

# A WEB SERVICES-SUPPORTED, CALENDAR-BASED, IRRIGATION DECISION SUPPORT SYSTEM

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## ABSTRACT

If irrigation decision support systems (I-DSS) are created with an internet server-based architecture they can benefit from internet tools, such as the machine-to-machine communication protocol known as Web Services, to collect and present information from remote sources at one location.

Web Services are computational functions that are exposed over the internet that allow users' machines to access remote computing resources about which they have no knowledge. In this way, a management tool or decision support system (DSS) that has access to the internet may source data, information and models based remotely, thus acting as a collection point for distributed knowledge, and deliver better support than could otherwise be achieved using information from just one or a few points.

This paper firstly presents an overview of the architecture of a server-based I-DSS, called the "*irriGATEWAY Calendar*", secondly it details how Web Services are used to access data relevant to irrigation scheduling in the Murrumbidgee Irrigation Area of NSW, thirdly it describes how an enhanced user interface (UI) can be made using 'Web 2.0' approaches to technology and fourthly it details how a combination of the Web Services and 'Web 2.0' technologies have been used to build a prototype I-DSS that allows the user to receive both biophysical and non-biophysical decision support from one system.

Finally, a brief description of a future version of the *irriGATEWAY Calendar* is given and the ultimate vision/goal for such a system might be.

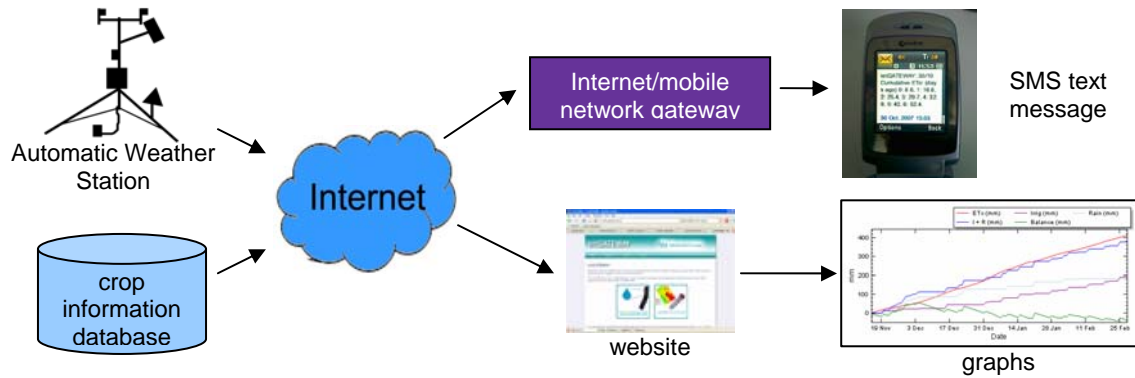
## INTRODUCTION

Objective means of irrigation decision support have suffered from a lack of uptake due to the actual or perceived expense and complexity of the systems involved. Recent ABARE statistics suggest that only about 1 in 5 irrigators use objective decision making (Montagu, Thomas et al., 2006), despite irrigation scheduling with objective help having realised great water savings by some irrigators (Sugarcane Research and Development Corporation, 2007).

One of the ways to combat the poor uptake of irrigation decision support systems (I-DSS) is to make the support readily available through multiple, different user interfaces. To this extent, some recent systems enhanced their user interfaces by branching out and delivering mobile decision support through the use of the mobile phone Short Messaging Service (SMS). One such system uses local weather data and field data to run a water balance and then deliver decision support (Car et al., 2007). Figure 1 shows the basic schema of such a system. It can be seen that the system uses internet connections to deliver both the SMS-based decision support and website-based support.

Other ways to enhance an I-DSS's appeal to irrigators and hence its uptake is to make it more interactive and also to allow it to present a wider range of useful data to the user than is currently the case. For enhanced interactivity, enabling non-technical users to access different information and data processing without technical knowledge of the DSS must be the goal. To increase the range of data sets, the inclusion of non-biophysical information, e.g. water price, electricity price, must be considered. Even the best current advanced I-DSS, that have a proven record of water

savings, such as WaterSense (Inman-Bamber, Attard et al., 2005), do not provide non-biophysical support to the irrigator. In both these regards, internet technologies have a significant role to play in the collection of data (both biophysical and non-biophysical) and its delivery and presentation.



