# Water Accounting Report 2: Water Accounting Data for Integrated Urban Management Modelling - A Focus on the South East Queensland Setting

Peter Daniels and Kate McBean

December 2010

Urban Water Security Research Alliance
Technical Report No. 37

Queensland Government
National Research FLAGSHIPS Water for a Healthy Country
CSIRO
Griffith UNIVERSITY
THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Urban Water Security Research Alliance Technical Report ISSN 1836-5566 (Online)
Urban Water Security Research Alliance Technical Report ISSN 1836-5558 (Print)

The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

For more information about the:

UWSRA - visit http://www.urbanwateralliance.org.au/
Queensland Government - visit http://www.qld.gov.au/
Water for a Healthy Country Flagship - visit www.csiro.au/org/HealthyCountry.html
The University of Queensland - visit http://www.uq.edu.au/
Griffith University - visit http://www.griffith.edu.au/

Enquiries should be addressed to:

The Urban Water Security Research Alliance
PO Box 15087
CITY EAST Qld 4002

Ph: 07-3247 3005; Fax: 07-3405 3556
Email: Sharon.Wakem@qwc.qld.gov.au

Authors: Griffith University, School of Environment.

Daniels, P. and McBean, K. (2010). *Water Accounting Report 2 - Water Accounting Data for Integrated Urban Management Modelling - A Focus on the South East Queensland Setting*. Urban Water Security Research Alliance Technical Report No. 37.

## Copyright

© 2010 Griffith University. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of Griffith University.

## Disclaimer

The partners in the UWSRA advise that the information contained in this publication comprises general statements based on scientific research and does not warrant or represent the accuracy, currency and completeness of any information or material in this publication. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No action shall be made in reliance on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, UWSRA (including its Partner's employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

## Cover Photograph:

Photographer: Peter Daniels
© 2010 Peter Daniels

# ACKNOWLEDGEMENTS

We wish to thank Mark Askins and Genevee Telford from the Queensland Water Commission for their kind assistance in providing extensive advice on the evolving form of South East Queensland's *WaterHub* – the primary water information system for the region.

We would also like to thank CSIRO Land and Water's Shiroma Maheepala, Stephanie Ashbolt, Andrew Grant, Fareed Mirza and Joel Rahman for their assistance in our understanding of the HydroPlanner SEQ prototype and for Andrew and Joel's input into our analysis of the synergies between the content and data requirements of the HydroPlanner prototype and water accounting frameworks relevant to the region. Also thanks to Lisa Alder for her comments and ideas.

# FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, through targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

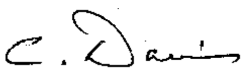
As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, e-Water CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over 5 years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- ensuring the reliability and safety of recycled water systems.
- advising on infrastructure and technology for the recycling of wastewater and stormwater.
- building scientific knowledge into the management of health and safety risks in the water supply system.
- increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.



**Chris Davis**
Chair, Urban Water Security Research Alliance

# CONTENTS

# LIST OF TABLES



# GLOSSARY

| | |
|---|---|
| ABS | Australian Bureau of Statistics |
| AWRIS | Australian Water Resources Information System |
| BOM | Bureau of Meteorology |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DERM | Queensland Government Department of Environment and Resource Management |
| eWater CRC | eWater Cooperative Research Centre |
| GU | Griffith University |
| IDM | Integrated Data Management |
| IUWM | Integrated Urban Water Management |
| EUM | End Use Model |
| LCA-IM | Life Cycle Analysis and Integrated Modelling |
| PAM | Production Analysis Module |
| QWC | Queensland Water Commission |
| SEEAW | United Nation's System of Environmental-Economic Accounting for Water |
| SEQ | South East Queensland |
| SEQ-RP | South East Queensland Regional Plan |
| SEQWS | South East Queensland Water Strategy |
| SWIM | Statewide Water Information Management |
| UQ | The University of Queensland |
| UWSRA | Urban Water Security Research Alliance |
| TWCM | Total Water Cycle Management |
| VPM | Volumetric Point Measurement |
| WaterCAST | Water and Contaminant Analysis Simulation Tool |
| WEMP | Water Efficiency Management Plan |
| WG | Water Grid - a network of two-way pipelines connecting major bulk water sources in the South East Queensland region. This system will be able to redistribute water directly from areas of surplus and to those experiencing a shortfall. |
| WGM | Water Grid Manager |
| WSP | Water Service Providers |
| WSUD | Water Sensitive Urban Design |
| WTP | Water Treatment Plant |
| WWTP | Wastewater Treatment Plant |

# EXECUTIVE SUMMARY

## Introduction

The research summarised in this report has aimed at: (1) identifying the empirical data requirements for the HydroPlanner SEQ (South East Queensland) prototype and related integrated urban water management (IUWM) models; and (2) assessing the extent to which they can be sourced in existing and planned water accounting systems pertinent to the region.

While the results are focused upon South East Queensland (SEQ), they would also have widespread relevance for enhancing systems development for the fruitful exchange of data between empirical efforts of water accounts and conceptual, simulation and process-based models.

The major outputs are the systematic description of the empirical water data needs typical of IUWM models (especially HydroPlanner), and the identification of the availability of appropriate data, at useful spatial and temporal resolutions, in existing and proposed water accounting systems. A key goal is to identify high priority "data gaps" where data that would be very useful for integrated model needs do not exist or are not available at required spatial and temporal configurations.

## Justification

Water accounting data that describe the totality of natural and human water cycles provide the necessary basis for creating efficient and sustainable urban water systems. The identification of IUWM modelling data requirements (and priority shortcomings) can help guide the development and modification of water accounting systems so they better contribute to sustainable water management policy and practice.

In the past, urban water management was dominated by a linear approach where water demands would be supplied from the primary collection system, and wastewater and stormwater were typically conveyed away from urban areas (Makropoulos, Natsis *et al.*, 2008). Alternately, integrated urban water management (IUWM) and modelling approaches involve the conceptualisation, analysis and coordinated management of freshwater, wastewater, and stormwater as components of basin-wide systems where urban water use, loops and cycles are cast within (and often redesigned to emulate) a mass balance perspective of relevant regional "natural" water cycles. It is a system analysis view where the flows and interdependencies between all relevant natural and anthropogenic components are clearly enunciated and considered. This perspective provides a much wider basis for designing and implementing options for resource-efficiency and security of supply.

Integrated approaches to modelling require system-wide data. The development of water accounting systems that can provide this information will underpin accurate and useful models. This report examines the forthcoming capability of water accounts to provide this basis in the SEQ context.

Hence, ready access to water accounting data that are available at appropriate spatial and temporal detail is essential for effective urban (and regional) hydrological modelling. The urgent need to consolidate abstract hydrological models with empirical data bases is clearly evident in many recent scientific publications in the field. For example:

> *As modelling power has increased, there has been a concurrent reduction in "data power", particularly in the collection of hydrological data* (Silberstein, 2006 p.1340).

> *The first step is to use the model uncertainties (which represent those aspects of the hydrological systems that are least understood) to collect new or better data, improve data assimilation techniques or study specific processes. In the second step, the model should be improved using these data, methods and concepts* (Buytaert, Reusser *et al.*, 2008 p.4175).

Empirical water account data can be utilised to support IUWM models in many ways. These uses include:

- as data inputs for decision variables and scenario formulation or specification;
- in system conceptualisation;
- in the model structural identification process;
- for model and process parameter estimation or calibration; and
- for model evaluation or validation (and ongoing improvement).

More detail on the contribution that water accounting data can make to hydrological modelling, in a general sense, is provided in McBean, Daniels and Braddock, 2010.

Hence, empirical water data plays a critical role in hydrological modelling throughout all stages of model development, calibration, implementation and validation. In so doing, it helps create more realistic, transparent and accountable hydrological models. Good frameworks also help minimise error and uncertainty associated with model outputs (Beven, 2007; Kirchner, 2006; Silberstein, 2006). Without access to such information, the accuracy of models and their capacity to be used as predictive tools are compromised.

## Extended Application

Water accounting systems that properly serve IUWM models will also be well-suited for total water cycle management (TWCM). Given their comprehensive and integrated nature, many of the conceptual and related data needs of IUWM approaches are consistent with those for the TWCM approach that has become a key principle in sustainable water management in the SEQ region. In line with the integrated resource management philosophy, the TWCM approach incorporates all aspects of natural water cycles and urban-rural water use, and the linkage between the natural and anthropogenic domains. This is considered ideal so that sustainable urban (and regional) water planning options can be evaluated, designed and implemented in a cost-effective way – where cost-effectiveness is assessed in a triple bottom line (TBL) accounting sense covering the full range of economic, environmental and social effects (including external effects or "externalities" that are not resolved within markets). Typical options aligned with the TWCM approach include a focus upon natural and human aspects and linkages at a comprehensive catchment level, water efficiency and recycling, water sensitive urban design (WSUD), stormwater management for water quality and supply management, and the contextual relationship between water supply, quality, pollution, and related health aspects.

## Method

The approach used to examine the availability of relevant data from the water accounting systems is quite straightforward. It simply involves:

(a) systematically listing all known data series that were likely to be covered at some level, in the water accounts examined (refer to Table 4).
(b) analysing the HydroPlanner SEQ prototype (and the general IUWM model approach) and identifying the likely empirical data needs for their various components. Consultation and advice from the principal developers of the HydroPlanner SEQ prototype were major sources of information for this part of the research method.
(c) matching the complete list of individual water accounting variables ("measurands") under consideration to the IUWM data requirements (including a general assessment of their priority and model component relevance).

The method used to identify potential data exchanges and key missing data series is encapsulated in the format of primary results of Table 4, diagrammatically explained below:

| **1. CLIMATE DATA - Biophysical attribute group being measured e.g. climate, water supply-storage** etc | | |
|---|---|---|
| **Total rainfall**<br><br>= the specific data series being assessed | **H**igh **L**ow **H**igh<br>= the relevance of that data series (total rainfall) for the HydroPlanner (HP) and IUWM models in general<br>- includes the relevance for *specific* HP components | 4 4<br><br>= indicators of data availability in the water accounts systems (WaterHub, BOM and SWIM) and their spatial and temporal measurement suitability |

This process reveals whether specific data series are available, and if they are in a spatial and temporal format that is useful for typical IUWM modelling needs. However, as the table rows have been based on the compilation of all known variables considered in water accounting systems under development, it does not reveal additional empirical data that could be utilised in the integrated modelling. This has been ascertained by the analysis of the HydroPlanner SEQ prototype and related IUWM modelling approaches to identify new or quite different variables that could be included in water accounting data collection processes. This technique has been somewhat constrained by the developmental nature of IUWM modelling and limited information available.

This methodology was originally outlined in McBean, Daniels and Braddock (2010). That report also had several other roles including an explanation of the nature of water accounting, its potential benefits and capabilities, and an overview of the Queensland Water Commission’s (QWC’s) WaterHub water information system for SEQ. Report 1 was originally released in mid-2008 as a background document to inform the Life Cycle Analysis and Integrated Modelling Project team about the relevance of water accounting and to garner feedback on the best way to identify linkages and data feeds into the integrated modelling components. Unexpected delays slowed finalising Report 1 and the progression to Report 2. The methodology originally outlined in Report 1 was redeveloped considerably before it was applied for the research summarised in this report. There were also significant changes in the QWC WaterHub water information system and in the nature of the HydroPlanner SEQ prototype model itself over this period.

## Results

In this second report, a methodology has been applied to systematically match existing and proposed water accounting data and that required to support the development, implementation and evaluation of IUWM modelling. As discussed, the research has targeted the HydroPlanner SEQ prototype model but has broader relevance for any IUWM modelling for the region.

Based on the systematic analysis of information about the structure, assumptions and logic of the HydroPlanner SEQ prototype model, the relevance and priority of data requirements from the analysed water accounting systems have been identified and are presented in the extensive information provided in Table 4, Section 5. An indicative excerpt from the results of this data matching process is provided below.

The research undertaken reveals that the WaterHub, BOM and SWIM water information systems can provide much of the data requirements for the development, calibration, operation and validation of the HydroPlanner SEQ prototype and other IUWM models that are likely to be widely used in integrated, total water cycle approaches in the region over the next few decades.

The analysis of existing water accounting systems (and their plans for development) reveals that major areas of good data availability for IUWM modelling include: climate, water supply, stream-flow, groundwater, water quality, water production, water use, effluent data, system loss and demand forecasting data. However, there are many instances where spatial and temporal resolutions are less than ideal (typically manifest as too coarse resolutions in the water accounting data). Naturally, the availability of many of these data is contingent upon the actual implementation of the plans as studied in this review.

*Extract Example:* Data interchange table – water accounting frameworks and IUWM models (based on the HydroPlanner SEQ prototype design. See Table 4, Section 5, for a complete listing.

| | IUWM MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | |
|---|---|---|---|---|---|---|---|---|---|
| INDICATOR | HydroPlanner SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | General Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework | | | Measurement / Resolution (See accompanying table for more detail) | |
| | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] | General IUWM Model Relevance | Notes –Preferred Unit, Spatial and Temporal Resolution | BOM (AWRIS) (NWA)[2] Water Reg Code | SWIM | WaterHub (WH) | Typical Measurement Frequency and Period Covered | Temporal and spatial res adequacy for IUWM models |
| **CLIMATE DATA** | | | | | | | | | |
| Total rainfall | **H** (=high) **L** (WW) (=low) | **H** (DMD,SRH) **L** (DES) | **H** | Daily, subcatchment for all HP and most IUWM models | | | 4 (PHASE 1) | 1. Daily 2. 24hrs | Suitable – most daily temporal resolutions are suitable |
| Average annual rainfall | **M** **L** (WW) | **M** (DMD,SRH) **L** (DES) | **M** | | | | 4 (PHASE 1) | 1. Annually 2 Annually | |
| Accumulated precipitation depth | **H** | **H** (DMD,SRH) **L** (DES) | **H** | | 4 (AWRIS) 4a, 4b | 4 | 4 | 1. Daily or as transmitted for | Stormwater – need sub daily res (6 min) |

IUWM = integrated urban water management DMD = demand-related SRH = storm and rainwater harvesting, DES = Desal OTH = Other

## Data Gaps

The unmet data needs of the HydroPlanner SEQ prototype and other IUWM models have been identified, directly or indirectly, using the detailed analysis of water accounting measurands summarised in Table 4. In view of the current situation in SEQ (which now has plentiful overall water supplies after 18 months of good rainfall), the paucity of water accounting data about water quality and related environmental flows is proposed as a top priority for data collection and access. Some of the major data needs that have emerged (in rough order of significance) include:

- water quality data available from the water accounts need to be developed to be consistent with the temporal and spatial needs of IUWM models and estimations. The underlying basis for sampling is not enunciated to concord with modelling activities.
- while there are some plans for better environmental flow data, only limited and quite aggregated information is currently available. However, the role of environmental flows has not been specified in the SEQ HydroPlanner prototype analysis undertaken here.
- the effluent data are very limited and coarse, and need much more detail and planning for consistency with IUWM modelling functions.
- recycled water data are only recorded quarterly at best and at broad spatial levels that are unlikely to be of much use to IUWM modelling without significant aggregation.
- all water use data are too aggregated in terms of temporal and spatial resolutions. This is also true of supply by type (and connections) data which are only available at weekly resolution and at WSP or scheme-wide geographic levels.
- while most relevant storages are quite well covered in terms of stocks, inflows, releases and transfers, unfortunately, volumes sourced (and often received) from bulk manufactured recycled, desalination, and the bulk supplier (Seqwater) are only available at weekly levels; and volumes sourced from dams, rivers and groundwater are very limited in availability and resolution.
- system loss information is too temporally and spatially aggregated for IUWM purposes except for crude summation comparability.

In the IUWM modelling approaches, catchment runoff and constituent generation and routing require detailed flow data for empirical validation and, while there is some information to be collected within the water accounts, it is not of adequate geographic detail nor with a consistent systematic spatial framework to optimally support IUWM models. Sub-daily data are also often ideal for these functions. Similarly, water quality (constituent balance) aspects of water account data need finer spatial and temporal resolution to enable application beyond assessment based on broad aggregation of modelling outputs.

Supply system yields and shortfalls, and resilience, reliance and vulnerability outcomes do have access to quite fine temporal level water account data but again this is primarily limited to broad geographic areas and further disaggregation, based on a dialogue with IUWM developers and their needs, would be fruitful.

Wastewater and other discharge data are reasonable but confined to weekly measures and it is uncertain whether the discharge points match IUWM modelling needs – especially for stormwater discharges. In general, there is minimal empirical information on stormwater and rainwater harvesting, local recycling and greywater use from the water accounts, and better sources are required for modelling purposes.

It is unclear how groundwater information in the accounting frameworks could be used in the SEQ HydroPlanner prototype. However, key land use and climate data are generally available and appropriate.

Demand and end use information are also available – potentially at lot level – but values are only available on a quarterly basis or longer. Greater clarification is needed to identify the potential interchange use of empirical information on environmental flows, but it is likely to be a major area for further investigation and improvement, given a strong shift towards pressing water quality and ecosystem impact issues since the Millennium Drought broke in 2009.

There are still many gaps, and appropriate modifications to water accounting content, timing and geographic coverage would be invaluable in helping to support robust, defensible, reliable and accurate IUWM models.

## Conclusions

While there are many opportunities for the provision of empirical water accounting data for IUWM models (and, potentially, reverse flows of data from models to water accounts), there are many inconsistencies and uncertainties in terms of the availability of suitable spatial and temporal resolutions for modelling purposes.

An important aspect for matching empirical water data, and that required for hydrological modelling, is the clarification of appropriate spatial and temporal resolutions. The effectiveness of modelling will be influenced by whether the data reflect key model processes and outputs. For useful data exchange with minimal information loss due to aggregation, careful consideration must be given to the frequency of data collection and the density of measurements within appropriate areas.

## Recommendations

The identification of the potential data feeds from existing and planned water accounting systems synergies is the first step in the process of ensuring that the data needs of hydrological models are well-serviced by evolving regional, state and national water accounting frameworks. These systems are under development and it is a critical and opportune time to ensure optimal information consistencies and economies. The ability to utilise the data linkages identified in this report requires ongoing support by the QWC, Bureau of Meteorology (BOM) and other relevant accounting authorities.

It is recommended that the water accounting and modelling entities consider the promising potential for mutually beneficial data exchange between their systems and undertake research and development and formalise communication channels in order to realise and enhance the synergies that have been identified in this report. Further consultation between hydrologists and water accounting developers is needed to strengthen data complementarities that will create more robust, valid and accountable models and add value to the flurry of water accounting under way. The BOM is currently (in 2010) conducting investigations into the user requirements of AWRIS and national water accounts, and hydrological modelling needs are substantive parts of this process. The QWC also invites potential users to submit requests for data requirements for consideration in its SEQ regional WaterHub system.

Integrated urban water management (IUWM) models such as the HydroPlanner SEQ prototype should be developed in close consultation with the evolving National Water Accounts administered by the BOM. Both IUWM models and the regional accounts framework under development by the BOM favour conceptual bases embedded in regional mass balance principles. The physical phenomena and processes being represented are essentially the same. Harmonised, economic and optimal data information linkages between these systems will be greatly facilitated by co-development.

This report recommends the adoption of Integrated Data Management (IDM) approaches to data collection and management for the benefit of IUWM practices such as modelling of the total water cycle (urban and regional components). Water accounting frameworks should aim at the comprehensive and conceptually robust total water cycle/balance and integrated management approach to facilitate system data consistency and exchange.

An integrated approach to data management for the water sector is ideally suited to the empirical needs of IUWM. Integrated approaches to management require the collation of measures taken across the entire urban water cycle. Management of data that is guided by the principles of this approach will ensure that data are delivered in an integrated, consistent and accessible format, whilst fulfilling the requirements of the specific problems under study. The IUWM and related total water cycle/regional water balance approach have consistent conceptual bases with BOM's National Water Accounts (and to some extent the AWRIS). All water accounting frameworks should progress towards logical structures that are compatible with this extensible, comprehensive and robust perspective.

