

Key words - Water, Irrigation, Efficiency, Crop transpiration, Cotton, Yield, Bales, Megalitre

## **Bales per Megalitre – An Industry Wide Evaluation of the 2006/2007 season**

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### **Background**

Benchmarking irrigation is crucial if an irrigation enterprise is going to improve their water use efficiency.

Knowing how you are performing compared to your region or industry, facilitates continuous improvement in management and water use. Unfortunately irrigation benchmarking data has in the past not been well recorded. The performance indicators measured are generally not well defined and calculations have not been standard across the industry. We talk about bales per megalitre, but what do we mean? The cotton industry has been developing an on-going process to capture water use information from growers and consultants. There are currently web-based tools available to collect this information, including the Water Benchmarking Tool (Cotton Catchments Communities CRC (Cotton CRC) and the Cotton Research and Development Corporation (CRDC) 2007) and the commercially available WATERTRACK RAPID™. The significance of these tools is that calculations of water use indices are standardised and are defined.

NSW DPI is working with the NSW Cotton industry (growers, the Australian Cotton Growers Research Association (ACGRA), CRDC, Cotton CRC, Catchment Management Authorities, Cotton Australia, Cotton Consultants Association, etc) to lift industry water use efficiency through a coordinated industry approach to advisory/extension services (including education/training) in water use efficiency (WUE). This cooperation is extended across the entire industry through the other Cotton CRC partners - Aquatech Consulting Pty Ltd and the Queensland Department of Primary Industries & Fisheries (QDPI&F).

To better understand water use efficiency in the industry, water use figures for the 2006/2007 cotton season in the Namoi and Gwydir Valleys were collected utilising Aquatech's online calculator WATERTRACK RAPID™. This water balance model provides a simple approach to rigorous calculation of essential irrigation performance indicators and is an important starting point in establishing the water use efficiency of a farming operation. By collecting the data from a number of farms, an indication of the current level of water use performance could be established for each valley.

Prior to the collection of any data, the perceived benefits were seen to be important enough to expand the scope of the study to cover the entire Australian cotton industry. The data was to be collected by one person to ensure consistency of data collection and recording. In addition, this

collection of water use data was the first to be undertaken utilising a common format that incorporated crop transpiration, rainfall, yield data (based on actual gin results) in addition to water data.

## Data Collection

42 irrigated cotton farms from Hillston to Emerald were visited in the first half of 2008. The majority of these crops were grown using surface irrigation, however there was a small area under laterals and one paddock that was on drip irrigation. It was not possible to separate the water used on the laterals from furrow irrigation so they had to be included as part of the whole farm water budgets. The field on drip irrigation used a significant amount of water to germinate the crop putting its water use into the vicinity of the surface irrigated crops.

It took no more than two hours to collect the information from any individual grower and at the end of collection, RAPID™ generates two reports allowing growers to see their results on the spot with most figures calculated in bales/Ha or ML/Ha.

When this data is collated anonymously with information from other growers, it is possible to compare the data across a given region or the whole of industry.

Of the 42 farms visited, 37 farms had complete sets of data. These 37 farms grew 12,000 Ha (average per farm 322 Ha) of cotton in the 2006/2007 season which was 9% of the area grown that season. This crop yielded 152,000 bales (average per farm 4104 bales) which were 12% of the total yield in 2006/2007. There were 109,500 Megalitres of irrigation water used to grow this crop (average per farm 2960 ML). A further farm was later excluded due to a data entry error, which left 36 farms for comparison across the industry.

The data collected was easily extracted from the numerous forms of farm records held with each grower. This data included yield from ginning reports, several water input values (incorporating combinations of rainfall, soil water, storages, harvested, pumped), irrigation dates and the identification of soil type based on water holding and infiltration characteristics. Most participants expressed that they “might not have all the data” prior to the survey, however this was not the case.

RAPID™ obtained calculated evapotranspiration ( $ET_o$ ) and rainfall from SILO online. To determine crop evapotranspiration ( $ET_c$ ), the RAPID™ calculator combined the  $ET_o$  values from SILO with a set range of crop coefficient ( $K_c$ ) values for Cotton. The crop coefficients were kept standard across all the farms to assist consistency and are shown in Table 1.

Stage in days	30 days	50 days	55days	45 days
crop coefficient ( $K_c$ )	0.15	1.15	1.15	0.50

**Table 1:** Crop Coefficient ( $K_c$ ) for each growth stage used to calculate  $ET_c$  in RAPID™

It is important to note that the calculation of crop transpiration by RAPID™ is an estimation based on extrapolated SILO data and the fixed  $K_c$  values which are not precisely related to the actual crop in the ground.