**Figure 1:** Irrigation Decision Support System schema using web and mobile technologies

We have recently developed the *irriGATEWAY: Calendar (IGC)* to provide irrigation scheduling support for wine grape growers using pressurised systems in the Murrumbidgee Irrigation Area (MIA). The technologies and principles that are being applied and tested in the MIA will be able to be implemented for other crops and in other areas.

The *irriGATEWAY Calendar (IGC)* calculates a crop water balance by using daily crop water requirement figures, rainfall and irrigation volumes. The daily crop water requirement is calculated by multiplying daily reference evapotranspiration ( $ET_0$ ), calculated from local weather conditions, with empirically determined crop factors ( $K_c$ ) for the crop in question. The rainfall and irrigation volume data are supplied to the system by the irrigator sending in data by SMS from their mobile phone.

The IGC also calculates the cost of water used in irrigation by multiplying irrigation volumes with water price information and also the cost of electricity needed to pump the water. This allows the user to see the cost of each irrigation as it occurs.

The following background section of this paper gives an overview of relevant internet technologies and then we outline the IGC architecture (DSS Architecture). After which we describe how the IGC uses internet back-end technology to collect data (Web Service Usage) and how internet user interface (UI) technologies are used to present data and information (Web 2.0 Usage). Finally, we outline a future vision for the direction of the *irriGATEWAY Calendar* (Future Work).

## BACKGROUND

The term 'Web Services' refers to software protocols defined by the World Wide Web Consortium designed to facilitate machine-to-machine interactions over the internet (World Wide Web Consortium, 2008). For example, a desktop 'widget' program that communicates with Amazon.com and each day updates a listing of the best selling books for the day could use Web Services as could a website that collects information from a number of places and presents it on one page. The Australia-wide Water Resources Observation network (WRON), currently being constructed by the CSIRO, makes available widgets that allow users of internet-connected desktop computers to see dam heights and discharge rates in close-to real-time (CSIRO Land and Water, 2007). Web pages and websites can make use of Web Services to bring data and information, made available by third parties, into one place for presentation. For example, Google Inc. offers users the possibility of setting up an account that allows them to view a single page that contains multiple information feeds that they have chosen (Google Inc., 2008). This is often known as a 'mash-up' for the way it collects information from heterogeneous sources and presents it in one place.

Web Services are technically realised as computer program functions hosted on remote machines that can be accessed by internet-applications without knowledge of the internal workings of the

function. A Web Service provider publically exposes details of the function's required inputs and possible outputs on the internet and the user, or user application works around these. What sets Web Services-based technology apart from other communication technologies is firstly the flexibility and interoperability of the standard which allows it to be used across virtually all computing systems. For this reason, virtually all of the large software companies, such as Microsoft, IBM, Sun Microsystems, Amazon and so on have integrated support for Web Services into their internet software development suites. Secondly, its use of already well-supported core internet technologies, such as the eXtensible Mark-up Language (XML) and the Hyper Text Transfer Protocol (HTTP) mean that no new hardware or software need be put in place over the current internet systems to use Web Services – it's just a case of writing additional functions in existing software that conform to the standard.

