WATER INFORMATION R&D ALLIANCE CASE STUDY 1

BOX 1 EXECUTIVE SUMMARY

Key findings

The Water Information Research and Development Alliance (WIRADA) has produced the following:

- Greatly improved forecasts of stream flows and more reliable data on Australia's water resources provided through two new national water forecasting services
- New water data standards that have radically improved the sharing of data nationally and internationally
- Users report economic benefits from WIRADA-enabled services provided by the BoM

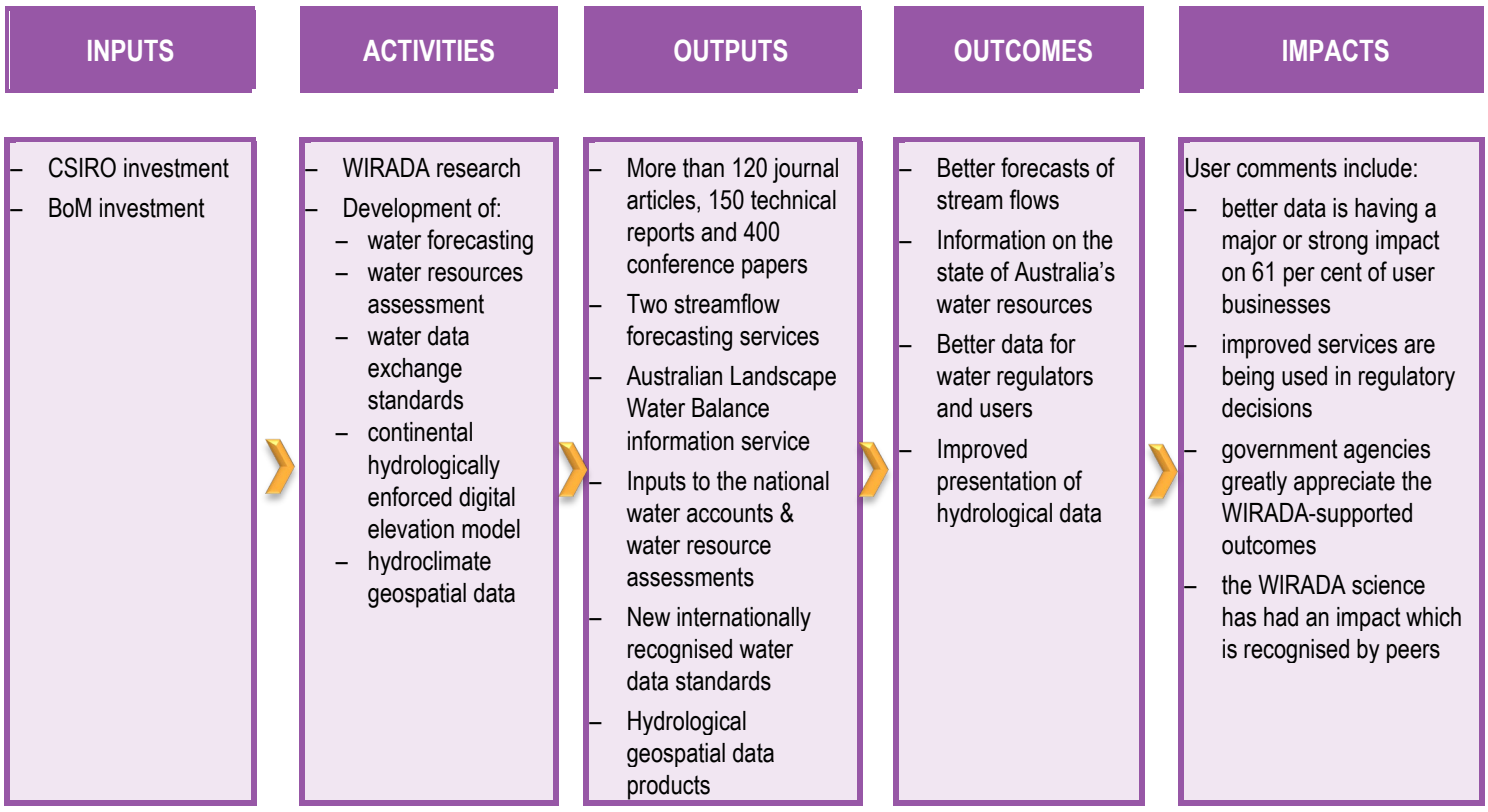
Innovation impact

The following elements of WIRADA were new or innovative:

- more reliable estimates of future rainfall from weather and climate models
- New statistical methods and forecasting systems

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the WIRADA case study are summarised in **Figure 1.1**.

