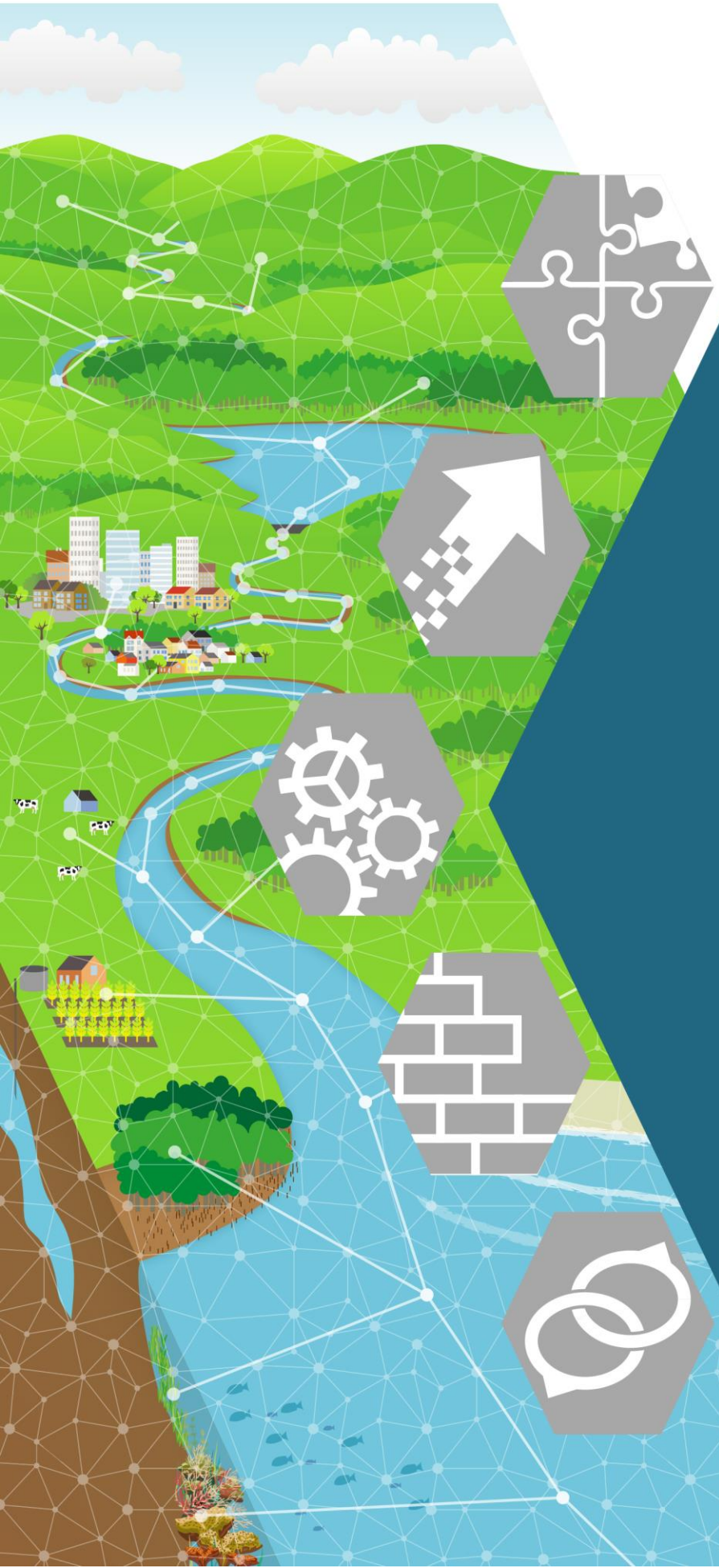
Queensland Government



Queensland Water Modelling Network

Technical Forum

Summary Report

14-15 November 2017

EXECUTIVE SUMMARY

The Queensland Water Modelling Network (QWMN) convened a Technical Forum in Brisbane 14-15 November 2017. Seventy-two participants from state and local government agencies, public research bodies, universities, statutory authorities, not for profit organisations and the private sector attended.

The Forum provided an opportunity for a range of public and private organisations to discuss emerging issues and to network with others working in the field of water modelling.

The Forum comprised of: short technical presentations on some of the QWMN's projects and proposal; facilitated sessions to discuss possible network goals and activities, propose priority projects and evaluation approaches and explore 'blue-sky' outcomes for the Network.

Over the two days, participants identified commonalities in critical issues facing water modelling in Queensland, and a strong commitment to establish and contribute to the Queensland Water Modelling Network across multiple roles and issues (e.g. modellers, modelling practices, types of models, applications, uptake by decision makers and end users), and how better linkages and communication channels can generate better outcomes.

The Forum affirmed that:

- the Network include all areas of water modelling, foster a diverse membership and look for synergies and connections and a more holistic approach.
- there was strong support for building capability through seminars, sharing of information, opportunities to collaborate and mentoring.
- collaboration between all levels of government, universities and the private sector on projects which have the potential to significantly impact on water management and modelling practices would be fundamental for success.
- through the QWMN, seek to establish a 'Community of Practice' to encourage collaborations on projects, educational opportunities and opportunities to develop leading edge water models.
- the Network could aim to become the authority in water modelling, endorsing or recommending water models and forming expert groups.
- students should be encouraged to undertake research in areas of relevance to the broader Queensland community, perhaps through targeted projects and local workshops.
- regular reviews and evaluations of the QWMN were needed to ensure that it maintained diversity, was effective in delivering outcomes related to educational and collaboration goals and that it continued to be relevant to its members – both organisational and individuals.

Opportunities during the workshop to facilitate networking were well received and attended. Attendance and participation in all workshop activities was high, with preliminary feedback indicating the workshop was an effective starting point for the establishment of a diverse and strong network that would deliver improved outcomes in water modelling to Queensland. This initiative by the Queensland Government and its opportune timing was acknowledged and appreciated.

Contents

Outline and process

The Queensland Water Modelling Network (QWMN) Forum was held in Brisbane 14-15 November 2017 and attracted 72 participants from state and local government agencies, public research bodies, universities, statutory authorities, not for profit organisations and the private sector. The full list of participants is at Appendix 1. A copy of the Agenda is provided at Appendix 2.

The Forum comprised a series of technical presentations on several current and potential QWMN projects complemented by a briefing on the Network and talks on the strategic vision for modelling and the Network. Copies of the presentations are provided at Appendix 3.

Following the presentations, participants were broken into small groups and asked to reflect on what they had heard so far and to discuss how the Network could work, what the Network should focus on and how water modelling capacity could be built. Participant responses were distributed under the framework of: Initial Feedback; Network Goals and Activities; Outcomes and Evaluation, Making a difference and QWMN priority activities. Similar responses were then clustered and a descriptive summary developed, supported by key examples.