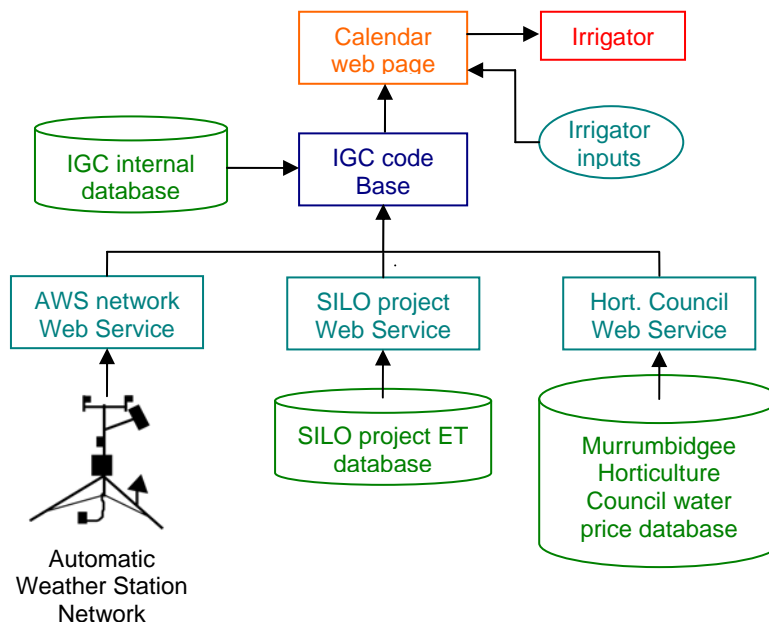
Internet user interactivity has evolved from the initial situation where the majority of users viewed static content posted by a few publishers to some dynamic content posted by a few publishers, to the current situation where users can interact with the information publishers and other users to post content their own. The incarnation of the internet that allows for this great interaction has become known as 'Web 2.0' (Forrest, 2006). One of the much touted hall marks of this 'Web 2.0' paradigm is that it allows users to perform tasks that involve extensive interaction with remote computing resources with limited technical knowledge, another is that remote computing resources are able to be accessed with ease: approaching that of using a desktop computer. The AJAX approach to software programming, using existing internet software and protocols to create internet interfaces that appear to act as smoothly and instantaneously as a desktop interface (Garrett, 2005) allow much of this ease of use. The AJAX approach can be seen making the once complex task of defining hyperlink regions on photographs simple with 'drag and drop' actions on a recent social networking website that allows users to indicate people in photos and create a link to them which is then instantly available to others (Facebook.com, 2008). This is done without requiring the users to have any technical computer knowledge.

A major point in favour of using the AJAX approach is that it doesn't require new hardware or software, it's a simple new approach that generated the functionality. This paradigm in web development is providing unparalleled access for non-technical people to server resources, databases and other networked information providers. The challenge for the irrigation sector is to take advantage of these developments to provide irrigators and irrigation water suppliers with more useful and easier to use (and customise) decision support systems.

## **DSS ARCHITECTURE**

The *irriGATEWAY Calendar (IGC)* basic architecture is given in Figure 2. Information used by the I-DSS comes from 4 data sources, namely an Automatic Weather Station Network, the Special Information for Land Owners (SILO) project, the Murrumbidgee Horticulture Council's Web Service and irrigator inputs to the calendar user interface (UI). Additional information is stored in an internal database.

The IGC code base, internal database and calendar web page shown in figure 2 are all hosted on a server that is the same machine for all users and remote to them. The 3 data sources linked to the IGC code base via web services are hosted by the organisations that generate the data and not by the IGC server. This distributed architecture is one of the key features of this I-DSS.



**Figure 2:** Outline of the *irriGATEWAY Calendar* decision support system basic architecture

## WEB SERVICES USAGE

The *irriGATEWAY Calendar* uses Web Services to collect data used in its decision support from three sources which are:

1. Automatic Weather Stations (operated by Murrumbidgee Irrigation Ltd)
2. An online national evapotranspiration calculation service, SILO (operated by Queensland Department of Natural Resources and Water)
3. The Murrumbidgee Water Exchange (operated by Murrumbidgee Horticultural Council)

### Automatic Weather Station Data

The data from the Automatic Weather Station (AWS) network is used to calculate historical daily reference evapotranspiration ( $ET_0$ ) that is then delivered to the internet via Web Services at [www.clw.csiro.au/services/weather/webservice](http://www.clw.csiro.au/services/weather/webservice). By using Web Services, or more correctly using functions that comply with the Web Services protocol specification, far more flexibility is given to clients that wish to collect data from the AWS than would be possible simply through the use of other non-Web Service compliant data delivery such as via file transfer protocol (FTP) or common web pages. The Web Service front-end allows the *irriGATEWAY Calendar*, or any other Web Services-compliant client, to submit two dates and a weather station location identifier to the Web Service and receive a series of  $ET_0$  readings in return. As any past dates and any location may be requested at any time, the client system may change the range of data it selects at every request. This means that a user who once used the past week's  $ET_0$  readings from Griffith could easily change to using the past fortnight's values from Hay and the *irriGATEWAY Calendar* is able to make that change without changing its collection method, just the parameters used. Table 1 provides a comparison of collecting data from the AWS network via three methods: Web Services, FTP, HTML (web page).