FIGURE 1.1 WIRADA CASE STUDY – IMPACT FRAMEWORK DIAGRAM



SOURCE: ACIL ALLEN

1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from the Water Information Research and Development Alliance (WIRADA).

This evaluation is being undertaken to assess the positive impacts arising from WIRADA undertaken by CSIRO. However, it can also be used to inform a range of other stakeholders. The case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of the Land & Water (L&W) Business Unit's activities as a whole, relative to the funds invested in these activities.

This information in this case study is provided for accountability, communication and continual improvement purposes. This case study is primarily intended to be an input into the independent review of the L&W Business Unit however other audiences for this report may include Members of Parliament, Government Departments, CSIRO and the general public.

1.2 Background

The sustainable and productive management of Australia's water resources has to meet competing water demands from the agricultural, environmental and urban sectors, impacts of over-allocation and resource extraction, uncertainty in water resource availability, and the effects of hydroclimate variability and climate change. The Australian Government recognised these challenges and legislated additional responsibilities for the BoM under the *Water Act (2007)*. The WIRADA partnership between CSIRO and the BoM was established in 2008 in response to this new mandate. It brings together CSIRO's leading expertise in water and information sciences and the BoM's operational role in hydrological analysis and prediction to deliver value-added water information products and tools to Australians, governments and industry.

1.3 Impact Pathway

1.3.1 Project Inputs

The total cost for WIRADA was about $68 million in cash and in-kind contributions (see **Table 1.1**). Since 2008-09 CSIRO has co-invested $27.2 million as in-kind support for the project (around 40 per cent of the total cost). WIRADA activity is on-going in 2017-18.

WIRADA has involved more than 170 CSIRO researchers and 40 BoM staff.

TABLE 1.1 SUPPORT FOR WIRADA

Contributor / type of support	2008-09 ($ m)	2009-10 ($ m)	2010-11 ($ m)	2011-12 ($ m)	2012-13 ($ m)	2013-14 ($ m)	2014-15 ($ m)	2015-16 ($ m)	2016-17 ($ m)
Cash									
BoM	4.8	5.4	6.78	6.78	5.88	3	3	3	2.16
In-kind									
CSIRO	3.2	3.6	4.52	4.52	3.92	2	2	2	1.44
Total	**8.0**	**9.0**	**11.30**	**11.30**	**9.80**	**5.0**	**5.0**	**5.0**	**3.60**

SOURCE: CSIRO

1.3.2 Project activities

Water forecasting

WIRADA has addressed the significant challenges of forecasting streamflow for the wide-ranging climates, hydrologic regimes and catchment conditions across Australia (from zero flows to major flooding). The research undertaken by CSIRO underpins two new national water forecasting services operated by the BoM—seasonal streamflow forecasting, and seven-day streamflow forecasting services.

These forecasting services have been designed to integrate weather and hydrological observations, weather and climate modelling, catchment and river flow modelling and new statistical methods. WIRADA researchers developed a world-first Bayesian hierarchical model. Statistical methods were developed to significantly reduce errors in precipitation forecasts from weather and climate models.

Precipitation observations and forecasts were incorporated into numerical models that simulate catchment and river flow processes to provide downstream river flow forecasts.

Water resources assessment

WIRADA researchers built an integrated approach to analyse daily streamflow from more than 700 catchments and other data to produce a continental-scale system that simulates water fluxes and stores on a daily time scale, at a current spatial resolution of five kilometres. Water balances have been calibrated and verified across the diversity of Australia's climate and hydrological systems and landscapes. This has involved combining the best of three data and modelling sources—*in-situ* climate and streamflow measurements, satellite observations and state-of-the-art hydrological modelling.

Water data standards

WIRADA brought together experts in information science and hydrology to develop data exchange standards that have catalysed significant change in both the Australian and the international hydrological data exchange capability and adopted by the water data management software industry.

Hydrological geospatial data products

WIRADA researchers have helped develop a suite of new geospatial data products, called the Australian Hydrological Geospatial Fabric (or Geofabric) to represent the features of Australian hydrological system (streams and waterbodies) in different ways, in order to support a range of hydrological applications including mapping, river modelling, network analysis, reporting and management. The Geofabric products are underpinned by a common conceptual model and sophisticated identity framework that allows for the efficient integration of information. A high-resolution, hydrologically-enforced digital elevation model was created through the development of sophisticated processing of satellite data captured by NASA, with automated methods to remove features that incorrectly represent the flow path of water across and through Australia's largely low relief landscapes and river systems.

