FINAL REPORT

GAINING ACCEPTANCE OF WATER USE EFFICIENCY FRAMEWORK, TERMS AND DEFINITIONS

Final Report – Stage 2
AQC1

May 2003

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NATIONAL PROGRAM FOR
Sustainable Irrigation

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ABSTRACT

Land & Water Australia are progressing a four-stage project, “Determining a Framework, Terms and Definitions for Water Use Efficiency in Irrigation” through the National Program for Sustainable Irrigation.

The first two stages have been completed, and a nationally accepted framework and terms and definitions for water use efficiency in irrigation have been developed in an exhaustive and inclusive process over the last four years.

This framework and terms should now be formally adopted to allow consistent evaluation and monitoring of irrigation systems throughout Australia. Development of measurement protocols (Stage 3) and data interpretation and presentation (Stage 4) are the next steps in the project.

CONCLUSION

A nationally accepted framework and terms and definitions for water use efficiency in irrigation have been developed in an exhaustive two-stage process over the last four years.

Figure 1 outlines a general framework for irrigation performance indicators including water use and irrigation system efficiency. **Figure 2** outlines a detailed framework for water use efficiency as it applies to a generalised irrigation system and **Figure 3** shows a generalised irrigation system with the adopted terms for the elements of supply and drainage from the upper catchment through the joint water supply, farm system and joint drainage system. **Table 1** details the adopted irrigation efficiency definitions.

To avoid confusion, even when using the above terms, it is essential to **clearly define all water use indices and irrigation efficiencies with units and spatial and temporal boundaries**. While this project is clearly focussed on agricultural irrigation, the selected definitions apply equally to urban recreational, landscape and turf irrigation and the appropriate water use indices can also apply to dryland cropping.

Land & Water Australia needs to formalise the adoption of the framework and terms through the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) or similar. It would be desirable to move quickly towards Stage 3 (measurement protocols) and Stage 4 (data interpretation and presentation) to fine tune the framework and terms and maintain momentum with the project.

BACKGROUND

The efficient use of Australia's scarce water resources for irrigated crop production is vital for the sustainability of the irrigation industry in a competitive market for water. The Australian irrigation industry must perform at a level equal to the world's best. Evaluation of irrigation performance is a fundamental step towards improving and maintaining this performance.

To be able to evaluate and monitor irrigation systems and compare the performance of different crops and regions, it is first necessary to agree on how the evaluation and comparison is to be carried out. A necessary first step in this process is the determination of an agreed Australian framework, terms and definitions for water use efficiency in irrigation.

The project

In early 1999 a four-stage project, *Determining a Framework, Terms and Definitions for Water Use Efficiency in Irrigation*, was initiated by the National Irrigation Efficiency Group (NIEG), a subcommittee of the National Program for Irrigation Research and Development (NPIRD), to progress the development of consistent irrigation standards throughout Australia. The four stages were:

1. Determining a framework, terms and definitions for water use efficiency in irrigation.
2. Gaining acceptance of the framework, terms and definitions determined in Stage 1.
3. Developing and gaining acceptance of measurement protocols.
4. Developing suitable methods for data interpretation and presentation.

The aim of each of the four stages is to have outcomes that are accepted nationally as irrigation industry standards.

Current status

Stage I was completed in September, 1999 by Barrett Purcell and Associates Pty Ltd(5). This report concludes Stage 2 and summarises two rounds of detailed feedback from sixty three individuals out of the three hundred and fifty selected as representing the Australian irrigation industry.

The framework and definitions proposed at Stage 1 have been slightly modified and expanded as a result of the Stage 2 feedback and enjoy a very high level of acceptance.

PROCESS AND RESULTS

Stage 1

In March, 1999 Barrett Purcell and Associates Pty Ltd of Narrabri, NSW, was contracted to complete Stage 1 of the project. This consultancy included:

- ☐ Conducting a literature review and summarising existing terms and definitions.
- ☐ Preparing an issues paper suitable as background material for a national workshop.
- ☐ Selecting workshop participants from each state and each sector of the Australian irrigation industry.
- ☐ Running a one-day national workshop in Sydney in June, 1999.
- ☐ Preparing a draft report.
- ☐ Obtaining feedback from the National Irrigation Efficiency Group members initially, then all workshop attendees.
- ☐ Finalising the report.

Agreement with the adoption of the report was very high.