Future Vision - Design and challenges for modelling in Queensland

Modelling Overview – Prof Paul Greenfield, Chair, International Water Centre

Prof Greenfield gave an overview of the key challenges facing the modelling in the water sector. Key insights included:

- Before developing or using a quantitative model, it is essential to have developed a conceptual model or framework of the system being studied. People need to have an understanding of what they are aiming to achieve by building or using a model.
- Ideally a model should involve as little complexity as possible to address a particular issue. The Achilles heel of most water models is their validation - rarely can you find or afford to generate sufficient, appropriate data to satisfy the purists (i.e. statisticians).
- Need to encourage modellers to go into the field and 'get muddy' in case it turns out the mud they were modelling is not actually out there in the real world. Putting modellers into a silo, cut-off from field staff, is a recipe for disaster or irrelevance.
- Increasingly, developing open-source tools is the way to go - competitive advantage then becomes how you use the models and the data.
- Use state government's needs as a base, expand to service broader community and pull in those broader resources as we do.

Visioning – Prof Bronwyn Harch, Executive Director, Institute for Future Environments, QUT

- Bronwyn is Executive Director of QUT's Institute for Future Environments and has a background in statistical modelling, data analytics and their application at the interface between agriculture and the environment. She has enjoyed being part of the Network and contributing to the Core Group, seeing the government departments come together with shared passion and investment for the common goal of an enduring future for water modelling in Queensland.
- Collectively the actions and strategies developed by the Network have been helping move Queensland's water modelling capability from "Good to Great". This was not just in technical capability but also in stakeholder relationships, moving beyond simple

engagement to true partnerships. These partnerships needed to be guided by user demand coupled with the research and innovation emerging from research organisations, universities and the private sector. Stakeholder engagement was a key part of a successful network and the QWMN was seeking to be an excellent practitioner.
- Visualisation of model input and output could greatly enhance stakeholder communications, particularly for government around risk informed decision making and investment and this consideration has informed the QWMN's five themes – not just technical capability but also communication and engagement.
- This first Technical Forum represented the 'sweet spot' where a broader spectrum of views were sought to inform the Network's direction and priorities and ensure everyone benefits from the investment and momentum. The Forum was also a great opportunity for networking with others working in water modelling across Queensland.

The Queensland Water Modelling Network – Progress to Date – Dr Paul Lawrence, A/Executive Director, Science Delivery, Department of Science, Information Technology and Innovation

Dr Lawrence gave an overview of the Network, its key aims and activities.

- Aims
  - Focus of the QWMN is on R&D of models; development and delivery of models to maximise their value for decision making.
  - State-wide coverage, linking modelling tools across temporal and spatial scales and spaces, improving integration of modelling water processes for hydrology, water quality and groundwater.
  - Improving models, from accuracy to data sharing and model management.
  - Integrate modelling and visualisation to enhance communication and understanding (especially catchments and basins).
  - Enhance opportunities to co-invest and co-produce with partners.
  - A sustained approach to building capacity – skilling up the next generation.

- The QWMN comprises 5 Themes - Model Integration, Model Improvement, Model Management, Building Model Capacity and Uptake and Communications and Engagement.
- Light governance structure - Core Group, Steering Panel, Technical Working Groups
- Activities: many projects already underway across all themes, primarily focused on delivering to government, five of these will be highlighted in presentations.
- Future directions –blend of four focal areas which will evolve based on interest/support.
- Forum will provide important information, feedback and views from across all sectors that will be used to shape the future and direction of the Network.

Technical Presentations

Snapshots of selected QWMN projects 2017-18

Development and delivery of data management and visualisation to support modelling teams - Dr Nick Marsh, Managing Director, Truii

Objective – Data visualisation capability is fundamental in improving uptake and application of model outputs and recommendations by policy makers and resource managers. While developed for the Great Barrier Reef, the project outputs will have much broader relevance and application.

The tools Truii P/L develop support easy visualisation, with a focus on simplifying the inclusion of a data wrangler tool and version control in the normal workflow. The tool allows users (modellers) to point at data, generate graphs and use any page as a template to make it easy to build dashboards. There are also some tools for mapping and spatial data wrangling.

The focus was on importing data easily – matching different time series, etc., to bring different datasets together into a cohesive visualisation. Truii functions as a data warehouse, so will help hold the data. The short story is that Truii cares about the whole data workflow (management, version control, wrangling, analysis, visualisation) but the aim is in getting visualisations of model results into the hands of decision makers.

eWater Core Coding Project – Geoff Davis, Executive Manager Software Development, eWater

- *Objective* – faster run, load and save times for eWater Source model, ease of model configuration, and improved stability of the Source model.
- Project so far:
  - Project clipping tool developed (select and then disable/delete bulk sections of the model)
  - Faster removal of time series
  - Stability improvements
  - Monitoring tools – performance tests and general user interface performance
- Ongoing work
  - Project runtime profiling tool
  - Further improvements to runtime and load and save time.

Development of an approach to allow daily outputs from paddock models to be fed into Source – Joel Stewart, Director, Catchment Research Pty Ltd

- *Objective*: Project working to embed paddock scale models into catchment models, using a Source plugin to connect paddock hydrology and water quality, with a specific focus on sugarcane nitrogen and pesticide exports in GBR catchments.
- Currently these models are only linked through loads, not flows, so it's difficult to show impact of management actions on hydrology and water quality outcomes.
- The paddock scale models represent hydrology differently from the catchment scale models. Connecting these models together in the same modelling framework has been achieved through the development of a Source plugin which may be adaptable to other model inputs. Importing the hydrology allows the paddock scale loads (and sensible water quality concentrations) to also be imported, addressing past mismatch issues between paddock scale load time series and catchment scale hydrology time series.
- Direct importation of paddock model outputs into catchment models raises issues of scale and model fit. Initial results suggest the calibration penalty of importing paddock model time series to calibrated catchment models can be managed, but without consensus on what model fit is good enough, issues will remain on the appropriateness of the methodology.
- In summary, a Source plugin had been developed to import paddock scale hydrology and water quality to catchment models. Work is ongoing for evaluation of water quality loads and concentrations

Gullies and streambank model workshop – Rob Ellis, Principal Scientist Modelling, Department of Science, Information Technology and Innovation

- Proposed project will revisit gully and streambank models through a facilitated review and workshops based on an inventory of all relevant models (Australian with a Queensland focus). Planned for 2017/18.
- Ever-expanding models add more and more uncertainties while model outputs are still too often taken as gospel.
- There are many gullies but little data – from sediment densities to how long ago a gully started to form. A further complication is knowing what to model, e.g. a stream or a gully or a channel?
- Existing Source P2R models could do with a 'reset' – a re-examination of data and how this is processed, check how they handle uncertainties, uses and look beyond the GBR.
- Quantifying uncertainty through models is tough. There are a few academic concepts that are currently underutilised
- Although the P2R model is strong, at the scale it sits at it is ultimately not useful as a decision support tool. Assumptions need to be described – better estimations/thresholds between gullies and streams would be nice, but the model needs the support of real monitoring of real landscape conditions.