1.3.3 Project outputs

This strategic collaboration has delivered nationally-consistent and regionally-relevant water information products and services to support sound decision-making at a national, state and local level. In commenting on the delivery of the project, the former CEO of the BoM has stated:

The (WIRADA) Project has been very well planned and executed. It has involved extensive end user consultation, ensuring that the research focus and the design of the final product addressed the problems of the end user. This project is a breakthrough for Australia and internationally.

Water forecasting

Advanced methods have been developed for quantifying uncertainty of streamflow forecasts, to provide users with information to assess and manage operational risk. A suite of statistical methods verifies and communicates probabilistic forecasts, providing users with information on forecast accuracy.

Water resources assessment

The interactive Australian Landscape Water Balance models[1] provide information updated daily on water fluxes and stores at the continental, catchment and grid cell scale. These outputs are used directly by the BoM to deliver National Water Accounts, the Australian Water Resources Assessment (AWRA) and annual Water in Australia reports. The BoM products provide daily updates of basin, regional and national water perspectives, and help water managers and policy makers understand the present state of water resources across the continent and its variation over the last century, significantly enhancing water intelligence and situational awareness.

Water data standards

WIRADA has developed data exchange standards including:

— WaterML2.0 - Part 1 (Timeseries), an exchange standard that allow users to share and/or discover hydrometeorological observations and measurements;

[1] See http://www.bom.gov.au/water/landscape/

- WaterML2.0 - Part2 (Ratings, Gaugings and Sections), an information model to exchange river gauging observations, river cross sections and rating tables that relate river height to river flow volume;
- TimeseriesML1.0, a time series data exchange for applications beyond hydrometeorology;
- GWML2.0, a standard to exchange data on groundwater features (e.g. aquifers, boreholes, wells) and observations; and
- HY Features, a conceptual model for hydrological features like rivers, catchments, networks and basins.

Publications

In the period 2008-17 WIRADA research resulted in more than 131 journal articles, 417 conference papers, 155 published reports and more than 100 other documents.[2] A little under half of these publications have been produced since 2013. Of the journal articles, some of the most significant are:

1. Robertson D, Shrestha D and Wang Q 2013, Post-processing rainfall forecasts from numerical weather prediction models for short-term streamflow forecasting, Hydrology and Earth System Sciences 17(9): 3587. [42 citations]
2. Bennett JC, Robertson DE, Shrestha DL, Wang Q, Enever D, Hapuarachchi P and Tuteja NK 2014, A System for Continuous Hydrological Ensemble Forecasting (SCHEF) to lead times of 9 days, Journal of Hydrology 519: 2832-2846. [25 citations]
3. Schepen, A, Wang Q and Robertson DE 2014, Seasonal forecasts of Australian rainfall through calibration and bridging of coupled GCM outputs, Monthly Weather Review 142(5): 1758-1770. [21 citations]
4. Renzullo L, van Dijk A, Perraud J-M, Collins D, Henderson B, Jin W, et al. (2014). Continental satellite soil moisture data assimilation improves root-zone moisture analysis for water resources assessment. Journal of Hydrology. 2014: 519:2747-62.
5. Dutta D, Teng J, Vaze J, Lerat J, Hughes J, Marvanek S, 2013. Storage-based Approaches to Build Floodplain Inundation Modelling Capability in River System Models for Water Resources Planning and Accounting. Journal of Hydrology, 504 (2013) 12–28. DOI: http://dx.doi.org/10.1016/j.jhydrol.2013.09.033.
6. Vaze J, Viney N, Stenson M, Renzullo L, Van Dijk A, Dutta D, Crosbie R, Lerat J, Penton D, Vleeshouwer J, Peeters L, Teng J, Kim S, Hughes J, Dawes W, Zhang Y, Leighton B, Perraud JM, Joehnk K, Yang A, Wang B, Fros, A, Elmahdi A, Smith A, Daamen C 2013, The Australian Water Resource Assessment System (AWRA), Proceedings of the 20th International Congress on Modelling and Simulation (MODSIM2013), Adelaide, Australia, 1–6 December 2013.