By using Web Services, the *irriGATEWAY Calendar* essentially leaves the task of storing the data to the AWS computer system and just undertakes data requests as required. In this way, the management of the data is left to the data producers and not the DSS. If the managers of the data were to revise values for some reason, the IGC would simply use those revised values next time it requested data, the traditional process of making checking and updating its own copy now being redundant.

**Table 1:** A comparison of three methods of collecting ET<sub>0</sub> data from the web

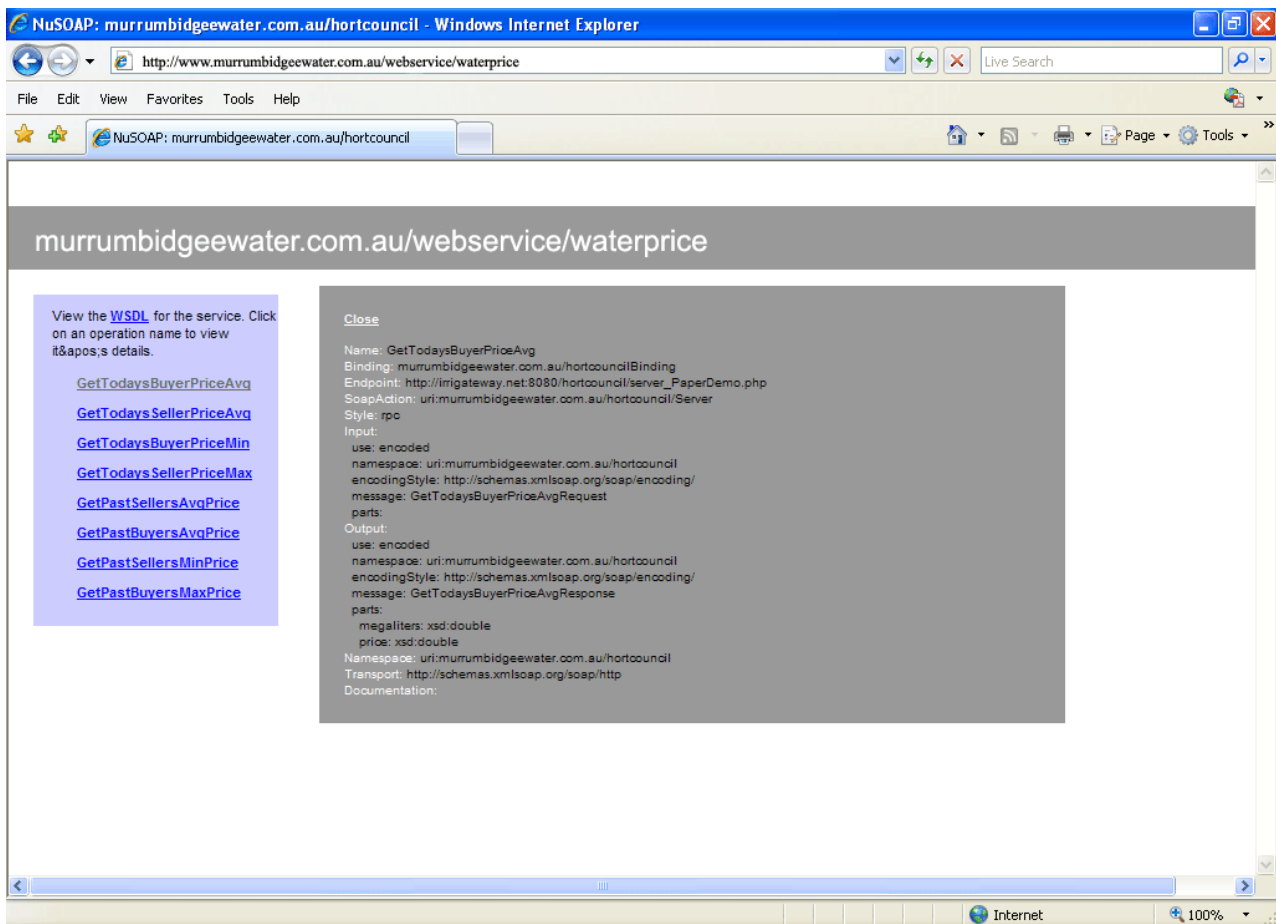
Method	Process	Advantages	Disadvantages
FTP	User or DSS browses a folder on the website and selects a data file for download	Simple and widely supported	Inflexible: requests must always match pre set data formats (files)
HTML (web page)	User views or DSS collects data directly from a web page	Simple and widely supported, data is directly visible	As above
Web Service	Data is delivered in a standard format to the DSS upon request	Flexible: one client may make many, varied requests  Transformable: any subset of the available data may be delivered to another interface in an altered form  Version control: data can be updated without the client having to correct it's own copy of it	Not visible 'to the naked eye' without a special client.