Stage 2

In late 2000, NPIRD initiated Stage 2 of the project with the following objective:

> "To promote and seek national acceptance of the Water use efficiency framework, terms and definitions developed in Stage 1".

This consultancy was awarded to Aquatech Consulting Pty Ltd of Narrabri NSW in conjunction with Naturally Resourceful Pty Ltd of Alstonville, NSW.

The Stage 2 consultancy involved:

- ☐ Summarising the 1999 Barrett Purcell report.
- ☐ Developing a comprehensive distribution list of stakeholders and interested parties throughout Australia who may want to provide comments on the proposed framework, terms and definitions developed as part Stage 1.
- ☐ Posting and publicising a summary document and full 1999 report on the NPIRD website with links to related websites like the Irrigation Association of Australia (IAA), Australian National Committee on Irrigation and Drainage (ANCID), Murray Darling Basin Committee (MDBC) and the National Irrigation Science Network (NISN).
- ☐ Promoting the summary document through the irrigation industry media and chat groups requesting comments.
- ☐ Thoroughly reviewing comments and feedback and incorporating these into the summary document and full report.
- ☐ Printing 1,000 copies of the updated documents and forwarding to the full distribution list and anyone who provided comments.
- ☐ Posting updated documents to the above websites and writing appropriate media releases and distributing and promoting the final documents.

Results

Feedback was obtained in two steps:

1. In October 2002 initial feedback was requested from fifty seven individuals who had some involvement with Stage 1. This was done to capture any new work or changes which may have occurred since September 1999, when the final report of Stage 1 was completed. Twenty detailed responses were received.
2. In April 2003 an updated report was produced which incorporated the October 2002 feedback. Forty four detailed responses were received from a distribution list of 350. This second step feedback was extended to people not directly involved in Stage 1 and enabled clarification of issues raised during the October 2002 feedback.

Of particular interest was the work done by Hydro Environmental Pty Ltd of Camberwell(26) in 2002 for the Victorian Department of Sustainability and Environment (DSE) and Department of Primary Industries (DPI).

This Victorian project had four objectives, as follows:

1. To develop and foster an understanding of standard WUE terminology across DSE and DPI.
2. To develop WUE reporting indicators to enable the performance of key irrigated agricultural industries to be benchmarked over time.
3. To improve understanding of the factors that affect WUE performance on different industries and regions.
4. To generate information that can assist in developing DSE and DPI strategic directions and investment in WUE.

While DSE, DPI and ANCID representatives were part of the 1999 NPIRD national workshop, Hydro Environmental started from the position that "there was no agreed industry understanding of the term WUE". The study then proposed a series of indicators which were to be used in Victoria which were different from those proposed in Stage 1 of this project. Fortunately Hydro Environmental and Aquatech Consulting were able to work through most of the differences and compromises were made by both groups. A paper was then prepared by Hydro Environmental in January 2003, *Comparison of Reporting Approaches – Discussion Paper* (27). The differences in approach reduced to three items, as follows:

1. The Victorian study proposed using the term "Water Use Indicator" rather than "Water Use Index".
2. The Victorian terminology for Distribution Efficiency was the same as the FAO term for Conveyance Efficiency.
3. The Victorian study proposed using "crop water requirement" for irrigation efficiency in place of the FAO definition, which uses "irrigation water available to the crop".

These three questions were specifically raised for comment in the second step feedback of May 2003 as part of this study and the NPIRD approach was strongly supported on all three questions.

Next steps

The two remaining stages of this project are:

- ☐ Stage 3 – Developing and gaining acceptance of measurement protocols
- ☐ Stage 4 – Developing suitable methods for data interpretation and presentation.

These stages will no doubt refine and extend the details of the adopted terms and definitions.

MAJOR ISSUES

Performance indicators

Figure 1 represents the adopted general framework for irrigation performance indicators. The 1999 National Workshop introduced the concept of performance indices when dealing with mixed units. For example, from Figure 1:

$$\text{Crop Water Use Index} = \frac{\text{Total Product (kg)}}{\text{Evapotranspiration (mm)}}$$

while

$$\text{Irrigation Field Application Efficiency} = \frac{\text{Irrigation Water Available to the Crop \%,}}{\text{Water Received at Field Inlet}}$$

is a real efficiency expressed as 80% or 0.8? The feedback in October 2002 agreed with the index concept but some respondents felt that specific indices should in fact be called indicators. The detailed responses of May 2003, however, overwhelmingly supported the structure shown in Figure 1.