It is strongly recommended that development of water accounting frameworks in Australia be substantively informed by approaches and guidelines being adopted in national and international physical and economic accounting systems for water and other environmental resources. A major proposal is to ensure that disaggregated household, commercial, and other urban industrial water extraction, supply and use data be classified by the Australian and New Zealand Standard International Classification (ANZSIC) 2006 as soon as possible. ANZSIC is the primary classification system for economic industry data in Australia and is compatible with the Standard International Classification Rev. 3. Currently, the use of water at disaggregated urban levels can only be classified according to the Qld Department of Environment and Resource Management (DERM) land use codes. The ability to identify water consumption levels at this detailed resolution will facilitate research into consumption patterns, efficiency options, and other assessment for effective strategies for the sustainable management of water resources.

Compatibility and inter-operability of all water accounts, and also with IUWM models, would be greatly enhanced by investigating existing and developing national and international water and other environmental resource physical and economic accounting standards and guidelines (for example, the United Nation's System of Environmental-Economic Accounts for Water (SEEAW)) to ensure that Australian water accounting frameworks are consistent with these formats and can be used in a wide range of strategic applications and triple bottom line assessments.

It is recommended that further study be undertaken for a more detailed investigation of high-value data needs for IUWM modelling that are not currently addressed or planned for coverage in the water accounting frameworks that relate to SEQ.

The thorough investigation of extant "data gaps" between water accounts and IUWM models would include identification of the appropriate spatial and temporal resolutions for effective information exchange. Catchment runoff and constituent generation and routing require detailed flow data for empirical validation and, while there is some information to be collected within the water accounts, it is not of adequate geographic detail nor with a consistent systematic spatial framework to optimally support IUWM models. Sub-daily data are also often ideal for these functions. Similarly, water quality (constituent balance) aspects of water account data need finer spatial and temporal resolution to enable application beyond assessment based on broad aggregation of modelling outputs.

Supply system yields and shortfalls, and resilience, reliability and vulnerability outcomes do have access to quite fine temporal level water account data, but, again, this is primarily limited to broad geographic areas and further disaggregation based on a dialogue with IUWM developers and their needs would be fruitful. Wastewater and other discharge data are reasonable but confined to weekly measures and it is uncertain whether the discharge points match IUWM modelling needs – especially for stormwater discharges.

In general, there is minimal empirical information on stormwater and rainwater harvesting, and local recycling and greywater use from the water accounts and better sources are required for modelling purposes. It is unclear how groundwater information in the accounting frameworks could be used in the HydroPlanner SEQ prototype. However, key land use and climate data are generally available and appropriate. Demand and end use information are also available – potentially at the lot level – but values are only available on a quarterly basis or longer. Greater clarification is needed to identify the potential interchange use of empirical information on environmental flows, but it is likely to be an area for further investigation and improvement, given a strong shift towards pressing water quality and ecosystem impact issues since the Millennium Drought broke in 2009.

# 1. INTRODUCTION

The aim of the research summarised in this report has been to:

(1) identify the empirical data requirements for the integrated urban water management (IUWM) models being considered for South East Queensland (SEQ), and

(2) assess the extent to which they can be sourced in existing and planned water accounting systems pertinent to the region.

While the results are focused upon SEQ, they also have widespread relevance for enhancing systems development for the fruitful exchange of data between empirical efforts of water accounts and conceptual, simulation and process-based models.

The major outputs are the systematic description of the empirical water data needs typical of IUWM models (especially the HydroPlanner SEQ prototype model being considered at the time of the research), and the identification of the availability of appropriate data, at useful spatial and temporal resolutions, in existing and proposed water accounting systems. A key goal is to identify high priority "data gaps" where data that would be very useful for integrated model needs do not exist or are not available at required spatial and temporal configurations.

It is widely recognised that lack of information on water resource stocks and flows has been a major source of problems in ensuring Australia's water supply and sustainability and has compromised effective water resource management and planning (Bureau of Meteorology 2009d). The November 2009 revised draft South East Queensland Water Strategy (subsequently referred to as the SEQ Water Strategy) provides the framework for achieving water security for the SEQ region for the next 50 years. Developed under the auspices of the Queensland Water Commission (QWC), this plan defines a combination of water demand management initiatives, supply options and drought response plans to be implemented within the region in order to support the Strategy's Water Supply Guarantee. The Urban Water Security Research Alliance (UWSRA, subsequently referred to as the "Alliance") was formed to support the SEQ Water Strategy through research and development focused upon long-term, sustainable water management in the region. The Alliance is a partnership between the Queensland Government, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the University of Queensland (UQ) and Griffith University (GU). The objective of the Alliance is to "collaboratively develop the knowledge and tools to inform and support the implementation of the strategy" (Queensland Water Commission 2009a, p.173).

A number of project groups have been created within the Alliance to satisfy this objective. This report is a product of the project theme titled "Life Cycle Assessment – Integrated Modelling" (LCA-IM). A major component of this project is the development of the HydroPlanner SEQ prototype. The HydroPlanner SEQ prototype is a hydrological modelling tool capable of the integrated modelling of all hydrological, supply and demand aspects of the urban water system within a total water cycle perspective (Ashbolt, Maheepala et al 2010). The tool is designed to identify water quantity (water balance) and quality outcomes of alternative scenarios built on various supply and demand options. The focus is upon those outlined in the sustainable water management proposals in the SEQ Water Strategy. In this Alliance project, the integrated modelling component is complemented by life cycle assessment and water accounting research in order to "provide methodologies to quantify the dynamics of an integrated urban water system in terms of water flows, nutrient discharges, energy consumption and greenhouse gas emissions (GHGs) at sub-regional and regional scales" (Maheepala, Mirza et al 2009 p.1-2).

Modelling the myriad of natural and human influences and processes across the entire regional water cycle is a very complex and demanding task. Integration of the traditional component approaches introduces a new level of sophistication. The access and use of detailed, relevant and timely empirical water data within regions being modelled has become essential to effective and realistic hydrological modelling. This assertion is clearly evident in many contemporary scientific publications in the field. For example:

> *as modelling power has increased there has been a concurrent reduction in "data power", particularly in the collection of hydrological data. ...It is argued that* ***modelling in the absence of adequate data is not science,*** [emphasis added] *unless it is to develop hypotheses that are to be tested by observation [empirical water accounting data].* Silberstein (2006, p.1430)

> *high quality data sets facilitate empirically based conceptualization of hydrological processes that may be linked with elegant modelling, providing scientific advance and richer insights into catchment function.* Soulsby, Neal et al (2008, p.2057)

> *Developing integrated environmental models...are demanded by the requirements of, for example, implementing the Water Framework Directive in Europe, is constrained by the limitations of current understanding and data availability.* Beven (2007, p.460)

> *the first step is to use the model uncertainties (which represent those aspects of the hydrological systems that are least understood)* ***to collect new or better data, improve data assimilation techniques or study specific processes*** [emphasis added]. *In the second step, the model should be improved using these data, methods and concepts.* Buytaert, Reusser et al (2008)

The concurrent development of several important and relevant water accounting information systems – including the QWCs' WaterHub, Bureau of Meteorology's (BOM) Australian Water Resources Information System (AWRIS) and National Water Accounts (*NWA*), and Queensland Water Directorate's (qldwater) Statewide Water Information Management (SWIM) project – provides an ideal opportunity to gain access to an extensive range of empirical water data integral to the development and operation of HydroPlanner SEQ prototype and related IUWM models. The calibration and verification of the prototype is currently a primary task in its implementation in the Logan Catchment case study (Maheepala, Mirza et al 2009). The crucial developmental phase for water accounting systems also represents an opportunity to inform them of the empirical data needs of hydrologic models.

The SEQ WaterHub is a regional database and information management system that compiles and standardises water-related data and information for the SEQ region. It aims to ensure that data are available to assist in facilitating strategic water planning and the achievement of the total water balance in SEQ. The QWC has been engaged in negotiations with the BOM concerning the provision of data from the WaterHub. This procedure is intended to support the development of the BOM's AWRIS as the primary national water information source – a structured data warehouse or secure repository for the extensive data required for a broad range of decision-making and strategic planning for the community's benefit (including information required under the Water Regulations 2008). The AWRIS will systematically compile and store data collected by the Bureau from over 200 entities throughout Australia through an online information system.

Initially released in 2008, the first report in this water accounting series (McBean, Daniels and Braddock 2010) provided an overview of the purpose, scope and evolution of the SEQ WaterHub and, to a lesser extent, the BOM's *Water Regulations 2008* information requirements. It also proposed a methodology for identifying the potential, detailed linkages between the evolving water accounts and IUWM models. In the interim period since 2008, some substantive changes were made in the scope of the HydroPlanner SEQ tool and, to a lesser extent, in the content and approach of major water accounting frameworks. Hence, there are some differences in the actual method employed for the data matching process. However, this report presents specific results, based on an updated method and data review, that identify details of how emergent water accounting frameworks can support the development, implementation and evaluation of the HydroPlanner SEQ prototype and related modelling.

The report begins by describing the notion of urban water cycles and providing a general introduction to the increasing development and adoption of integrated urban water management practices. It is important to note that the "urban" label refers to an emphasis on ensuring security of adequate water supply for urban requirements in the region rather than a broader analytical restriction regarding supply and demand options. Integrated and optimal resource management within a region necessarily includes natural, rural and urban domains and this is undoubtedly highly relevant for information and analysis directed towards the sustainable and efficient management of water. Section 3 provides a more detailed description of the key components of the HydroPlanner SEQ prototype and an indicative summary of its principal empirical data needs, inputs and outputs. This is followed by a review of the current status of major relevant water accounting systems – notably the QWC's WaterHub, the Queensland Water Directorate's (qldwater*)* SWIM, and the BOM's AWRIS in Section 4. This section includes a background assessment of the integrated data management approach (which can logically frame water accounting systems) as a useful approach for hydrological modelling at regional levels and beyond. Section 5 provides a systematic presentation and summary of the useful data linkages and relationships between the major water accounting frameworks and the development, operation and ongoing enhancement of the HydroPlanner SEQ prototype. In the conclusion, overall general findings are highlighted to assess the importance of providing appropriate hydrological data for the IUWM models via the appropriate development of state and national water accounts. Recommendations concerning how the synergies between hydrological models and water accounts can be realised are also considered.

# 2. THE SEQ URBAN WATER CYCLE

In this section we provide an overview of the relevance of the "urban water cycle" concept for systematic and useful water accounts. Accurate and detailed conceptualisation of the key processes, systems and linkages within the urban water cycle is an essential basis for the effective implementation of integrated urban water management (IUWM) practices and their empirical data needs.

## 2.1 What is the Urban Water Cycle?

The urban water cycle is a diverse, dynamic and complex amalgamation of the natural and human-influenced water cycles. The natural water cycle consists of the hydrological processes that occur naturally without direct human interference. Water is input into the catchment as rainfall which then infiltrates soil or groundwater, or flows to surface water bodies. This water can either be transferred back to the atmosphere through evapotranspiration or flow to the sea where it may be evaporated by the sun, continuing the cycle. Rural activities have a very significant impact on natural water cycles. However, our focus here is predominantly on urban activities where a major modification to the natural water cycle occurs through the addition of infrastructure for water supply, use, and discharge (Marsalek, 2007). This human-influenced aspect of the water cycle diversifies the movement of water in an urban area, creating "artificial" hydrological processes. These hydrological features are unique to the urban water cycle. The processes occurring within urban water supply, wastewater, stormwater and groundwater systems, together with natural hydrological processes, such as precipitation and evapotranspiration, make up the urban water cycle. In addition, land use changes by humans affect the infiltration and runoff characteristics of "natural" catchment water cycles.

The urban water cycle processes begin when water flowing through streams is harnessed in dams or infiltrates into the ground where it can be stored in soil as soil moisture or in groundwater aquifers. Water that is captured in dams is stored and typically released or pumped to water treatment plants (WTP). After treatment, the water is then distributed to consumers via a pipe distribution network. Water may also be supplied to the system via alternative sources such as rainwater tanks, desalination, groundwater supplies, wastewater or through stormwater harvesting (Mitchell *et al.*, 2007).

Consumed water and wastes are then transported to wastewater treatment plants (WWTP) where, after treatment, effluents are discharged into receiving water bodies or may be recycled for reuse in the supply system. Stormwater runoff that is not harvested is also collected through distribution networks and discharged into receiving water bodies, such as streams, creeks and rivers, along with a certain amount of nutrients, sediment and rubbish. The sun continuously evaporates water that is being stored in dams or surface water bodies, maintaining the cycling of water between terrestrial, aquatic and atmospheric realms (SEQ Healthy Waterways Partnership, 2009).

## 2.2 Integrated Urban Water Management (IUWM) and Modelling the Urban Water Cycle

Hydrological modelling of the entire urban water cycle is fundamental to support the adoption of integrated urban water management (IUWM) practices within Australia (Maheepala and Blackmore, 2008a). IUWM is a multidisciplinary and trans-boundary approach to managing water resources. IUWM strategies adopt system-wide and holistic approaches to urban water management as opposed to independent management of individual urban water cycle components, such as supply, stormwater, wastewater and groundwater systems (Mitchell *et al.*, undated).

Traditional approaches to managing the urban water cycle emphasised an individual focus on water supply, stormwater and wastewater components and failed to account for the interrelationships between these components (Coombes and Kuczera, undated).They also typically failed to account for groundwater as an integral component of the urban water cycle and one that requires careful management (Fletcher, 2008). IUWM recognises that it is no longer acceptable to manage components of the urban water cycle as centralised autonomous units. Instead, management has taken a decentralised perspective and the interactions and feedback loops between cycle components are beginning to be taken into account (Mitchell *et al.*, 2007).

These IUWM approaches rely upon a comprehensive understanding of the hydrological processes operating within and between each component of the urban water cycle. Integrated hydrological modelling of the urban water cycle provides information allowing “the behaviour of the individual water cycle components, and their interactions, to be examined, understood, and predicted” (Fletcher 2008, page v) and is therefore an integral element towards the adoption of IUWM strategies for urban water issues.

# 3. THE HYDROPLANNER SEQ PROTOTYPE – AN APPLICATION IN HYDROLOGICAL MODELLING OF THE URBAN WATER CYCLE

This section provides a concise overview of the approach and components of the HydroPlanner SEQ prototype, and a preliminary review of major relevant empirical data needs within its structure.

## 3.1 What is the HydroPlanner SEQ Prototype?

The emergence of integrated urban water management (IUWM) practices within Australia in recent years has galvanised efforts to design a related tool for SEQ – one that can facilitate integrated and holistic management approaches. The HydroPlanner SEQ prototype (HydroPlanner) is a comprehensive hydrological modelling tool, in advanced stages of development, aimed at simulating the complete urban water cycle within a single modelling framework. The model is intended to be used to assess and contribute to effective water management strategies as outlined in the SEQ Water Strategy and to inform decision makers in identifying optimal management options for the region. It includes outputs that can help assess both economic and security of supply issues, as well as the real costs and benefits associated with environmental impacts of alternative water management options.

The prototype HydroPlanner tool models and estimates water quality and quantity outcomes of various urban water management scenarios envisaged across all cycle components – from supply catchments to receiving waters. A unique and valuable feature is the incorporation of complex interaction effects and feedback within the total water cycle. The model aims to enable regional analysis of alternative configurations of the urban water cycle involving stormwater harvesting, wastewater reuse, greywater reuse, desalination, new dams, inter-basin water transfers, rainwater tanks and demand options, under various land use, climate change, environmental flow, level of service and population and urban form conditions (Maheepala, 2008b). Thus, it aims to track performance of the urban water system under various strategic management scenarios (typically for a basin) relative to a baseline. This performance can be measured as system reliability, resilience, vulnerability and yield (see Ashbolt *et al.*, 2010). The tool is designed to support sub-regional and regional total water cycle plans at subregional and regional scales, providing water quality and quantity outcomes on a daily basis applicable to city, catchment and regional levels. The information generated from the model simulations will be available to decision makers to help assess water resource outcomes in the region and the design of appropriate water management strategies that will ensure water balance and optimal social and environmental benefits.

The SEQ region is undergoing rapid growth in urban population and the potential contribution of urban land use and point sources to water quality problems is anticipated to escalate markedly over the next couple of decades. Within the LCA-IM Alliance project theme, HydroPlanner provides water balance outcome estimates and hence plays a key role in helping address important sustainability water resource project questions such as (Maheepala *et al.*, 2009, p.2-2):

- appropriate urban water management options that have the potential to reduce the amount of nutrients and sediments discharging to waterways;
- the contributions of various urban water management options to securing water supplies; and
- the financial cost, energy use and greenhouse gas emission of such options.

### Current Status of the HydroPlanner SEQ Prototype

As of early 2010, a prototype of HydroPlanner had been developed and the methodology applied to the Logan-Albert catchment in SEQ. The aim of the prototype was "to demonstrate how to quantify the dynamics of whole-of-urban water systems in both water quantity and quality term on a daily basis" (Maheepala *et al.*, 2009, p.1-2). In the test case study described in Maheepala *et al.* (2009), the aim was to assess how continued urbanisation and population growth in the region will dynamically affect supply system yield and storage and receiving water quality with a focus upon water management options such as wastewater recycling and large-scale stormwater harvesting for urban and irrigation uses, rainwater tanks (for urban use), and reduction schemes for point and diffuse water pollutants. The test application is proposed as allowing:

> *...rapid assessment of various alternative supply option and land use scenarios, such as wastewater recycling and urban growth, in terms of the impact on outcomes such as storage volume, demand deficit, system yield and receiving water quality. This illustrates the potential to compare different management and augmentation scenarios, and assess the impacts against defined targets. In particular, the integrated modelling approach allows the identification of system behaviour arising from many complex parameters and variables* (Maheepala *et al.*, 2009, p.viii).

The Logan-Albert test case basin was utilised as a simplified version of a SEQ catchment facing typical drivers for IUWM such as rapid population growth, reduced surface flows, climate change contingencies and ecological health pressures. Focused upon the modelling questions listed in the previous paragraph, a number of scenarios were developed and evaluated, including: base case; base case with stormwater harvesting; base case with wastewater recycling; and future business as usual and with wastewater recycling. An extensive range of external and component input data included climate, rainfall-runoff, node-link networks, constituent generation, routing, land use and change, storage and dynamics, demands, wastewater and system performance to calculate key response variables covering system storage, outlet flows and constituents, total demand, system yield, reliability and so forth (Ashbolt *et al.*, 2010). Preliminary runs and initial calibration and validation for the test case basin demonstrated that the HydroPlanner prototype tool could generate estimates of key water quantity and quality outcomes based on scenarios and future conditions, taking into account multiple objectives and complex interactions within the system.

## 3.2 The Structure of the HydroPlanner SEQ Prototype and an Overview of Useful Model Data

HydroPlanner assesses the impact and sensitivity of urban water system characteristics (yield, reliability, resilience and vulnerability) to different various land use, climate change, environmental flow, level of service and population conditions. Unlike most, more delimited modelling approaches in the past, it does this in a system-wide, integrated fashion by establishing process and data connections between hydrological, demand, and supply simulation models (Ashbolt *et al.*, 2010).

HydroPlanner utilises the essential user interfacing and network integration features developed for the eWater CRC's E2 catchment and river hydrology models WaterCast and River Manager.[1] However, the E2 approach was not designed to specifically address detailed and comprehensive urban water management issues. Hence, HydroPlanner extends the E2 mass balance framework to focus on estimating subcatchment flow generation and constituent output to interlinked nodes within a spatially-lumped network (given the geographic, soil and climate characteristics of these subcatchments). HydroPlanner builds upon the catchment-wide water quantity and quality continuous simulation modelling capabilities of E2 by augmentation with a new suite of functionalities required for effective urban water management.

A key attribute for urban systems is the ability to simulate processes and interactions between multiple supply options (such as rainwater and stormwater harvesting, wastewater, and greywater and desalination output in addition to conventional surface and groundwater sources), and detailed processes relevant to generation, transfer and treatment for these supply and use systems. End use or consumption and demand management dimensions are also critical in urban water system management. These extensions are supplemented with an Alliance project theme emphasis upon environmental, energy, greenhouse gas and other major "externality" effect outcomes.

