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A water resources information system for Australia

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Abstract: Modelling is used extensively to support water management decisions, and covers a range of activities such as estimation of water balance components (e.g. evapotranspiration), calculation of water balances, performing water resource assessments for multiple scales and systems, producing water accounts, and supporting water management operations. One of the key elements to effective modelling is access to data.

In Australia, water data and information required to support sound decisions is gathered and held by a multitude of agencies, authorities and corporations, to the point where it is not possible to readily and reliably estimate the nature and use of our water resources across systems, states and nationally. These data range from surface flows and groundwater levels, to water held in storage, water use in irrigation and urban areas, and water entitlements, allocations and trades. Water quality data are generally collected and managed by a less diverse set of authorities, although the analysis and investigation required to add-value to water resource assessment means that water quality data are also complex to manage.

Improving access to water data to support effective modelling is not simply a matter of everyone making their data available – the plethora of formats, monitoring points, ratings, and data relationships means that making sense of Australia's water data requires a significantly different view. In this view, access to data includes good and continuous data harvesting and harmonisation, tools to explore, view and obtain relevant data, smart data services so that modellers have access to up-to-date data and are disinclined to hoard data sets, and tools to analyse these data in consistent and standardised ways.

Under the Commonwealth *Water Act, 2007*, the Bureau of Meteorology was given responsibility for "collecting, holding, managing, interpreting and disseminating Australia's water information". Consequently, the Bureau started a multi-phase program to develop the Australian Water Resources Information System (AWRIS). The goal for AWRIS is to provide a national, authoritative water data and information resource, giving access to relevant and recent water data from across the country, and to provide added value in terms of a National Water Account and national water resource assessments that will aid in determining what and how we are managing Australia's water.

The first phase of AWRIS began in 2008 and will progress into 2010. Initial efforts in support of better water resource management, planning and policy development are to:

- build upon links with end users and to raise awareness and understanding of the development of AWRIS and what it offers to potential users
- develop core infrastructure,
- gather and harmonise data from multiple sources in close conversation with data suppliers,
- plan and develop initial data exploration and delivery product capabilities and products, and
- develop a base set of tools to make data available to modellers and decision makers.

Early planning to enhance data provision and modelling resources is also underway.

Keywords: *AWRIS, water data, water information*

1. INTRODUCTION

Water resource decision making in Australia is often made difficult by the fragmented nature of our natural resource management structures, our data and information structures and the interplay between jurisdictions across three levels of government and multiple commercial and community organisations.

Water resources are largely planned and overseen at a state level, with operational management occurring at system, catchment, and basin scales. Thus, it is difficult to obtain a broad and inclusive understanding of the distribution and use of the resource. Reliable forecasting of future water availability is also difficult. There are more than 250 agencies, authorities, corporations and organisations that have an interest in part of the resource, and which therefore hold pieces of the water resources puzzle. Effective water resources management and policy development, and effective modelling to support decision making, is thus impeded.

Recent decades of growing water scarcity, and factors such as over-allocation and declining river health, have sharpened national attention on the questions of the state and scope of Australia's water resources. In 2007 this resulted in a new national focus on water information, with responsibility vested in the Bureau of Meteorology (Bureau), and supported by the Commonwealth *Water Act 2007*. The Act expands the role of the Bureau beyond its traditional warnings, weather and climate roles to encompass water information. Specifically, the new functions are (Government of Australia, 2007):

- collecting, holding, managing, interpreting and disseminating Australia's water information;
- providing regular (e.g. monthly, annual) reports on the status of Australia's water resources and patterns of usage of those resources;
- providing regular forecasts on the future availability of Australia's water resources;
- compiling and maintaining water accounts for Australia, including a set of water accounts to be known as the National Water Account;
- issuing National Water Information Standards;
- giving advice on matters relating to water information;
- undertaking and commissioning investigations to enhance understanding of Australia's water resources;
- any other matter, relating to water information, specified in the regulations.

The first four of these relate directly to support of modelling for decision making, either through provision of data, standard methods for analysis, analysis tools, or value-added outcomes of analysis and assessment of Australia's water resources. Underpinning this will be the Australian Water Resources Information System (AWRIS). AWRIS will be an authoritative national repository for Australia's water data and information, and will offer end-to-end coverage of data from more than 250 primary collection agencies across the country, to data supply, analysis and reporting (Figure 1). Associated development of standard analysis methods will also support modelling for decision making.