Model parallelisation – Dr John Doherty, Watermark Computing

- *Purpose*: enhancing efficiency and capability of Source model though modulisation of processing of data before and post model runs, as well as the structure of the- run manager within the model.
- A considerable amount of uncertainty is associated with many decision-critical model predictions. This is an outcome of the innate complexity of natural systems, and the paucity of data used in the calibration of models which simulate them.
- The making of decisions requires that predictive uncertainty be quantified so that the risks that accompany any proposed management strategy can be assessed. It also requires that the costs of implementing a desired management strategy be minimized, subject to the constraints of achieving required management outcomes with predictive uncertainty accommodated.
- Quantification of predictive uncertainty is achievable, but at a high cost in terms of model runs. The cost of optimisation under uncertainty is even higher. Parallelization of model runs, and flexibility of model construction (including parameter pre-processing and model outpost-processing) are central to achieving these aims.
- Non-intrusive model run parallelisation at the network, HPC and cloud level can be achieved through use of the YAMR run manager used by PEST++. This is based on the BEOPEST run manager. Model interaction is achieved through template and instruction files. Manager/agent communication is achieved using TCP/IP.
- It is proposed that the YAMR parallel run manager be improved in a number of ways, and then made available as a public domain module that is callable from just about any programming language. This will allow programmers anywhere to build model-run-parallelizable applications with little difficulty.
- It is also proposed that the suite of “model-value-adding” applications available as part of the PEST and PEST++ suites (including inversion, global optimisation, global sensitivity analysis and uncertainty analysis) be made into an inter-operable “super-suite” with improved documentation and training material.

Case Study – The Flood Community of Practice – Dr Piet Filet, Research Development Officer, QUT

- Piet is convenor of the Flood Community of Practice (CoP) which had an international connection with a Dutch Water Professionals group who were keen to share their expertise and learn from our handling of the Queensland floods in 2011.
- The CoP IS a grassroots movement based firmly on sharing knowledge, much less corporate. It is very diverse, with members ranging from landscapers, scientists to insurance people.
- The CoP held a Flood Hypothetical in 2016 based on 'What would Brisbane look like in 2036 after a major flood?' A Thinktank approach worked on designing responses to flooding, and produced a document outlining findings.
- Piet is a very strong champion for this – poking and prodding to make sure it happens.

Related initiatives

Water Modelling Products at the Bureau of Meteorology – Dr Chantal Donnelly, Water Resource Modelling Unit, Bureau of Meteorology

- BoM was keen to hear back about how the data (including model outputs) they provide is used, how useful it is and what products or improvements customers are interested in them producing.
- BoM water products provide perspective (climatologies), situational awareness (nowcasts) and foresight (forecasts and projections). As well as observations and water models, BoM has a suite of water products that combine information from multiple sources to give a bigger picture of water, www.bom.gov.au/water
- BOM develops, runs and improves a national landscape water balance model, AWRA-L, at 5 km grid across the whole country. Data is readily available from www.bom.gov.au/water/landscape and by mailing awrams@bom.gov.au. Future developments to this model will include higher resolution (1 km) and new hydrological response units.
- BOM also develops, runs and improves a suite of national river region models using, AWRA-R (Australian Water Resources Assessment-River). These models simulate the daily river water balance at reach level for all major catchments and urban regions in Australia. New insights from this model include quantifying channel groundwater losses and overbank flow.
- AWRA-L is available as an open-source, community developed model, AWRA-CMS. For example, a user might like to run AWRA-L locally by cookie-cutting their region of interest, and improving with own local data and calibration. BoM also run training in using the AWRA-CMS. Contact awracms@bom.gov.au to register interest in next course, possibly early 2018.
- It was important to include a range of models (no one model is perfect) and to communicate new information from models (especially when they're updated!) to stakeholders.
- Future BoM modelling work will include a move towards seasonal forecasting of soil moisture, evapotranspiration and runoff and climate projections for all of Australia.

Plenary and group discussions on the QWMN

Initial feedback

Scope and focus of the Network

Participants sought further information on the Network scope and coverage with a roadmap or similar suggested to illustrate what parts of the water cycle were included. There was strong interest in being involved, once it was confirmed that the Network was not solely focused on Reef activities, a perception that may have been linked to the mix of presentations. The group noted the need for the Network to set achievable goals that matched available resources and to identify an appropriate focus. The importance of clear deliverables was flagged as well as targeting data-gathering weaknesses. The current Network focus was seen as strongly aligned to government and there were questions on how this might be broadened.

- *It would be useful to have a roadmap – what parts of the water cycle are we examining? What geographic or environmental spheres are being engaged with?*
- *How does the Network move from being strongly government orientated to a broader network?*

Linking modellers to end-users/decision makers

The group noted the critical importance of strengthening links between modellers and end users – be they policy makers or farmers. Communication between these groups needed to be improved to facilitate understanding, trust and relevance. Collaboration mechanisms to build understanding amongst non-modellers of modelling concepts and applications, e.g. treatment of uncertainty, were seen as valuable. The importance of modellers getting out in the field to reality check their models was also noted.

- *There's a need to include decision makers, expand beyond just modellers. Develop mechanisms for collaboration, including training non-modellers to give them an understanding of what we're doing*

Engaging with other groups

Participants recognised the importance of the Network engaging with other relevant groups and leading individuals both in Queensland (e.g. Flood Community of Practice) and more broadly. The Network also needed to be placed within the broader government strategy framework for maximum impact. The potential for influencing the national agenda was flagged, although not before the Network was ready to take this on.

- *It would be great to influence the national agenda, though it's important to not bite off more than we can chew*

The next generation of modellers

There was a possible role for the Network in encouraging students to consider modelling as a career and help build broad modelling capability in Queensland. The issues of attracting students to study modelling and then retaining them within the sector needed to be addressed. It was suggested that the Network could include younger modellers to diversify its member base and expand its approach. Modelling needed to be made interesting and exciting for students to take it up initially and then to continue with it.

- *Even at this stage of the process it could be important to include young modellers, diversify our representation*

Developing the Network

Harness existing passion and goodwill

Participants expressed strong passion and enthusiasm for water modelling throughout the Forum. This was confirmed in the animated technical conversations during the breaks and active participation during the working sessions. This energy and passion coupled with the ability to influence the Network's goals and structure would help design a Network that responded to user needs.

- *A strong passion about water being expressed by many guests. This collective passion can be harnessed.*

Cultivate an open, diverse, evolving group of stakeholders

To be successful and impactful, the Network needs to function as a bridge between technical modellers and the broader community, to build understanding and ensure relevance. It has to be flexible and driven by needs, evolving to address changing demands and membership, considering various business models from the private and government sectors. Membership had to be inclusive and diverse, drawn from state and local government, universities, utilities and the private sector, and include modellers, decision makers and consumers of model output. A website link was suggested to allow interested individuals to self-enrol. Data scientists and other people with complementary skills were suggested as members, fostering links between modelling and monitoring. Social science modellers were also suggested as members, linking water to the social context. The Network had to engage with and support members across the state, not just the Reef, and expand beyond its initial government focus.