Examples include the elaboration of the WaterCAST water quality capabilities to include modelling of demand-based wastewater discharges and recycling, The HydroPlanner model also enhances stormwater harvesting potentialities in the integrated model by introducing smaller surface water storages in sub-catchments for capture and reuse of water in the urban systems.

[1] eWater Cooperative Research Centre (CRC) is focused on hydrological modelling for catchments and on improving the ecological condition of Australia's inland waters.

However, the full range of functionalities has not yet been incorporated into HydroPlanner. In Stage 1, the primary new capabilities include wastewater generation, treatment, and discharge and recycling (direct) as well as stormwater flows. In Stages 2-5, other additions were proposed, including rainwater and stormwater harvesting, indirect potable wastewater recycling, desalination, leakage and overflows and consumption and demand management. The Logan-Albert test case study was restricted to Stage 1 functionality only.

In overview, the HydroPlanner prototype couples several hydrological models to eventually represent the entire SEQ urban water cycle. While the focus of the tool is the urban water system, any integrated water management perspective necessarily includes all natural and rural aspects of a region. In fact, if embodied water use is considered, rural-agricultural activities account for greater water consumption in the region than urban uses (Daniels, 2010).

Each component of the HydroPlanner prototype addresses a different aspect of the urban water cycle such as catchment processes (runoff volumes), water allocation and supply, water demand, wastewater generation and discharge, stormwater runoff and discharge, groundwater flows and manufactured water. Coupling these systems within a single modelling framework allows the interactions and feedback loops between them to be assessed and understood.

Table 1 provides a broad overview of the various components of the total water cycle covered in the current and future structure of the HydroPlanner prototype. It also provides some commentary on the urban-related limits of the E2 components and the nature of HydroPlanner extensions addressing these limits.

**Table 1: Major components in current and future versions of the HydroPlanner SEQ prototype.**

| Current HydroPlanner SEQ prototype | | Future HydroPlanner and linked external components |
|---|---|---|
| **E2-related components** | **HydroPlanner current extensions** | |
| * Climate - variability; change<br>* Evaporation<br>* Catchment river routing<br>* Runoff and constituent generation - river/stream flows; water quality<br>* Surface water storage<br>* Urban water demands – part (not multiple supply)<br>* River/stream abstractions (mainly to agriculture)<br>* Off-stream storage – mainly rural<br>* Unsupplemented demand – Flood harvesting model<br>* Stormwater harvesting – limited mainly farms<br>* Environmental flows<br>* Groundwater – subsurface flows, inter-surface flows | * Urban water – multiple supply paths; all regional sources<br>* Wastewater generation ; treatment<br>* Off-stream storage – splitter functions<br>* Stormwater harvesting – options beyond mainly farm dams<br>* Consumption and demand management (linked to external model only?); land use<br>* Recycling – wastewater (centralised); | * Rainwater harvesting<br>* End use models/demand forecasting<br>* Desalination<br>* Recycling – decentralised<br>* Leakage and losses; overflows |

Source: Adapted from Maheepala *et al.* (2009)

Table 2 lists the general informational categories that contain the input, response, system performance and scenario variables and factors relevant for the HydroPlanner SEQ prototype development, operation and validation. There is considerable overlap in the categories listed but the table provides a good indication of the diversity of data requirements.

**Table 2: General data groups useful to the HydroPlanner SEQ prototype - input, response, system performance and scenario variables and factors**.

- **catchment runoff and constituent generation and routing**

- inflows and outflows from catchments, links and nodes (a system performance indicator)

- **water streams**

- identify and quantify spatial and temporal distribution; *city and regional*

- **water supply systems**

- storage behaviour - total system storage (a system performance indicator) and change in volume storage and level?
- surface water storage - individual storage levels and volumes (a system performance indicator)
- storage releases - supply diversions, inter-storage transfers, routing, losses

- **changes to water balances and constituent balances**

– quantify at city and regional scale due to different water mgt options
- overall capacity of the system for scenarios given level of service criteria

- **levels of water service details**

- and receiving water quality

- **supply system yield; shortfall**

- total demand shortfall (a system performance indicator)

- **supply system resilience**

- **supply system reliance**

- reliability of supply performance indicator

- **supply system vulnerability**

- **sediment, nutrient and contaminants**

- identify and quantify sources, sinks and transport
- constituent loads and concentrations for inflows and outflows (a system performance indicator)
- daily flow and constituent loads/concentration at any point in the system; including basin outlet (e.g. nitrogen under wastewater recycling versus small-scale stormwater harvesting)

- **wastewater**

- generation levels, transport, treatment, disposal of flows, constituents (water quality)

- **stormwater**

- generation levels, transport, treatment, disposal of flows constituents
- ability to represent WSUD at a subregional level

- **centralised supplies**

- large scale stormwater harvesting, managed aquifer recharge, wastewater recycling
- desalination, new dams, groundwater

- **decentralised supplies**

- rainwater tanks (regional effect), local recycling, stormwater recycle and greywater use

- **environmental flows regimes**

- **land use change, climate**

- influence on system yield, resilience, reliability and vulnerability etc
- modelling of historical, future, stochastic and climate change scenarios
- rainfall (as driver)
- evapotranspiration (as driver)

- **demand / end uses**

- historical, demand forecasting, demand management options; individual end uses and irrigation demands
- total demand requested (a system performance indicator)

Appendix A presents a fairly detailed overview of data inputs and outputs for each general component of the HydroPlanner prototype (at the time of the research) and the corresponding spatial and temporal resolutions required. The left-hand column lists the major empirical data series of potential use in HydroPlanner and provides the basis for: (1) assessing existing water accounting data available from the water accounts (in Table 4); and (2) missing information (or "data gaps") that could be requested from future water accounting systems. General data categories of this HydroPlanner empirical data table list include climate, stream flow, groundwater, water quality, water supply, recycled water, effluent and discharges, water consumption and demand, water production, including desalinated water volumes, stormwater and system losses. The model also requires information such as existing and predicted land use changes, population, digital elevation maps, details of water entitlements and trades, details of water allocations, management requirements and drought restrictions.

Together, Appendix A and Table 2 represent our best attempt at identifying empirical data series that would be useful for the development, operation and validation of the HydroPlanner prototype as of June 2010. Model outputs include time series data and visualisation of current and future water availability, runoff volumes, concentrations and constituent loads (suspended solids, nitrogen and phosphorus) at various points throughout the system, stream flow volumes, volumes of water in active storages, volumes of water at various points in the river and supply networks, water demand, wastewater volumes, flows and discharges, groundwater, stormwater runoff volumes and desalination water supplied to the system.

Within the modelling framework, outputs from one component are often used as inputs to other components. Interaction between component models is the essence of the IUWM approach. The approach allows the relationships between cycle components under different scenarios to be measured, predicted and understood on a system-wide holistic basis, including complex feedback mechanisms and sophisticated, more realistic scenario assessment.

# 4. WATER ACCOUNTING FRAMEWORKS FOR THE SEQ IUWM MODELS

In this section, we provide an overview of the current status of water accounting frameworks relevant to SEQ. These frameworks provide the primary sources of systematic empirical water data for a variety of applications in IUWM models including the HydroPlanner prototype. In addition, the concept of integrated data management (IDM) is introduced as a facilitating basis to ensure that water accounting systems are developed to realise the advantages of integrated urban water management and total water cycle approaches.

## 4.1 Water Accounting Frameworks in Australia

The recent proliferation in the development of water accounting frameworks at the state and national levels within Australia is testament to the growing need for empirical water-related data. Water accounting involves the systematic collection and compilation of empirical information measuring physical volumes of water flows and stocks within, or at, predefined spatial and temporal boundaries and nodes. It typically involves the measurement of both "natural" flows and stocks within the ecosphere as well as significant flows that are extracted, diverted, modified, collected, used, embodied or discharged by human activities (McBean, Daniels and Braddock, 2010). Water accounting may also be concerned with measuring the qualitative characteristics of water resources such as nitrogen or phosphorus loads and concentrations and suspended solids levels. The overarching use of water accounts is to provide the primary supply and use data required for the efficient management and planning for water resources within a defined geographical area.

The SEQ WaterHub (QWC), SWIM (Qld Water Directorate, qldwater) and AWRIS and National Water Accounts (Bureau of Meteorology) are the prominent relevant water accounting initiatives for SEQ. They are in various stages of implementation but all are undergoing continued development. Together, these initiatives will compile the most comprehensive account of water resources ever produced in Australia. The extensive data from these sources will provide much of the information required to effectively develop, operate and validate IUWM models, and for ongoing water resource planning, decision making and policy across government, business and community levels.

### 4.1.1 The QWC's SEQ WaterHub – Purpose and Scope

The WaterHub is a regional database and information management hub that compiles and standardises water-related data and information for the SEQ region. It is a custom built, modular, water information collection, storage and dissemination tool. The system has been designed to support the efficient delivery of consistent, robust and defensible water-related information to the QWC, SEQ Water Grid Manager (WGM), DERM and national stakeholders.

The WaterHub aims to ensure that the necessary information is available to support the efficacious implementation of the SEQ Water Strategy and effective water planning and total water balance security in SEQ in both the short- and long-term (QWC, 2008a; 2008b; 2008c). Originally titled the "SEQ Water Accounting Framework" (SEQWAF), the framework was intended to compile a very extensive set of "measurands" or indicators covering many aspects of the urban water cycle in the region. However, as outlined in the first report of this series (McBean, Daniels and Braddock, 2010), the scope of the WaterHub has been modified since work commenced on compilation of the report in 2008.

The WaterHub will continue to be developed with a modular approach and will provide data related to bulk water measurements throughout the region, consumption and production information and future demand forecasts. A significant role for the system is to collect, validate, store and provide access to the data required for the accurate and efficient technical, policy and financial operation of the SEQ Water Grid. The Water Grid was one of the major strategic responses to the Millennium Drought and is an extensive system of inter-connector pipelines between major water sources, treatment plants, storages and other existing water transport networks. It enables water from new and existing water sources to be transferred across several key areas of the region (see Box 1).

**Box 1 The SEQ Water Grid**

The Queensland Government's $9 billion South East Queensland Water Grid is the largest urban drought response in Australia. The Water Grid is securing the region's water supply now and for the future. The water grid is a network of connected water supplies, storages and pipelines allowing water to be transported from areas of water surplus to areas facing a shortfall.

The project features more than 450 kilometres of pipeline, one new dam and dam upgrades, a desalination plant and three advanced water treatment plants. Once complete, the water grid will deliver around 350,000 megalitres of additional water a year. The Queensland Government has worked in collaboration with other levels of government and in partnership with the private sector to deliver on its multi-billion dollar water plan.

Source: Department of Infrastructure and Planning (2010) http://www.dip.qld.gov.au/seqwatergrid

In addition, the WaterHub will provide ready access to data required for many other strategic water planning purposes – including information for the effective design and accuracy of IUWM models such as HydroPlanner. It is a principal product of the Regional Water Information Program (RWIP) of the QWC. The RWIP provides a range of database, research, analysis, modelling and reporting coordination services to an array of stakeholders such as the QWC, Water Grid Manager, DERM, Seqwater, Linkwater, WaterSecure, SEQ Councils, qldwater (SWIM), the Bureau of Meteorology and the Australian Bureau of Statistics.

The remainder of this section describes the revised scope of the WaterHub.

As one of the key aspects of the WaterHub, the Volumetric Point Measurement (VPM) module is now operational and provides information to the Water Grid Manager and the QWC about the actual volumes of water that move through the water grid. Volumes of water are measured at various primary nodes throughout the system to enable regional daily breakdowns on the volumes of water consumed (litres/person/day). These data are accessible by water retailers and councils such as Brisbane City Council, Gold Coast City Council and Logan City Council.

A recent WaterHub module is the Production Analysis Module (PAM). This module will provide the capacity to perform analysis on the raw data that is reported through the VPM tool. Information that is produced by the PAM will be output by the QWC to retailers and councils.

The Consumption Information Module (CIM) provides information on the actual consumption of water for residential and non-residential entities in the SEQ region. The CIM has the functionality to collect, store, process and analyse consumption billing data, generating data tables, graphs and reports relating to consumption trends throughout SEQ (QWC, 2009b). Data on consumption at lot level are provided by a number of water retailers in the SEQ region including Unity Water, Queensland Urban Utilities and Allconnex.

The Water Efficiency Management Plan (WEMPs) module provides data to enable performance monitoring of non-residential water users who each consume more than 10 million litres of water annually.

A Demand Forecasting Module predicts short- and long-term residential and non-residential water demand. Daily, monthly and annual forecasts can be produced at various spatial resolutions for both urban and rural areas. The inclusion of functionality allowing the user to model different management strategies (e.g. water restrictions) provides the capacity to assess change in demand resulting from various water-saving measures (QWC, 2008d). The resulting outcomes can be compared against baseline demands in order to analyse the efficiency of a variety of water management options.

Forecasts will be based on consumption billing data received from water retailers and will be used to assess water demand and how future demand will affect the regional water balance (Askins, 2009).

There is also the Reporting Facilitation Module (RFM) designed to automate the collection, systematic compilation and report generation from SEQ Water Grid entities and provide them to recipients using convenient and efficient information technologies. This module focuses first upon the reporting requirements to the BOM initiated from the Water Regulations 2008 (QWC, 2009c).

In the short term, the QWC is primarily concerned with the operational development of each of the WaterHub's modules and providing data for the immediate needs of the QWC and the Water Grid Manager, as outlined in McBean, Daniels and Braddock (2010). In the longer-term, the QWC anticipates that the WaterHub will become accessible to a wider range of planners and researchers who can benefit from detailed regional water accounts. Access to data that is not generally made available to the public will be assessed on a case-by-case basis. For example, the Australian Bureau of Statistics (ABS) has requested that the QWC provide it with water production data for Brisbane and the Gold Coast and the QWC continues to liaise with the BOM about the provision of data for the AWRIS. Direct access to the WaterHub data will not be possible due to data confidentiality and technical limitations. Instead, provision of data will involve specific arrangements between the QWC and the applicant (Askins, 2009).

### 4.1.2 The Bureau of Meteorology's Australian Water Resources Information System (AWRIS) and National Water Accounts (NWA)

With the onset of severe drought conditions in Australia in the 21st Century, one of the major impediments to effective research and strategic planning and responses was clearly apparent with the lack of useful and accessible water information in an appropriate format and system.

Directed by Section 7 of the Commonwealth Water Act 2007, the Improving Water Information program is a 10-year $450 million program administered by the Bureau of Meteorology as part of the $12.9 billion Water for the Future program designed to provide secure long-term water supply for Australia. This water information program aims to expand and reform the nation's water resources information collection and storage system in order to improve water resource planning and management. The Bureau will be responsible for collecting and compiling water information on water availability, condition and use from over 200 entities nation-wide. A major objective is to ensure that data are delivered in an accessible, consistent and usable format to government, industry and the community through the Australian Water Resources Information System (AWRIS) and National Water Accounts (Bureau of Meteorology, 2009a). The standardised and freely available information is intended to provide strong support for better decision-making (across government agencies, the private sector, rural landholders and households) for the economical and sustainable management of water in Australia.

As defined by the Water Act 2007, "water information" covers raw data or value-added information products that relate to: (a) the availability, distribution, quantity, quality, use, trading or cost of water; or (b) water access rights, water delivery rights or irrigation rights and includes metadata describing characteristics of datasets (e.g. definitions, structure and administration) and contextual information relating to water (such as land use information, geological information and ecological information) (Bureau of Meteorology, 2009a). The information is explicitly integrated and operationalised within a spatial framework (Geofabric). This not only facilitates ready application and organisation within appropriate geographic settings but facilitates the connection of diverse hydrological and other natural and human-related information. The complete list of measurands required for the AWRIS is described in Water Regulations 2008 Schedule 3 and can be accessed at:

http://www.frli.gov.au/ComLaw/Legislation/LegislativeInstrumentCompilation1.nsf/0/3E774350F5F1488DCA2575FA0008B8DA/$file/WaterRegs2008.pdf

The AWRIS is a secure repository for consistent water data and manages the data collected by the Bureau through an online information system or "one-stop" water information portal. It is implemented as a distributed database system with a suite of web-based tools for ready, and easy, access by all potential users. Standardisation, efficiency and automation in the transfer of required water data across entities is also a key role of the system (note the development of the Water Data Transfer Format (WDTF)).

The AWRIS is being built over a 10-year period and an important achievement for the system will be careful development designed to provide value-adding information to the diverse range of tools for the effective and sustainable management of water. IUWM modelling is one of the most important tools in this process and an intensive dialogue is likely to generate many benefits. The Bureau has intimated that it intends to work collaboratively with AWRIS stakeholders and users to ensure that their data requirements are understood (Bureau of Meteorology, 2008b).

AWRIS data will include information about river flows, groundwater levels, reservoir storage volumes, water quality, water use, water entitlements and water trades (Bureau of Meteorology, 2009b). AWRIS will contain a variety of products and functions, including:

- a water data download service;
- regular national water resource assessments;
- national water accounts;
- real-time water reporting services;
- real-time water availability forecasts; and
- support for flood design.

The water storage capability of AWRIS has been completed, and currently Category 6 (information about rights, allocations and trades in relation to water) is under development.

One of the major functions of AWRIS is to provide the platform for compiling the first National Water Accounts (NWA) and a series of National Water Resource Assessments. While a total, integrated water cycle conceptual basis (covering all natural and human aspects) is not readily identifiable for AWRIS, the developing NWAs seem assured to take a regional water (mass) balance, and often a catchment-based, approach and are organised according to the Water Accounting Conceptual Framework (WACG). The annual NWAs have a more directed focus than AWRIS – they are designed to make systematic assessments of the physical relationship between water availability, access rights and water take and trade, and can connect entitlement regimes and allocation to take measures (Bureau of Meteorology, (2009e). This focus on availability and human take complements the detailed accounting of water use by economic unit or activity type in the Australian Bureau of Statistics' (ABS) Water Account, Australia. The ABS account also links into broader national and international environmental accounting systems that can be integrated into economic systems. Together, they are intended to form a quite comprehensive environmental-economic accounting system to clearly depict, analyse and strategically respond to regional water balance issues.

Typical questions targeted by the NWA include:

- What were the changes in water inflows, outflows and storages?
- What water access entitlements existed?
- What water management plans applied that governed access?
- How much water was allocated as available for use?
- How much of the total water entitlement was traded and between which locations?
- How much water was taken for use?
- How much water was made available to the environment?

Source: Bureau of Meteorology (2009e p.1)

Several test case studies of NWAs are under way or completed in pilot form. These include accounts for the Murrumbidgee River Catchment, Melbourne, SEQ, Gnangara Mound, Murray Darling Basin, the Namoi and Onkaparinga. The accounts for SEQ were completed in 2010 but not released in view of statistical confidentiality issues.

While the NWA is intended to be based on data provided by the AWRIS, it has a comprehensive conceptual framework that shares much in common with the integrated urban water management approach. Hence, many of its data requirements align with those of IUWM and identifying these shared informational needs should help support the systematic inclusion of useful data, or new collection if necessary, within the AWRIS. Examples include environmental flows and detailed climate-hydrological data that is consistent with IUWM modelling but not well covered in existing water accounts. Unfortunately, the temporal resolution of the NWAs is currently focused upon annual accounts, so further refinement of key data series may need to be promoted.

### 4.1.2 The Statewide Water Information Management (SWIM) System

The Statewide Water Information Management (SWIM) on-line system was implemented (in 2008) as an efficient means of dealing with the extensive data reporting tasks of the numerous local government Water Service Providers (WSPs) in Queensland (see http://www.qldwater.com.au/). The Qld Water Directorate (qldwater) has developed the system and acts as a "data broker" by collecting all required water data (in consistent formats) for a given period, in one transaction, and then distributing the information to the multiple government agencies that require this information. The coordinating activities and tools of the SWIM system have reduced the number of collected indicators from 900 to fewer than 200. The system has recently been upgraded to enable reporting of the detailed BOM Water Regulations 2008 data (see the previous section). A list of all measurands compiled in the SWIM can be accessed from the SWIM website by logging in to its data portal as a guest http://www.swim.qldwater.com.au/GetPassword.php (for further information, contact qldwater at swim@qldwater.com.au or phone 07-3252 4701). Many of the indicators in the database are shared with the BOM and the WaterHub.