Figure 1. AWRIS end-to-end water information chain

This paper explores key aspects of effective use of Australia's water information in modelling to inform and support water management decisions. These are:

- the effective engagement of stakeholders and end users, to enhance adoption and ensure that the data and information supplied to decision makers is relevant and timely
- the AWRIS products, covering the nature of delivery of services to explore and obtain data, and to provide model inputs and modelling results
- the value-adding that will occur beyond data provision, in terms of rolling water assessments and water accounts

2. END USERS, ENGAGEMENT AND STAKEHOLDERS

Stakeholder engagement is a key aspect to the successful development of AWRIS and the provision of relevant and timely water data and information to modellers and decision makers as well as to the general public. The stakeholder engagement plan for AWRIS identifies four key principles to successful stakeholder engagement:

- *Collaboration: required across the spectrum from primary water data collectors to researchers, modellers, policy makers and public users of water information.*
- *Engagement: will be used to help balance the competing needs of stakeholders, respond to their concerns and manage issues in an informed and effective manner.*
- *Consultation: needed to consider the diverse range of perspectives and experiences. This will work through methods such as formalised advisory and consultative committees, and expert panels.*
- *Communication: used to develop and enhance our relationships with all stakeholders along the AWRIS water information chain.*

Planning for adoption of AWRIS data, tools and models within the modelling and policy community is a cyclical process (Figure 2).

Early activity in the cycle involves exploration of the adoption situation and awareness of the water information activity and its proposed services and products, such as data from modelling, the development of models and standards, and the application of these to support decision making.

As products are developed attention moves around to delivery, service provision and support, to ensure that data and information products are well and appropriately disseminated. Finally, longer term examination of use of the water data and information is used to inform the next wave of development.

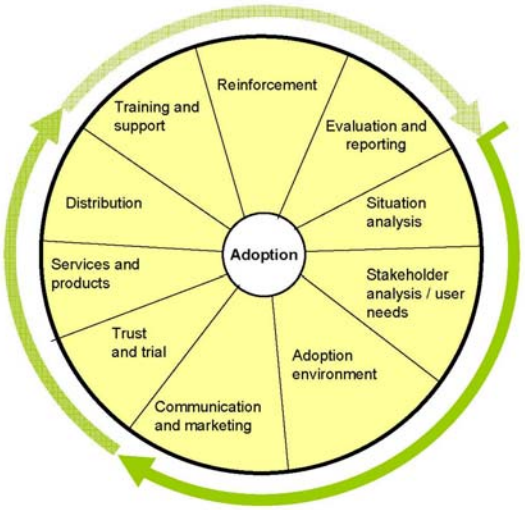

Figure 1 – The cyclical process of planning for adoption.

For AWRIS the first phase is complicated by the nature of water resource decision making in Australia, and the broad range of data and information that will be made available. With respect to AWRIS Phase 1, the end-user groups are:

- Formal data providers (affected persons)
- Policy developers (advisors, analysts)
- Planners (business planners and managers)
- Management and operations (program, project and resource planners and managers)
- Research (advanced and elementary)
- Public enquiry and education
- Formal consultation
- Bureau of Meteorology – Water Division
- Bureau of Meteorology – Other areas, such as forecasting and monitoring systems

Each of these groups have particular needs for data and information, and also varying degrees of interest in modelling inputs, tools, methods and results. The water information products planned for development with AWRIS are designed to consider these.

3. AWRIS PRODUCTS

The spread of AWRIS products being developed to support water resource decision making over the 10-year program is given in Table 1. This ranges from reasonably straightforward data provision, to standards-based analysis products, to hydrological predictions over short to medium to long time frames.

Table 1. AWRIS Product categories

AWRIS Product categories	
Water Information Standards	• Water information standards
Data	• Current data
	• Historical data
On-line Information	• At a glance summaries
	• Present status and usage queries - standard
	• Present status and usage queries - customised
	• Water availability forecasts
Reporting	• Water resources assessments
	• National Water Account
	• Customised water accounts
Advice	• Flood forecasting and warning
	• Hydrometeorology advisory services

In the early stages of the AWRIS project, product development will focus on a 'capability build' that starts from a core set of data exploration and retrieval capabilities, which then expand over time to provide a broader set of services and functions. The capability groups for AWRIS are given in Table 2, along with a description of the capability. For each capability a phased development is planned, with low levels of capability (e.g. mapping of points) in initial development, and more advanced features (e.g. mapping specific sub-network or system monitoring points) being developed later. Feedback from end users, such as modellers, will be sought and used to help prioritise capability development. These capabilities will be used to support the development of early AWRIS products, and will serve in the longer term to underpin the larger and more complex AWRIS delivery challenges, such as annual National Water Accounts and periodic water resource assessments for a range of scales.