Awards

- CSIRO Impact from Science Medal (2016)
- ACT Australian Water Association Award for Innovation in Water Research, for AWRA (2015)
- International Association of Hydrological Science Tison Medal for joint publication with overseas partners on hydrological modelling (2015)
- Engineers Australia Alexander Medal, for streamflow forecasting and for landscape/catchment hydrological modelling (2014)

Innovation / commercialisation

The WIRADA project has led to innovations in:

- the integration of weather and hydrological observations
- more reliable estimates of future rainfall from weather and climate models
- catchment and river flow modelling
- new statistical methods and forecasting systems
- closing the continental water balance, and
- new water data exchange standards.

1.3.4 Project Outcomes

In a comment on the project outcomes, the Director of IRSTEA[3] has stated:

[2] Bureau of Meteorology 2016, WIRADA Research bibliography 2008-2016, accessed on 24 April 2018 at http://www.bom.gov.au/water/about/waterResearch/document/WIRADA-research-bibliography-2008-2016.pdf

[3] Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture

In terms of scientific excellence, the (CSIRO and the BoM) achieved a unique system able to work seamlessly for the wide range of climate and catchment conditions present in Australia. The performance of the system is excellent, uncertainties are efficiently communicated. Advances have been made in the post-processing of precipitation forecasts from weather and climate models. The papers published by (CSIRO and the BoM) have raised considerable interest in our hydrological community in the last years. In recognition of this work, Dr QJ Wang is now the c-chair of a major international initiative in hydrology (HEPEX).

Water forecasting

WIRADA R&D has resulted in two new national water forecasting services: a seasonal streamflow forecast service[4] that provides probabilistic forecasts of water flowing into major dams and rivers for the next three months, and a seven-day streamflow forecast service[5] that issues forecast of likely hourly streamflow volumes for the next seven days. These services provide, for the first time, national forecasts, allowing for informed decisions based on the latest science.

The seasonal streamflow forecasts are being used to guide operations of multi-storage water supply schemes, informing water market, planning field work and surveys and deciding cropping strategies. The seven-day streamflow forecasts guide reservoir operations, on-farm management decisions, water releases to supply irrigation and environmental watering. Specific examples include the Murray-Darling Basin Authority (MDBA) using the seven-day streamflow forecast to inform river operations to meet irrigation demands and environmental needs in River Murray, and the Water Corporation of Western Australia using the seasonal streamflow forecast to optimise reservoir water release to reduce spills and achieve water supply and environmental objectives in far south-west Western Australia.

Water resources assessment

For the first time anywhere in the world, the AWRA system delivers internally consistent and comparable water metrics to users, including runoff and river flow, soil water storage, groundwater recharge and vegetation water use that are updated daily across Australia. The AWRA outputs are used directly by the BoM to deliver National Water Accounts, Water Resources Assessments and annual Water in Australia reports. These BoM products provide updates of basin, regional and national water perspectives, and help water managers and policy makers understand the present state of water resources across the continent and its variation over the last century.

Users of AWRA outputs include the Australian Bureau of Agricultural and Resource Economics and Sciences for crop production and economic commodity modelling, and NSW Department of Primary Industries for agricultural, water and climate applications. The AWRA model has been adapted and already used in several significant initiatives including the current impacts of coal seam gas and coal developments on water related assets across eastern Australia and the development potential in northern Australia.[6]

Water data standards

WIRADA research has led to a significant step forward in the sharing of hydrological information in Australia and globally through the development of internationally adopted water information standards. Standards developed in WIRADA have been adopted by organisations including the Open Geospatial Consortium, World Meteorological Organisation, Environment Canada and the United States Geological Survey. The data exchange standards developed by WIRADA have enabled different types of data and knowledge to be shared, reused and integrated into various water information products and services.

Hydrological geospatial data products

The Geofabric methodology has been adopted for the production of a range of geospatial information products, most notably the Foundation Spatial Data Framework suite covering ten key themes of national data.[7] The high resolution digital elevation model is being used for a range of applications across Australia and underpins billions of dollars of infrastructure investment, including siting of dams and locating transport and energy infrastructure.

1.3.5 Adoption

As noted above, WIRADA outputs have been adopted in Australia and overseas. Users include government agencies, researchers, industry (particularly agriculture and mining) and others.

- Water forecasting is particularly valued by water management authorities and the agricultural sector
- Water resources assessments are used by government planning agencies and water management authorities

[4] See http://www.bom.gov.au/water/ssf/
[5] See http://www.bom.gov.au/water/7daystreamflow/
[6] CSIRO 2018, Northern Australia Water Resource Assessment, accessed on 24 April 2018 at https://www.csiro.au/en/Research/Major-initiatives/Northern-Australia/Current-work/NAWRA
[7] See http://fsdf.org.au/ accessed on 24 April 2018.