## 4.2 Making Water Accounting Systems Work for Integrated Urban Water Management Models

The concept of Integrated Data Management (IDM) for environmental data is primarily concerned with systematically collating all the relevant interdisciplinary data required to model and analyse environmental issues at all geographic levels (Harmancioglu, 2003). It is widely recognised that such an approach to data management is necessary for supporting effective strategic responses to our environmental problems (Fletcher, 2008; Geerders, 2003; Harmancioglu, 2003; Loetscher *et al.*, 2007; Maurer, 2003). The *ad hoc*, scattered and inconsistent nature of existing data sources relating to environmental resources, and the difficulty in accessing this data, are fundamental impediments to sustainable resource management – hence, the need for IDM (UNDESA, 1993; Maurer, 2003).

To some extent, the regional water balance conceptual framework developed, and being refined, for the National Water Accounts is following IDM principles and provides a good example of the need for dissemination of the concept for all water accounting frameworks that can feed data into IUWM models.

In practice, IDM systems would compile data with careful consideration of the applications for which the data are required. This requires ongoing communication and cooperation between data collectors and users to ensure that all of the data necessary to support an application is accessible within a standardised framework. Ideally, data should be collected to reflect the integrated nature of the problems which they are being used to solve. This would involve a holistic approach to data collection that draws together data from a variety of disciplines and across political boundaries (Maurer, 2003). IDM systems should employ the use of standardised procedures and formats, and adhere to national and international standards and guidelines for data collection, processing, and analysis (Fletcher, 2008). This would ensure that data can be made available across diverse regional, national and international contexts for research into environmental issues (such as climate change). Data measurement and collection should also consider the appropriate spatial and temporal resolution for each variable. Subsequently, data are best archived in a systematic, consistent and accessible format to ensure that they can be made available through standardised retrieval systems.

The adoption of IDM principles to the collection and management of water-related data and information would alleviate existing problems with accessing, retrieving and sharing reliable water data at appropriate temporal and spatial resolutions (UNDESA, 1993). Ideally, data management for IUWM should involve a network that draws together data and information from each of the water cycle components, including water supply and treatment, stormwater, economic and household use, wastewater and groundwater components. In early system design phases, data requirements (variables and parameters) should be framed to facilitate analysis of all potentially relevant aspects of the urban water cycle – from the initial design of the data system. Demographic information, climate data, catchment features, supply, demand, wastewater, stormwater and groundwater data should be compiled using standardised procedures (and criteria) for collection, storage, presentation and analysis (Fletcher, 2008).

Water data should be collected and compiled in coordination with hydrology and all relevant interdisciplinary experts to ensure that data provided are suitable to their specific application (Silberstein, 2006). Data within this system can then be made available to those responsible for strategic planning for secure and sustainable urban water management. IDM application to water data will increase the flow of high quality hydrologic data and will reduce unnecessary and redundant efforts. As a result, improvements and progress in the research, monitoring and decision making process will be realised, while the duplication of data collection and processing will be prevented, saving time and resources (Harmancioglu, 2003).

The current flurry of development of water accounting frameworks in Australia offers a unique opportunity to embrace the principles of IDM for the benefit of the HydroPlanner prototype and related IUWM modelling and management. The WaterHub's approach to data collection and dissemination currently embraces a number of these principles. Data are being drawn together from a variety of sources and compiled in a standard format and, while access to these data is currently limited, the QWC aims to ensure that future water data needs are incorporated in the design of these systems. The QWC is also committed to working in partnership with the BOM to guarantee the provision of SEQ water data for the AWRIS (Askins, 2009).

Driving the development of the BOM's AWRIS is the recognition that the state of Australia's water information has "compromised the effectiveness of water resources planning" (Bureau of Meteorology, 2009d, p.1). The Bureau is already committed to an integrated approach to data collection and is confident that "improved accessibility, integration and use of national water resources information will result in better informed policy and infrastructure decisions and better evaluation of water sector reforms" (Bureau of Meteorology, 2009d, p.1). The Bureau endeavours to ensure that data collection, management and transfer standards are consistent across the nation through the development of National Water Information Standards. The Bureau has also pledged its commitment to working with data users to ensure that data requirements for the diversity of users are considered in the evolving implementation of the AWRIS (Bureau of Meteorology, 2009b).

IDM principles are closely aligned with the data requirements of an integrated hydrological model, such as the HydroPlanner prototype. This enables the water cycle to be described in a way to comprehensively cover and link all natural processes and human components and activities. To be fully-integrated, data must also be presented in a standard, consistent and accessible format at the appropriate temporal and spatial data resolution. This will be invaluable for the entire process of development, operation and improvement of regional IUWM models and significantly improve the robustness of each model and the accuracy of its outputs. The emergence of the WaterHub, SWIM, AWRIS and National Water Accounts offers an excellent opportunity to achieve this integration. Their concurrent development with the HydroPlanner prototype and the increasing recognition of the need for appropriate data for hydrological modelling comprises a unique setting for a mutually beneficial dialogue. Delivering expert information on the data requirements of regional IUWM models to the water accounting activities of QWC, BOM and other relevant organisations, and the adoption of the principles of IDM in the development of these water accounting frameworks, would represent a very positive step towards effective and coordinated implementation of modelling, water account empirical data, and the strategic planning process for sustainable water management.

# 5. WATER ACCOUNTING DATA FOR THE HYDROPLANNER SEQ PROTOTYPE – SPECIFIC DATA SERIES AND FEATURES

The aim of this section is to identify the useful empirical data feeds and other relationships that exist between: (1) the various water accounting frameworks (WaterHub, SWIM, AWRIS and the NWA); and (2) the development, operation and ongoing improvement of the HydroPlanner prototype. The section begins with an explanation of the methodology that has been employed to identify the informational synergies. This report is limited to potential flows of data from the existing or planned coverage of water accounts into the HydroPlanner prototype design, operation and evaluation. This includes commentary on the appropriateness of the spatial and temporal resolution of water accounting data and its suitability for the IUWM model. A subsequent report may focus upon identifying significant data needs that would be of value to integrated modelling and sustainable regional management of water in general, but that are not yet covered in the planned water accounts. A preliminary identification of the nature of data gaps is presented as an indication of additional useful data that might be considered in future water data collection and warehousing. Highlighting data needs of IUWM models such as the HydroPlanner prototype provides the opportunity for the QWC, BOM and other entities responsible for water data collection to identify useful data requirements for effective water planning and research in the region.

## 5.1 Methodology

The methodology employed to identify the specific empirical data series that could be provided to the HydroPlanner prototype and other IUWM models from the WaterHub, SWIM and AWRIS involved the compilation of an extensive list of measurands (indicators or variables) that were identified as definite or proposed items to be delivered by the QWC and the BOM. In order to identify which measurands could provide useful data feeds to HydroPlanner, an empty matrix containing all the existing and planned water accounting measurands was distributed to each of three of the model's primary developers. They were requested to indicate which of the measurands were relevant to the component models of the SEQ IUWM. At the time of the original analysis, the relevant components planned for HydroPlanner were the River Manager, WaterCAST, the End Use Model (EUM), Wastewater, Stormwater and Desalination models. Since that time, the model prototype has been restructured and the relevance and priority rankings have been re-sorted into two groups – the current HydroPlanner stage (including the eWater CRC E2-related aspects) and future extensions. The nature of the original components and their data needs is broadly equivalent to the existing prototype.

The HydroPlanner developers were asked to identify the level of relevance of the model components. Ratings were limited to "high", "medium" or "low" (or no relevance if left blank). The experts were also requested to comment upon the appropriateness of available water accounting temporal and spatial resolutions. The overall relevance rating involved an "averaging" process that combined the expert ratings for each measurand and component, guided by the rules outlined in Table 3.

**Table 3: Averaging rules for identifying relevance ratings of water accounts measurand for the HydroPlanner SEQ prototype.**

| Rating by Expert 1 | Rating by Expert 2 | Rating Attributed in Combined Matrix |
|---|---|---|
| High | High | High |
| High | Med | High |
| High | Low | High |
| High | - | High |
| Med | Med | Med |
| Med | Low | Med |
| Med | - | Med |
| Low | Low | Low |
| Low | - | Low |
| - | - | - |

For example, the measurand for Total Rainfall was given a "high" priority in Matrix Expert A and a "medium" priority in Matrix Expert B and hence this measurand is considered to have an overall "high" priority rating in the final combined matrix for the existing HydroPlanner prototype.

Compiling the matrices using this methodology ensured that if one matrix consistently indicated measurands as high priority while the other indicated them as low – these potential high priority measurands were retained. This method was deemed to be the most appropriate due the fact that there were only two matrices used as the primary data sources. Successful completion of more expert evaluations would have given a more accurate depiction of the data requirements of the HydroPlanner prototype.

## 5.2 Results

Table 4 presents the first two pages of the main results of this analysis by identifying the relevance ratings of the existing and planned water accounting indicators for the HydroPlanner prototype and related IUWM models. The full table of results is presented in Appendix B. This table is a critical part of the analysis and it has only been placed in the appendices in order to facilitate readability of the main report. The extract in Table 4 should help identify the procedure undertaken and nature of results provided.

The "average" relevance ratings of water accounting measurands are shown in the first three columns of Table 4. An indication of the relevance of each water account variable is noted in column 4 together with comments on the ideal spatial and temporal resolution for IUWM application. Additional measurement details for the same water accounting indicators in the rows of Table 4, are presented in Appendix C. The detailed measurand list includes their measurement units and frequencies, and locations, and reporting entities. Some of these data are only provided in Appendix C and not in the main summary data interchange results in Table 4.

The rows of Table 4 contain the water accounting measurands. They have been organised by data category type (e.g. climate, water supply data) and represent the complete list of indicators from the WaterHub, SWIM, AWRIS and (to a lesser extent) NWA accounts. For each indicator, the table shows the averaged relevance rating for the current HydroPlanner prototype, likely future extensions, its required ideal spatial and temporal resolution for modelling, and an estimate of its general IUWM relevance. Typically, daily and sub-catchment or finer measures are best suited for modelling purposes, but aggregation can still provide useful information for the operation and testing of IUWM models. The table also indicates the water accounting framework(s) where the data may be sourced with some added details on accounting spatial and temporal resolution availability. As discussed, additional measurement details for the same water accounting indicators are presented in Appendix C.

The approach used to examine the availability of relevant data from the water accounting systems is quite straightforward, it simply involves:

(a) Systematically listing all known data series that were likely to be covered, at some level, in the water accounts examined.

These are the rows in Table 4. Some water accounts data series that were irrelevant to the IUWM approaches were dropped. A more complete list of measurands and their measurement details is provided in Appendix C.

(b) Analysing the HydroPlanner prototype (and the general IUWM model approach) and identifying the likely empirical data needs for their various components.

Existing HydroPlanner documents and consultation and advice from the principal developers of the HydroPlanner prototype were the major sources of information for this part of the research method.

(c) Matching the complete list of individual water accounting variables (the measurands) under consideration to the IUWM data requirements, including a general assessment of priority and relevance to the model component.

The method used to identify potential data exchanges and key missing data series is encapsulated in the format of primary results table (Table 4). The data format of Table 4 is diagrammatically explained below:

| **1. CLIMATE DATA - Biophysical attribute group being measured e.g. climate, water supply-storage etc** | | |
|---|---|---|
| **MEASURAND**<br>**Total rainfall**<br>= the specific data series being assessed (compiled from all water account info sources). | **MODELLING DATA NEEDS**<br>**H**igh **M**edium **L**ow<br>= the relevance of that data series (total rainfall in this example) for HydroPlanner and IUWM models in general<br>- includes the relevance for *specific* HP | **WATER ACCOUNTS AVAILABILITY**<br>4 4<br>= indicators of data availability in the water accounts systems (WaterHub, BOM and SWIM) and their spatial and temporal measurement suitability. |
| **Average annual rainfall** | | |

This process reveals whether specific data series are available, and if they are in a spatial and temporal format that is useful for typical IUWM modelling needs. However, as the table rows have been based on the compilation of all known variables considered in water accounting systems under development, it does not reveal additional empirical data that could be utilised in the integrated modelling. This has been ascertained by the analysis of the HydroPlanner prototype and related IUWM modelling approaches to identify new or quite different variables that could be included in water accounting data collection processes. This technique has been somewhat constrained by the developmental nature of IUWM modelling and the limited information available at the time.

This methodology was originally outlined in McBean, Daniels and Braddock (2010) (Report 1). Report 1 also had several other roles including an explanation of the nature of water accounting, its potential benefits and capabilities, and an overview of the WaterHub water information system for SEQ. Report 1 was originally compiled in mid-2008 as a background document to inform the Life Cycle Analysis and Integrated Modelling Project team about the relevance of water accounting and to garner feedback on the best way to identify linkages and data feeds into the integrated modelling components. Unexpected delays slowed the succession to finalising Report 2 and the methodology originally outlined in Report 1 was redeveloped considerably before it was applied for the research summarised in this report. There were also significant changes in the WaterHub and in the nature of the HydroPlanner prototype model itself over this time period.

**Table 4: Water Accounting Data for IUWM Models – Main Data Interchange Matrix.**

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner (HP) SEQ Prototype – Potential Relevance** (H = high, M= medium, L = low, "-" = not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal OTH = Other) | General IUWM Model Relevance | Notes Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| **1. CLIMATE DATA** | | | | | | | | | | |
| Total rainfall | **H** (=high)<br>**L** (WW) (=low) | **H** (DMD,SRH)<br>**L** (DES) | **H** | Daily, subcatchment for all HP and most IUWM models | | | 4<br>(PHASE 1) | 1. Daily<br>2. 24hrs | Suitable – most daily temporal resolutions are suitable | |
| Average annual rainfall | **M**<br>**L** (WW) | **M** (DMD,SRH)<br>**L** (DES) | **M** | " | | | 4<br>(PHASE 1) | 1. Annually<br>2 Annually | | |
| Accumulated precipitation depth | **H** | **H** (DMD,SRH)<br>**L** (DES) | **H** | " | 4<br>*(AWRIS)*<br>4a, 4b[2] | 4 | 4 | 1. Daily or as transmitted for flood warning and forecasting | Stormwater – need sub daily resolution (6 min) | |
| Average Maximum temperature | **M**<br>**L** (WW) | **H** (DMD)<br>**L** (SRH,DES) | **M** | " | | | 4<br>(PHASE 1) | 1. Daily<br>2. 24hrs | | |
| Average Minimum temperature | **M**<br>**L** (WW) | **M** (DMD)<br>**L** (SRH,DES) | **M** | " | | | 4<br>(PHASE 1) | 1. Daily<br>2. 24hrs | | |
| Evaporation data | **H**<br>**L** (WW) | **H** (DMD,SRH)<br>**L** (DES) | **H** | " | 4<br>(NWA) | | 4<br>(PHASE 1) | 1. Daily<br>2. 24hrs | Most NWA data are presented in annual accounts at subcatchment level | For NWA data, substantial (dis-) aggregation required |
| Total daily Class A pan evaporation | **H**<br>**L** (WW) | **H** (DMD,SRH)<br>**L** (DES) | **H** | " | 4<br>*(AWRIS)*<br>4d | | | 1. Daily | | |
| Instantaneous wind speed and direction and wind-run | **H**<br>**L** (WW) | **M** (DMD)<br>**L** (SRH,DES) | **M** | " | 4<br>*(AWRIS)*<br>4c | 4 | | 1. Daily | | |
| Instantaneous solar radiation flux | **H**<br>**L** (WW) | **M** (DMD)<br>**L** (SRH,DES) | **M** | " | 4<br>*(AWRIS)*<br>4e | | | 1. Daily | | |
| Instantaneous net radiation flux | **H**<br>**L** (WW) | **M** (DMD)<br>**L** (SRH,DES) | **M** | " | 4<br>*(AWRIS)*<br>4f | | | 1. Daily | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner (HP) SEQ Prototype – Potential Relevance** (H = high, M= medium, L = low, "-" = not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal OTH = Other) | General IUWM Model Relevance | Notes Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Instantaneous dry-bulb air temperature | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | Daily, subcatchment for all HP and most IUWM models | 4 (*AWRIS*) 4g | | | 1. Daily | | |
| Instantaneous wet-bulb air temperature | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | 4 (*AWRIS*) 4h | | | 1. Daily | | |
| Instantaneous relative humidity | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | 4 (*AWRIS*) 4i | | | 1. Daily | | |
| Instantaneous vapour pressure deficit | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | 4 (*AWRIS*) 4j | | | 1. Daily | | |
| **2. WATER SUPPLY DATA** | | | | | | | | | | |
| **WATER SUPPLY - STORAGE** | | | | | | | | | | |
| Storage inflows (from the treatment plants to the water grid, not flows from the dams to the treatment plants) | **L, M** **L** (WW) | **H** (DMD) **L** (SRH,DES) | **M** | " | 4 (NWA) | | 4 (PHASE 1) | 1. Daily and weekly 2. 24 hrs | | NWA annual data only |
| Volume of water released from major storage to water course | **H** **-** (WW) | **L** (DMD, DES) **-** (SRH) | **M** | " | 4 (*AWRIS*,NWA) 3c | 4 | | 1. Daily 2. 24 hrs | | |
| Storage volume in major and minor storage (ML) | **H** **-** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | 4 (*AWRIS*,NWA) 3b,3e | 4 | 4 (PHASE 1) | 1. Daily 2. 24 hrs | | |
| ***Contd. (see Appendix B)*** | | | | | | | | | | |

[1] In order to better assess the potential data linkages between the HydroPlanner prototype and existing water accounts, the model foci components have been grouped into two categories: (1) the current HydroPlanner (HP) prototype system that extends on eWater CRC E2-related components with important urban aspects; and (2) potential future HP components. Some more detail of the functions and scope of these aspects is provided in Table 1. The relevance of water account data for the current HydroPlanner prototype is shown separately for wastewater (WW) when appropriate. The potential future HydroPlanner data relevance is also identified for demand-related (DMD), stormwater and rainwater harvesting (SRH), and desalination (DES) and other (OTH) functions where possible.

[2] The bottom labels (eg "4a", "4b") refer to the relevant proposed scope of the regulations for the provision of water information to the BOM under Section 126 of the *Water Act 2007*, Select Legislation Instrument 2008 No. 106. Attorney-General's Dept., Canberra.

## 5.3 Discussion

Based on the data matching process between the water accounting framework and the analysis of the HydroPlanner prototype, there are many opportunities for accessing water accounting data for a diverse range of information needs of the HydroPlanner model. Table 4 provides a useful guide to how the IUWM models can access useful empirical data for ongoing development, calibration, input and validation and also helps identify the potential gaps. However, it is only a basis for this beneficial exchange and further detail on potential data needs from the IUWM modellers would enhance this potential and help specify useful new data to be collected in water accounting approaches.

Turning to specific linkages, the **climate data** in water accounting systems are generally relevant to both the existing HydroPlanner prototype and future extensions and tend to be available from at least one of the accounting frameworks in appropriate spatial and temporal resolutions. High relevance measures include precipitation levels and evaporation data. Wind speed, solar radiation, air temperature and relative humidity and vapour pressure are high for the existing HydroPlanner but less so for future stages (excluding demand-related functions). The climate data are typically less important for wastewater aspects and future desalination but useful for demand functions. NWA data requirements could also enhance the availability of climate and rainfall-runoff modelling data (though this is currently implemented primarily at annual levels in the NWA development).

**Water supply – storage** water accounting data is of high relevance for the existing HydroPlanner (except for wastewater) though it is less crucial for future stages. The exception is information on storage inflows, which is of high relevance for demand, but of low to medium relevance for most other aspects. These data are also available in the appropriate spatial and temporal resolutions including daily and weekly storage inflow data from the WaterHub. There are also resolution uncertainties associated with storage, watercourse, and watercourse discharge levels.

