & farm outlets**	**ID**
TUBBO1,2	5/3|TUBBO-1|TUBBO-2|	1
TUBBO10,11	507/2|673/1|TUBBO-10|TUBBO-11|	2
TUBBO11,12	2020/1|540/2|TUBBO-11|TUBBO-12|	3
TUBBO12,ESC TUBBO	2010/1|ESC TUBBO|TUBBO-12|	4
TUBBO2,3	18/3|KERARBURY|TUBBO-2|TUBBO-3|	5
TUBBO3,4	120/3|639/1|TUBBO-3|TUBBO-4|	6
TUBBO4,5	11/3|TUBBO-4|TUBBO-5|9002/2|	7
TUBBO5,6	ESC TUBBO-1|TUBBO-5|TUBBO-6|TUBBO3|	8
TUBBO6,7	221/1|4005/1|7/4|TUBBO-6|TUBBO-7|	9
TUBBO 4 OT, 2026	TUBBO 4 OT|2026/1|2026/2|2026/3|	10
TUBBO OFFTAKE, BOONA	TUBBO OFFTAKE| 1/1|1/2|2/3|TUBBO-1| BOONA|	11
TUBBO7,8	TUBBO 4 OT|TUBBO-7|TUBBO-8|	12
TUBBO8,9	226/1|31/4|TUBBO-8|TUBBO-9|	13
TUBBO9,10	4004/1|6/3|661/1|663/1|TUBBO-10|TUBBO-9|	14

Table F.7 List of gates and farm outlets in different pools of YAMMA main channel

YAMMA main channel		
Pool name	**Gates & farm outlets**	**ID**
YAMMA 1-1, 1-2	524/1|YAMMA 1-1|YAMMA 1-2|	1
YAMMA 1-2, 1-3	525/1|YAMMA 1-2|YAMMA 1-3|	2
YAMMA 1-3, 1-4	526/1|527/1|YAMMA 1-3|YAMMA 1-4|	3
YAMMA 1-4, 1-5	527/2|YAMMA 1-4|YAMMA 1-5|	4
YAMMA 1-5, 1-6	529/1|530/1|YAMMA 1-5|YAMMA 1-6|	5
YAMMA 1-6, 1-7	531/1|532/1|YAMMA 1-6|YAMMA 1-7|	6
YAMMA 1-7, 1-8	533/1|YAMMA 1-7|YAMMA 1-8|	7
YAMMA 1-8, ESC 1	533/2|534/1|534/2|YAMMA 1-8|	8
YAMMA 1A-1, 1A-2	YAMMA 1A-1|YAMMA 1A-2|	9
YAMMA 1A-2, 1A-3	YAMMA 1A-2|YAMMA 1A-3|	10
YAMMA 1A-3, 1A-4	504/1|504/2|YAMMA 1A-3|YAMMA 1A-4|	11
YAMMA 1A-4, 1A-5	507/1|YAMMA 1A-4|YAMMA 1A-5|	12
YAMMA 1A-5, 1A-6	508/1|YAMMA 1A-6|YAMMA 1A-5|	13
YAMMA 1A-6, 1A-7	511/1|512/1|YAMMA 1A-8|YAMMA1A-7|	14
YAMMA 1A-7, 1A-8	513/1|666/1|YAMMA 1A-8|YAMMA 1A-9|	15
YAMMA 1A-8, 1A-9	514/1|514/2|ESC YAMMA 1A|YAMMA 1A-9|	16
YAMMA 1A-9, ESC 1A	535/1|YAMMA 1B|YAMMA 1B-1|	17