- *We are trying to address the concerns of a broader community, and that community needs representation, both to learn and to influence*
- *A bridging organisation that connects a diverse range of stakeholders*
- *Inclusive and diverse membership, not purely a professional society – Driven by champions of specific areas, but also collaborative*

Build understanding of modelling and its use in decision making

A key role identified for the Network was that of influence, building understanding and support for the use of water modelling. The Network needed to focus on fostering trust between decision makers and modellers, providing external and independent validation of model results and advising on best practice and fit for purpose models. The Network had to create a space for public, honest and informed debate on modelling issues between modellers, end users and decision makers. This dialogue will help improve understanding of issues like uncertainty analysis and model plurality amongst end users as well as help modellers better understand user needs. Stronger connections to end users, coupled with consistent language and greater use of visualisation and digitalisation tools to better illustrate model outputs.

- *Need for help in providing validation that models are effective and validated approaches – to build trust in the expertise of water modelling. A network can provide unilaterally agreed checkpoints and standards, to provide a uniform approach. External, recognised validation.*

Impact and influence the agenda

The Network needed to develop a reputation as a trusted and authoritative source to a range of stakeholders, building understanding amongst decision makers about models and helping researchers and modellers improve the relevance and application of their work. The Network should influence the direction of future research and investment, identifying and prioritising based on business priorities. A national water modelling network was needed but this would be a longer term consideration. Following up with the Bureau of Meteorology and other jurisdictions on issues of national importance will be an important part of the QWMN.

- *Should develop a reputation as trusted, effective, authoritative to a range of stakeholders*
- *Ultimate need for a national network, but QLD is a good place to start*

Connect with non-modellers

It was important for the Network to facilitate strong relationships between modellers, science communicators and decision makers so that all were aware of how they could work together for mutual benefit. This could include businesses, politicians and natural resource managers. Connecting beyond water modelling provided new opportunities and approaches to problems to be explored, both for the Network and for the external partners.

- *It's important to forge strong relationships between technically gifted modellers, science communicators (or other ancillary/support staff) and decision makers.*

Communicate and share information

Communication is a key Network function. A QWMN website was seen as a critical resource to profile the Network to potential partners and support ongoing dialogue between modellers and end users. In addition to traditional newsletters and reference materials, the website could act as a dedicated forum for learning, hosting on-line seminars and moderated discussions to complement in-person workshops and forums. On-line discussions on contested issues would allow all to benefit from and be informed by the debate, benefiting all.

- *Open Communication – transparency, not email trails - Requires a moderator and regular, high quality communication – Should have a clear and coordinated network operation, with mechanisms for updates so that everyone is kept informed.*

Foster Collaboration

For maximum impact, the Network needed to learn from already established communities of practice and tap into existing organisations (e.g. Engineers Australia), and mimicking the collaborative aspects of the CRC program. Co-leverage principles where by everyone contributes and benefits needed to be observed. Clearly outlining member benefits and contributions from the beginning would help to inform collaborations, results from these activities needed to be measurable and communicable to everyone to justify investment.

- *Base the network on the principles of co-leverage – resources, skills, projects – everyone contributes + benefits*

Connect modelling challenges with resources

A successful Network integrates modellers and end-users as well as across the water domain. It is driven by current needs, connecting projects with the resources required, not just funding but also data, models and students. Activity focused workgroups, fostering learning and skills development underpin the Network. These mostly focus on critical issues but would also include ongoing generic issues.

- *A successful network is valuable/useful. Funding, connections (formal and informal), new tech. Integration between modellers and end-users. Integrates the different areas water touches on.*

Build capability

Building capability was seen as a priority goal for the Network. This ranged from contributing to university curricula through mentoring students and early career modellers and improving the skills of end-users. Knowledge sharing was a fundamental Network function, building understanding of individual models' strengths and weaknesses and also creating shared tools and communicating emerging data. The creation of expert groups and fellowship schemes similar to the Churchill fellowship model would also help lift capability.

- *Knowledge sharing a key function of the network – increasing know how and understanding of limitations, strengths of different models, increase in socialised awareness*

Follow a two tiered approach

Recognising that there are ongoing general modelling issues and more specific topics that could be addressed by targeted workgroups, a two-tier approach was recommended to maintain the strategic vision and direction while delivering concrete outcomes.

- *Adaptive approach between R&D within modelling – evolving as specialised project groups address specific issues, giving credit to the overarching, more broad, aims of the network.*

Clarify the role of models in the Network

It was important to realise that the Network was more than just modelling but also a forum for communication. Physical models, such as those held at the Queensland Government's Deagon facilities, should be included in the Network as well as conventional mathematical models.

- *Need for placement of the role of modelling within the bigger picture of the network.*

Support integrated approaches and scenarios

There was strong support for the development of holistic scenarios for use within modelling to investigate the impacts of issues like climate change and population increases. This needed to include economic and social models as well as the different scales of water models. The development of agreed model suites with standardised outputs that are accessible to others would build understanding and inform policy responses. This could be demonstrated through a project focused on the integrated scenario approach.

- *More holistic scenarios – need to address challenges of population increases, global warming, etc. – perhaps a project that tackles the consideration of these issues*

Manage data and metadata better

The collection of data and metadata were flagged as important topics for the Network. Priority gaps needed to be identified across all catchments and then action taken to address these. Data collection could be improved through sharing experiences in the use of existing techniques and the application of new approaches. Citizen science initiatives could contribute data but careful consideration was needed on the trade-offs between quality, cost and frequency to ensure it was fit for purpose. Developing and applying metadata standards combined with clear articulation of the metadata would add value to future datasets and the models using them. This could be through an agreed protocol for new project sites.

- *Data – Standardising a repository of metadata, with articulations of the metadata*
- *Optimizing data collection with techniques available across the network.*

Evaluation, Scope of QWMN.

The Forum characterised a successful Network by the following outcomes with supporting evaluation approaches.

Existence

Fundamentally, the Network needs to exist, be visible to and used by end users, modellers and decision makers.

- *It's clearly been successful if it's still here – if the scale and importance don't fade out*

Active community

The QWMN supports an active community with strong buy-in from diverse stakeholders, modellers, decision-makers and end-users. Frank and constructive conversations on technical or conceptual issues can take place between practitioners in the space the Network has created. This could be evaluated through membership surveys.

The Network hosts a series of workshops and seminars, providing opportunities for people to talk about their projects and share insights. This keeps the Network connected to new developments through external speakers but also strengthens links within the Network. This could be assessed through participant surveys and workshop attendance.

The QWMN website acts as a digital platform to tell the story of modelling to non-modellers and provide more detailed technical information and links to modellers. Evaluation is through the establishment of the website, web traffic, posting of resources (e.g. webinars, documents).