The relevance of **water supply – volume sourced or received** water account information is mixed . For the existing HydroPlanner, medium to high ratings apply for desalination, recycling (bulk manufactured, purchased and total), total volumes from bulk suppliers, dams, rivers, groundwater and irrigation diversions and returns (excluding "individual extractor" details). This data category has low or no relevance to wastewater except for recycling-related indicators. For future HydroPlanner stages, desalination functions would obviously benefit from desalination volume sources (and also bulk supplier volumes received) and the demand aspects will benefit from total volumes and bulk supplies received and volumes from total surface water, dams, rivers and groundwater. Data will be available from the WaterHub for desalination, bulk recycled and total bulk supplier water at weekly temporal resolution. Most of the other indicators are also available from AWRIS at weekly frequencies except for the daily measures for irrigation water (diverted and returned) and self-extractor supplied, extracted, pumped and returned to watercourses.

Disregarding wastewater, **water supply – water supplied and exported** data for residential, total bulk and bulk exports are of high relevance for current HydroPlanner functions. However, they are only considered of low importance for non-residential uses. The residential and non-residential supply volumes are rated high for wastewater but lower for urban water supplied and bulk exports. Most indicators in this group have high relevance for demand functionality in future HydroPlanner stages. Residential supply data is listed as "medium" for stormwater and rainwater harvesting and desalination. Information in this group is only available from AWRIS and SWIM at weekly resolution and apparently at highly aggregated water service provider (WSP) levels.

**Water supply – water production** data from water treatment plants (WTP) is of medium to high relevance for most current HydroPlanner functions (including wastewater) but is less important in future stages. This information is available at useful resolutions in the WaterHub.

**Groundwater** level and pressure data are considered of low significance for catchment runoff-related modelling but high for river manager network functions. Information is available from SWIM, AWRIS and perhaps the NWAs, but the temporal and spatial resolutions have no apparent systematic consistency with modelling needs.

**Water quality information** is rated as highly relevant for most current HydroPlanner functions (except wastewater) and future stormwater and rainwater harvesting functions. It is available from BOM and AWRIS, but has unclear resolutions for matching to IUWM modelling needs.

Bulk flow measures for **water distribution** are similar to the bulk flow indicators in the water supply categories. They are of high relevance for future demand and medium relevance for wastewater and perhaps river network management aspects of the current HydroPlanner. They are available from the WaterHub at appropriate resolutions.

The relevance of **water use or consumption** accounting data varies considerably. Power station data is of medium use for E2-related HydroPlanner functions and future demand aspects. It is rated as unimportant for wastewater, stormwater and rainwater harvesting and desalination. Residential and commercial and industrial use data are perceived as having medium relevance for river network management and high relevance for wastewater functions. In future HydroPlanner stages, they are also considered to be very useful for demand components and of medium relevance for stormwater and rainwater harvesting. Demand forecasting outputs are medium to high relevance for all modelling functions. As with many of the use water account measures, the WaterHub data have the potential for lot-level spatial resolution but are limited to quarterly billing.

The demand connection and population data are generally considered useful for many aspects of the HydroPlanner modelling – especially for wastewater and demand functions. Annual data are available from SWIM and the WaterHub but are limited to totals for water and sewerage areas.

**System loss** data include total leakages which are highly relevant for most current and future modelling functions excluding desalination, and of medium use for catchment rainfall-runoff simulation aspects. Losses are of medium relevance for E2-related components and high for demand aspects of modelling but, unlike leakages, they are not considered useful for wastewater, storm water and wastewater harvesting and desalination. Losses rank medium to high overall. Although some system loss data are available through SWIM and possibly the NWA, unfortunately, it is only specified at annual levels and at broad water scheme scale.

For the **water discharges, outflows – from SEQ boundary** group, some of the locations for effluent data (see next group) would actually contribute to these system boundary outflows. The relevance of environmental flows was not specified by the HydroPlanner developers. There is little information available on this topic – currently only SWIM provides annual data at relatively broad geographic levels, though it is a potential area for both the WaterHub and NWA frameworks. Bulk water exports from the region have medium to high significance for E2-related modelling aspects and are highly relevant for wastewater functions. However, they are not useful in the other modelling areas and there are very few data currently available or planned (and this is anticipated at weekly frequency at best).

For **effluent data**, wastewater treatment plant (WWTP) flows are important for wastewater modelling components and also for demand-related aspects in future HydroPlanner modules. WWTP inflows are of limited relevance for other modelling functions and data is virtually non-existent (though it is considered a possible daily measurand in the WaterHub). WWTP outflows data is of medium-high relevance for E2-related areas. Aggregated annual SWIM data are available for WWTP outflows and daily measures are "probable" in future WaterHub developments. Sewage volumes discharged into watercourses are closely related to the WWTP outflows (with similar model component relevance ratings) and weekly measures are available through AWRIS. A similar situation exists for total weekly volumes for stormwater discharges. These flows are also important for storm and rainwater harvesting modelling. SWIM also has (highly aggregated) data on the volume of residential and trade and non-trade waste sewage collected and proportions for sewage treated to various levels.

**Recycled water supplied** is classed into residential, industrial/commercial, municipal, agricultural, on-site and environmental recycled water.[2]

[2] The "volume of recycled water supplied - environmental recycled water" covers water discharged to a waterway for environmental purposes as prescribed by the environmental regulator (NWC, 2010). There must be a quality characteristic that is a net benefit to the environment as determined by the relevant regulator. The "volume of recycled water supplied - on-site" is recycled water used on-site external to the treatment process. Total volumes of recycled water supplied within the period i.e. volumes must capture total water supplied in a continuous process irrespective of whether it is re-used within a cycle.

All of these indicators are low to medium relevance ratings for the E2-related functions except for municipal recycled water supplied which is considered of good use to river manager network type modelling aspects. The relevance for wastewater functions is mixed, with low levels for residential, industrial and commercial but high for municipal, agriculture, on-site and environmental supplies. For future modelling needs, recycled water supplies are not relevant to stormwater and rainwater harvesting and desalination, but residential, industrial/commercial, municipal and agriculture recycled water supplied will be very useful for demand purposes. Data on recycled water supplies are mainly available from SWIM (with some industrial/commercial information from the WaterHub), but the temporal resolution is typically limited to the billing period (usually quarterly at best) and on a scheme-wide geographic basis.

The details of **water entitlements and trade** tend to be important for river manager/network activities and less so for catchment rainfall-runoff related modelling. They are of medium relevance for future demand modelling functions but not considered relevant for wastewater and other aspects. Information on self-extraction from bores or watercourses is useful for catchment rainfall-runoff modelling but less so for river manager/network aspects and not important for wastewater. It has been rated as having low, if any, relevance for demand in future IUWM modelling. Drought restrictions information is of low and medium relevance for catchment rainfall-runoff and river manager/network models respectively. It is rated as having medium relevance for all wastewater model functions and highly useful for future demand components, but is not relevant for other aspects. Between the WaterHub and AWRIS, data on restrictions are all available for the relevant modelling geography and are revised with significant change.

### Data Gaps

The data series matching analysis suggests that many useful data exchanges will be possible to aid IUWM modelling and the future value and development of water accounting frameworks. However, several significant data gap areas can be identified. Summarising the shortcomings within the water accounting measurand list in Table 4 we note that:

- while most relevant storages are quite well covered in terms of stocks, inflows, releases and transfers, unfortunately volumes sourced (and often received) from bulk manufactured recycled, desalination, and the bulk supplier (Seqwater) are only available at weekly levels; and volumes sources from dams, rivers and groundwater are very limited in availability and resolution.
- water quality data available from the water accounts needs to be developed to be consistent with the temporal and spatial needs of IUWM models and estimations. The underlying basis for sampling is not enunciated to concord with modelling activities.
- all water use data are too aggregated in terms of temporal and spatial resolutions. This is also true of supply by type (and connections) data which are only available at weekly resolution and at WSP or scheme-wide geographic levels.
- system loss information is too temporally and spatially aggregated for IUWM purposes except for crude summation comparability.
- there are some plans for better environmental flow data but there is only limited and aggregated information available. However, the role of environmental flows has not been specified in the HydroPlanner prototype analysis undertaken here.
- effluent data are very limited and coarse and need much more detail and planning for consistency with IUWM modelling functions.
- recycled water data are only recorded quarterly at best and at broad spatial levels that are unlikely to be of much use to IUWM modelling without significant aggregation.

Looking through the full data needs of the HydroPlanner prototype summarised in Table 2 reveals some aspects where potential data types for IUWM modelling are not to be found within water accounting plans. Catchment runoff and constituent generation and routing required detailed flow data for empirical validation and, while there is some information to be collected within the water accounts, it is not of adequate geographic detail or with a consistent systematic locational framework to optimally support IUWM models. Sub-daily data are also often ideal for these functions. Similarly, water quality (constituent balance) aspects of water account data need finer spatial and temporal resolution to enable application beyond assessment based on broad aggregation of modelling outputs.

Supply system yields and shortfalls, and resilience, reliability and vulnerability outcomes do have access to quite fine temporal level water account data but again this is primarily limited to broad geographic areas and further disaggregation based on a dialogue with IUWM developers on their needs, would be fruitful.

Wastewater and other discharge data are reasonable but confined to weekly measures and it is uncertain whether the discharge points match IUWM modelling needs – especially for stormwater discharges. In general, there is minimal empirical information on stormwater and rainwater harvesting, and local recycling and greywater use from the water accounts and better sources are required for modelling purposes.

It is unclear how groundwater information in the accounting frameworks could be used in the HydroPlanner prototype. However, key land use and climate data are generally available and appropriate. Demand and end use information are also available – potentially at lot level – but values are only available on a quarterly basis or longer. Greater clarification is needed to identify the potential interchange use of empirical information on environmental flows but it is likely to be a major area for further investigation and improvement, given a strong shift towards pressing water quality and ecosystem impact issues since the Millennium Drought broke in 2009.

A comparison of Tables 3 and 5 indicates that the WaterHub, SWIM and BOM water accounts can provide many useful data series for successful development and ongoing validation and improvement of the HydroPlanner prototype in strategic water planning in SEQ. However, it is important to acknowledge that some of the listed water accounting indicators may not be delivered. It is also critical to note that, where the information could be ascertained, there are many discrepancies between the temporal and spatial resolutions of the measurands provided by the water accounts. For example, for stormwater modelling functionality, accumulated precipitation depth measures proposed by the BOM should be measured at six minute intervals to capture runoff volumes for short events as opposed to daily readings. It was also indicated that if there exists significant variation in the weekly volume of water sourced from desalination, proposed by both BOM and the QWC, daily resolution would be preferred. Water quality observations such as concentrations of suspended solids, phosphorus and nitrogen are also required to be measured on a daily basis.

So, water accounting data are often only available at more aggregated temporal and spatial resolutions than required for direct application in the operational and review activities of the HydroPlanner prototype. In such cases, it is likely that model data feeds will need to be adjusted in one of two ways:

(1) by the temporal and/or spatial aggregation of IUWM model data outputs to enable comparison and assessment against water accounting statistics (e.g. the summation of daily HP estimates of sewage discharge to watercourses to weekly values to match water account data from BOM), or,

(2) by applying a temporal disaggregation/averaging process to water account data. This latter approach would be more difficult for spatial disaggregation without additional information.

There are still many gaps, and appropriate modifications to water accounting content, timing and geographic coverage would be invaluable in helping to support robust, defensible, reliable and accurate IUWM models.

# 6. CONCLUSIONS AND RECOMMENDATIONS

As in many parts of the world, there is growing recognition in Australia of the importance of compiling and improving the nation's water-related information for the benefit of effective and sustainable water resource management. Numerous initiatives have been developed that address the critical need for water resource information. For SEQ, major responses include the QWC's WaterHub, **qldwater**'s SWIM, and the BOM's Australian Water Resources Information System (AWRIS) and National Water Accounts (NWAs). These water accounts aim to change the region's water information systems from very limited in scope, scattered and inaccessible, to being comprehensive, centralised, accessible and consistent. The ongoing development of these water accounts is occurring at a time when SEQ is committed to implementing its 50-year Water Supply Strategy. To support the initiatives being implemented under the Water Strategy, integrated urban water management (IUWM) models capable of representing the entire urban water cycle in a single framework will play a key role. In this report, we have focused upon the HydroPlanner prototype tool for SEQ, designed to estimate and predict water quality and quantity outcomes of various urban water management scenarios from supply catchments to receiving waters and all major use and recycling activities in between.

Identification of gaps in appropriate hydrological data, to meet modelling needs, can help inform the development of state and national water accounting frameworks. Through the BOM, Australia has become a world leader in the field and is developing a sophisticated set of National Water Accounts based on the carefully planned Australia Water Accounting Standards (Bureau of Meteorology, 2010). The structure of the accounts appears to be well-suited to the integrated and systematic nature of integrated urban water management and access to empirical water data to support and guide the development and implementation of hydrological modelling as a key tool for the sustainable management of water resources. The NWAs are also supported by the extensive compilation of water data in the more eclectic AWRIS.

Matching the data needs of the HydroPlanner prototype with data proposed to be delivered through the WaterHub, AWRIS and other water accounting systems has identified which empirical water-related data to be collected and managed, by the QWC, BOM and others, will be relevant to the development, implementation and validation of the IUWM models. It is recommended that these entities invest further research into optimising synergies that have been identified in this report. Further consultation between hydrology experts and water account developers to develop and enhance these data synergies is recommended. The BOM is currently conducting investigations into the user requirements of the AWRIS and, as this report is completed, the optimal approach for informing the development of AWRIS about the data needs of hydrological modelling is being investigated. The QWC also welcomes submissions about the strategic need for water data.

An important aspect of defining the synergies between the data provided through the water accounts and the data required for hydrological modelling involves investigation of appropriate spatial and temporal resolutions. The effectiveness of modelling the natural and human-influenced water cycle will depend upon the representativeness of the processes being modelled. To ensure this representativeness, careful consideration must be given to the frequency of data collection and the density and location of measurements within the relevant study areas. Identification of the relationship between the spatial and temporal resolutions of data provided by the water accounting systems and the corresponding data requirements of the IUWM models was attempted but requires further investigation from both directions. It is recommended that more research be undertaken to specify the necessary temporal and spatial resolutions of IUWM model data and communicate these data needs to the primary water accounting system developers. Even if not provided at some fine level of detail, it is important that common data series can be aligned with or be aggregated/disaggregated to support IUWM model development, calibration and validation.

This report has also highlighted that integrated approaches to data management for the water sector are well-suited for providing comprehensive and systematic data for IUWM and related modelling activities. Integrated approaches to management will require the collation of data from across the entire urban water cycle. Management of data that is guided by the principles of integrated data management will ensure that relevant data are delivered in an integrated, consistent and accessible format with system-wide coverage of major phenomena and linkages. Water accounts should also be developed in accordance with local, national and international standards and practices to ensure that information collected can be utilised for research and strategic planning based on linking economic, environmental and social dimensions of water management (and is amenable to more generalised analysis across political boundaries).

One important area for further research to optimise the social and economic benefits of the development of national water accounts in Australia is to ensure that the process remains fully informed by approaches and guidelines being adopted in national and international physical and economic accounting systems for water and other environmental resources. A major recommendation is the need to ensure that disaggregated water extraction, supply and use data are classified by the Australian and New Zealand Standard International Classification (ANZSIC) 2006 as soon as possible. ANZSIC is the primary classification system for economic industry data in Australia and is compatible with the Standard International Classification Rev. 3. Currently, lot-level water use can only be classified according to the Qld Department of Environment and Resource Management (DERM) land use codes. This capability will facilitate an extensive range of productivity and environmental and economic strategic assessments for sustainable management of water resources.

Compatibility and inter-operability of all water accounts, and also with IUWM models, would be greatly enhanced by investigating existing and developing national and international water and other environmental resource physical and economic accounting standards and guidelines (for example, the United Nation's System of Environmental-Economic Accounts for Water (SEEAW)). This should aim to ensure that Australian water accounting frameworks are consistent with these formats and can be used in a wide range of strategic applications and triple bottom line assessments.

It is recommended that a more detailed investigation be undertaken into the "data gaps" between hydrological modelling and water accounting systems in order to pinpoint the high-value data needs for IUWM modelling that are not currently addressed or planned for coverage in the water accounting frameworks that relate to SEQ.

# APPENDIX A - An Overview of Indicative Data Requirements of the HydroPlanner SEQ Prototype

| E2-RELATED COMPONENTS | |
|---|---|
| **Data Type** | **Temporal/Spatial Resolution** |
| **DATA INPUTS** | |
| Climate data – rainfall, evaporation, temperature | Sub-daily, daily or monthly/ sub-catchment point measurements |
| Stream flow data | Sub-daily, daily or monthly/ sub-catchment measurements |
| Water quality observations – suspended solids, turbidity, phosphorus, nitrogen | Sub-daily, daily or monthly/ sub-catchment measurements |
| Groundwater information – levels, pressure | Sub-daily, daily or monthly/ sub-catchment measurements |
| Water supply data – major storage details, water volumes released to the water grid | Sub-daily, daily or monthly/ sub-catchment measurements |
| Volumes of water sourced – from dams, rivers, groundwater | Sub-daily, daily or monthly/ sub-catchment measurements |
| Effluent data – wastewater inflows and outflows | Sub-daily, daily or monthly/ sub-catchment measurements |
| Recycled water use | Sub-daily, daily or monthly/ sub-catchment measurements |
| Decision variables – minimum flow | |
| Catchment Digital Elevation Map (DEM) | |
| Significant catchment disturbances, such as bushfire, drought, flood or construction activity | |
| Land use map | |
| Variations in land-use, land management and climate change | |
| Catchment runoff volumes | Daily |
| Stream inflow volumes to reservoirs | Daily |
| Volume of water sourced from various supplies – dams, rivers, groundwater | Daily |
| Volume supplies (including supply from wastewater recycling and desalination) | Daily |
| Stormwater runoff volume | Daily |
| Total demand for smaller geographic units | Daily / gross demand for the city or broken down spatially |
| Water consumption data – residential and commercial | Daily |
| Total leakage and losses | Daily or able to be disaggregated |
| Water quality concentrations (suspended solids, phosphorus, nitrogen) or loads at different points throughout the river network | Daily or able to be disaggregated |
| Details of water entitlements and trades, details of water allocations trades and leases | |
| Information about the network structure – desalination plants, new wastewater linkages | |
| Decision variables – such as minimum flow requirements | |
| **DATA OUTPUTS** | |
| Catchment runoff volumes | Sub-daily, daily or monthly/ few square metres to thousands of square metres in rural and peri-urban catchments |
| Stream flow | Sub-daily, daily or monthly/ few square metres to thousands of square metres in rural and peri-urban catchments |
| Concentrations and loads of constituents (sediments, phosphorus, nitrogen) flowing to receiving waters<br>Concentrations and loads of constituents (suspended solids, phosphorus, nitrogen) flowing to receiving waters following catchment disturbances, land use change or climate variability<br>Pollutant loads<br>Spatial representation of pollutant generation within the model domain | Sub-daily, daily or monthly/ few square metres to thousands of square metres in rural and peri-urban catchments |
| Groundwater and surface-water pathways for flow and constituents | Sub-daily, daily or monthly/ few square metres to thousands of square metres in rural and peri-urban catchments |
| Flow volumes at various points in the river and supply network | Daily |
| Total active volume in all storages | Daily |
| Volumes of water that are in transit | Daily |
| A running balance of all water use since a specified point in time | Daily |
| Estimates of current and future water availability and quality | Daily |
| Estimates of total forecast inflows into all user's storages | Daily |
| Estimates of forecast rainfall into all users storages | Daily |
| Estimates of forecast evaporation from all users storages | Daily |
| Estimates of downstream tributary utilisation by all users | Daily |
| Estimates of transmission and operation losses for all users | Daily |
| Water ownership will be assigned to inflows, gains, losses, stored water and transit water | |

| CONSUMPTION AND DEMAND MANAGEMENT; END USE MODEL | |
|---|---|
| **Data Type** | **Temporal/Spatial Resolution** |
| **DATA INPUTS** | |
| Climate data – rainfall, temperature, evaporation | Daily/ sub-catchment point measurements |
| Time series of water supply (from treatment plant to the water grid) | Daily |
| Total leakage and losses within the system | Daily |
| Wastewater inflows to the wastewater treatment plant | Daily |
| Recycled water use | Daily |
| Information on where and how water is being used (water consumption) | |
| Efficiency of water appliances and their presence in the market | |
| Information relating to the implementation and the uptake of demand management measures, such as the types of restrictions applied and the number of days applied | |
| Number of population receiving water supply services | |
| **DATA OUTPUTS** | |
| Monthly and annual time series of demand | Monthly or annually and can be disaggregated to daily/ The EUM will have the capacity to model the demand of a single lot or water demand of 1000s of lots in the urban area |
| Change in mean annual demand | |
| Time series of indoor water use | Monthly or annually and can be disaggregated to daily/ The EUM will have the capacity to model the demand of a single lot or water demand of 1000s of lots in the urban area |
| **WASTEWATER** | |
| **DATA INPUTS** | |
| Rainfall data | Daily/ sub catchment point measurements |
| Volumes of water supplied – residential and commercial | Daily |
| Time series of demand | Daily/ single lot or 1000s of lots in the urban area |
| Water Treatment Plant bulk readings | Daily |
| Wastewater treatment plant inflows and outflow | Daily |
| Irrigation water supplied | Daily or able to be disaggregated |
| Commercial and industrial water consumption | Daily or able to be disaggregated |
| Connected residential and non-residential properties – water supply and sewerage services | |
| **DATA OUTPUTS** | |
| Time series of wastewater volumes | Daily |
| Time series of wastewater flows | Daily |
| Time series of wastewater discharges | Daily |
| Concentrations and loads of constituents (suspended solids, phosphorus, nitrogen) in the wastewater stream | |
| **STORMWATER** | |
| **DATA INPUTS** | |
| Climate data – rainfall and evaporation data | 6 min/ sub-catchment point measurements |
| Water quality concentrations (suspended solids, phosphorus, nitrogen) or loads in stream flow | |
| Total leakage in the system | |
| Volumes of stormwater discharge | 6 min |
| **DATA OUTPUTS** | |
| Time series of stormwater runoff volumes | Daily or 6 minutes |
| Concentrations and loads of constituents (suspended solids, phosphorus, nitrogen) in stormwater runoff | |
| **DESALINATION** | |
| **DATA INPUTS** | |
| Volumes of water sourced from desalination plants<br>Volumes of water sourced from the sea? | Daily/desalination plant outlet |
| **DATA OUTPUTS** | |
| Time series of desalination water supplied | Daily/ desalination plant outlet |

Sources: Personal communication with Andrew Grant, Joel Rahman, Shiroma Maheepala, CSIRO Land and Water, Melbourne (2008); Welsh and Podger (2008).