For this data, components such as yield and green area were very accurate. The SILO data was independent and consistent; however local farm rainfall figures were used instead of the SILO derived figures. The water volume data was difficult to quantify precisely, especially with the use of on farm storages and with water pumped onto or around the farm.

### ***Information Outputs***

Crop transpiration figures provide an accurate indication of the amount of water required per hectare to produce the crop in that season. By simply subtracting this crop water use figure from the total amount of water used on the farm to grow the crop, the volume of water not used by the crop is obtained. This figure is the amount of water surplus to crop production and is known as “losses”. With RAPID™ all farm water losses are combined into a single figure and these losses include:

- all seepage and evaporation losses from supply systems, ring tanks and dams, drainage and tailwater systems;
- infield losses such as evaporation from the soil surface and deep drainage; and
- rainfall run off that is not harvested.

However, experience has shown that it is possible to isolate each of these losses to some extent by calculation and elimination and having an understanding of the operation of the farm in that season. An estimation of whether the loss is acceptable or excessive is then made. This is important as it aids in the identification of the area on farm where improvements or savings can be made.

A number of irrigation performance indicators are calculated including Gross Production Water Use Index (GPWUI), Irrigation Water Use Index (IWUI) and Crop Water Use Index (CWUI). The data outputs included in the RAPID™ reports were mostly all expressed in Megalitre per Hectare, which was very useful and easy to compare and understand by all participants. Others are expressed as percentages, but the reports contained good definitions that explain the origin and relevance of most generated figures.

### ***Importance to the Irrigated Cotton Industry***

The opportunity to gather irrigation water use data and compare to yield and weather data across the cotton industry using a standardised method is invaluable. The preferred water use index (GPWUI) compares yield to all water inputs including effective rainfall and changes in soil moisture. For this to be done in such a simplistic manner also boosts the importance of the process.

For the first time, growers in different regions can compare their performance with the rest of the (sampled) industry with a high degree of confidence. The addition of the yield and weather data makes the resulting data an important asset to all sectors within the industry.

The cotton irrigators surveyed provided much discussion about the figures calculated in the RAPID™ reports. However, growers were keen to know “*where this data was going*”? “*Why was it being collected*”? “*This data could be dangerous*”. These comments show that the industry is still cautious about providing this data. However, without this data our industry cannot be defended properly.

This data not only provides benchmarking data to the individual, but continued collection of this data over time will enable the cotton (irrigation) industry to show how it is improving and the rate of improvement in water use efficiency and to also identify potential performance targets.

There was also good discussion with survey participants about the amount of water lost on farm, where the losses were occurring and why the differences in water use indices. “*This is exciting information*”, “*In the future I think it will be important to quantify and justify our water use and use a standard method of calculating water use numbers across the industry.*”

### ***Seasonal factors for the 2006/2007 season***

The 2006/2007 season was very dry. Soil profiles and channel pads were dry and few irrigation storages were used. First irrigations used a lot of water as did any transfer of water around farms. There was little to no in-crop rainfall across all regions. Surface water allocations too, were very low or non existent.

Groundwater and carryover of surface water allocations made up the bulk of the water used on crops. For Cotton farmers, there were only a few that grew crops in addition to cotton including winter cereals and some maize and sorghum. The majority of growers grew a cotton mono crop and areas were down significantly from seasons past.

However for the sake of the survey, this made the collection of data very easy. It removed the need to calculate the complexities of irrigation storage usage and having to determine how much water was diverted to other crops. Also estimations of rainfall volumes harvested were also limited.

A “normal” season would make the process some what harder due to increased complexity.

## ***Errors - Known and Suspected***

During the process of collecting the data for entry into RAPID™ and interpreting the data output, some data entry errors were identified. Some were minor in nature while others will need addressing if the accuracy of the process is to be improved.

When setting up each farm in RAPID™, the planting and finishing dates need to be entered for each crop. When there are multiple fields with a range of dates, a decision needs to be made on how to best represent the situation for that season. Unfortunately a decision was made to enter the earliest planting date and the latest finishing date. About a third of the data was collected before this error was identified. By entering these dates, the length of season was lengthened by a small percentage. Further entries were made by selecting a “representative” field for the particular farm.

Quite early on in the process it was noted that the SILO rainfall figure were not accurate when compared to farm rainfall records. As there was an option to enter farm rainfall records and as every grower had them, they were entered into RAPID™. The first few farms that were using SILO data were changed to use farm records.

After comparing crop water use across all regions, it was suspected that the SILO generated crop transpiration figures for two areas (Mungindi and Emerald) were lower than expected. However, the Emerald figures were cross checked by local extension staff and found to be more accurate than was initially thought.