Conveyance and distribution

Figure 3 and the table show the accepted terminology for a generalised irrigation scheme and irrigation efficiencies as defined by the Food and Agricultural Organisation of the United Nations (FAO)(10). This terminology differs from the existing Victorian Water Supply Authority terminology as described by Hydro Environmental, 2003(27). The 2003 feedback very strongly supported adopting the FAO approach.

Irrigation field application efficiency

The table details the FAO definitions for irrigation efficiencies adopted by 1999 national workshop and endorsed by the 2002 and 2003 feedback. Because “crop water requirement” as calculated from either general climatic data (Penman-Montieth) or pan evaporation and crop factors is currently proposed by the Victorian water supply authorities in benchmarking studies, it was suggested this could be used for Field Application Efficiency instead of “water available to the crop”. While crop water requirement may be more convenient to calculate theoretically, it does not offer a definition for field application efficiency for a preplant irrigation and is not consistent with the accepted international definition. Feedback responses strongly supported staying with the existing international FAO definition.

USE OF FRAMEWORK AND TERMS

Water use efficiency

Under the adopted framework water use efficiency (WUE) no longer has a specific meaning but should be used as a generic label for any performance indicators used to study water use in crop production. This label, WUE, need not be defined but should be considered like a label on the toolbox. Inside the toolbox are many specific performance indicators referred to as *water use indices*.

Under the framework described in Figure 1, WUE can be the label to discuss water use indices and irrigation system efficiencies. Under each of these performance indicators are a number of specific indices and specific efficiencies which are clearly defined and dimensionally correct.

Water use index

A water use performance index does not necessarily have to fit into the format of:

$$\frac{\text{Unit of product}}{\text{Unit of water}}$$

Any performance index can be tailor made to suit the purpose of the study. The index must, however, be **clearly defined with units specified**. For instance: bottles of chardonnay per megalitre of irrigation water applied, or boxes of oranges per megalitre of irrigation water supplied to the farm gate. The specific index used depends on the systems being compared and the parameters under review.

A performance index may vary between regions without relation to irrigation efficiency. For example, the Upper Condamine River Region in Queensland can produce more cotton per megalitre of irrigation water applied than the St George district on the same river system downstream. St George can have a lower irrigation water use index

$$= \frac{\text{Total product (bales of cotton)}}{\text{Irrigation water applied (ML)}}$$

because it has less effective rainfall and higher evapotranspiration and only slighter higher crop yields. Therefore, even though a system in the Upper Condamine district may be operating at a similar irrigation efficiency as another system at St George, it can have a significantly higher Irrigation Water Use Index.

Some examples of performance indices under the heading Water Use (see Figure 1) include:

- Gross Production Water Use Index $= \dfrac{\text{Total Product (kg)}}{\text{Total Water Applied (ML)}}$
- Irrigation Water Use Index (Applied) $= \dfrac{\text{Total Product (kg)}}{\text{Irrigation Water Applied (ML)}}$
- Marginal Irrigation Water Use Index (Applied) $= \dfrac{\text{Marginal Production due to Irrigation (kg)}}{\text{Irrigation Water Applied (ML)}}$
- Crop Water Use Index $= \dfrac{\text{Total Product (kg)}}{\text{Evapotranspiration (mm)}}$
- Gross Production Economic Water Use Index (Applied) $= \dfrac{\text{Gross Production (\$)}}{\text{Total Water Applied (ML)}}$
- Irrigation Economic Water Use Index (Applied) $= \dfrac{\text{Gross Production (\$)}}{\text{Irrigation Water Applied (ML)}}$
- Marginal Irrigation Economic Water Use Index (Applied) $= \dfrac{\text{Marginal Production due to Irrigation (\$)}}{\text{Irrigation Water Applied (ML)}}$
- Crop Economic Water Use Index $= \dfrac{\text{Gross Production (\$)}}{\text{Evapotranspiration (mm)}}$
- Irrigation Water Use Index (Farm Gate) $= \dfrac{\text{Total Product (kg)}}{\text{Irrigation Water Supplied to Farm Gate (ML)}}$

etc.
etc.
etc.

Note. All indices should be clearly defined with units specified. “Applied” means volume of water applied to the field where “Farm Gate” means volume of water supplied to the farm gate.