- *Getting to a place where constructive conversation can take place in the space that the network has created.*
- *Diverse and significant membership – private and public sectors, ages gender*
- *A platform for people talking about their projects, online and during seminars*

Strategic perspective and partnerships

The Network has a clear vision with quantifiable targets based on shared themes. Regular progress reports to catalogue contemporary practices and identify new strategic priorities. The Network provides a framework for the development of conceptual models and hosts widely used numerical models. Funding for Network projects comes from a range of sources with significant co-investment on shared problems, demonstrating the relevance of QWMN theme and priorities. This could be assessed through level and diversity of co-funding both in total and within themes.

- *A report that gives a summary of the work done, functions as a catalogue of contemporary practices, identifies strategic priorities moving forwards*
- *Co-investment on common problems; the ease of identifying common issues*

Influence/impact

The Network is used by modellers, decision makers and end-users to improve their processes. This ranges from support with tender writing, influencing decision making, debate and investment decisions. Members have improved professional support and access to improved and expanded networks, using the Network as a sounding board for important decisions. End users find the Network useful and are better informed of the value of modelling as an input in decision making. Impact can be evaluated through access rates and the impact the Network has on contemporary practices and policy decisions. Changes in understanding could be measured through surveys and individual case studies

- *Feeling of support and company, assistance (particularly with tender writing) – a feeling that information can be accessed and problems can be solved through the network.*
- *What is different in the network to the past – ability to demonstrate that it can influence policy, debate and investment – ability to provide good decision making based on models.*
- *Quantifying not only size, but also of the linkages made between groups (through case studies, stories shared)*

Recognised Authority

The Network is seen by stakeholders as the first point of contact for any question on water modelling, effectively functioning as an expert panel which can be drawn upon for independent advice. The Network develops clear standards for measuring modelling skill which are adopted by the sector. This could be assessed through opinion surveys of end users and quantifying increases in understanding.

- *Whether or not the network attains the status of being a main point of contact for decision makers, as an authority*

Building capability

The Network actively targets the next generation of modellers through sponsoring student projects which are focused on Network priorities and run in partnership with the universities. These would be complemented by local projects and workshops to promote the results and their applications. The QWMN could consider travel awards to support modellers linking with the world's best and bringing back new skills and knowledge. Specific targets are established around data accumulation and student outreach. Baseline and follow-up surveys of students, project sponsors and QWMN fellows will help capture subjective assessments.

- *Student engagement targeted at the network's priorities*
- *Travel awards*

Technical contributions

The Network makes significant technical contributions to modelling in Queensland, commissioning technical guidelines, open source models and modelling tools and facilitates workshops on topics like model integration. The Network maintains an online searchable catalogue of projects which allows people to identify potential collaborators, build on the experience of others and avoids projects being developed in isolation with the attendant risk of duplication. This could be assessed through the use of guidelines and models by modellers, access to the catalogue and the number of links facilitated.

- *Producing quality tools that are being used and accessed to enable cross-fertilisation*
- *There's a disconnect between contemporary projects. Would be amazing to have a database that lets you find what projects are going on, who you can find to collaborate and learn from. Avoid duplication.*

Future priorities, projects and actions.

Data and monitoring

Data and monitoring were seen as key priorities for action under the Network. In addition to identifying and addressing current data gaps, consideration needed to be given to which models and data will be needed in the future. A more coordinated approach to data collection was needed to generate databanks with increased targeted monitoring helping improve understanding of model uncertainty. There needed to be standardised data repositories with supporting metadata that include descriptions of constraints and uncertainties to build value. Investment in infrastructure, either advanced super computers or access to the cloud, would be increasingly needed to manage 'huge' data sets in a timely fashion. Soils data was suggested as one specific data set which would deliver significant impact.

- *DATA: standardised repository, include metadata (constraints, uncertainties). Optimise data collection to reduce uncertainty; standardise good practises of collection*
- *Identify gaps, be proactive about figuring out what data and models we will need in the future*

Forum/clearing house to facilitate discussion– connecting to end users

There was very strong support for the Network taking up a strategic bridging role between modellers and end users, liaising with consumers to find out their needs and build understanding of modelling processes, embedding feedback structures within the network that guide modelling R&D investment. There was clear demand for visualisation and communication tools to help communicate modelling concepts to end-users.

This forum would support informed discussions on model plurality and develop language that decision makers can understand, particularly around complex issues like uncertainty. Development of a tool to link model hypotheses and the impact and value of on-ground work is needed.

The Network should focus on improving connectivity within the modelling community, establishing itself as a centre of excellence that coordinates R&D, sources spokespeople and convenes valued webinars/seminars, presentations, training and capacity building events. The Network needed to support modellers across Queensland, establishing regional modelling hubs that hold workshops and facilitate meetings between experts, stakeholders and authorities.

- *Tell a cohesive story about what models can do for you (the end user), what they mean to people*
- *Communication – translation of literacy – develop a language politicians and decision makers can understand, esp. around tough/confusing stuff like uncertainty.*
- *Disrupt the governance structure*
- *Developing visualisation and communication tools for education*
- *Modelling Hubs around Queensland*
- *Increase connectivity within modelling community and between modellers and end users (ultimately improving models and communication)*

Collaboration

Collaboration was seen as fundamental to the success of the Network, allowing members to keep abreast of the latest science and engage with universities in research and training. The Network could be used to drive change in Queensland government modelling through facilitating sharing of ideas and methods between government and external network members. Products that would encourage collaboration needed to be developed and shared – including catalogues of products, models and skills. The Network could play a role fostering multi-disciplinary modelling hubs, bringing together the best people for the job.

- *Keep abreast of the latest science, have engagement with universities – research and teaching*
- *Bring in people from different disciplines. Be better at bringing in the people that are going to be best at the jobs*

Building capability

There were a range of capability building activities and initiatives suggested which focused on different groups within the Network. There was a very strong focus on cultivating the next generation of modellers, looking to engage students on research projects on topics relevant to Queensland. This could be designed to help build a cohort of multi-skilled rather than single issue modellers. Targeted scholarships and prizes were other avenues of attracting top students. More fundamentally, the Network could look at influencing university courses to include the latest science and seek to influence national STEM initiatives.

Current modellers would benefit from exposure to other modellers and national and international experts through training, conferences, secondments and guest speakers. Travel awards to support both outbound and inbound visits to world-leading centres would connect Queensland to world's best practice. These fellowships would not be restricted to government modellers but would be open to universities and consultants.

Best practice guidelines on models, project design and model engagement would help build capability in non-modellers on the strengths and weaknesses of models and equip them in the intelligent use of models.

- *Best practice guidelines (for users and modellers) defined by working group and/or expert panel (externally reviewed) which are used*
- *network could influence uni courses to update, include latest science*
- *student projects on topics important to qld with useful output*
- *An international connection – bringing in luminaries, sending out our own luminaries.*

Scenarios

There was support for greater integration and a more systems-approach to modelling. Models needed to be integrated across different scales but also linked to economic and social models to better describe holistic scenarios, e.g. climate change, population growth. Probabilities needed to be attributed to different climate scenarios to start to inform policy discussions. Standardised scenarios needed to be developed that could tested in different models to rank their value in different situations.