The most significant error that arose was in the estimation or measurement of water volumes on farm. This showed up quite significantly in the RAPID™ report when six farms had negative farm water losses. This is shown in the graphs that follow, but in essence, it means that the total amount of water used to grow a crop was less than the amount required for that crop in that season by the crop transpiration figure based on SILO Evapotranspiration data. Again, the SILO data was suspected, but neighbouring farms had similar figures so the only other explanation can be an under estimation of water volumes on farm. As this water includes water pumped, storage volumes and harvested rainfall, some of which are not metered, it is easy to understand that inaccuracies can occur. Measurement of water volumes, particularly on farm, needs to be improved significantly.

## **Data Interpretation and Trends from the 36 Cotton farms**

The information contained in the RAPID™ reports for each farm was loaded into a spreadsheet for interpretation, comparison and presentation.

The data from 36 farms shows a wide range in irrigation performance across the industry. Water losses on farm range from -1.43 ML / green Ha to 4.71 ML / green Ha, with an average loss (from the 30 farms with positive losses only) of around 1.53 ML / green Ha. This was around 15 percent

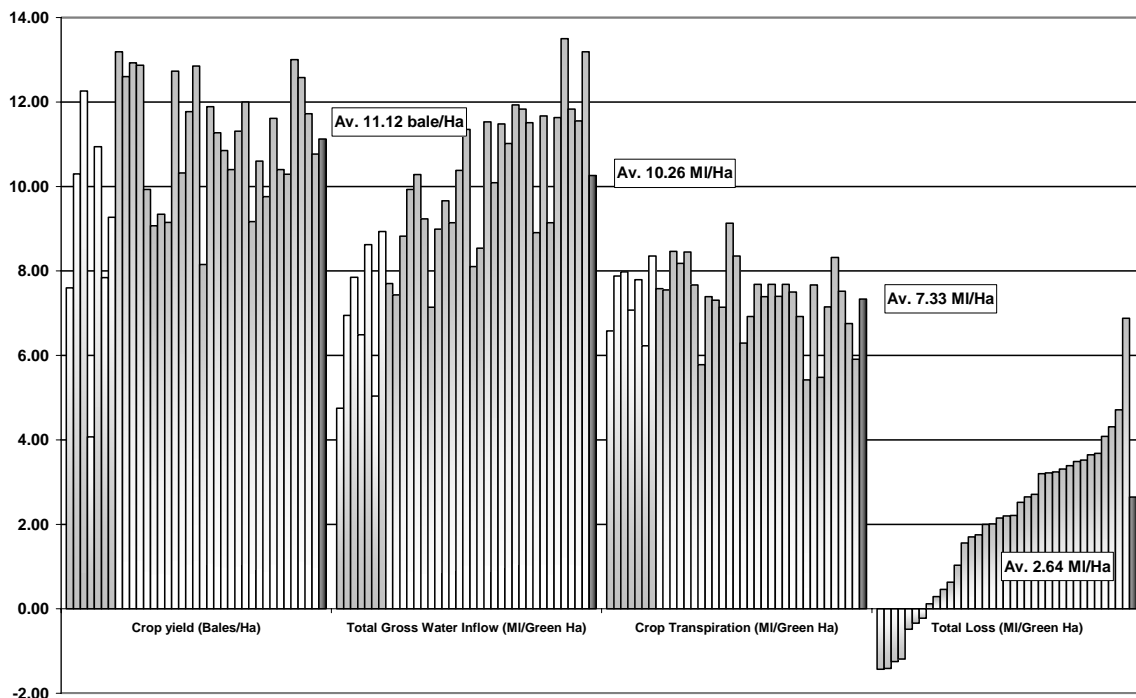
of all water used on farm for the crop, that is, water diverted from river and/or bores, water harvested on farm, effective rainfall and soil water. Therefore on average, the farms were able to utilise around 85 percent of their water through the plant productively. In this survey, the 6 farms with the highest combined farm water losses were only averaging around 65 percent of their total water through the crop in a productive manner. Given that there has been an underestimation of water volumes on some farms, these figures could be on the high side, however, to what extent has not been determined during this survey.

The average GPWUI was 1.13 bales per Megalitre, ranging between 0.82 and 1.71 bales per Megalitre.

### ***Trends from the WATERTRACK RAPID™ results in graph format***

The following graphs have been included to assist in highlighting the trends that have been identified from the RAPID™ data collected for the 2006/2007 season.