Irrigation efficiency

Irrigation efficiency is an important performance indicator in an irrigated cropping context. Unfortunately there has been an overabundance of available definitions for irrigation efficiency.

It is important to recognise the difference between irrigation efficiencies and water use indices. Irrigation efficiencies specifically review the volumetric efficiency of elements of an irrigation system and can be considered in isolation from crop production.

Conveyance and distribution

The adopted FAO definitions distinguish between conveyance efficiency and field canal/conduit efficiency at the point of inlet to a block of fields (e.g. a farm in Australia). That is, the conveyance system conveys irrigation supply water to a farm and the field canals or conduits deliver the water to the individual fields within the farm. FAO also defines a distribution system efficiency as the product of the field canal/conduit efficiency and conveyance efficiency (see Figure 1). That is, under this definition distribution efficiency covers the efficiency of the whole supply system from the headworks to the field. **Whenever these definitions are used the starting and finishing points for conveyance must be clearly defined for the particular study to avoid confusion.**

There was no irrigation system considered as part of this study, whether it be part of a large group scheme like Goulburn Murray Water in Victoria servicing 500,000 ha or a single farm taking water from a regulated stream or bore in Queensland, that could not fit into this framework. It now necessary to change terminology in some cases to fit the definitions. In particular, the large group irrigation schemes in Victoria and Southern New South Wales presently call the distribution system (the scheme works) from the headworks to the farm gate (the point of supply). There is a need for terminology change from these organisations from distribution to conveyance to fit into the adopted FAO framework.

The distribution system should include the complete system from the headworks to the field inlet as detailed by FAO and it seems prudent to change some local terminology to suit the recognised and adopted FAO definitions.

Spatial and temporal parameters

When dealing with either irrigation efficiencies or water use indices, spatial and temporal parameters need to be defined. It is necessary to be very specific about the spatial extent of the area under study and the timeframe over which performance is reviewed. For instance, a single irrigation application lasting less than one day on a single field will have different efficiencies and indices and measurement challenges than a full season irrigation over a large irrigation region.

Seasonal performance indices can easily mask individual events and regional indices can mask individual elements. Additionally, losses from distribution, application and drainage may be reclaimed elsewhere such as downstream pumping and groundwater pumping. Therefore a loss at one scale and point in time may not be a loss at a larger scale and time-frame.

Similarly, seasonal studies are more likely to be affected by rainfall, dew, subsoil moisture and water tables.