- *Integration of models – broad in terms of scale, also featuring economic and social models. More consistency in the outputs of models. More holistic scenarios – face increasing populations, climate change, mass migrations even*

Practical focus

Network activities needed to have a strong practical focus, prioritising and implementing specific model improvements while providing support to niche projects that do not have broad appeal. The Network needed to develop case studies which demonstrated specific problem solving, e.g. wetland information assessment tools and best practice guidelines covering the whole project cycle. The guidelines could be complemented by access to experts to provide technical input and strategic governance from concept to project completion.

- *Best practice guidelines*
  - *whole of project including data acquisition, conceptual models, project design, method, engagement, communication and expert review*
- *Example: wetland info assessment tool*
  - *Rainfall measurements (gauges)*
  - *Investigate emerging technology to increase monitoring*
  - *Coverage of streamflow + rainfall measurements in smaller tributaries*
  - *Connect to other modellers e.g. economic*
  - *Make sure you have the right feedback between systems*

Suggested priority activities

Following group discussions, participants were asked to suggest priority activities for the Network to launch in the short to medium term, which are categorised below. These will be circulated to the Queensland Water Modelling Network Steering Panel for further consideration at their next meeting (planned for February 2018).

Communication and profiling (e.g. website, seminars)

- A facility to distribute information on who else is in the field (and came to this workshop)
- Get that website up
- To get the project and model catalogues available and accessible online
- Metadatabase of models, forcing data, projects, conceptual models
  - outputs, language
  - open repositories
  - saving knowledge online
- A seminar series – or webinars or 'flushtube' – that shares even more information on what people are doing out there in the water modelling space
- Paid project to collate who does what in modelling world, QLD. Publish & maintain
- A call for student projects

Documentation

- A summary of what we have covered today, some firmer grounding of what we've identified that the network should cover
  - guideline development + repository e.g. MUSIC urban stormwater modelling guidelines
- Gap in flood modelling between guidelines + practical application/implementation
- Get documentation ('cheat sheets') on the Network – give people tools to talk about the value of the Network

Collaboration

- Hands-on activities – let’s do some model integration or start work on developing best practices
- Get a process on developing consensus for priorities in model development.

Appendix 1 - Queensland Water Modelling Network Forum Participants

Following the Technical Forum and as an initiative to establish a 'community of practice' the following list of attendees was created.

Attendee
1. Dr Eva Abal Adviser, Strategic Water Projects and Partnerships, International Water Centre
2. Dr Robert Argent General Manager Water, Bureau of Meteorology, 700 Collins Street, Docklands VIC 3008
3. Mark Askins Team Leader, Water Supply Modelling, Seqwater
4. Dr Rebecca Bartley Team Leader, Materials Fluxes Team, Catchment Processes Group, CSIRO, Ecosciences Precinct, Dutton Park, 4102
5. Dr Michael Barry Technical and Innovation Manager Market Lead – Water Quality BMT WBM Pty Ltd
6. Michael Bartkow Team Leader Water Policy and Research, Seqwater
7. Ed Beling Principal, BEng (Civil) MSc (Marine Science) MIEAust CPEng RPEQ Intrawater Pty Ltd
8. Dr Frederick Bennett Landscape Processes – Spatial Modeller, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct
9. Paul Boswood Principal Engineer, Coastal Impacts Unit, Science Division, Department of Science, Information Technology and Innovation, Deagon
10. Ken Brook Director, Land Surface Sciences, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct

Attendee
11. Dr Chris Carroll Adjunct Associate Professor Australian Rivers Institute Griffith University, Nathan
12. Lex Cogle, Senior Program Officer Office of the Great Barrier Reef Department of Environment and Heritage Protection, 400 George St, Brisbane
13. Dan Copelin, Senior Engineer, Water Management, Planning and Design, City Projects Office Brisbane Infrastructure, Brisbane City Council
14. Ryan Cosgrove Project Coordinator/ Researcher *qldwater* (Queensland Water Directorate) Albion Qld 4010
15. Dr Ramona Dalla Pozza, Science Leader, Grazing Land Systems, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
16. Shawn Darr Senior Catchment Modeller Resource Assessment & Information, South Region Department of Natural Resources and Mines, Toowoomba
17. Geoff Davis BE(Hons) SE, GradDipMgtIT Executive Manager Software Development eWater
18. John Doherty Principal, Watermark Computing
19. Chantal Donnelly Unit Head, Water Resource Modelling, Water Resources Assessment, Water Information Services, Environment and Research Division, Bureau of Meteorology, 69 Ann Street, Brisbane
20. Chas Egan PhD Hydrologist, Queensland Hydrology Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park

Attendee
21. Rob Ellis Principal Scientist Modelling, Soil and Land Resources, Science Division, Department of Science, Information Technology and Innovation, Bundaberg
22. Dr Amgad Elmahdi, Head of Water Resources Section, Bureau of Meteorology, 700 Collins Street, Docklands Victoria
23. Jean Erbacher A/Director, Landscape Sciences, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
24. Dr Bantigegne Fentie Senior Scientist (Modelling) Soil and Land Resources Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
25. Dr Piet Filet, Research Development Officer, QUT Business School, QUT
26. Marieke Frassi Research Fellow, Australian Rivers Institute Griffith University
27. Grant Fraser Principal Scientist, Soil and Land Resources, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
28. Dr Afshin Ghahramani Research Fellow, Agricultural Systems Modelling Institute for Agriculture and the Environment Division of Research and Innovation, University of Southern Queensland, Toowoomba
29. Dr Badin Gibbes Senior Lecturer – Civil & Environmental Engineering Aquatic Systems Research Group School of Civil Engineering, The University of Queensland
30. Matt Gooda Principal Project Officer, Queensland Hydrology, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park

Attendee
31. Professor Peter Grace Professor of Global Change and Theme Leader, Science and Engineering Faculty, QUT
32. Dr Paul Greenfield Chair, International Water Centre
33. Professor David Hamilton Deputy Director Australian Rivers Institute Level 4, Sir Samuel Griffith Centre, 170 Kessels Road, Nathan
34. Professor Bronwyn Harch Executive Director, Institute for Future Environments, QUT
35. Anna Hollingsworth Acting Coordinator Catchment Management, Gold Coast Water and Waste City of Gold Coast
36. Dr Chantal Huijbers Training and Scientific Support Officer Biodiversity & Climate Change Virtual Laboratory, eResearch Services Griffith University
37. Dr Mark Jacobs A/Assistant Director-General, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
38. Saji Joseph Director, Strategic Water Programs, Water Policy, Department of Natural Resources and Mines, 1 William St, Brisbane
39. Dr Paul Lawrence A/Executive Director, Science Delivery, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
40. Alex Loy Science Leader, Queensland Hydrology, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
41. Tony McAlister Director, FIEAust CPEng RPEQ WATER TECHNOLOGY