#### **1. Variations in whole farm water losses**



**Figure 1.** Variation in Total (whole farm) Water Loss compared to Yield, Total Gross Water Inflow (includes rainfall and soil water) and Crop Transpiration

Figure 1 shows the 36 farms ranked by their Total Water Loss per Hectare. Each farm is in the same position for each grouping. Also shown are the corresponding Crop Yield (bales/Ha), Total Water Inflow (ML/Green Ha) and Crop Transpiration (ML/Green Ha). All averages were only calculated on the farms that had a positive loss (i.e. the negative losses are not included in the averages. All averages only include 29 farms).

Seven farms reported a negative water loss. In theory this is not possible as the total amount of water used on the farm can not be less than the amount required to grow the crop (determined by SILO  $ET_0$  and  $K_c$  values). The only two variables affecting Total Loss are Total Water Inflow and Crop Transpiration. The weather data figures were checked against other sources and nearby farms that were in the study and found to be sufficient. Therefore it is likely the Total Water Inflow figure has been underestimated in these cases.

If these seven farms have underestimated their Total Water Loss, then it could be assumed that some of the farms with losses greater than zero have also underestimated their Total Water Inflow. If this is the case then the average Total Water Loss could be higher than stated.

A decision was made that in reporting the outcomes of the collection of this set of data for the 2006/2007 season that the actual data outputs would be reported. Therefore, analysis of the impact of underestimation has not been undertaken.

## 2. Water use indices

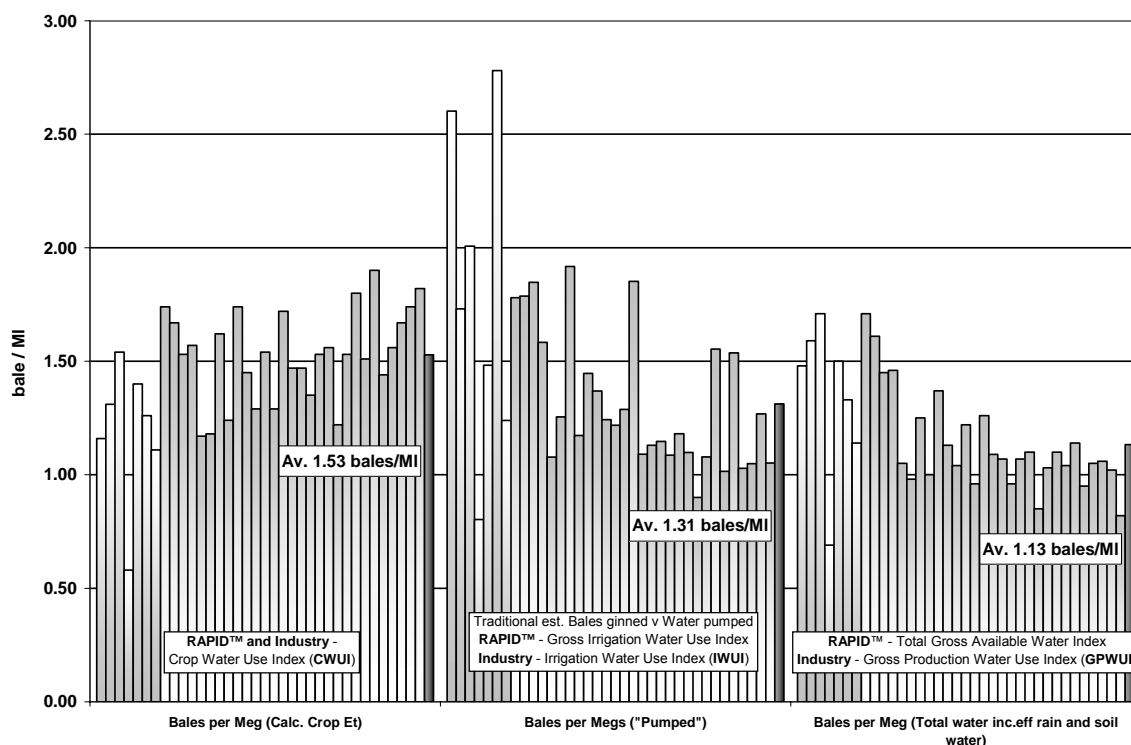


Figure 2. Water Use Index comparison

The water use indices used to benchmark irrigation water use are presented in Figure 2. Crop Water Use Index (CWUI) relates the total production to the amount of water consumed by the crop (Crop Evapotranspiration). Although interesting to see what amount of water the crop has actually consumed, this index is dependent mostly upon non-irrigation related factors such as variety, disease, pests, nutrition and soil constraints and can only be improved by increasing yields. The

CWUI will be affected by waterlogging and late irrigation timing. It is not a useful index for benchmarking irrigation water use but it is useful for estimating potential crop water use.