**Online Predicted ET<sub>0</sub> Data**

As AWS only provide historical ET<sub>0</sub> the IGC gathers future (predicted) ET<sub>0</sub> data from the SILO project (see [www.bom.gov.au/silo](http://www.bom.gov.au/silo)). Web services are used to access this data in much the same way as the AWS network data. The SILO project recalculates forecast ET<sub>0</sub> data every day. If a non-Web Service method were used to access the data, this would then need to be stored and managed. However, the *irriGATEWAY Calendar* avoids this by using Web Services thus obviating the need for it's own copy of this data.

**Water Price Data**

Water price data is collected by the IGC from the Murrumbidgee Water Exchange's database via Web services described at [www.murrumbidgeewater.com.au/webservice](http://www.murrumbidgeewater.com.au/webservice). Daily minimum, maximum and average prices for buyers and sellers can be requested along with other statistical measures of current sales. Any subset of the full set of stored historical data may also be requested by presenting the Web Service with the appropriate date range parameters. In this way almost the full functionality of the Murrumbidgee Horticulture Council's Water Price database is available for use by *irriGATEWAY Calendar*. A screen shot of the Water Price Web Service description page is given in Figure 3. Details of the inputs required and the outputs delivered by the Web Service's various functions can be inspected revealing how requests to it need to be formatted and what combinations of data are available.



**Figure 3:** Murrumbidgee Horticulture Council's Water Price Web Service description page. The functions available are listed on the left and details about each function in the centre in grey.

Figure 4 shows the descriptions of the functions available to enable a person to access the data using Web Services functionality. The *irrigATEWAY: Calendar* accesses a different version of the same information that is presented for machine use only. Figure 4 lists some of the code formally detailing the Web Services functions for machine use. Side A shows the code for a data type called 'ArrayOfDouble' which is an array of decimal-like values. Side B lists code for a function named 'GetTodaysSellerPriceAvg' for which the types of both the request parameters and response values are given (Request: there are none, Response: a double (decimal-like) value called 'megaliters' and a double value called price).

<pre> - &lt;xsd:complexType name="ArrayOfDouble"&gt;   - &lt;xsd:complexContent&gt;     - &lt;xsd:restriction base="SOAP-ENC:Array"&gt;       &lt;xsd:attribute ref="SOAP-ENC:arrayType"         wsdl:arrayType="xsd:double[]"/&gt;     &lt;/xsd:restriction&gt;   &lt;/xsd:complexContent&gt; &lt;/xsd:complexType&gt; </pre> <p style="text-align: center;"><b>A.</b></p>	<pre> &lt;message name="GetTodaysSellerPriceAvgRequest"/&gt; - &lt;message name="GetTodaysSellerPriceAvgResponse"&gt;   &lt;part name="megaliters" type="xsd:double"/&gt;   &lt;part name="price" type="xsd:double"/&gt; &lt;/message&gt; </pre> <p style="text-align: center;"><b>B.</b></p>
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**Figure 4:** eXtensible Mark-up Language code used to formally define Web service functions.

While the appearance of the function description given in Figure 3 may change depending on the program used to generate it, the coded description of the functions given in Figure 4 will not and adheres to the Web Service protocol specification.

The Web Services used to collect data from the three data sources detailed above 'loosely couple' the IGC client to the three sources. This means that the client designers needed not have any knowledge of the programming languages, database programs or computer systems used by the data source providers. One of the data source providers could radically alter their system and yet provide seamless data to the client by retaining only their adherence to the Web Service protocol.