Figure 1. Irrigation Performance Indicators

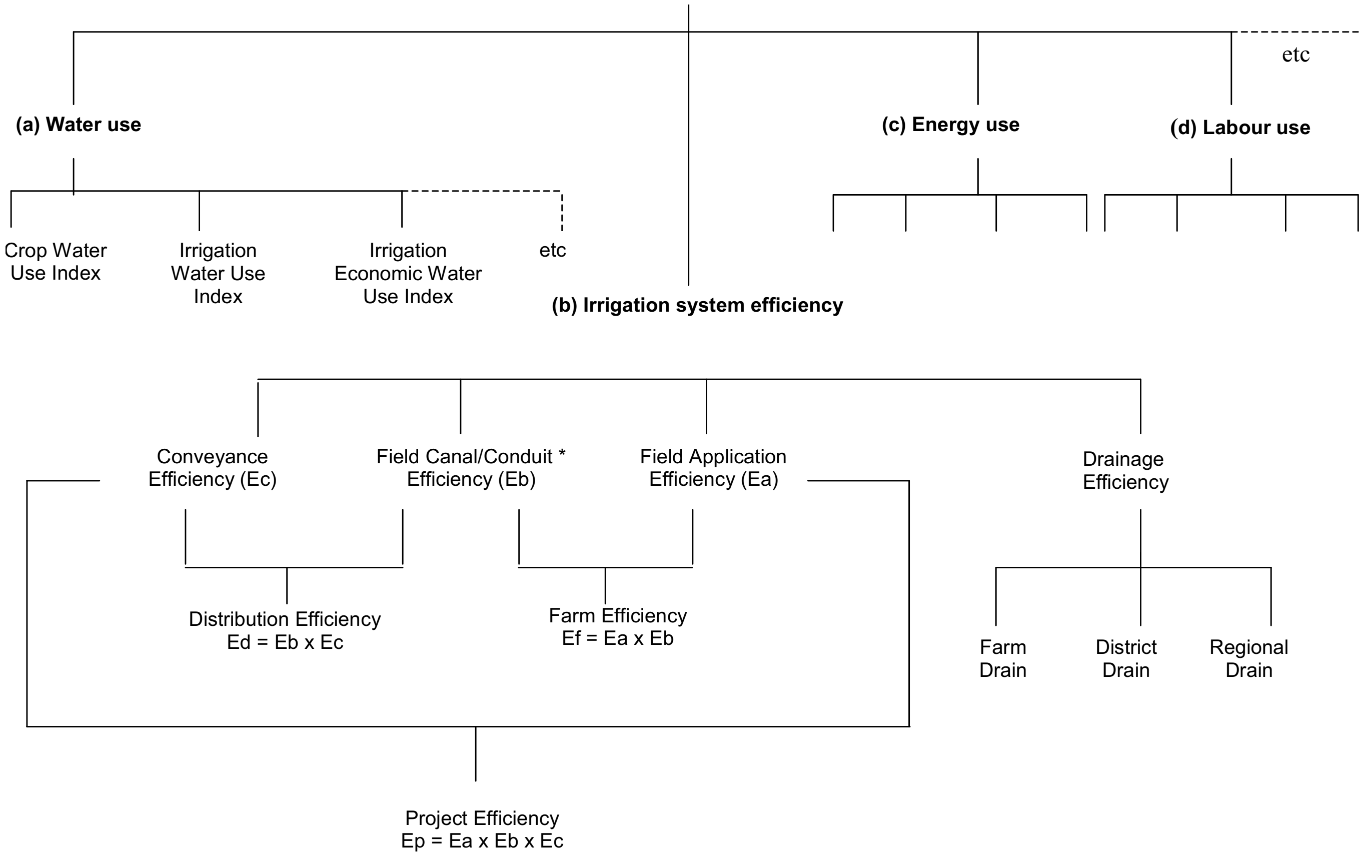

Figure 2. Framework for Water Use Efficiency

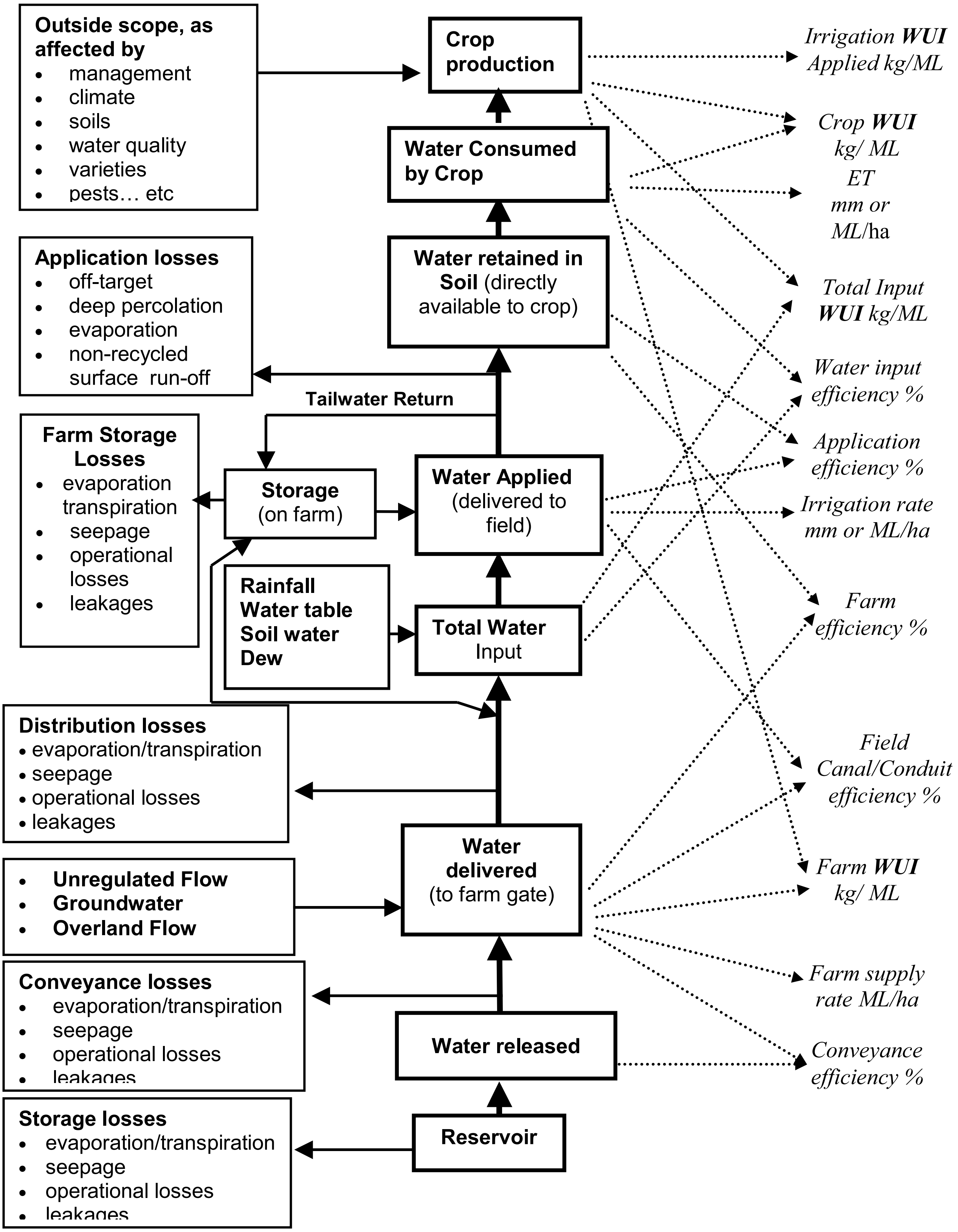

Figure 3. Generalised irrigation scheme layout

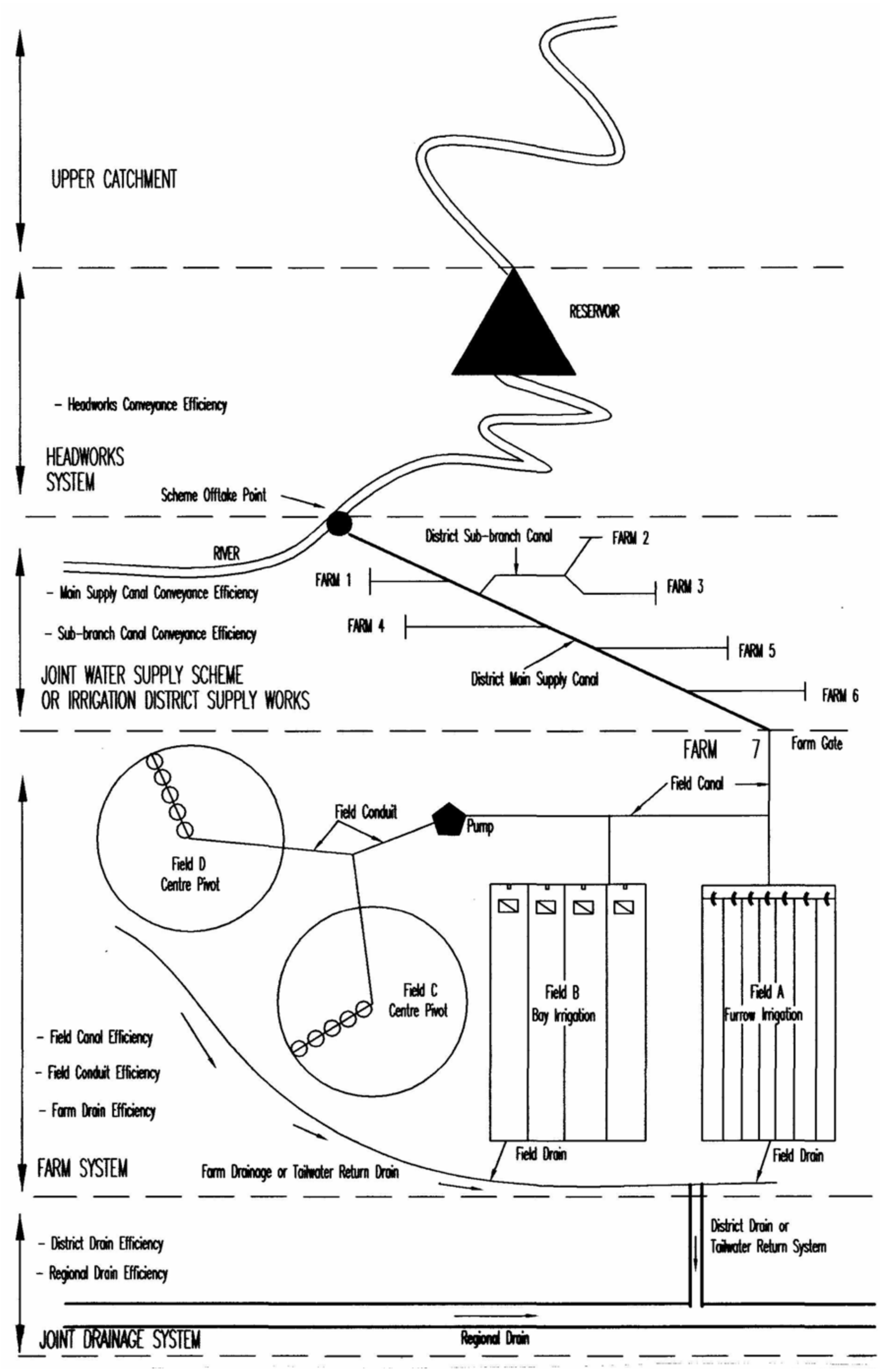

Table. Adopted irrigation efficiency definitions

Term	Definition
[1] Overall Project Efficiency (E_p)	Irrigation water available to the crop Water released at project headworks
[2] Conveyance Efficiency (E_c)	Water received at the inlet to a block of fields (Farm) Water released at project headworks
[3] Field Canal/Conduit Efficiency (E_b)	Water received at field inlet Water received at the inlet to a block of fields (Farm)
Field Application Efficiency (E_a)	Irrigation water available to the crop Water received at field inlet
[4] Drain Efficiency	Water leaving drain Water entering drain

[1] These definitions allow a "nested" approach for a particular irrigation event (assuming no rainfall or unregulated flow into the supply system) as follows:

Conveyance Efficiency (E_c) x Field Canal/Conduit Efficiency (E_b) x Field Application Efficiency (E_a) = **Overall Project Efficiency (E_p)**

Similarly, the product of Conveyance Efficiency and Field Canal/Conduit Efficiency is called **Distribution Efficiency (E_d)**

$E_c \times E_b = E_d$,

and the product of the Field Canal/Conduit Efficiency and Application Efficiency is called **Farm Efficiency (E_f)**