The traditional water use index often discussed between growers and is calculated using bales ginned and total water pumped. This figure is equivalent to the irrigation water use index (IWUI). However, some growers when calculating this figure for their farms include rainfall while others do not and this can lead to a wide range of figures being quoted which really aren't all that useful for making comparisons. Hence the need to clearly define how you have measured your bales per megalitre.

For the cotton industry the standard water use indices used are Irrigation Water Use Index (IWUI) and Gross Production Water Use Index (GPWUI)

The Irrigation Water Use Index (IWUI) relates total production only to the amount of irrigation water supplied to the farm (or pumped). **It does not include rainfall or soil moisture.** It is useful for comparing between nearby fields or farms in the same season, but as rainfall is not included it is not useful to compare over significant distances or between seasons. The average IWUI was 1.31 bales/ML, ranging between 0.90 and 1.92 bales/ML.

A more meaningful water use index for comparing irrigation water use between farms and regions and across seasons is the Gross Production Water Use Index (GPWUI) as it relates total production to the total amount of water used – all sources i.e. irrigation water, effective rainfall and soil moisture. The average GPWUI was 1.13 bales/ML, ranging between 0.82 and 1.71 bales/ML.

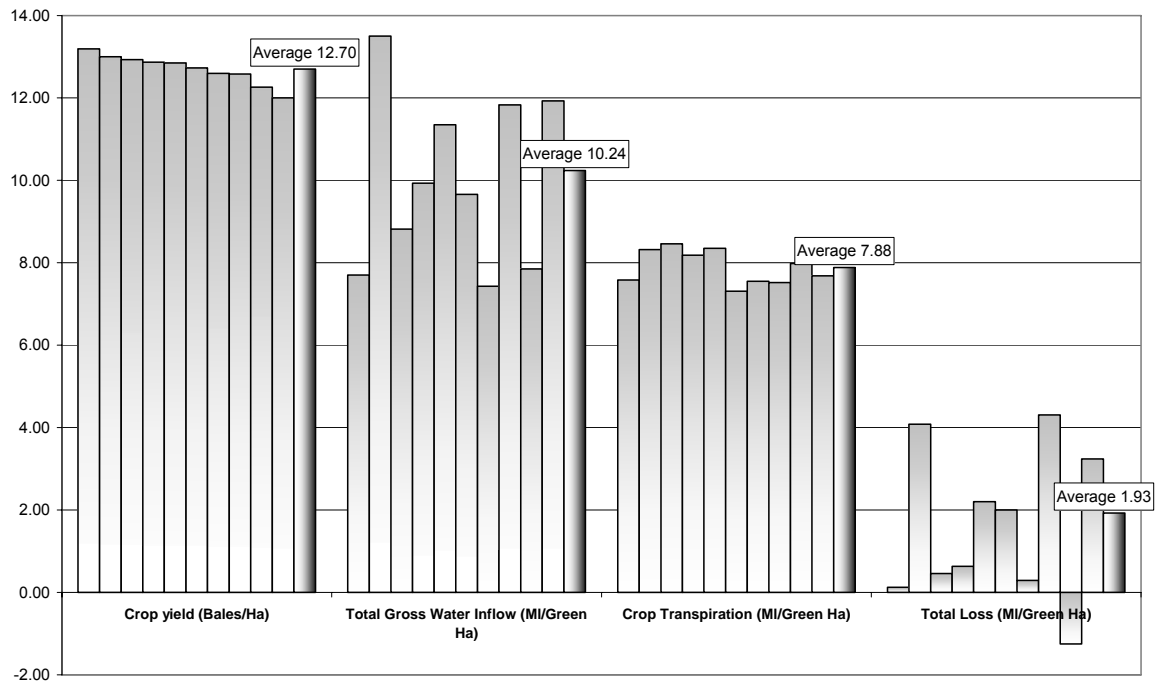
The significance of these results is that the collection and calculation of the water use indices has been standardised enabling meaningful comparison between the farms surveyed. The average IWUI is 1.31 bales/ML compared to the more meaningful GPWUI of 1.13 bales/ML. This is a significant difference and using the IWUI may give a false sense of security in irrigation performance.

**The average GPWUI of 1.13 bales per megalitre is the figure that is representative of the cotton industry water use in 2006/2007.** It is this figure that can be used to benchmark water use so industry can gauge if it is further improving and the rate of improvement over time.

Tennakoon and Milroy (2003) obtained production and water use data from 25 cotton farms and over 200 individual fields over 3 seasons, 1996/97, 1997/98 and 1998/99. They found the industry average GPWUI at this time to be 0.79 bales/ML. The data collected in this survey for 2006/2007 shows a significant increase in GPWUI of around 40 per cent to 1.13 bales/ML.