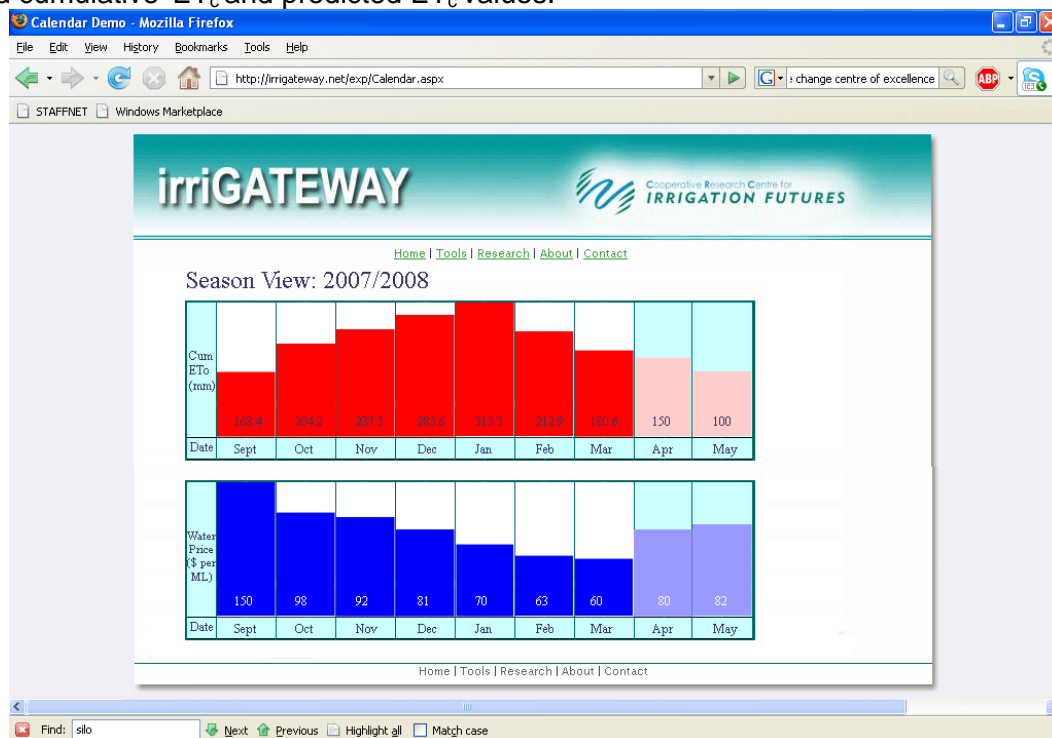
Due to adherence to the Web Service protocol which defines standardised data formats such as date values, integers and arrays of floating point numbers, data that is of the same type but differently derived may be collected and displayed together. For example, the *irriGATEWAY Calendar* does this by using predicted  $ET_0$  values from the SILO project but historical  $ET_0$  values from an AWS network.

As further providers of data relevant to irrigation scheduling make their data accessible via Web Services, they may be added in to the information streams available to users via the *irriGATEWAY Calendar*.