Attendee
42. Dr Nick Marsh Managing Director Truii
43. Paul Maxwell Principal Scientist – Monitoring and Research Healthy Land and Water
44. Ben McMullen Principal Program Officer Waterway Health and Integration, Brisbane City Council 266 George St Brisbane
45. Carl Mitchell Principal Project Officer Office of the Great Barrier Reef Department of Environment and Heritage Protection, 400 George St, Brisbane
46. Julie Morrison Senior Project Officer - Reef Sciences, Landscape Sciences, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
47. Professor Peter J Mumby Marine Spatial Ecology Lab, School of Biological Sciences, Goddard Building, The University of Queensland
48. Dr Kate O'Brien Senior Lecturer in Chemical-Environmental Engineering, School of Chemical Engineering, The University of Queensland
49. Jo Owens Research Fellow (Agricultural Engineering), National Centre for Engineering in Agriculture, Institute for Agriculture and the Environment, Division of Research and Innovation University of Southern Queensland
50. Mark Pascoe Chief Executive Officer, International Water Centre
51. Sanjeev Pandey General Manager, Office of Groundwater Impact Assessment, Department of Natural Resources and Mines, 1 William St, Brisbane
52. Ouswatta Perera Senior Engineer, Flooding and Planning, Natural Environment, Water & Sustainability Branch, City Planning and Sustainability Division, Brisbane City Council

Attendee
53. Keith Phillipson Director, Technical Projects, Office of Groundwater Impact Assessment, Department of Natural Resources and Mines, 1 William St, Brisbane
54. Joel Rahman Director, Flow Matters
55. Jinaraj Rajakaruna Principal Engineer, Water Supply Planning – Strategy, Water Supply Planning and Regulation, Department of Energy and Water Supply 1 William Street QLD 4000
56. Dr Ian Ramsay Science Leader, Environmental Monitoring and Assessment Science, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
57. Jenny Riches A/Program Manager Queensland Water Modelling Network, Landscape Sciences, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
58. Dr Cedric Robillot eReefs Project Director
59. Dr Barbara Robson Principal Research Scientist, CSIRO Land and Water *I will be moving to the Australian Institute of Marine Science from 11th December.*
60. Mike Ronan Manager, Wetlands Biodiversity Assessment, Wetlands, Species & Protected Area Analysis, Conservation and Sustainability Services Division, Department of Environment and Heritage Protection, 400 George Street, Brisbane
61. John Ruffini Director, Water Planning Services, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct
62. Dr J C Scanlan Principal Scientist, Pest Animal Research, Biosecurity Queensland, Department of Agriculture and Fisheries, Toowoomba

Attendee
63. Dr Melanie Shaw Senior Scientist (Mon-Thurs), Resource Assessment, Paddock to Reef, Department of Natural Resources and Mines, EcoSciences Precinct
64. Mark Silburn Principal Scientist, Resource Assessment, Department of Natural Resources and Mines, Toowoomba
65. Dr Ben Stewart-Koster Research Fellow Australian Rivers Institute Griffith University
66. Dr Joel Stewart Director, Catchment Research Pty Ltd
67. Greg Stuart National Manager Land & Maritime Transport, Bureau of Meteorology 69 Ann Street, Brisbane QLD 4001
68. Evan Thomas Principal Scientist, Land Resource Assessments, Science Division, Department of Science, Information Technology and Innovation, Ecosciences Precinct, Dutton Park
69. Craig Walton Principal Project Officer, Strategic Water Programs, Department of Natural Resources and Mines, 1 William St, Brisbane
70. Nigel Ward eResearch Manager, Queensland Cyber Infrastructure Foundation
71. Tony Weber Alluvium Consulting Fortitude Valley, Brisbane
72. Malcolm Wolski Director, eResearch Services, Office of Digital Solutions Griffith University

Appendix 2 – QWMN Technical Forum Agenda

Queensland Water Monitoring Network
TECHNICAL FORUM – 14-15 NOVEMBER 2017

TIME: 14 November 2017 9.00am to 5.00pm
15 November 2017 9.00am to 2.00pm

LOCATION: Members Dining Room, The Gabba Cricket Ground

WORKSHOP OBJECTIVES:

- Enhance the understanding, integration and inclusion of people and programs within the QWMN
- Gather information to guide the future direction of the QWMN
- Developing a community of practice

WORKSHOP OUTLINE

DAY ONE: 9.00am to 5.00pm

- Welcome and Introductions
- Future Vision – Professor Paul Greenfield
- QWMN – Progress to date – Paul Lawrence
- Presentations - eWater, Model Integration, Model Visualisation, Model Parallelisation, Gully/Streambank Erosion Project
- Future of Network – Professor Bronwyn Harch
- Plenary and group discussions on QWMN, Developing the Network, Building Capacity in Water Modelling and Determining Future Strategic Directions

OPTIONAL SOCIAL ACTIVITIES

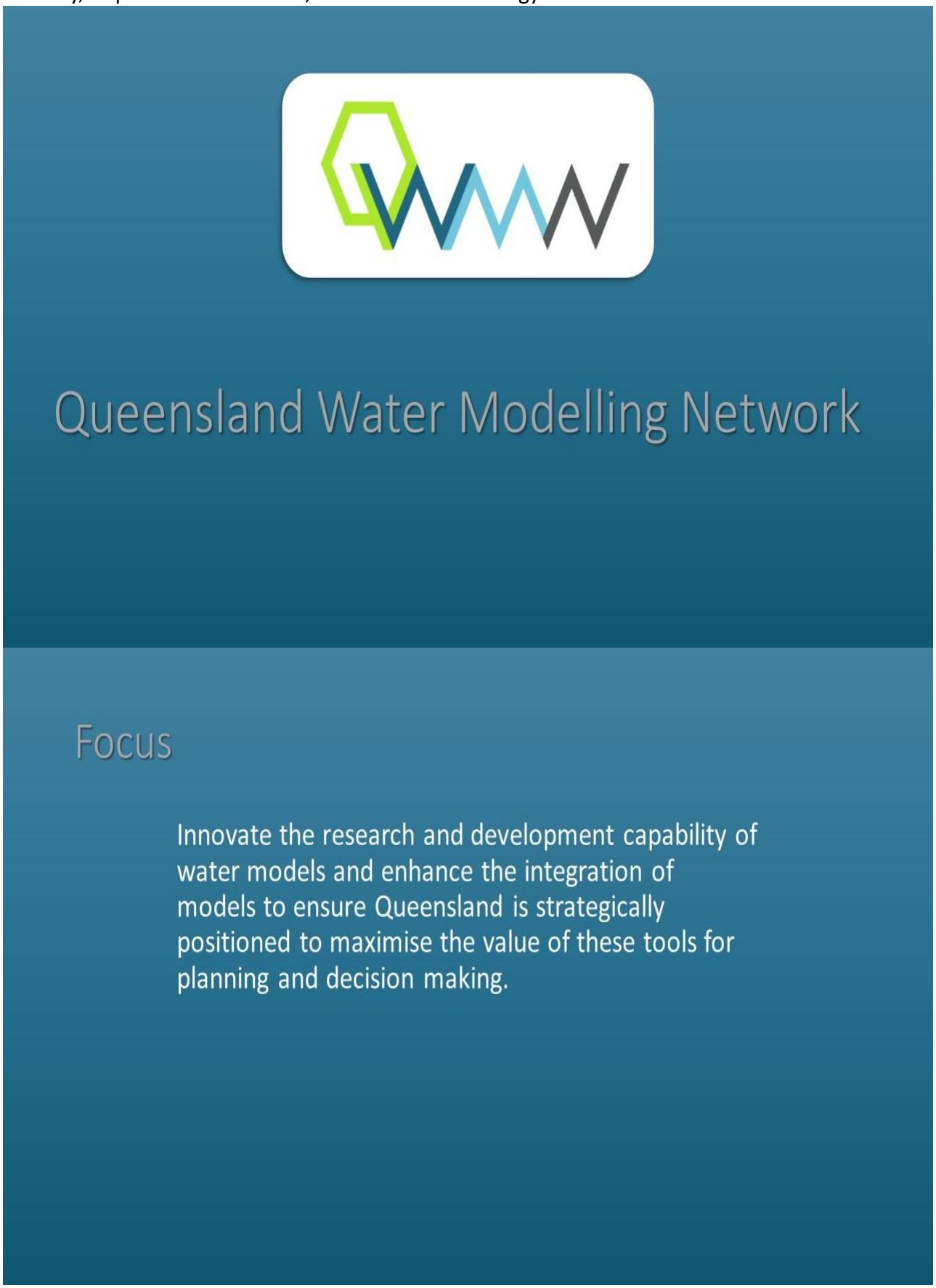
- Drinks and Networking: 5:30-6:30pm, The German Club, The Gabba
- Dinner: 6.30pm-late, The German Club, The Gabba