YAMMA 1B, 1B-1	537/1|537/2|YAMMA 1B-1|YAMMA 1B-2|	18
YAMMA 1B-1, 1B-2	539/1|540/1|YAMMA 1B-2|YAMMA 1B-3|	19
YAMMA 1B-2, 1B-3	541/1|ESC YAMMA 1B |YAMMA 1B-3|	20
YAMMA 1B-3, ESC 1B	189/1|YAMMA 2|YAMMA 2-1|	21
YAMMA 2, 2-1	185/1|186/3|190/1|YAMMA 2-1|YAMMA 2-2|	22
YAMMA 2-1, 2-2	206/1|YAMMA 2-2|YAMMA 2-3|	23
YAMMA 2-2, 2-3	200/1|206/2|YAMMA 2-3|YAMMA 2-4|	24
YAMMA 2-3, 2-4	201/1|202/1|205/1|YAMMA 2-4|YAMMA 2-5|	25
YAMMA 2-4, 2-5	204/1|205/2|YAMMA 2-5|YAMMA 2-6|	26
YAMMA 2-5, 2-6	191/1|YAMMA 3|YAMMA 3-1|	27
YAMMA 2-6, 2	191/2|YAMMA 3-1|YAMMA 3-2|	28
YAMMA 3, 3-1	192/1|YAMMA 3-2|YAMMA 3-3|	29
YAMMA 3-1, 3-2	192/2|209/1|YAMMA 3-3|YAMMA 3-4|	30
YAMMA 3-2, 3-3	208/1|YAMMA 3-4|YAMMA 3-5|	31
YAMMA 3-3, 3-4	2006/1|ESC YAMMA 3|YAMMA 3-5|	32
YAMMA 3-4, 3-5	659/1|YAMMA 4|YAMMA 4-1|	33
YAMMA 3-5, ESC 3	515/1|YAMMA 4-1|YAMMA 4-2|	34
YAMMA 4, 4-1	516/1|YAMMA 4-2|YAMMA 4-3|	35
YAMMA 4-1, 4-2	517/1|YAMMA 4-3|YAMMA 4-4|	36
YAMMA 4-2, 4-3	518/1|519/1|YAMMA 4-4|YAMMA 4-5|	37
YAMMA 4-3, 4-4	521/1|YAMMA 4-5|YAMMA 4-6|	38
YAMMA 4-4, 4-5	571/1|YAMMA 4-6|YAMMA 4-7|2007/1|2009/1|	39
YAMMA 4-5, 4-6	2008/1|ESC YAMMA 4|YAMMA 4-7|	40
YAMMA 4-6, 4-7	508/2|510/1|YAMMA 1A-6|YAMMA1A-7|	41
YAMMA 4-7, ESC 4	118/3|119/2|501/1|YAMMA|YAMMA1 OFFTAKE|YAMMA-1|	42
YAMMA 1A-6, 1A-7	170/2|YAMMA-1|YAMMA-2|	43
YAMMA, 1	502/1|502/2|YAMMA 1A-1|YAMMA 1A|	44
YAMMA-1,2	YAMMA 2-6|209/3|219/3|	45
YAMMA1A, 1A-1	YAMMA 1 OFFTAKE|645/1|YAMMA 1A|YAMMA 1B|YAMMA 1-1|	46
YAMMA 2-6, ESC 2	171/2|YAMMA-2|YAMMA-3|	47
YAMMA 1 OFFTAKE, 1-1	172/2|173/1|181/1|ARGOON|ARGOON 1|YAMMA-3|YAMMA-4	48
YAMMA-2,3	182/1|187/1|187/2|188/1|188/2|YAMMA 2|YAMMA 3|YAMMA 4|YAMMA-4|	49
YAMMA-3,4		50
YAMMA-4, 3		51

APPENDIX G

Linking the related pools to seepage hot spots of Allen, (2006)

Table G.1 Linking the related pools to seepage hot spots of Allen, (2006) priority 1

Approximate location	Main channel	Pool ID
Murrumbidgee Offtake directly downstream	MAIN CANAL	19
Around the end of Wallace Road	MAIN CANAL	24
Farms 56 and 57 between Culley Rd and Channel 9Rd	COLY	40
Upstream of the Escape		
Farms 503 and 504	YAMMA	11
Farm 535	YAMMA	18
Farm 549 (northeast block)	BUNDURE	2
Farm 548 and 549 (southwest block)	BUNDURE	1

Table G.2 Linking the related pools to seepage hot spots of Allen, (2006) priority 2