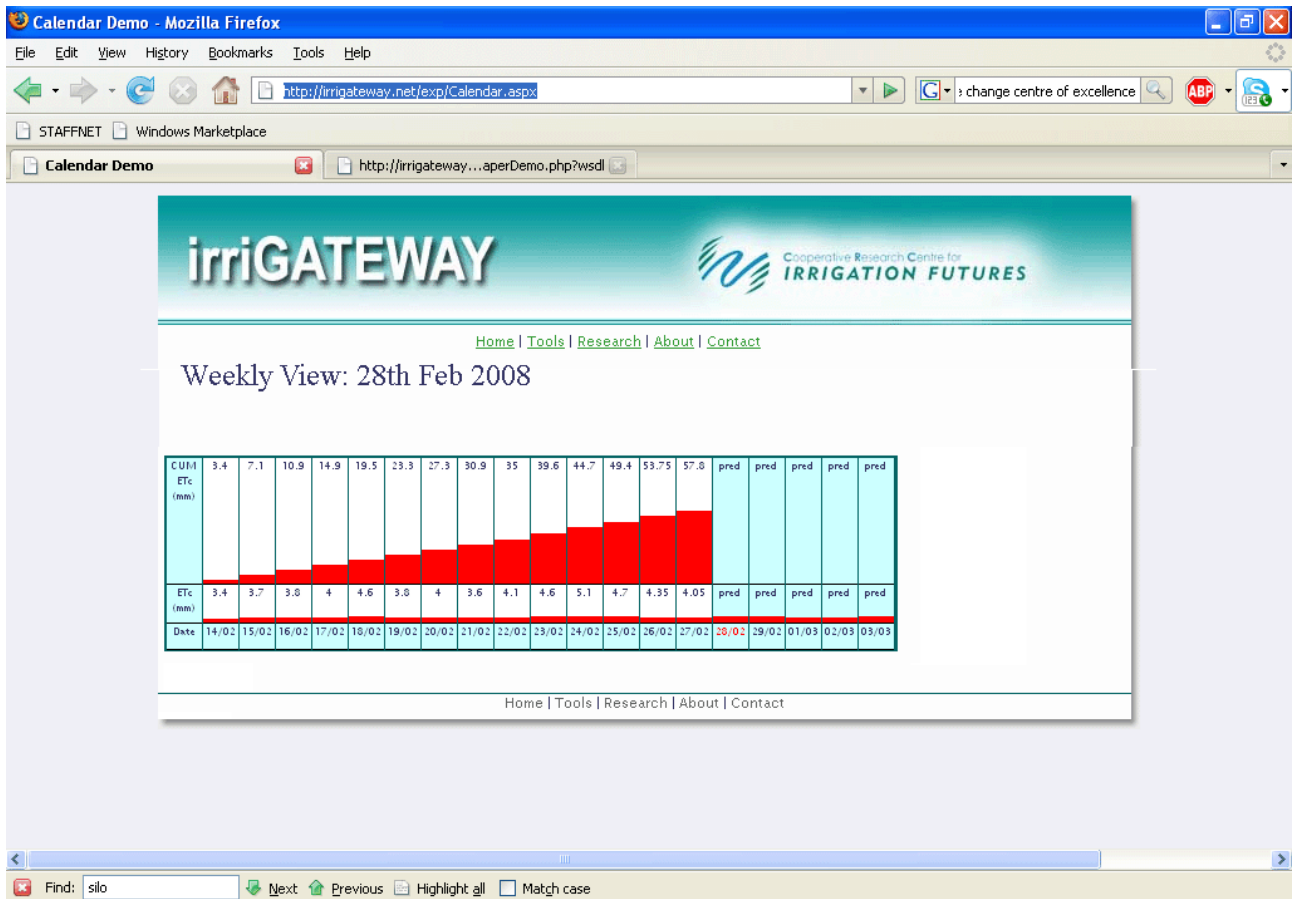
## WEB 2.0 USAGE BY THE USER INTERFACE

The calendar-based user interface (UI) of the *irriGATEWAY Calendar DSS* presents information derived from the four data sources (three Web Service data sources and data input by the irrigator). This data is displayed by time periods (daily, weekly, seasonally). This calendar mode of display has been developed as a result of the authors' research into irrigator decision making behaviour. Irrigators rely on much calendar-based organisation due to the seasonal nature of their crops, the weather, water supply constraints and the requirements of their buyers (e.g. wineries). The calendar display allows irrigators to view likely waterbalance results and the expense relating to future scheduling decisions as well as the accumulated actual costs and waterbalance results of past scheduling actions. The interface uses 'standard measures' to relate data streams to one another. For example, the water applied to a block of grapevines via irrigation and via rainfall is related to the water used by the vines via evapotranspiration. These three values which are measured via pump output, rain gauges and weather stations respectively are related by their standard unit of measure - millimetres. In the same way, water used, the cost of pumping water and potentially saved water are related through the 'standard measure' of \$ cost of each action.

Figure 5 shows the calendar UI displaying a season view of  $ET_0$  and water pricing data. The monthly  $ET_0$  is shown graphically for relative comparison and also textually, in millimetres, for quantitative comparison. This data can then be compared with other data sources that may be requested for display, such as irrigation events. Figure 6 shows the UI displaying a weekly view of daily and cumulative  $ET_c$  and predicted  $ET_c$  values.