— Water data standards and used by researchers and agencies responsible for water monitoring, but underpin the services provided to all users

— Hydrological geospatial data products are used by planners and engineers involved in infrastructure development.

International adoption of WIRADA outputs includes:

— The US National Oceanographic and Atmospheric Administration (NOAA)'s Climate Prediction Center routine use of the CSIRO-developed Calibration Bridging and Merging[8] approach to generate seasonal climate forecasts for North America. These forecasts are contribution to NOAA's official seasonal climate forecast, which is generated by experts integrating a range of different forecast products.

— A French R&D agency, IRSTEA, New Zealand's National Institute of Water and Atmospheric Research (NIWA) and the University of Manitoba, Canada, are investing in research to evaluate rainfall forecast post-processing methods developed through WIRADA with the view to apply these for operational short-term and seasonal streamflow forecasting.

The examples provided above demonstrate the breadth of the user community.

1.3.6 Impacts

The science and technological innovation and breakthroughs in WIRADA, and the translation of science into operational water products, has enabled the BoM to fulfil its national water information mandate, delivering direct impact to the Australian community and the water and related industries. WIRADA research in the water forecasting, water resources assessment and water informatics areas has significantly advanced the soil and water National Research Priority and helped to address practical challenges in water management.

Through WIRADA, Australia now has a set of nationally-consistent and regionally-relevant water information products and services based on high quality data, innovation through science, and timely delivery systems, to support robust decision making across national, state and local levels. The hydrological community now has a suite of open standards and tools that will be the backbone of global hydrological data exchange for years to come.

The science and technology from WIRADA has led to new opportunities, collaborations across different disciplines and impact beyond Australia. The hydrological models in AWRA are being used for numerous applications including the ongoing and nationally significant large resource and impact assessments (Bioregional Assessment and Northern Australia Water Resource Assessment). Spinoff applications from AWRA include floodplain inundation modelling in the Murray-Darling to support Basin Plan implementation, development of prototype digital and cloud hydrological modelling platforms and establishment of AWRA modelling system as a community model. The water forecasting models have been applied to river forecasting in northern Victorian catchments. Overseas, the water forecasting methods are being used to support sustainable development projects in South Asia, collaborations with China and Singapore, and experimental forecasting programmes in the USA.

Australia is now recognised as an international leader in the development of water information exchange standards and systems. These international standards and engagement in the standards development process support Australian requirements, maximise capture and use of the large array of different hydroclimate, hydrological and related data, and presentation of curated, analysed, modelled, integrated and interpreted data and water information by the BoM and other agencies. The value of these standards to Australia is demonstrated by their use in delivering water data and water information, and commercial software providers now implementing the standards developed in WIRADA.

Seasonal streamflow forecasts feature prominently in the Bureau of Meteorology's National Climate and Water Briefing which is televised nationally on the ABC's Landline. This is broadcast to a national audience of agricultural producers who make decisions related to water use based on the information presented.

The CIE valuation

The benefits from WIRADA and the BoM's national water information products have been valued at $287 million per year by the Centre for International Economics.[9] To quantify the value of water information services to users, the CIE estimated users' willingness to pay for these services. This was done by surveying 21 users across Commonwealth and state government agencies, researchers, hydrologists, mining and agricultural industry representatives. Survey respondents recognised the value of the BoM products, which they considered to be an independent and authoritative source of information. Key benefits identified by respondents related to better investment decisions, risk management and operational decision-making, as well as consistency across regions.

[8] CBaM forecasts, now being run in real time by NOAA, see http://www.cpc.ncep.noaa.gov/products/people/sstrazzo/cbam/
[9] CIE 2015, Economic analysis of the Bureau of Meteorology's water information – Final report, December 2015.

- The services are used for a variety of reasons including flood mitigation, infrastructure design, policy advice, river management, when to impose or lift water restrictions, urban and rural water supply decisions, water trading, property investment, and groundwater management.
- In many cases if the BoM's information were not available, respondents would have had to use substitutes, but noted that the quality and/or accuracy would have been reduced and the cost would have been greater.
- Services that utilise the BoM's combined weather, climate and water expertise, such as flood warning and streamflow forecasting, are highly valued.
- Standard setting is valued as a means of ensuring consistency between regulators and industry.
- Many respondents use the BoM information in conjunction with their own information to achieve desired outcomes. The value of activities that compile and enable access to data varies between users, particularly as some are data providers as well as users of services.