$E_b \times E_a = E_f$ (see Figure 1).

[2] Conveyance efficiency can be broken up into a number of sub-sets depending on the system involved eg headworks conveyance efficiency, district main supply canal conveyance efficiency, district sub-branch canal conveyance efficiency, etc (see Figure 3).

[3] The **conduit** term has been added to the original FAO definition in recognition that irrigation water can be supplied by either canals or pipes.

[4] Drainage efficiency has been added to the original FAO definitions.

OTHER ISSUES

Crop water use efficiency

Crop water use efficiency, in particular, has a long standing history of use by agronomists defined as:

$$\frac{\text{Crop production (kg)}}{\text{Evapotranspiration (mm)}}$$

Most workshop participants felt that this should change to a "Crop Water Use Index" to be consistent. It is recognised that there may be some resistance to this change.

Field application efficiency with localised irrigation

The definition adopted for field application efficiency in the table is based on "irrigation water available to the crop." The point was made through feedback that the depth and area of the soil moisture reservoir may need to be defined to enable a fair comparison between system types. This would normally not be an issue but may be important for instance, when comparing bay irrigation to sub-surface drip irrigation of tree crops. Ideally a widely spaced tree crop should only require irrigation close to the tree. It is therefore possible that some of the irrigation water applied by bay irrigation may not be "available to the crop".

It was agreed that the adopted definitions still applied but noted that the soil reservoir volume would need to be modified with localised irrigation.

Drainage system efficiency

While the FAO definitions concentrate on the supply side of an irrigation system the volumetric efficiencies of the drainage systems should be considered in a similar fashion as conveyance efficiencies. With reference to Figure 3 the drainage system could be split up into:

- farm drain
- district drain
- regional drain.

The efficiency of each could be defined (as a percentage) as follows:

$$\frac{\text{water leaving the drain}}{\text{water entering the drain}}$$

Tailwater return systems which recycle irrigation tailwater (run-off) are important to improve field application efficiency. Some tailwater is necessary on large surface irrigated fields to maintain high uniformity of distribution and the volumetric efficiency of the farm drainage and recycling system must be known to calculate field application efficiencies. Similarly, large group schemes which use drainage from one section of the scheme for supply to another also need to determine drain efficiency similar to conveyance efficiency.