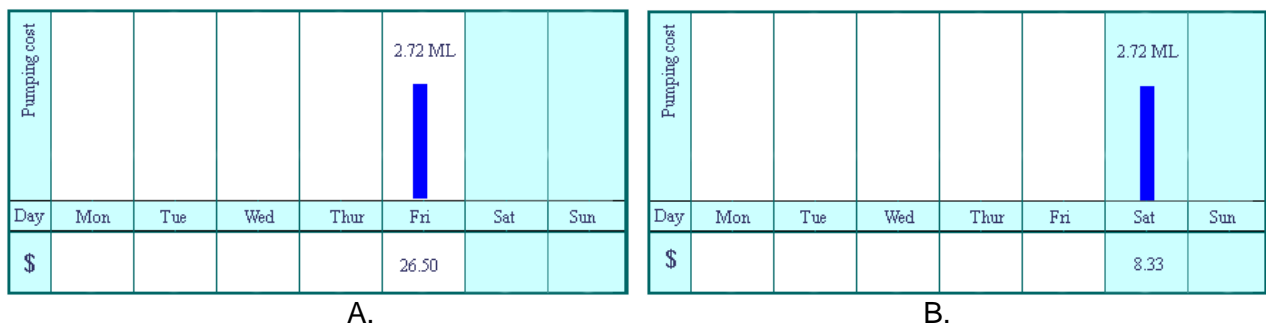


**Figure 5:** Calendar UI seasonal view for 2007/2008 showing  $ET_0$  and water pricing data.  $ET_0$  data is from the CSIRO's Griffith Laboratories Automatic Weather Station and the water price data is from the Murrumbidgee Horticulture Council's database. Forecast values given in light blue & red.



**Figure 6:** Calendar UI weekly view for the 28<sup>th</sup> of February, 2008 showing daily and cumulative ET<sub>0</sub>, and predicted ET<sub>c</sub> values. (ET<sub>c</sub> data derived with ET<sub>0</sub> data from the CSIRO Griffith Laboratory Automatic Weather Station.

Web 2.0 programming techniques are used to enable the calendar interface to instantaneously react to user input such as mouse clicks. Figure 7 shows two screen shots of the calendar UI in weekly view mode, the first (A) with an irrigation planned for a Friday and the second (B) with an irrigation planned for a Saturday when off-peak electricity is available. The corresponding cost of pumping the 2.72 ML irrigation event is shown in the bottom row of the viewing area.



**Figure 7:** Calendar UI in weekly view showing different timing and cost of a proposed irrigation event.

The challenge for Web 2.0 programming, in the instance demonstrated in Figure 7, is to allow a non-technically skilled I-DSS user to complete the described comparison action. This may be achieved by the use of 'drag-and-drop' interface functions which let the user simply select an 'irrigation event' object from a tool box, enter a volume, depth or pump time value and then 'drag-and-drop' it onto the Friday timeslot and then the Saturday timeslot with the corresponding pumping cost being instantaneously displayed underneath. The IGC interface will also in future present the effect that such actions have on the crop water balance. Functionality of this sort will allow irrigators to simulate the effects of future planned irrigation actions and view the results of

past actual irrigation actions. This will allow comparison of the relative costs of each action and analysis of the crop water balance to avoid water stress or over watering.

The IGC when used at multiple time scales such as seasonally and weekly, will allow irrigators to plan a season's irrigations. Thereafter, 'zooming in' to smaller time scales as the season progresses will allow refinement of their irrigation timings and volumes as more data and information comes to hand.

## SUMMARY

The *irriGATEWAY Calendar* (IGC) is an irrigation decision support system unlike any other currently used in the irrigation sector. It has a distributed architecture with data providers housing and maintaining their own data which is then called at will. Data used by the IGC comes from a range of sources and incorporates both biophysical and non-biophysical data that affect irrigation scheduling. Data is displayed in a unique style with interactivity that allows for new types of comparisons and simulations at the will of the irrigator. It is hoped that these advances will make the IGC attractive and easy to use for irrigators and hence the gains that are possible by objective quantitative irrigation scheduling may at last start to be realised.

## FUTURE WORK

Further incorporation of non-biophysical time series data into the interface from third party data sources through Web Services. One such data source for wine grape growers could be from their winery, e.g. predicted harvest date, spray withholding period. As the season progressed, these dates would be refined. The ultimate goal of the IGC will be to incorporate as many useful non-biophysical data sets that affect irrigation scheduling as possible.

Incorporation (overlay) of previous seasons' irrigation management and outcomes.

Benchmarking irrigation water use by using anonymous statistics from multiple users. The benchmarking database becomes a third party data source relevant to irrigators' scheduling.

## ACKNOWLEDGEMENTS

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