In developing AWRIS products based upon access to an expanding national coverage of water data types and networks, careful consideration needs to be given to which of the vast array of possibly products and features should be developed earlier rather than later. To be successful, AWRIS products will need to appropriately reflect the data that have been made available from primary data collectors, and which are of acceptable quality, in terms of value, currency, position and hydrological significance. Key aspects for early consideration are:

- Data
  a) Data categories: observations of the same data type (e.g. stream level) from different observation networks and systems into a common warehouse using a consistent data structure
  b) Metadata: capturing and associating the relevant attributes of observations within the warehouse
- Coverage
  a) Data categories: Assimilating data of all primary types into a consistent framework
  b) Spatial: national coverage for the majority of data types
  c) Temporal: significant length of historical records (≥ 20 years) for many data types

- Presentation
  a) Design: user-focussed, with feedback mechanisms
  b) Form: creative and visually appealing
  c) Context: data alongside related information that promotes understanding;
  d) Mode: primarily via the internet but demonstrates mobile capability

Table 2: Proposed AWRIS capabilities

Capability	Description
Map	Provides the means to construct maps to show the spatial distribution of water data parameters. Sample components of the mapping capability include: presentation of spatial views of data (e.g. coloured triangles showing river level), configuration of contextual spatial layers and textual annotation/labelling, and tools that allow users to navigate and zoom.
Search	Provides a means for users to specify one or more criteria about an item of interest and have a 'search engine' find matching items. The results of the matching will typically be sorted or ranked by some measure of relevance. Search includes of spatial exploration via geographical relationships and interactive maps.
Download	Provides means to request and receive data, metadata and information products and to select formats and delivery modes. Download capabilities extend to enabling users to print AWRIS web pages to file and save displayed graphics to appropriate image formats.
Plot	Provides the means to generate graphs of data. The archetypal use of a plot is to show the variation of a parameter through time (e.g. a stream hydrograph). The plotting capability supports a range of standard plot types (e.g. column and bar charts, line and scatter plots) as well as custom types (e.g. spells analysis output, box and whisker charts). User control of plot scales and views is also considered (e.g. zoom/scroll along a time axis).
Analyse	Ability to compare data sets, calculate statistics, evaluate trends, calculate spatial averages, interpolate between sites and interpolate between data values.
Tabulate	Provides the means to organise raw and derived data in tables. Fine control of table content will be needed, including table and column spanning headings, stubs and stub headings, and table notes. Advanced capabilities include logic-driven table formatting (e.g. highlight minimum values in red) and auto-generation (e.g. based on selected region of interest).
Dashboard	The ability to configure a view on data using dials, gauges and other custom-designed graphical objects. The design of the objects will enable rapid and intuitive interpretation of water data and contextual information. The graphics will imply a conceptual model of the way a water system operates. As AWRIS matures, the ability to configure dashboards (e.g. by pointing the objects to particular data sources, or subscribing to feeds and widgets) will be provided to users.
Configurability	The ability to configure a User Interface that both organises product components (i.e. Maps, Plots, Tables and Dashboard elements) and enables delivery of contextual information, help and tips, and user feedback.

In the initial stages of AWRIS, attention will focus on two primary products of the 'on-line information' type (Table 1): i) a generic system for finding, exploring and downloading data, and ii) a tailored system for reporting on Australia's major water storages.

The generic product is designed to meet the 'data warehouse' needs of many end users, particularly those needing inputs to models and for other analysis and reporting. AWRIS will provide the first national water information coverage for Australia, with data to include streamflow, groundwater, storages, meteorological

data, water use, urban water, trades entitlements and allocations, restrictions and water quality. The coverage and availability of these data will depend heavily on the timely supply and processing of data from suppliers, and the consistency of data formats.

Standard functionality, such as is available for any normal on-line data source, will include viewing data and metadata, search by a range of single and combined key words and other parameters, and downloading of reasonable data volumes for off-line use. Support for advanced searching, such as for monitoring stations in a particular system (e.g. Canberra water supply) or in the catchment upstream of a particular point, will require high quality linking of monitoring points to an underlying spatial 'geofabric', somewhat similar to the Observations Data Model (Horsburgh et al., 2008), that manages data associations such as between points and hydrological features, and between the features themselves

The provision of data services is considered a high priority to support 'live' applications relying of connection to, and availability of, up-to-data data. Although few environmental models or modelling systems, such as E2 (Argent et al., 2009), make good use of web-served data, the growth of these services and the growth of web-served models, is occurring, and so needs to be a part of the AWRIS delivery activity.