### 3. Yield comparisons – Highest 10 whole farm yields

Figure 3 compares the RAPID™ results from the top 10 yielding farms in the sample of 36 farms. On average these farms grew 12.70 Bales/Ha using 10.24 ML/Ha of water. The crop was estimated as requiring 7.88 ML/Ha of water to grow, leaving an average loss per farm of 1.93 ML/Ha. The variation in yield and crop transpiration was minimal, whereas the total water inflow and total farm losses are quite varied. This variation could be attributed to a number of factors including differences in rainfall, soil moisture storage, irrigation scheduling, farm design and storage management



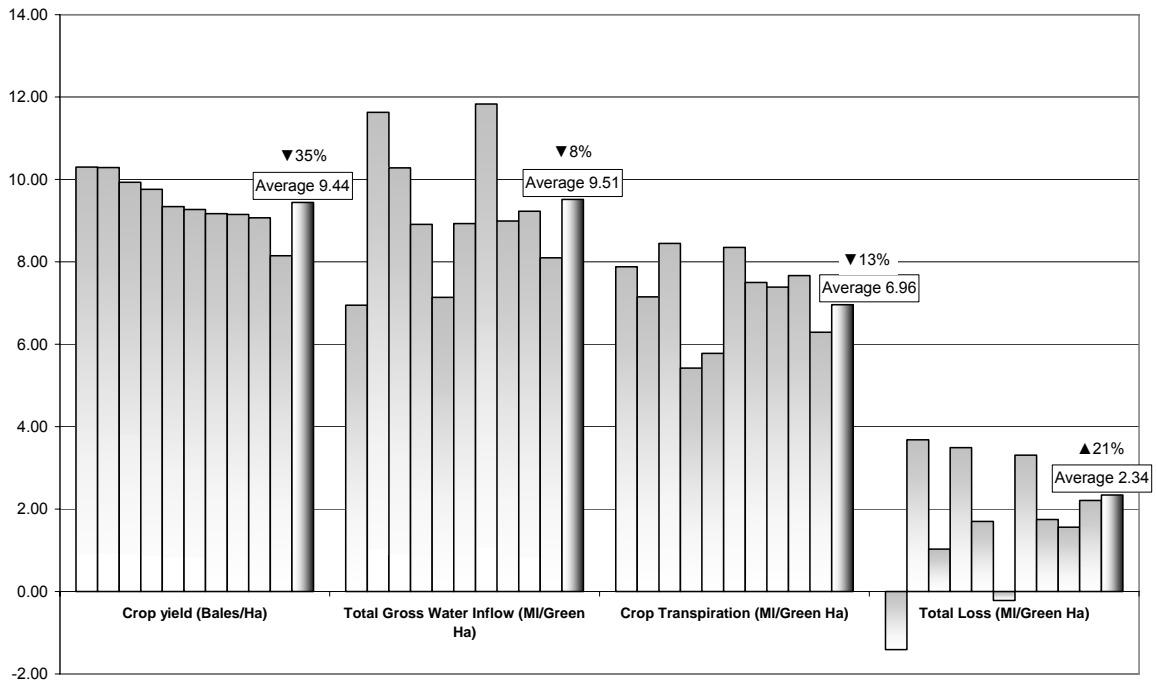
**Figure 3.** Highest 10 whole farm yields

The figures for the highest yielding farms have been verified and tell an interesting story. With a yield over 13 bales/Ha, this crop was a single field, closely managed by an experienced grower, but was watered by a bore pumping straight into the head ditch. There was no rain and no tailwater due to tight irrigation management. The impressively low loss figure demonstrates what can be done, but this situation was far from a normal setup.