BoM 2017 user survey

A BoM survey of users in 2017 drew the following responses:

- *Clear standards for electronic data transfer have revolutionized data access and use. We now have much better data*
- *The landscape water balance is a fantastic tool for us in fire management to get a better understanding of how dry the soil may be at various levels"*
- *Landscape Water Balance gives national perspective on soil moisture and has implications for stock sales and seasonal prospects*
- *Landscape water balance gives the big picture situation but not refined enough for on-farm purposes*

Sixty one per cent of users of water forecasting products said the products have a "major or strong impact" on their business.

The top four most used products remained the same as in 2015, namely:

- Water Data Online
- Flood forecasts & warnings
- Seasonal streamflow forecasts
- 7-day forecasts

1.3.7 Potential future impacts

The outcomes from WIRADA will continue to have impact for many years. For example, the new BoM services based on WIRADA will continue to provide valuable information to users well into the future. The water data standards can also be expected to provide significant future benefits even if, over time, the standards are further developed.

As the Executive Director for river management at the MDBA has stated:

We are confident that these streamflow forecasting products will play an increasingly important part in operating rivers to meet both consumptive and ecological water demands, particularly as environmental water portfolios increase to the levels required by the Basin Plan.

The cost to individuals and business owners from flooding associated with the operation of the Wivenhoe and Somerset dams in 2011 floods was of the order of billions of dollars, according to media reports. If in the future, the costs associated with such an event could be reduced by just a few per cent as a result of using the outcomes of WIRADA, the resultant savings would easily cover the entire cost of the WIRADA program.

1.4 Counterfactual and Attribution

1.4.1 Counterfactual

The partnership with the BoM provided: the depth and breadth of scientific capabilities required which are not available in any other Australian institution; and procurement efficiencies. A key for WIRADA's success lies in the enduring partnership that has been built between the research and operational teams within CSIRO and the BoM respectively.

In the absence of CSIRO, the BoM would have had considerable difficulty in assembling the range of expertise needed to undertake this work. If the BoM had succeeded in sourcing the necessary expertise from elsewhere, it is unlikely that innovative outcomes such as those of WIRADA would have been achieved. Even if other expertise were able to be sourced, it is unlikely that the same quality and novelty of outputs would have been achieved, the work would have taken longer and would likely have cost more.

1.4.2 Attribution

The BoM and CSIRO were partners in WIRADA. Other contributions to WIRADA came through collaboration with overseas scientists and with other Australian researchers.

1.5 Evaluating the Impacts

1.5.1 Cost-Benefit Analysis

Costs

As noted in section 1.3.1, the total cost of WIRADA in the period 2008-09 to 2016-17 was approximately $68 million. Of this, approximately $28.4 million was spent in the period 2012-13 to 2016-17.

Benefits

CIE used the survey information to estimate the value of the BoM information. Their estimates are only indicative, as there were a number of limitations to the approach. The analysis does not fully account for the quality of BoM services relative to other suppliers, and excludes non-market value such as the environment and the value of the BoM's independence. Additionally, many of the BoM information products had become available only recently, meaning that awareness and adoption rates are relatively low; over time benefits could increase if adoption increases.

Key points from the 2015 CIE economic valuation are:

- **The net present value of benefits ranges between $0.8 billion and $2.7 billion** if products and services remained available and fall to between $0.6 and $2.1 billion otherwise. This is based on the cumulative value of benefits from 2008 to 2022.
- Annual benefits are between $67 million and $287 million at the time of the survey.
- The largest benefits accrue to those products that utilise the BoM's combined weather, climate and water expertise, for example, flood warning, seasonal forecasting and modelling.
- Benefits are spread relatively evenly between industry, research and policy outcomes and flood mitigation.
- Of the water products, Water Data Online is clearly highly valued.
- The value of other products varies with the knowledge of the user and the scale of information they need. Users needing local information typically do not require national scale information and will therefore not necessarily be willing to pay for it.

Users of WIRADA-enabled services are generating environmental benefits through better informed environmental allocations of water.

Sensitivity analysis

We have relied on the CIE cost benefit analysis but lack the data and details of their calculations. It is therefore not possible for us to undertake a sensitivity analysis.

Assessment of benefits against costs

At the upper bound of the estimated benefits, the benefit cost ratio is approximately **31**.