Uniformity of distribution

Uniformity of distribution of an irrigation event is another in-field performance indicator which describes how evenly irrigation water is applied throughout a field. Application efficiency and uniformity of distribution of an irrigation event are closely linked but should be considered independently. For example, an irrigation event may apply an average application equal to the total average soil moisture deficit, but over irrigation may occur in parts of the field and under irrigation may occur in other parts. The application efficiency of this event could be high but the uniformity of distribution could be low and the irrigation would be unsatisfactory. This performance indicator can be described as a Uniformity Coefficient (C_u), Christiansen (1942)[8] or as a percentage, Kruse (1978)[17].

A clear distinction must be made between canal distribution efficiency and uniformity of distribution of an irrigation event when either is used.

Leaching fraction

There was discussion at the workshop and in the feedback about whether a leaching fraction should be considered part of the field application efficiency. It was resolved that while leaching was a beneficial use of irrigation water, it should be considered as part of deep percolation losses thus reducing the application efficiency. That is, an irrigation enterprise that requires more leaching of the soil will be less efficient than one that requires less or none.

Effective irrigation

It should be noted that an irrigation event can be very efficient yet be ineffective. For example, a crop requires an application depth of 90 mm (0.9 ML/ha) to refill the rootzone soil back to field capacity. An irrigation event applies an average application of 50 mm (0.5 ML/ha). Application loses only amount to 8% and the remaining 92% (46 mm) of the irrigation application is **available to the crop**.

$$\text{Irrigation field application efficiency} = \frac{\text{Irrigation water available to the crop}}{\text{Water received at the field inlet}}$$

This is high at 92% but the irrigation event is ineffective because the farmer wanted to apply 90 mm. Further, the uniformity of distribution of the irrigation application should also be checked to gauge how evenly the irrigation was applied. In summary, an effective irrigation event should apply:

- the required amount (no more or no less)
- at the correct time for the crop
- evenly
- reliably
- the conveyance system should provide water to farms on an equitable basis.

Evapotranspiration during irrigation

One response from the 2003 feedback raised the issue of accounting for crop evapotranspiration (ET) during the irrigation event. When using the FAO definitions for field application efficiency (where irrigation water available to the crop is the numerator) ET during the irrigation could be considered a loss because it would not be measured as an increase in the rootzone soil moisture. While the ET during irrigation is normally low it should be included. This issue should be studied more carefully in Stage 3 of this project.

Measuring water available to the crop

Fundamental to all terms and definitions is the ability to readily measure the terms. The numerator of field application efficiency definition is “irrigation water available to the crop”. To measure this, it is necessary to obtain reliable rootzone soil moisture levels during the irrigation season. Details of this process will be studied in Stage 3.

ADOPTION

The process to reach agreement on this framework, terms and definitions has been comprehensive and inclusive. Compromise by some has been necessary but a logical and recognised set of definitions has resulted. All of this work will be wasted, however, if the adoption process is not successful. Land & Water Australia must now build on this work to ensure full adoption.

This report is being made available to around 350 individuals and organisations Australia wide, which should ensure awareness, but L&WA needs to champion this cause at all levels to ensure adoption.

Developing measurement protocols and data interpretation and presentation as stages 3 and 4 of the project will also help with fine tuning and adoption but **must be completed soon** to stop loss of momentum and the possibility of other state studies like the Hydro Environmental study in Victoria from confusing the process.

Every study conducted by any national or state agency or industry body must now adopt this framework and terms. Many states are currently setting policy and strategic plans for water reform and water use efficiency improvement and it is vital that these documents use this framework and terms. It may be necessary to formalise the adoption process through the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) or similar.

FURTHER INFORMATION

An extended version of this report (Final Extended report – Stage 2, May, 2003) along with a background report forwarded to stakeholders for feedback (Second Draft for Comment – Stage II, April, 2003) is available on the L&WA website:

http://www.lwa.gov.au/irrigation/news.asp?news=9&title=policy

Included with the report is:

- a copy of the letter requesting feedback and the feedback form
- a summarised 2003 distribution list of stakeholders asked to contribute
- a summary of the 2003 feedback.

It also includes more detail on the history and process of the project. If you want information about this project you can go to the website address above or contact the following:

The Project

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