Approximate location	Main channel	Pool ID
5 isolated prior streams in a 12km stretch in the vicinity of Tom Bullen Reservoir		
2 isolated deep seepage pathways between Wallace Road and Mellington Road	Main canal	21
Farm 1009	TUBBO	11
The Boona Offtake	TUBBO	11
Farm 5, O'Neil Rd	TUBBO	1
Between O'Neil and Donald Ross Rds - various prior stream sands linked to deeper prior stream complex.		
Just downstream of Tubbo 3 offtake	TUBBO	6
Was not surveyed but priority 2 is inferred from results in the adjacent Tubbo segment. To F14 only.		
Just upstream of Demo Farm, Tubbo 4 offtake	TUBBO	10
West of Cockys Lane	BOONA	1
Farm 1022, Pine Dr	BOONA	25
Farm 118, Morundah Rd	YAMMA	44
Parts of features on farms 502, 645 and 510	YAMMA	46
Farm 535	YAMMA	18
Farm 537	YAMMA	19
West of the airstrip bridge, Farm 510	YAMMA	14
Just downstream of the Main Offtake	BUNDURE	1
Just downstream of Bundure 3 offtake	BUNDURE	15
Bundure 1 was empty and not surveyed but its location suggests that it has a priority site	BUNDURE	2
Bundure 2 was empty and not surveyed but its location suggests that it has a priority site		
Farm 650, McLarty Rd	BUNDURE	13
Farm 634, McLarty Rd	BUNDURE	5
Just near Bundure 3 offtake	BUNDURE	15
Lloyd Rd, Farm 557	BUNDURE	18
near the Bundure 5 escape	BUNDURE	34
just downstream of the Bundure offtake	BUNDURE	46
Various sites on Ramsay property		

Table G.3 Linking the related pools to seepage hot spots of Allen, (2006) priority 3

Approximate location	Main channel	Pool ID
F661 was F90, Kook Rd	COLY	50
West of Cockys Lane		
Farm 16	COLY	8
West end of Farm 169, Bull Rd	BOONA	4
Farm 119		
Downstream end of Yamma, Farm 507, prior stream probably just east of the canal	YAMMA	12
Where Argoon crosses Morundah Rd	ARGOON	1
Upstream of Yamma 1a offtake	YAMMA	44
Parts of features on farms 502, 645 and 510	YAMMA	43
Farm 537	YAMMA	19
Farm 205, Fairlie Grange Road	YAMMA	26
Farm 515, the canal runs adjacent to a prior stream	YAMMA	36
Farm 589	MAIN CANAL	5
Just downstream from Bundure offtake	MAIN CANAL	11
near the Bundure 6 escape	BUNDURE	40
at the Bundure 7 escape	BUNDURE	43
Ramsay property generally (excluding priority 2 features)		

Table G.4 Linking the related pools to seepage hot spots of Allen, (2006) priority 4

Approximate location	Main channel	Pool ID
Wallace Rd to Mellington Road	MAIN CANAL	13
Farm 26	MAIN CANAL	21
Farm 19, near Kidman Way	COLY	11
Pine Dr just south of Lovegrove Rd		
Farms 1038 and 1013		
4 shallow prior streams between Channel 9 Rd and Morundah Rd		
Just east of Farm 7000, Bull Rd		
Farms 61 and 58	COLY	47
Farm 89	COLY	51
Farm 171, Morundah Rd	YAMMA	49
Downstream end of Yamma, Farm 507, prior stream probably just east of the canal	YAMMA	12
north-south stretch - farm 93	COLY	48
farm 194	ARGOON	21
Various features along Hannabus Rd		
Four Corners Road	ARGOON	22
Upstream of Yamma 1a offtake	YAMMA	48
Two isolated shallow prior streams - Farms 188 and 189, Hutchings Rd	YAMMA	51
Various isolated shallow prior streams along Fairlie Grange Road		
Farms 510 and 516, the canal runs adjacent to a prior stream		
Farms 518, 517, 516, 515 and 510, the canal runs adjacent to a prior stream	YAMMA	39
Between Main and Bundure 4 offtakes (excluding priority 1 and 2 sites)		
Farm 592		
Farms 619 and 664, 3 shallow prior streams, Glenn Rd	BUNDURE	7
Farm 631, McLarty Rd, Two shallow prior streams	BUNDURE	5
Farm 583, Three shallow prior streams		

Table G.5 Linking the related pools to seepage hot spots of Allen, (2006) priority 5

Approximate location	Main channel	Pool ID
West end of Kyola Rd		
Parts of the downstream end of the canal, Bull Rd		
Farms 61 and 58	COLY	40
Farm 83	COLY	42
Farm 97(north)	COLY	64
Kerslake Rd		
Generally along Hanabus Rd		