## APPENDIX B - Water Accounts Data for IUWM Models – Main Data Exchange Matrix – Complete Table (Full Version of Table 4)

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | **Water Accounting Framework** (Water Regulation Code[2]) | | | **Measurement / Resolution** (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| **1. CLIMATE DATA** | | | | | | | | | | |
| Total rainfall | **H** (=high) **L** (WW)(=low) | **H** (DMD,SRH) **L** (DES) | **H** | Daily, subcatchment **for all HP and most IUWM models** | | | 4 (PHASE 1) | 1. Daily 2. 24hrs | Suitable – most daily temporal resolutions are suitable | |
| Average annual rainfall | **M** **L** (WW) | **M** (DMD,SRH) **L** (DES) | **M** | “ | | | 4 (PHASE 1) | 1. Annually 2 Annually | | |
| Accumulated precipitation depth | **H** | **H** (DMD,SRH) **L** (DES) | **H** | “ | 4 (*AWRIS*) 4a, 4b | 4 | 4 | 1. Daily or as transmitted for flood warning and forecasting | Stormwater – need sub daily resolution (6 min) | |
| Average Maximum temperature | **M** **L** (WW) | **H** (DMD) **L** (SRH,DES) | **M** | “ | | | 4 (PHASE 1) | 1. Daily 2. 24hrs | | |
| Average Minimum temperature | **M** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | “ | | | 4 (PHASE 1) | 1. Daily 2. 24hrs | | |
| Evaporation data | **H** **L** (WW) | **H** (DMD,SRH) **L** (DES) | **H** | “ | 4 (NWA) | | 4 (PHASE 1) | 1. Daily 2. 24hrs | Most NWA data are presented in annual accounts at subcatchment level | For NWA data, substantial (dis-) aggregation required |
| Total daily Class A pan evaporation | **H** **L** (WW) | **H** (DMD,SRH) **L** (DES) | **H** | “ | 4 (*AWRIS*) 4d | | | 1. Daily | | |
| Instantaneous wind speed and direction and wind-run | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | “ | 4 (*AWRIS*) 4c | 4 | | 1. Daily | | |
| Instantaneous solar radiation flux | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | “ | 4 (*AWRIS*) 4e | | | 1. Daily | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Instantaneous net radiation flux | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | **4** (AWRIS) 4f | | | 1. Daily | | |
| Instantaneous dry-bulb air temperature | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | Daily, subcatchment for all HP and most IUWM models | **4** (AWRIS) 4g | | | 1. Daily | | |
| Instantaneous wet-bulb air temperature | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | **4** (AWRIS) 4h | | | 1. Daily | | |
| Instantaneous relative humidity | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | **4** (AWRIS) 4i | | | 1. Daily | | |
| Instantaneous vapour pressure deficit | **H** **L** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | **4** (AWRIS) 4j | | | 1. Daily | | |
| **2. WATER SUPPLY DATA** | | | | | | | | | | |
| **WATER SUPPLY - STORAGE** | | | | | | | | | | |
| Storage inflows (from the treatment plants to the water grid, not flows from the dams to the treatment plants) | **L, M** **L** (WW) | **H** (DMD) **L** (SRH,DES) | **M** | " | **4** (NWA) | | **4** (PHASE 1) | 1. Daily and weekly 2. 24 hrs | | NWA annual data only |
| Volume of water released from major storage to water course | **H** **-** (WW) | **L** (DMD, DES) **-** (SRH) | **M** | " | **4** (AWRIS,NWA) 3c | **4** | | 1. Daily 2. 24 hrs | | |
| Storage volume in major and minor storage (ML) | **H** **-** (WW) | **M** (DMD) **L** (SRH,DES) | **M** | " | **4** (AWRIS,NWA) 3b,3e | **4** | **4** (PHASE 1) | 1. Daily 2. 24 hrs | | |
| Level of water held in major and storage (m) | **H** **-** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **M** | " | **4** (AWRIS,NWA) 3a | **4** | | 1. Daily | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Volume of water transferred between major storages | **H** - (WW) | **L** (DMD,DES) - (SRH) | **M** | “ | 4 (*AWRIS*,NWA) 3d | 4 | | 1. Daily 2. 24 hrs | | |
| Record of instantaneous watercourse level (and provisional record) | **H** - (WW) | **H** (SRH) - (DEM, DES) | **M** | “ | 4 (*AWRIS*) 1a,1d | 4 | | 1. Daily | | |
| Record of instantaneous watercourse discharge (and provisional record) | **H** - (WW) | **H** (SRH) - (DEM, DES) | **M** | “ | 4 (*AWRIS*) 1b,1c | 4 | | 1. Daily | | |
| Storage Closures – *note about period storages closed* | - | - | - | “ | | | 4 (Possible) | As required | | |
| Registers of major storages and of dams referred under dam safety regulations | **H** - (WW) | - | **M** | “ | 4 (*AWRIS*) 3f | | | 1. Annual | | |
| **WATER SUPPLY - VOLUME SOURCED OR RECEIVED** | | | | | | | | | | |
| Volume sourced from **desalination (bulk manufactured water authority)** | **M, H** - (WW) | **H** (DES) **L** (DMD) - (SRH) | **M** | “ | | | 4 (PHASE 1) | Weekly | | |
| Total weekly volume of water sourced from desalination | **M, H** - (WW) | **H** (DES) **L** (DMD) - (SRH) | **M** | “ | 4 (*AWRIS*, NWA) 7c | 4 | 4 (PHASE 1) | Weekly | Prefer daily res if significant variation throughout the week | NWA annual data only |
| Volume sourced from **recycling (bulk manufactured water authority)** | **M, H** **H** (WW) | **L** (DMD) - (SRH,DES) | **M** | “ | | | 4 (PHASE 1) | Weekly | | |
| Total weekly volume of water sourced from recycling | **M, H** **H** (WW) | **L** (DMD) - (SRH,DES) | **M** | “ | 4 (*AWRIS*,NWA) 7d | 4 | 4 (PHASE 1) | Weekly | | |
| Total weekly volume of bulk recycled water purchased | **M, H** **H** (WW) | **L** (DMD) - (SRH,DES) | **M** | “ | 4 (*AWRIS*,NWA) 7f | 4 | | Weekly | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Total weekly volume of total water sourced (and provisional record) | **M, H** **L** (WW) | **H** (DMD) **M** (DES) **-** (SRH) | **M** | “ | 4 (*AWRIS*,NWA) 7g,7n | 4 | | Weekly | | |
| Volume received from **bulk supplier (SEQwater)** | **M, H** **L** (WW) | **H** (DMD) **M** (DES) **-** (SRH) | **M** | “ | | | 4 (PHASE 1) | Weekly | | |
| Total weekly volume of water received by bulk supplier | **L, H** **L** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **L-M** | “ | 4 (*AWRIS*) 7e | 4 | | Weekly | | |
| Total weekly volume of water sourced from surface water | **L, H** **-** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **L-M** | “ | 4 (*AWRIS*,NWA) 7a | 4 | | Weekly | | |
| Volume sourced from **dams** | **H** **-** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **M** | “ | 4 (NWA) | | 4 (Possible) | | | NWA annual data only |
| Volume sourced from **rivers** | **H** **-** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **M** | “ | 4 (NWA) | | | | | Very difficult to estimate actual taken; allocation and licence data indicative only |
| Volume sourced from **groundwater** | **H** **-** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **M** | “ | 4 (NWA) | | 4 (Possible) | | | |
| Total weekly volume of water sourced from groundwater | **H** **-** (WW) | **M** (DMD) **L** (DES) **-** (SRH) | **M** | “ | 4 (*AWRIS*) 7b | 4 | | 1. Weekly | | Especially important if groundwater levels are significant in the catchment |
| Volume of water diverted from watercourse to a managed irrigation scheme via a bulk diversion point | **H** **-** (WW) | **-** (DMD, DES, SRH) | **M** | “ | 4 (*AWRIS*) 5a | | | 1. Daily | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | HydroPlanner SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | General Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Total volume of water returned from a managed irrigation scheme via a channel or a pipe to a watercourse | **H**<br>**-** (WW) | **-**<br>(DMD, DES, SRH) | **M** | " | **4**<br>(*AWRIS*)<br>5b | | | 1. Daily | | |
| Total volume of water returned from a managed irrigation scheme via a channel or a pipe to a storage | **H**<br>**-** (WW) | **-**<br>(DMD, DES, SRH) | **M** | " | **4**<br>(*AWRIS*)<br>5c | | | 1. Daily | | |
| Total daily volume of water supplied to all irrigators in a managed irrigation scheme | **H**<br>**-** (WW) | **-**<br>(DMD, DES, SRH) | **M** | " | **4**<br>(*AWRIS*)<br>5d | | | 1. Daily | | |
| Total monthly volume of water supplied to individual irrigators in a managed irrigation scheme | **M**<br>**-** (WW) | **-**<br>(DMD, DES, SRH) | **L-M** | " | **4**<br>(*AWRIS*)<br>5e | | | 1. Daily<br>2. Month | | |
| Total monthly volume of water supplied to individual self extractors | **-** | **-** | **-** | " | **4**<br>(*AWRIS*)<br>5f | | | 1. Monthly<br>2. Month | | |
| Total monthly volume of water pumped from a watercourse by 'self-extractors' | **-** | **-** | **-** | " | **4**<br>(*AWRIS*)<br>5g | | | 1. Monthly<br>2. Month | | |
| Total monthly volume of water extracted from bore by 'self-extractors' | **-** | **-** | **-** | " | **4**<br>(*AWRIS*)<br>5h | | | 1. Monthly<br>2. Month | | |
| Total monthly volume of water returned by 'self-extractor' to a watercourse | **-** | **-** | **-** | " | **4**<br>(*AWRIS*)<br>5i | | | 1. Monthly<br>2. Month | | |
| Provisional record of total weekly volume of total sourced water | **M,H**<br>**L** (WW) | **H** (DMD)<br>**M** (DES)<br>**-** (SRH) | **M** | " | | | | 1. Weekly<br>2. Week | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| **WATER SUPPLY - TOTAL WATER SUPPLIED AND EXPORTED** | | | | | | | | | | |
| Total weekly volume of residential water supplied | **M,H**<br>**H** (WW) | **H** (DMD)<br>**M** (SRH,DES) | **M-H** | " | 4<br>(*AWRIS*)<br>7h | 4 | | 1. Weekly | Daily res better for estimating demand-climate relationship *SWIM* - WSP-wide for all | Also split by potable and non-potable in *SWIM* data |
| Total weekly volume of commercial, municipal and industrial water supplied | **L**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>7i | 4 | | 1. Weekly | *SWIM* - WSP-wide for all | Also split by potable and non-potable in *SWIM* data |
| Total weekly volume of other water supplied | **L**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>7j | 4 | | 1. Weekly | | Also split by potable and non-potable in *SWIM* data |
| Total weekly volume of urban water supplied (and provisional record) | **L**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>7k,7o | 4 | | 1. Weekly | | Also split by potable and non-potable in *SWIM* data |
| Total weekly volume of bulk water exports | **M,H**<br>**L** (WW) | **M** (DMD)<br>**L** (DES)<br>**-** (SRH) | **M** | " | 4<br>(*AWRIS*)<br>7l | 4 | | 1. Weekly | | Also split by potable and non-potable in *SWIM* data |
| Total weekly volume of bulk recycled water exports | **M,H**<br>**M** (WW) | **M** (DMD)<br>**L** (DES)<br>**-** (SRH) | **M** | " | 4<br>(*AWRIS*)<br>7m | 4 | | 1. Weekly | | Also split by potable and non-potable in *SWIM* data |
| **WATER SUPPLY - WATER PRODUCTION DATA** | | | | | | | | | | |
| Water Treatment Plant (WTP) bulk readings | **M,H**<br>**H** (WW) | **L** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4<br>(PHASE 1) | 1. Daily<br>2. 24 hours | | |
| **WATER SUPPLY - GROUNDWATER RESOURCE INFORMATION** | | | | | | | | | | |
| Groundwater level | **L,H**<br>**-** (WW) | **L** (OTH)<br>**-** (DMD,SRH,DES) | **M** | " | 4<br>(*AWRIS*, NWA)<br>2a | 4 | | 1. the mean daily value or periodically measured value, depending on availability | | Especially significant if groundwater levels are significant in the catchment |