### 4. Yield comparisons – Lowest 10 whole farm yields

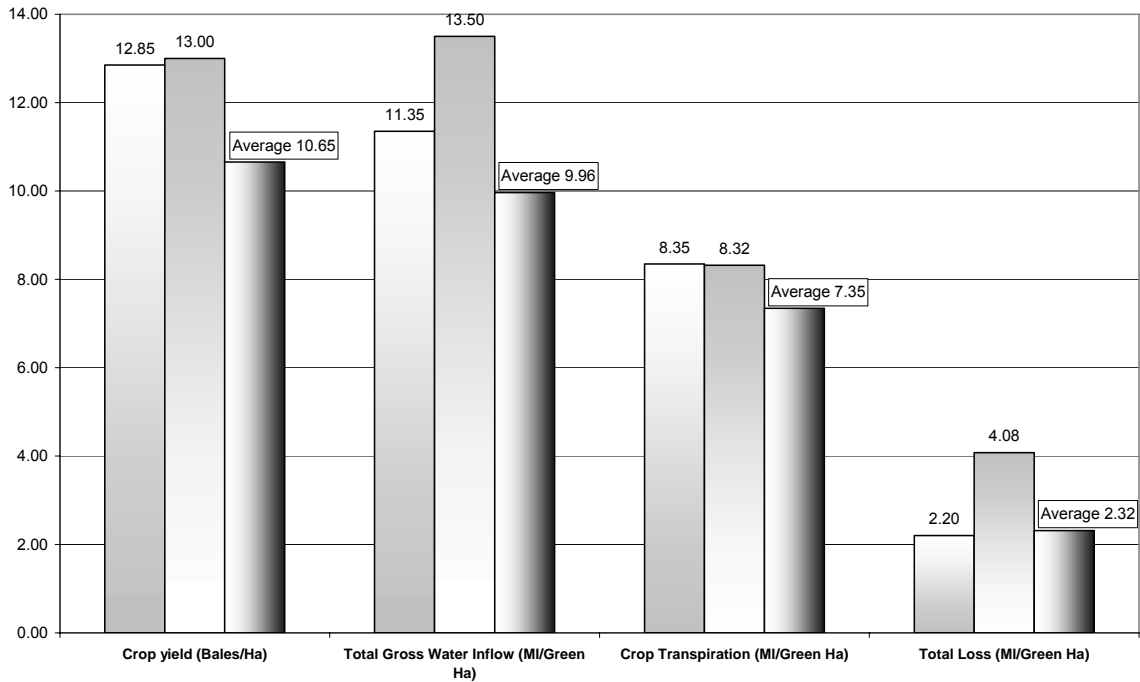
Figure 4 compares the RAPID™ results from the lowest 10 yielding farms in the sample of 36 farms. On average these farms produced 35 per cent less cotton with 8 per cent less water compared to the average of the ten highest yielding farms. The crop was estimated as requiring 6.96 ML/Ha of water to grow. This is 13 per cent lower than the average crop transpiration for the 10 highest yielding farms, although these 10 lowest yielding farms experienced cooler seasonal

conditions which would result in lower crop transpiration. On farm water losses were 21 per cent higher with an average loss per farm of 2.34 ML/Ha.



**Figure 4.** Lowest 10 whole farm yields (with % difference from top 10 average)

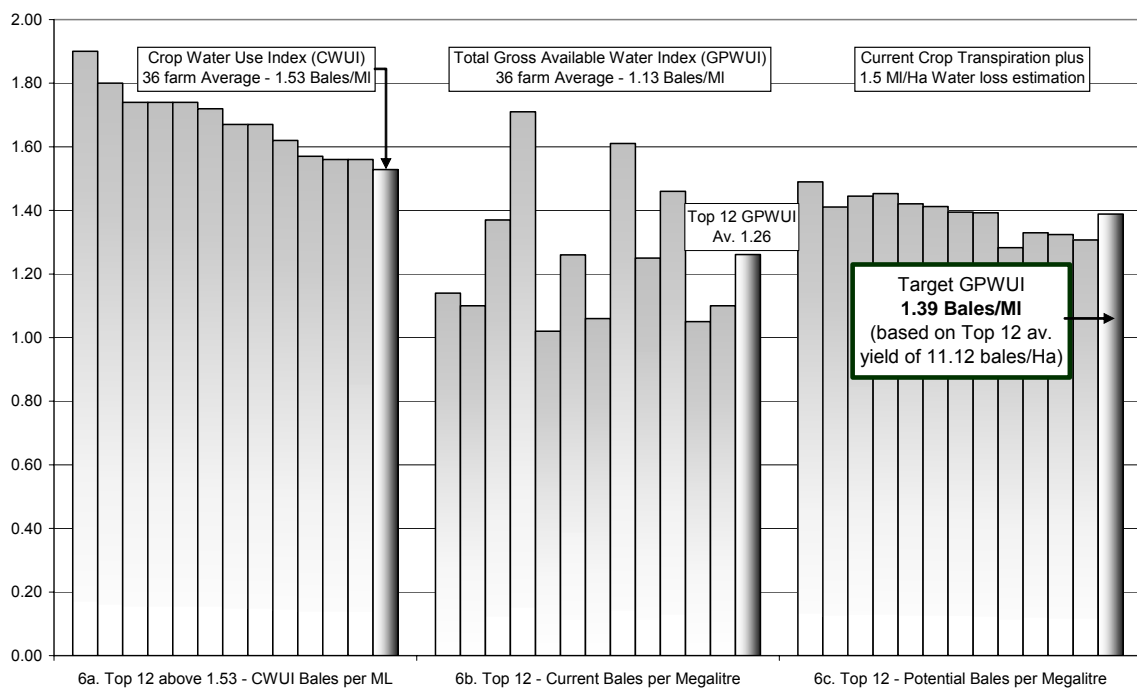
**5. Efficiency results are often site specific.**