The first product tailored to a particular type of water data will provide scaleable coverage of the state of our water storages; from single storages, to systems, states, drainage divisions, and national. Users will be able to search and navigate to a dam, region or scale of interest, and view the most recently available data on storage levels and volumes, including combined system "percent full" such as is done currently in individual jurisdictions. Viewed data would be able to be downloaded and saved to text and image formats for onward processing and communication to support the decision making needs of water resource managers.

Further to these initial products, the Bureau will be developing modelling methods and tools to support standardised water resources assessment and accounting needs.

4. ANALYSES, METHODS TOOLS AND MODELLING

To support the Bureau's role in water information it is important to not only make data available, but to also support decision making through establishment of standard methods for water resources assessment and accounting, and standard tools for undertaking such assessments. One of the issues with long term management of water resources is being able to establish baselines against which performance in resource use can be assessed. Fundamental to understanding the nature of our water resources is a water balance, which can be defined as a comprehensive evaluation of the inputs to, outputs from, and movements of water within a hydrological entity, which includes precipitation and evapotranspiration, as well as other fluxes of water though the terrestrial environment.

A water balance framework, consisting of a nested suite of baseline water balances, is being developed by the Bureau. This will underpin water resources assessments and accounts. Many of the water balance elements will be determined directly from AWRIS data, while many others will be estimated using standard methods. Given the nature of data coverage and dominant processes, the water balance framework has three different levels of complexity that can be nested to also allow analysis and interpretations across scales.

The key features of the water balance framework are that it:

- Focuses on the fluxes of water through the physical landscape (hydrosphere), encompassing both natural and man-made processes.
- Strictly adheres to the concept of a mass balance (i.e. Inputs = Outputs + ΔStorage), applied to a fixed volume, that is, a 3 dimensional box, for a fixed period of time (typically daily, aggregated to monthly-annual). A water balance may contain multiple input, output and storage terms, depending on the level of detail required.
- Is applied to a physically-defined entity, such as a (surface) hydrological catchment or basin, which has clearly defined boundaries, and is typically 10,000-100,000's of km^2 in size. The lower boundary is set below a depth where the groundwater level fluctuates.
- Is consistent with the way in which the concept of water balance is used in hydrological modelling, and the conceptualisation of the hydrological cycle, and is bounded by the energy balance via evapotranspiration.

The simplest level water balance in the framework has approximately 25 components, given in Table 3, while intermediate and complex balances have approximately 40 and 75 elements, respectively, with the latter being somewhat similar to the approach used for AWR 2005 (http://www.water.gov.au/).

Table 3. Proposed structure for a simple water balance

Component	Value
Opening storage balance	Landscape water store
	Surface water store
	Groundwater store
	Water transport system
Precipitation input	Total precipitation
Water input	Total interbasin transfers in
	Marine desalination
	Total groundwater inflow
Evapotranspiration output	Total evapotranspiration
Surface and groundwater output	Total surface water outflow (from landscape and surface water stores)
	Total groundwater outflow
Water export	Total interbasin transfers out
	Marine outflow of sewage
Closing storage balance	Landscape water store
	Surface water store
	Groundwater store
	Water transport system
Error	Extent to which balance does not close
Major internal fluxes	Total inflow to surface water store (runoff)
	Total inflow to groundwater store
	Total extractions and diversions for water use
Change in water availability	Estimated % change in Surface water store
	Estimated % change in Landscape water store
	Estimated % change in Groundwater store

Quality Assurance and Quality Control are both central to the development of AWRIS, the delivery of data and information, and the analysis and assessment of Australia's water resources. A long term investment is being made in these areas, with initial activities including scoping and understanding of current quality processes applied by primary data collectors, and system design for AWRIS to flexibly support a range of quality processes.

5. CONCLUSIONS

The Bureau of Meteorology, in fulfilling its new role in water information, is undertaking multiple activities to support the effective use of modelling to inform and support water management decisions. We are contributing to long term improvement in water resources decision making by providing more timely and comprehensive access to Australia's water data, by developing standard methods for assessing water resources, and producing formalised accounts of our water use to support long term analysis of the results of water management decisions.

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REFERENCES

Argent, R. M., Perraud, J. M., Rahman, J. M., Grayson, R. B., Podger, G. M., 2009. A new approach to water quality modelling and environmental decision support systems. Environmental Modelling & Software, 24 (7), 809-818.

Government of Australia, 2007. Water Act 2007, p. 235.

Horsburgh, J. S., Tarboton, D. G., Maidment, D. R., Zaslavsky, I., 2008. A relational model for environmental and water resources data. Water Resources Research, 44 (5).