| **MEASURAND** | **MODELLING DATA NEEDS** | | | | **WATER ACCOUNTS AVAILABILITY** | | | | | **Other Comments** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | **Water Accounting Framework** (Water Regulation Code[2]) | | | **Measurement / Resolution** (See accompanying table for more detail) | | |
| **(NB: More details on measurement units and reporting are provided in Appendix C)** | **HydroPlanner SEQ prototype[1]** (WW = wastewater) | **Potential future HydroPlanner[1]** DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | **General IUWM Model Relevance** | **Notes** –Preferred unit, spatial and temporal resolution | **BOM (AWRIS) (NWA)** | **SWIM** | **WaterHub (WH)** | **Typical measurement frequency and period covered** | **Temporal and spatial resolution adequacy for IUWM models** | |
| Groundwater pressure | **L,H** - (WW) | - (DMD,SRH,DES) | **M** | “ | 4 (*AWRIS*) 2b | 4 | | 1. the mean daily value or periodically measured value, depending on availability, and the aquifer layer and depth at which the pressure is measured | | Especially significant if groundwater levels are significant in the catchment |
| **3. WATER QUALITY INFORMATION** | | | | | | | | | | |
| Instantaneous electrical conductivity of streamflow | **H** - (WW) | **H** (SRH) - (DMD,DES) | **M** | “ | 4 (*AWRIS*) 9a | 4 | | 1. Daily (time interval of data to be limited to five minutes or greater) | | Assuming that the software measures water quality |
| Instantaneous electrical conductivity of groundwater | **L,H** - (WW) | - (DMD,SRH,DES) | **L** | “ | 4 (*AWRIS*) 9b | 4 | | 1. Unclear; as measurements taken | | |
| Instantaneous temperature of streamflow | **-, H** - (WW) | - (DMD,SRH,DES) | **M** | “ | 4 (*AWRIS*) 9h | 4 | | 1. Unclear; as measurements taken | | |
| Instantaneous total suspended solids concentration in streamflow | **H** - (WW) | **H** (SRH) - (DMD,DES) | **M** | “ | 4 (*AWRIS*) 9c | 4 | | 1. Unclear; as measurements taken | | Assuming that the software measures water quality |
| Instantaneous turbidity of streamflow | **H** - (WW) | **H** (SRH) - (DMD,DES) | **M** | “ | 4 (*AWRIS*) 9d | 4 | | 1. Unclear; as measurements taken | | Assuming that the software measures water quality |
| Instantaneous total phosphorus concentration of streamflow | **H** - (WW) | **H** (SRH) - (DMD,DES) | **M** | “ | 4 (*AWRIS*) 9e | 4 | | 1. Unclear; as measurements taken | | Assuming that the software measures water quality |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner SEQ Prototype – Potential Relevance** (H = high M= medium L = low "-" not relevant) | | **General Integrated Urban Water Management (IUWM) Models** | | **Water Accounting Framework** (Water Regulation Code[2]) | | | **Measurement / Resolution** (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Instantaneous total nitrogen concentration of streamflow | **H**<br>**-** (WW) | **H** (SRH)<br>**-** (DMD,DES) | **M** | " | 4 (*AWRIS*) 9f | 4 | | 1. Unclear; as measurements taken | | Assuming that the software measures water quality |
| Instantaneous pH of streamflow | **H**<br>**-** (WW) | **H** (SRH)<br>**-** (DMD,DES) | **M** | " | 4 (*AWRIS*) 9g | 4 | | 1. Unclear; as measurements taken | | Assuming that the software measures water quality |
| Water quality performance | **-** | **-** | **-** | " | | | 4 (Probable) | | | Published at www.water.Qld.gov.au |
| Compliance reporting and water quality monitoring **(will eventually be built into the system)** | **-** | **-** | **-** | " | | | 4 (see comments) | Monthly | | SEQ Water Grid Manager monitors water quality and reports are published monthly |
| *SWIM* – data on % samples compliant BOD, SS, N, P, E coli | | | | " | | | | 1. Annual | Water schemes | |
| **4. WATER DISTRIBUTION DATA** | | | | | | | | | | |
| **Water Grid / market compliance / water quality compliance** | **-** | **-** | **-** | " | | | | | | |
| Bulk flow measures within the Grid System **(VPM Volumetric Point Measurement Tool)** | **L,M**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4 (PHASE 1) | 1. daily<br>2. 24 hours | | |
| **5. USE OF WATER / DEMAND CONSUMPTION** | | | | | | | | | | |
| Power Station Water Consumption | **M,H**<br>**-** (WW) | **M** (DMD)<br>**-** (SRH,DES) | **M-H** | " | 4 (NWA) | | 4 (PHASE 1) | | | Not publicly disclosed |
| Residential water consumption | **L,M**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **H** | " | 4 (NWA) | | 4 (PHASE 1) | 1. depends on collection of billing data (mostly quarterly) | Detailed lot level (Qld NRW land use codes) | NWA annual data only |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | HydroPlanner SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | General Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Commercial and industrial water consumption | **L,M**<br>**H** (WW) | **H** (DMD)<br>**M** (SRH)<br>**-** (DES) | **H** | " | 4 (NWA) | | 4 (PHASE 1) | 1. depends on collection of billing data | Detailed lot level (Qld NRW land use codes) | |
| Demand Forecasting Tools | **M,H**<br>**M** (WW) | **H** (DMD)<br>**M** (SRH,DES) | **M-H** | " | | | 4 (PHASE 1) | | | |
| **DEMAND UNITS** | | | | " | | | | | | |
| ***Connected Properties and Population*** | | | | " | | | | | | |
| Population receiving water supply services | **L,-**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | 4 (PHASE 1) | 1. Annual | Water schemes, nonpotable water schemes only | |
| Connected residential properties - water supply | **L,-**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | 4 (PHASE 1) | 1. Annual | Water schemes, nonpotable water schemes only | |
| Connected non-residential properties - water supply | **L,-**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | 4 (PHASE 1) | 1. Annual | Water schemes, nonpotable water schemes only | |
| Population receiving sewerage services | **-**<br>**H** (WW) | **-**<br>(DMD,SRH,DES) | **L** | " | | 4 | | 1. Annual | Sewerage schemes | |
| Connected residential properties – sewerage | **-**<br>**H** (WW) | **-**<br>(DMD,SRH,DES) | **L** | " | | 4 | | 1. Annual | Sewerage schemes | |
| Connected non-residential properties – sewerage | **-**<br>**H** (WW) | **-**<br>(DMD,SRH,DES) | **L** | " | | 4 | | 1. Annual | Sewerage schemes | |
| **6. SYSTEM LOSS** | | | | | | | | | | |
| Total Leakage | **M,H**<br>**H** (WW) | **H** (DMD,SRH)<br>**-** (DES) | **M-H** | " | 4 (NWA) | 4 | | Annual | | NWA annual data only<br>*SWIM* infrastructure and volumetric leakage (annual; water schemes) |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | <u>HydroPlanner</u> SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | <u>General</u> Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Losses | **M**<br>**-** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M-H** | " | 4<br>(NWA) | 4 | | Annual | | *SWIM* real water losses (annual; water schemes) |
| **7. WATER DISCHARGES, OUTFLOWS – from SEQ boundary** | | | | | | | | | | |
| Environmental flows | ? | ? | **M** | " | 4<br>(NWA) | 4 | 4<br>(Possible) | | Uncertain | NWA annual data only<br>*SWIM* data - volume of water supplied - environmental |
| Volume of bulk water exports | **M,H**<br>**H** (WW) | **L** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4<br>(Possible) | Weekly | | |
| **8. EFFLUENT DATA** | | | | | | | | | | |
| Wastewater inflows at WWTP (sewerage treatment plants) | **L, -**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4<br>(Possible) | 1. Daily<br>2. 24hrs | | |
| WWTP (sewerage treatment plants) outflows | **M,H**<br>**H** (WW) | **-** (DMD,SRH,DES) | **L-M** | " | | 4 | 4<br>(Probable)) | 1. Daily<br>2. 24hrs | | |
| Total weekly volume of sewage discharges into a watercourse | **M,H**<br>**H** (WW) | **-** (DMD,SRH,DES) | **L-M** | " | 4<br>(*AWRIS*,NWA)<br>7n | | | 1. Weekly | All sewage discharge points | |
| Total weekly volume of stormwater discharges into a watercourse | **M,H**<br>**H** (WW) | **H** (SRH)<br>**-** (DMD,DES) | **M-H** | " | 4<br>(*AWRIS*.NWA)<br>7o | | | 1. Weekly | All measured stormwater discharge points (unsure of detail) | |
| *SWIM* has data on – volume of residential and non-trade, trade waste sewage collected | | | | " | | 4 | | 1. Annual | Sewerage scheme | |
| *SWIM* – data on % sewage treated to primary, secondary, tertiary | | | | " | | | | | | |
| **9. RECYCLED WATER USE** | | | | | | | | | | |
| Residential recycled water supplied | **L,M**<br>**-** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | | *SWIM* data all annual | For *SWIM* - Water scheme, WSP or sewerage scheme | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | HydroPlanner SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | General Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Industrial/commercial recycled water supplied | **L,M**<br>**-** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | 4<br>(PHASE 1) | WH data resolution depends on collection of billing data – most quarterly | For *SWIM* - Water scheme, WSP or sewerage scheme | |
| Municipal irrigation water supplied | **L,H**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | | | For *SWIM* - Water scheme, WSP or sewerage scheme | |
| Agricultural recycled water supplied | **L**<br>**H** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | 4 | | | For *SWIM* - Water scheme, WSP or sewerage scheme | |
| On-site recycled water supplied | **L,M**<br>**H** (WW) | **-** (DMD,SRH,DES) | **M** | " | | 4 | | | For *SWIM* - Water scheme, WSP or sewerage scheme | |
| Environmental recycled water supplied | **H**<br>**H** (WW) | **-** (DMD,SRH,DES | **M** | " | | 4 | 4<br>(Possible) | WH data resolution uncertain | For *SWIM* - Water scheme, WSP or sewerage scheme | |
| **10. WATER ENTITLEMENT AND WATER TRADE INFORMATION** | | | | | | | | | | |
| Details of water entitlements | **L,H**<br>**-** (WW) | **M** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>6a, 10d | | | 1. Annually; as updated | | |
| Details of permanent water entitlement trades | **L,H**<br>**-** (WW) | **M** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>6b | | | 1. Annually | | |
| Details of temporary water allocation trades and leases | **L,H**<br>**-** (WW) | **M** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>6c | | | 1. Weekly | | |
| Announcements of water allocations made | **L,H**<br>**-** (WW) | **M** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>6d | | | 1. Weekly | | |
| Minor Storage permits | **L,H**<br>**-** (WW) | **M** (DMD)<br>**-** (SRH,DES) | **M** | " | 4<br>(*AWRIS*)<br>6e | | | 1. Annually | | |
| Permits to 'self-extract' water from a bore | **M,L**<br>**-** (WW) | **L** (DMD)<br>**-** (SRH,DES) | **L-M** | " | 4<br>(*AWRIS*)<br>6f | | | 1. Annually | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | HydroPlanner SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | General Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| Permits to 'self-extract' water from a watercourse | **M,L**<br>**-** (WW) | **L** (DMD)<br>**-** (SRH,DES) | **L-M** | " | 4 (*AWRIS*) 6f | | | 1. Annually | | |
| **Drought Response Restrictions** | | | | " | | | | | | |
| Special drought response restrictions | **L,M**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4 (PHASE 1) | | | |
| Description of restrictions | **L,M**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4 (PHASE 1) | | | |
| Total number of days water restrictions applied during the year | **L,M**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | | | 4 (PHASE 1) | | | Exact dates are required |
| Water use restriction announcements indicating level, commencement, date and termination date | **L,M**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | 4 (*AWRIS*) 8a | | | 1. All announcements, as made; as updated | | |
| Description of water restriction levels and where they apply | **L,M**<br>**M** (WW) | **H** (DMD)<br>**-** (SRH,DES) | **M** | " | 4 (*AWRIS*) 10c | | | 1. As updated | | |
| Description of all water management areas | **-** | **-** | **-** | " | 4 (*AWRIS*) 10e | 4 | | 1. As updated | | |
| Rating tables for watercourse discharge derivation | **-** | **-** | **-** | " | 4 (*AWRIS*) 10a | 4 | | 1. As updated | | |
| Rating table for major storages surface area and storage volume derivation | **-** | **-** | **-** | " | 4 (*AWRIS*) 10b | 4 | | 1. As updated | | |

| MEASURAND | MODELLING DATA NEEDS | | | | WATER ACCOUNTS AVAILABILITY | | | | | Other Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HydroPlanner** SEQ Prototype – Potential Relevance (H = high M= medium L = low "-" not relevant) | | **General** Integrated Urban Water Management (IUWM) Models | | Water Accounting Framework (Water Regulation Code[2]) | | | Measurement / Resolution (See accompanying table for more detail) | | |
| (NB: More details on measurement units and reporting are provided in Appendix C) | HydroPlanner SEQ prototype[1] (WW = wastewater) | Potential future HydroPlanner[1] DMD = demand-related SRH = storm & rainwater harvesting, DES = Desal, OTH = Other) | General IUWM Model Relevance | Notes –Preferred unit, spatial and temporal resolution | BOM (AWRIS) (NWA) | SWIM | WaterHub (WH) | Typical measurement frequency and period covered | Temporal and spatial resolution adequacy for IUWM models | |
| **11. ENVIRONMENTAL EXTERNALITIES** | | | | | | | | | | |
| *SWIM* has data on greenhouse gas emissions for water, sewage, other | | | | “ | | 4 | | 1. Annual | WSP-wide | Tonnes per 1000 properties |

[1] In order to better assess the potential data linkages between the HydroPlanner prototype and existing water accounts, the model foci components have been grouped into two categories: (1) the current HydroPlanner (HP) prototype system that extends on eWater CRC E2-related components with important urban aspects; and (2) potential future HP components. Some more detail of the functions and scope of these aspects is provided in Table 1. The relevance of water account data for the current HydroPlanner prototype is shown separately for wastewater (WW) when appropriate. The potential future HydroPlanner data relevance is also identified for demand-related (DMD), stormwater and rainwater harvesting (SRH), and desalination (DES) and other (OTH) functions where possible.

[2] The bottom labels (eg "4a", "4b") refer to the relevant proposed scope of the regulations for the provision of water information to the BOM under Section 126 of the *Water Act 2007*, Select Legislation Instrument 2008 No. 106. Attorney-General's Dept., Canberra.

## APPENDIX C – Available Water Accounting Data - Details of Measurement and Spatial and Temporal Resolution

| Measurand | 1. Unit<br>2. Water quality differentiation<br>3. Water state - raw, treated, recycled, manuf, discharge | 1. Measurement frequency<br>2. Period covered | 1. Measurement node – geog location/ sites<br>2. Measurement geographic coverage (if applicable) | 1. Reporting entity<br>2. Reporting frequency<br>3. Lag from Measurement to Reporting | Temporal Resolution | Spatial Resolution | Other comments |
|---|---|---|---|---|---|---|---|
| **CLIMATE DATA** | | | | | | | |
| Total rainfall | 1. mm<br>2. Quantity<br>3. Raw | 1. Daily<br>2. 24hrs | 1. Brisbane Aero<br>2. Point Source | 1. BOM website<br>2. Weekly<br>3. 1 Week | Daily | for each station, all observations and the time of each observation | |
| Average annual rainfall | 1. mm<br>2. Quantity<br>3. Raw | 1. Annually<br>2 Annually | 1. Brisbane Aero<br>2. Point Source | 1. BOM website<br>2. Annual | Annual | for each station, all observations and the time of each observation | |
| Accumulated precipitation depth | 1. mm | 1. Daily or as transmitted for flood warning and forecasting | 1. for each station, all observations and the time of each observation | 2. Daily | Daily | for each station, all observations and the time of each observation | |
| Average Maximum temperature | 1. degrees C | 1. Daily<br>2. 24hrs | 1. Brisbane Aero<br>2. Point Source | 1. BOM website<br>2. Weekly<br>3. 1 Week | Daily | for each station, all observations and the time of each observation | |
| Average Minimum temperature | 1. degrees C | 1. Daily<br>2. 24hrs | 1. Brisbane Aero<br>2. Point Source | 1. BOM website<br>2. Weekly<br>3. 1 Week | Daily | for each station, all observations and the time of each observation | |
| Evaporation data | 1. mm | 1. Daily<br>2. 24hrs | 1. evaporation observing stations (see BOM website) | 1. BOM Website<br>2. Monthly/ Annually<br>3. Monthly | Daily | evaporation observing stations (see BOM website) | |
| Total daily Class A pan evaporation | 1. mm/d | 1. Daily | 1. for each station, the total daily value | 2. Daily | Daily | for each station, the total daily value | |
| Instantaneous wind speed and direction and wind-run | 1. m/s, km | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |
| Instantaneous solar radiation flux | 1. W/m2 | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |
| Instantaneous net radiation flux | 1. W/m2 | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |
| Instantaneous dry-bulb air temperature | 1. degrees C | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |
| Instantaneous wet-bulb air temperature | 1. degrees C | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |

| Measurand | 1. Unit<br>2. Water quality differentiation<br>3. Water state - raw, treated, recycled, manuf, discharge | 1. Measurement frequency<br>2. Period covered | 1. Measurement node – geog location/ sites<br>2. Measurement geographic coverage (if applicable) | 1. Reporting entity<br>2. Reporting frequency<br>3. Lag from Measurement to Reporting | Temporal Resolution | Spatial Resolution | Other comments |
|---|---|---|---|---|---|---|---|
| Instantaneous relative humidity | 1. % | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |
| Instantaneous vapour pressure deficit | 1. mbar | 1. Daily | 1. for each station, all observations and the time of each observations | 2. Daily | Daily | for each station, all observations and the time of each observations | |
| **WATER SUPPLY DATA** | | | | | | | |
| **STORAGE** | | | | | | | |
| Storage inflows (from the treatment plants to the water grid, not flows from the dams to the treatment plants) | 1. ML<br>2. Quantity<br>3. PRW, Treated | 1. Daily<br>2. 24 hrs | 1. Stream point gauge stations, located at treatment plants<br>2. Catchments for major measured storages | 1. SEQ Water, Local Councils<br>2. Daily | Daily | each major storage | |
| Volume of water released from major storage to water course | 1. ML/d | 1. Daily<br>2. 24 hrs | 1. each major storage | 2. Daily | Daily | each major storage | |
| Storage volume in major and minor storage (ML) | 1. ML<br>2. Quantity<br>3. Raw, PRW | 1. Daily<br>2. 24 hrs | | 1. SEQ Water, Local Councils<br>2. Daily | Daily | each storage | |
| Level of water held in major and storage (m) | 1. m | | 1. for each station, all observations and the time of each observation | 2. Daily | Daily | for each station, all observations and the time of each observation | |
| Volume of water transferred between major storages | 1. ML/d | 1. Daily<br>2. 24 hrs | 1. each major storage | 2. Daily | Daily | each major storage | |
| Record of instantaneous watercourse level (and provisional record) | 1. m | | 1. for each station, all observations and the time of each observation | 2. Daily | As required | for each station, all observations and the time of each observation | |
| Record of instantaneous watercourse discharge (and provisional record) | 1. cumecs | | 1. for each station, all observations and the time of each observation | 2. Daily | As required | for each station, all observations and the time of each observation | |
| Storage Closures – *note about period storages closed* | | | | | As required | | |
| Registers of major storages and of dams referred under dam safety regulations | | 1. Annual | 1. for each register all details relating to the location, dimensions, capacity, ownership and owners contact details for major storages and for referable dams | 2. Annually | As required | for each register all details relating to the location, dimensions, capacity, ownership and owners contact details for major storages and for referable dams | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOLUME SOURCED OR RECEIVED** | | | | | | | |
| Volume sourced from **desalination (bulk manufactured water authority)** | 1. ML<br>2. Quantity<br>3. Manuf | 1. Monthly (moving to weekly)<br>2. Monthly (moving to weekly) | 1. Gold Coast Desalination Facility | 1. Gold Coast Desal Facility<br>2. Monthly (moving to weekly) | Monthly (moving to weekly) | Gold Coast Desalination Facility | |
| Total weekly volume of water sourced from desalination | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value sourced | 2. Annually | Weekly (prefer daily res). | For each urban water utility, the total weekly value sourced | Prefer daily temporal resolution if significant variation throughout the week |
| Volume sourced from **recycling (bulk manufactured water authority)** | 1. ML<br>2. Quantity<br>3. Recycled | 1. Monthly (moving to weekly)<br>2. Monthly (moving to weekly) | 1. Bundamba Advanced Water Treatment Plant (AWTP), Western Corridor Recycled Water Project, Luggage Point Advanced Water Treatment Plant, Gibson Island AWTP | 1. Bundamba Advanced Water Treatment Plant, Western Corridor Recycled Water Project<br>2. Monthly<br>3. none | Monthly (moving to weekly) | Bundamba Advanced Water Treatment Plant (AWTP), Western Corridor Recycled Water Project, Luggage Point Advanced Water Treatment Plant, Gibson Island AWTP | |
| Total weekly volume of water sourced from recycling | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value sourced | 2. Annually | Weekly | For each urban water utility, the total weekly value sourced | |
| Total weekly volume of bulk recycled water purchased | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value purchased | 2. Annually | Weekly | For each urban water utility, the total weekly value purchased | |
| Total weekly volume of total water sourced (and provisional record) | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value sourced | 2. Annually | Weekly | For each urban water utility, the total weekly value purchased | |
| Volume received from **bulk supplier (Seqwater)** | 1. ML<br>2. Quantity<br>3. WTP | 1.Daily<br>2. 24hrs | 1. Outflow from the WTP | 1.Seqwater reports on data from Luggage Point Advanced Water Treatment Plant, Gibson Island WTP (need to confirm which plants they receive data from)<br>2. Weekly<br>3. Weekly | Daily | Outflow from WTPs | |
| Total weekly volume of water received by bulk supplier | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value received | 1. Each water utility<br>2. Annually | Weekly | For each urban water utility, the total weekly value received | |
| Total weekly volume of water sourced from surface water | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value received | 1. For each urban water utility provider, the total weekly value (Monday to Sunday inclusive)<br>2.Annually | Weekly | For each urban water utility, the total weekly value received | |
| Volume sourced from **dams** | | | | 1. DERM | | | |
| Volume sourced from **rivers** | | | | 1. DERM | | | |
| Volume sourced from **groundwater** | | | | 1. DERM | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total weekly volume of water sourced from groundwater | 1. ML/week | 1. Weekly | | 1. For each urban water utility, the total weekly value sourced 2.Annually | Weekly | WSP-wide | Especially important if groundwater levels are significant in the catchment |
| Volume of water diverted from watercourse to a managed irrigation scheme via a bulk diversion point | 1. ML/d | 1. Daily | 1 For each bulk diversion point | 2. Daily | Daily | For each bulk diversion point | |
| Total volume of water returned from a managed irrigation scheme via a channel or a pipe to a watercourse | 1. ML/d | 1. Daily | 1. For each channel or pipe the total daily value returned | 2. Annually | Daily | For each channel or pipe the total daily value returned | |
| Total volume of water returned from a managed irrigation scheme via a channel or a pipe to a storage | 1. ML/d | 1. Daily | 1. For each channel or pipe the total daily value returned | 2. Annually | Daily | For each channel or pipe the total daily value returned | |
| Total daily volume of water supplied to all irrigators in a managed irrigation scheme | 1. ML/d | 1. Daily | 1. For each scheme, the combined total daily value supplied | 2. Annually | Daily | For each scheme, the combined total daily value supplied | |
| Total monthly volume of water supplied to individual irrigators in a managed irrigation scheme | 1. ML/d | 1. Daily<br>2. Month | 1. For each irrigator the total monthly value supplied | 2. Annually | Monthly | For each irrigator the total monthly value supplied | |
| Total monthly volume of water supplied to individual self extractors | 1. ML/month | 1. Monthly<br>2. Month | 1. For each self-extractor, the total monthly value supplied | 2. Annually | Monthly | Each irrigator/self extractor? | |
| Total monthly volume of water pumped from a watercourse by 'self-extractors' | 1. ML/month | 1. Monthly<br>2. Month | 1. For each self-extractor, the total monthly value extracted | 2. Annually | Monthly | Each irrigator/self extractor? | |
| Total monthly volume of water extracted from bore by 'self-extractors' | 1. ML/month | 1. Monthly<br>2. Month | 1. For each self-extractor, the total monthly value extracted | 2. Annually | Monthly | Each irrigator/self extractor? | |
| Total monthly volume of water returned by 'self-extractor' to a watercourse | 1. ML/month | 1. Monthly<br>2. Month | 1. For each self-extractor, the total monthly value returned | 2. Annually | Monthly | Each irrigator/self extractor? | |
| Provisional record of total weekly volume of total sourced water | 1. ML/week | 1. Weekly<br>2. Week | 1. For each urban water utility, the total weekly value sourced | 2. Weekly | Weekly | WSP-wide? | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **TOTAL WATER SUPPLIED AND EXPORTED** | | | | | | | |
| Total weekly volume of residential water supplied | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value supplied | 2. Annually | Weekly (prefer daily res) | For each urban water utility, the total weekly value supplied | Daily res better for estimating demand-climate relationship |
| Total weekly volume of commercial, municipal and industrial water supplied | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value supplied | 2. Annually | Weekly (prefer daily res) | For each urban water utility | |
| Total weekly volume of other water supplied | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value supplied | 2. Annually | Weekly (prefer daily res) | For each urban water utility | |
| Total weekly volume of urban water supplied (and provisional record) | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value supplied | 2. Annually | Weekly (prefer daily res) | For each urban water utility, the total weekly value supplied | |
| Total weekly volume of bulk water exports | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value exported | 2. Annually | Weekly | For each urban water utility, the total weekly value exported | |
| Total weekly volume of bulk recycled water exports | 1. ML/week | 1. Weekly | 1. For each urban water utility, the total weekly value exported | 2. Annually | Weekly | For each urban water utility, the total weekly value exported | |
| **WATER PRODUCTION DATA** | | | | | | | |
| Water Treatment Plant (WTP) bulk readings | 1. ML<br>2. Quantity<br>3. WTP | 1. Daily<br>2. 24 hours | 1. All WTP outflows | 1. Seqwater, Link Water, Logan Council, Ipswich Council (plus others – not sure)<br>2. weekly<br>3. end of week | Daily | All WTP outflows | |
| **GROUNDWATER RESOURCE INFORMATION** | | | | | | | |
| Groundwater level | 1. m | 1. the mean daily value or periodically measured value, depending on availability | 1. for each bore | 2. Monthly | Daily or periodically | for each bore | Especially significant if groundwater levels are significant in the catchment |
| Groundwater pressure | 1. kPa | 1. the mean daily value or periodically measured value, depending on availability, and the aquifer layer and depth at which the pressure is measured | 1. for each bore | 2. Monthly | Daily or periodically | for each bore | Especially significant if groundwater levels are significant in the catchment |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **WATER QUALITY INFORMATION** | | | | | | | |
| Instantaneous electrical conductivity of streamflow | 1. microsiemens/cm @25degrees C | 1. Daily (time interval of data to be limited to five minutes or greater) | 1. For each watercourse, all values, indicating time of sampling | 2. Daily | Daily (time interval of data to be limited to five minutes or greater) | For each watercourse, all values, indicating time of sampling | Assuming that the software measures water quality |
| Instantaneous electrical conductivity of groundwater | 1. microsiemens/cm | 1. Unclear; as measurements taken | 1. For each bore, all values, indicating time of sampling | 2. Annually | Sampling frequency | For each bore, all values, indicating time of sampling | |
| Instantaneous temperature of streamflow | 1. degrees C | 1. Unclear; as measurements taken | 1. For each watercourse, all values, indicating time of sampling | 2. Annually | | For each watercourse, all values, indicating time of sampling | |
| Instantaneous total suspended solids concentration in streamflow | 1. mg/L | 1. Unclear; as measurements taken | 1. For each watercourse, all values, indicating time of sampling | 2. Annually | | For each watercourse, all values, indicating time of sampling | Assuming that the software measures water quality |
| Instantaneous turbidity of streamflow | 1. NTU | 1. Unclear; as measurements taken | 1. For each watercourse, all values, indicating time of sampling | 2. Annually | | For each watercourse, all values, indicating time of sampling | Assuming that the software measures water quality |
| Instantaneous total phosphoros concentration of streamflow | 1. mg/L | 1. Unclear; as measurements taken | 1. For each watercourse, all values, indicating time of sampling | 2. Annually | | For each watercourse, all values, indicating time of sampling | Assuming that the software measures water quality |
| Instantaneous total nitrogen concentration of streamflow | 1. mg/L | 1. Unclear; as measurements taken | 1. For each watercourse, all values, indicating time of sampling | 2. Annually | | For each watercourse, all values, indicating time of sampling | Assuming that the software measures water quality |
| Instantaneous pH of streamflow | | 1. Unclear; as measurements taken | | | | For each watercourse, all values, indicating time of sampling | |
| Water quality performance | | | | | | | |
| Compliance reporting and water quality monitoring **(will eventually be built into the system)** | | | | | | | |
| *SWIM* – data on % samples compliant BOD, SS, N, P, E coli | | 1. Annual | | | | | |
| **WATER DISTRIBUTION DATA** | | | | | | | |
| **Water Grid / market compliance / water quality compliance** | | | | | | | |
| Bulk flow measures within the Grid System **(VPM Volumetric Point Measurement tool)** | 1. ML<br>2. Quantity<br>3. WTP, Recycled, Manuf | 1. daily<br>2. 24 hours | 1. Bulk supply meters located within the SEQ water grid | 1. Seqwater, Link Water, Logan Council, Ipswich Council (plus others ?)<br>2. weekly<br>3. end of week | Daily | At bulk supply meters | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **USE OF WATER / DEMAND CONSUMPTION** | | | | | | | |
| Power Station Water Consumption | | | | | Daily? | Each power station | |
| Residential water consumption | 1. ML & L/person/day<br>2.Quantity (quality to be built in)<br>3. Metered and non-metered, potable and non-potable | 1. depends on collection of billing data (mostly quarterly) | 1. Household /account basis<br>2. whole SEQ | 1. Councils<br>2. Depending on councils billing data (mostly quarterly) | Typically quarterly | Individual lot | |
| Commercial and industrial water consumption | 1. ML<br>2. Quantity (quality to be built in)<br>3. Metered and non-metered, potable and non-potable | 1. depends on collection of billing data | 1. Accounts are aggregated into sub-sectors i.e. Manufacturing, refineries, sports etc (approx 15)<br>2. whole SEQ | 1. Councils<br>2. Depending on councils billing data (mostly quarterly) | Typically quarterly | Individual lot | |
| Demand Forecasting Tools | | | | | Daily? | | |
| **DEMAND UNITS** | | | | | | | |
| ***Connected Properties and Population*** | | | | | | | |
| Population receiving water supply services | 1. thousands | 1. Annual | 1. Water Meter + Household Account<br>2. Council region | 1. PIFU (Population Forecasting Unit) PIFU updates the serviced population | Annual | WSP-wide | |
| Connected residential properties - water supply | 1. thousands | 1. Annual | | | Annual | WSP-wide | |
| Connected non-residential properties - water supply | 1. thousands | 1. Annual | | | Annual | WSP-wide | |
| Population receiving sewerage services | | 1. Annual | | | Annual | WSP-wide | |
| Connected residential properties – sewerage | | 1. Annual | | | Annual | WSP-wide | |
| Connected non-residential properties – sewerage | | 1. Annual | | | Annual | WSP-wide | |
| **SYSTEM LOSS** | | | | | | | |
| Total Leakage | 1. m3/km | 1. Daily<br>2. 24hrs | | | Daily | ? | |
| Losses | 1. L/km | 1. Daily<br>2. 24hrs | | | Daily | ? | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **WATER DISCHARGES, OUTFLOWS – from SEQ boundary** | | | | | | | |
| Environmental flows | | | | | | | |
| Volume of bulk water exports | | 1. Monthly (moving to weekly)<br>2. Monthly (moving to weekly) | | | Weekly | For each urban water utility, the total weekly value exported | |
| **EFFLUENT DATA** | | | | | | | |
| Wastewater inflows at WWTP (sewerage treatment plants) | 1. ML<br>2. Quantity<br>3. Effluent | 1. Daily<br>2. 24hrs | 1. WWTP – Bundamba, Goodna, Oxley, Wacol, Luggage Point, Gibson Island | 1. Council<br>2. Weekly<br>3. Weekly | Daily | WWTP – Bundamba, Goodna, Oxley, Wacol, Luggage Point, Gibson Island | |
| WWTP (sewerage treatment plants) outflows | 1. ML<br>2. Quantity<br>3. Treated Discharge | 1. Daily<br>2. 24hrs | 1. WWTP – Bundamba, Goodna, Oxley, Wacol, Luggage Point, Gibson Island | 1. Council<br>2. Weekly<br>3. Weekly | Daily | WWTP – Bundamba, Goodna, Oxley, Wacol, Luggage Point, Gibson Island | |
| Total weekly volume of sewage discharges into a watercourse | 1. ML/week | 1. Weekly | 1. For each sewage discharge point, total weekly value discharged | 2. Annually | Weekly | For each sewage discharge point, total weekly value discharged | |
| Total weekly volume of stormwater discharges into a watercourse | 1. ML/week | 1. Weekly | 1. For each stormwater discharge point, total weekly value discharged | 2. Annually | Weekly | For each stormwater discharge point, total weekly value discharged | |
| *SWIM* has data on – volume of residential and non-trade, trade waste sewage collected | | 1. Annual | | | | | |
| *SWIM* – data on % sewage treated to primary, secondary, tertiary | | | | | | | |
| **RECYCLED WATER USE** | | | | | | | |
| Residential recycled water supplied | | WH data resolution uncertain<br>*SWIM* data all annual | | | | | |
| Industrial/commercial recycled water supplied | | WH data resolution uncertain | | | | | |
| Municipal irrigation water supplied | | WH data resolution uncertain | | | | | |
| Agricultural recycled water supplied | | WH data resolution uncertain | | | | | |
| On-site recycled water supplied | | WH data resolution uncertain | | | | | |
| Environmental recycled water supplied | | WH data resolution uncertain | | | | | |

| **WATER ENTITLEMENT AND WATER TRADE INFORMATION** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Details of water entitlements | | 1. Annually; as updated | 1. For each entitlement issued, the type, volume of water, and the water management area in which the entitlement resides | 2. Annually | | | |
| Details of permanent water entitlement trades | | 1. Annually | 1. For each trade, the type of entitlement traded, the transaction commencement and finalisation dates, the volume of water traded or entitlement share traded, the gross and net share sale price and the water mgmt areas from and to which water has moved. | 2. Annually | | | |
| Details of temporary water allocation trades and leases | | 1. Weekly | 1. For each trade, the type of entitlement traded, the transaction commencement and finalisation dates, the volume of water traded or entitlement share traded, the gross and net share sale price and the water management areas from and to which water has moved. | 2. Weekly | | | |
| Announcements of water allocations made | | 1. Weekly | 1. All formal announcements of water allocations made to entitlement holders and all formal announcements of reductions to allocations already made. The water mgmt area to which allocation announcement applies and the type of entitlement affected | 2. Weekly | | | |
| Minor Storage permits | | 1. Annually | 1. For each minor storage permit, the location of the storage and the maximum storage | 2. Annually | | For each minor storage permit, the location of the storage and the maximum storage | |
| Permits to 'self-extract' water from a bore | | 1. Annually | 1. For each permit the location and depth of the bore, the maximum permissible extraction volume and any other conditions of use | 2. Annually | | For each permit the location and depth of the bore, the maximum permissible extraction volume and any other conditions of use | |
| Permits to 'self-extract' water from a watercourse | | 1. Annually | 1. For each permit the location of the extraction point, the maximum permissible extraction volume and any other conditions of use | 2. Annually | | For each permit the location of the extraction point, the maximum permissible extraction volume and any other conditions of use | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **DROUGHT RESPONSE RESTRICTIONS** | | | | | | | |
| Special drought response restrictions | | | | | | | |
| Description of restrictions | | | | | | | |
| Total number of days water restrictions applied during the year | | | | | | | Exact dates are required |
| Water use restriction announcements indicating level, commencement, date and termination date | | 1. All announcements, as made; as updated | | 2. As announcements are made | | | |
| Description of water restriction levels and where they apply | | 1. As updated | 1. For each region in which a particular suite of restrictions applies, definitions for each restrictions level, the water savings target and the geographic area in which the restriction conditions apply, indicated by a polygonal boundary file | 2. As updated | | | |
| Description of all water management areas | | 1. As updated | 1. For each water management area, the name and a polygonal boundary file indicating the geographic extent of the water management area. | 2. As updated | | | |
| Rating tables for watercourse discharge derivation | | 1. As updated | 1. For each watercourse station, the complete historic sequence of rating tables, indicating the time span across which the rating should apply | 2. As updated | | | |
| Rating table for major storages surface area and storage volume derivation | | 1. As updated | 1. For each major storage the complete historic sequence of rating tables relating major storage water level to reservoir surface area and storage volume, indicating the dead storage level and volume, and indicating the time span across which the rating should apply | 2. As updated | | | |
| **ENVIRONMENTAL EXTERNALITIES** | | | | | | | |
| *SWIM* has data on greenhouse gas emissions for water, sewage, other | | 1. Annual | | | | | |

# REFERENCES


Ashbolt, S., Maheepala, S., Mirza, F., Neumann, L., Kinsman, D. and Coultas, E. (2010). "HydroPlanner: Towards a regional integrated urban water modelling tool", Proceedings of Ozwater '10, 8-10 March 2010, Brisbane.

Askins, M. (2009). Interview. [Personal interview with Mark Askins, Manager, Regional Water Information Management Unit. Qld Water Commission. Brisbane, 7 January 2009].

Beven, K. (2007). Towards integrated environmental models of everywhere: uncertainty, data and modeling as a learning process. Hydrological Earth Systems Science 11(1): 460 – 467.

Bureau of Meteorology (2009a). Water Information Information Sheet 2: The Water Act 2007 and Water Regulations 2008. Accessed March 12, 2010. http://www.bom.gov.au/water/publications/Sheet2_Act_and_Regs_Mar09.pdf

Bureau of Meteorology (2009b). Water Information Sheet 3: The Australian Water Resources Information System. [Fact Sheet] Accessed March 2, 2010. http://www.bom.gov.au/water/publications/Sheet3_AWRIS_Mar09.pdf

Bureau of Meteorology (2009c). Water Information Sheet 4: Water Information Research and Development. Accessed March 2, 2010. http://www.bom.gov.au/water/publications/Sheet4_WIRADA_Mar09.pdf

Bureau of Meteorology (2009d). "Water Information Research and Development Alliance Annual Report 2008-09." Australia Government. Canberra.

Bureau of Meteorology (2009e). "Water Information Sheet 7: The National Water Account." [Fact Sheet] Accessed Oct 19, 2009. www.bom.gov.au/water/nwa/document/InfoSheet_7.pdf

Bureau of Meteorology (2010). The First National Water Account. On-line resource. Accessed September 20, 2010. http://www.bom.gov.au/water/nwa/nwa2010.shtml

Buytaert, W., Reusset, D. *et al.*, (2008). Why can't we do better than Topmodel? Hydrological Processes (22): 4175-4179.

Coombes, P. and Kuczera, G. (n.d.). Integrated Urban Water Cycle Management: moving towards systems understanding. University of Newcastle: Unpublished Paper.

Daniels, P. (2010). An Integrated Framework for Sustainable Water Management: The Material Flow Analysis of Water in SEQ. Griffith School of Environment. Griffith University. Brisbane. Unpublished report.

eWater CRC (2006a). Water and Constituent simulation product (WaterCAST). [Fact Sheet]. Accessed April 28, 2009. http://www.ewatercrc.com.au/downloads/technologies/P5.pdf

eWater CRC (2006b). RiverManager Product. [Fact Sheet]. http://www.ewatercrc.com.au/downloads/technologies/P2.pdf

Fletcher, T. (2008). Data Requirements for Integrated Urban Water Management. France: UNESCO.

Geerders, P. (2003). "Information – Integration – Inspiration: Aspects of integrated Management of Environmental Data." In Harmancioglu, N. et al (eds) Integrated Technologies for Environmental Monitoring and Information Production. New York: Springer.

Grant, A. (2008). Interview [Personal interview with Andrew Grant, CSIRO Land and Water. Melbourne, 5th of September 2008].

Harmancioglu, N.B. (2003). "Integrated Data Management: Where are we headed?" In Harmancioglu, N. et al (eds.) Integrated Technologies for Environmental Monitoring and Information Production. New York: Springer.

Kirchner, J. W. (2006). Getting the right answers for the right reasons: Linking measurements, analyses, and models to advance the science of hydrology. Water Resources Research (42): 1-5.

Loetscher, H. W. *et al.*, (2007). Enhancing water cycle measurements for future hydrologic research. America Meteorological Society 88(5): 669 – 676.

Maheepala, S. and Blackmore, J. (2008a). Integrated Urban Water Management. In Newton, P. W. (ed.) Transitions: Pathways Towards Sustainable Urban Development in Australia. Victoria: Springer.

Maheepala, S. (2008b). "SEQ Integrated Urban Water Management (IUWM) Modelling Tool: Preliminary Description and Modelling Approach." A report delivered under the Urban Water Security Research Alliance. Australia: CSIRO.

Maheepala, S., Mirza, F., Ashbolt, S., Neumann, L., McMahon, J., Kinsman, D., Coultas, E., Rahilly, M. and Lane, B. (2009). "HydroPlanner: A prototype modeling tool to aid development of integrated urban water management plans." A report delivered under the Urban Water Security Research Alliance. Australia: CSIRO. 15 October 2009.

Makropoulos, C. K., Natsis, K., Liu, S., Mittas, K. and Butler, D. (2008). Decision support for sustainable option selection in integrated urban water management. Environmental Modelling and Software 23(12), 1448-1460.

Marsalek, J. *et al.*, (2007). Urban Water Cycle Processes and Interactions. France: UNESCO.

Maurer, T.E. (2003). Intergovernmental arrangement and problems of data sharing. Proceedings of MTM-IV – Intergovernmental arrangements and data sharing. pp. 51-60.

McBean, K., Daniels, P. and Braddock, R. (2010). *Water Accounting Report 1: South East Queensland Water Accounts and Data for Integrated Urban Water Management Models – Introduction and Methodology*. Urban Water Security Research Alliance Technical Report No 36.

Mitchell, V. *et al.* (n.d.). “Integrated Urban Water Modelling – Past, Present and Future.” Australia: Unpublished Paper.

Mitchell, V. *et al.* (2007). “State of the art review of integrated urban water models.” Australia: Unpublished Paper.

NWC (National Water Commission) (2010). National Performance Framework 2009 - 10 Urban Water Performance Report Indicators and Definitions Handbook. Water Services Association of Australia, National Water Commission and the NWI Parties. May 2010.

QWC (Queensland Water Commission) (2008a). “South East Queensland Water Accounting Framework (SEQWAF).” Qld Water Commission. Brisbane. Australia.

QWC (Queensland Water Commission) (2008b). Queensland Water Commission Information Management and the South East Queensland Water Accounting Framework (SEQWAF). PowerPoint Presentation.

QWC (Queensland Water Commission) (2008c). The South East Queensland Water Accounting Framework proposed to be re-named as QWC’s WaterHub. A Power Point Presentation.

QWC (Queensland Water Commission) (2008d). WaterHub – Demand Forecasting Module. Project Scope and Requirements. Qld Water Commission. Brisbane. Australia.

QWC (Queensland Water Commission) (2009a). South East Queensland Water Strategy. Revised Draft. Nov 2009. Brisbane, Qld Government.

QWC (Queensland Water Commission) (2009b). WaterHub – Consumption Information Module - Business Requirement Statement. Queensland Water Commission.

QWC (Queensland Water Commission) (2009c). WaterHub - Technology Project Reporting Facilitation Module (RFM) Business Requirements. V1.6. 14 December, 2009.

Rahman, J. (2008). Interview [Personal interview with Joel Rahman, CSIRO Land and Water, Brisbane, 19th of September 2008].

SEQ (South East Queensland) Healthy Waterways Partnership (2009). The Water Cycle Fact Sheet. Accessed June 10, 2009. http://www.healthywaterways.org/FileLibrary/water_cycle.pdf

Silberstein, R.P. (2006). Hydrological models are so good, do we still need data? Environmental Modelling and Software (21): 1340-1352.

Soulsby, C., Neal, C. *et al.* (2008). Catchment data for process conceptualisation: simply not enough? Hydrological Processes (22): 2057 – 2061.

UNDESA (United Nations Department of Economic and Social Affairs) (1993). “Agenda 21: Earth Summit - The United Nations Programme of Action 1993.” (c.18 and 40) United Nations Department of Economic and Social Affairs: Division for Sustainable Development.

Urban Water Security Research Alliance (2008). “Annual Report 2007-2008” Accessed Sept 2, 2009. http://www.urbanwateralliance.org.au/publications/UWSRA-Annual-Report2007-08.pdf Brisbane, Australia.

Welsh W.D. and Podger G.M. (2008). “Australian Hydrological Modelling Initiative: River System Management Tool (AHMI: RSMT) functionality specifications.” eWater Technical Report. Canberra: eWater Cooperative Research Centre. http://ewatercrc.com.au/reports/Welsh_Podger-2008-RSMT_functionality.pdf

Urban Water Security Research Alliance