**Figure 5.** One grower, two farms

Figure 5 shows the results from two farms that are managed by the one grower. Both farms are yielding around 13 bales/Ha demonstrating that the grower is experienced. Both farms have similar crop transpiration and are located about 25km apart. However the water use and losses on the two farms are quite different. The first farm is the home farm which has been irrigated each year and is well understood and setup. The second farm was leased and had not been irrigated for some time. The increase in losses is mostly contributed to filling up dry channels and soil profiles. There would also be some losses associated with irrigating an unfamiliar farm. This survey using RAPID™ has been useful in demonstrating or interpreting a situation like this.

## 6. Current and future industry potential for bales per megalitre.



**Figure 6.** An estimated Target GPWUI based on current best practice

The data that was collected for the RAPID™ survey provides an interesting insight to the potential theoretical water use indices that can currently be achieved as well as providing projections to what could be achieved in the future.

The average CWUI for all farms was 1.53 bales/ML (refer Figure 2). This figure represents the ability of the plant to produce lint for the given water use in isolation. **It relates yield to the crop water use ( $E_{tc}$ ), not total water delivered to the farm and therefore there are no water losses.** There were 12 farms that had a CWUI greater than 1.53 and these 12 farms are presented in Figure 6a. We can assume that crop management on these 12 farms allowed the crop to produce more lint (bales) per ML of water consumed by the plants ( $E_{tc}$ ). That is, crop stress from pests, disease, nutrition or water management were minimal. Therefore these farms represent the current potential in which the rest of industry can move towards.

These 12 farms had an average GPWUI of 1.26 bales/ML (refer Figure 6b) compared to the average GPWUI of all farms, 1.13 bales/ML.

The average yield for these 12 farms was 11.12 bales/ML. Taking into account the crop water use ( $E_t$ ) for each farm and assuming that the best irrigation practice results in a total water loss of 1.5ML/ha, Figure 6c shows the theoretical potential GPWUI for each farm. The average of these farms therefore represents the industry GPWUI that growers should be targeting, which is a GPWUI of 1.39 bales/ML.

Using this same scenario, but assuming a yield of 14 bales/Ha, the potential GPWUI is 1.64 bales/ML, which is significantly higher than the current 1.13 bales/ML 2006/07 survey average.

## Conclusions

The process of collecting Water Use data for the 2006 / 2007 Cotton season has been a valuable exercise. The information obtained is very useful at all levels of the industry. It has provided a benchmark to gauge how industry Gross Production Water Use Index (GPWUI) has improved since the last attempt to estimate industry WUE by Tennakoon and Milroy (2003). It will also be used as a benchmark for future comparisons of water use indices. The process was simple and quick and more importantly, utilised a consistent approach which included rainfall and seasonal weather conditions, allowing on farm water use to be compared across the industry. The calculation of the water use indices were standardised and defined enabling meaningful comparison.

The survey has highlighted the need for better measurement of water volumes. For the process to improve further and become more valuable, the inaccurate estimation of water volumes on farm needs to be addressed.

Additional work will be required to determine ways of dealing with more complex water use situations on farm, where an industry wide sample is taken in a simplistic manner as demonstrated in this survey. The increased complexity likely to arise in a “normal” season involves determining the volumes of water uses on multiple crops from multiple sources (surface and groundwater allocation and on farm storages and rainfall runoff). This did not occur in the survey of the 2006/2007 season.

Determining where water is used and lost across a whole farm can be a challenging exercise. However, identifying where losses are occurring is fundamental to achieving greater farm water use efficiency. Whilst it is possible to perform some basic calculations at the whole farm level, it can be quite difficult to partition water use and loss to different components of the irrigation system. This requires increased measurement opportunities and more accurate measurement on farm through better monitoring and the adoption of more accurate metering equipment.

The 2007/2008 cotton water use data is ready to be collected now as ginning figures become available. All of the participants from this survey who grew cotton this year have agreed to provide data again. This data collection needs to be done in a consistent manner for both the 2007/2008 season and for future seasons. Increased participation can only provide a better picture of water use practices in the industry. It would be most beneficial to industry if it were to support the continued collection of industry wide water use data.

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