DAY TWO: 9.00am to 2.00pm

- Recap/follow up questions.
- Evaluation, Scope of QWMN - Plenary and group discussion.
- Future priorities, projects and actions. An opportunity to discuss possible projects to be undertaken by the network which align with the strategic directions - Plenary and group discussion.
- Workshop summary and close.

Appendix 3 – Technical Presentations

The Queensland Water Modelling Network – Paul Lawrence, A/Executive Director, Science Delivery, Department of Science, Information Technology and Innovation

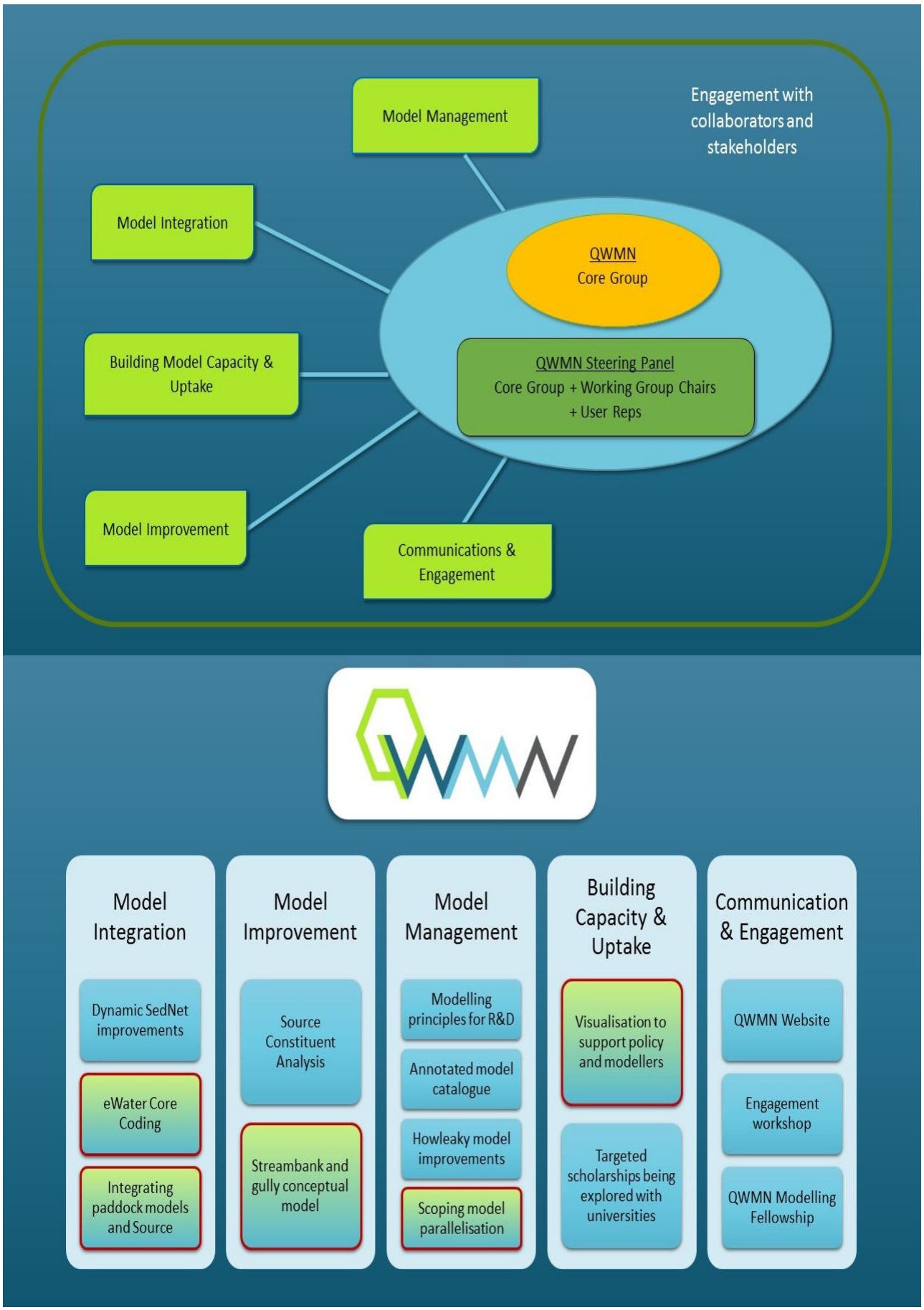


Background and aims

- Improve the integration of modelling water processes for hydrology, groundwater and water quality
- Be state-wide, and work to link modelling tools across the different scales (paddock-enterprise-catchment-basin-regional-coastal)
- Support the integration of monitoring, modelling and visualisation, particularly in priority catchments and basins
- Focus on modelling R&D and innovation to deliver efficient and effective operational modelling tools to end users
- Enhance opportunities for co-investment and co-production with other modelling providers
- Develop a sustained approach towards capacity building in modelling skills.

QWMN Themes

- **Model Integration** – enhance integration across surface water, groundwater and water quality and across temporal and spatial scales.
- **Model Improvement** – improve R&D and capability of models by incorporating known process understanding of water, sediment and nutrient movement.
- **Model Management** – develop and implement best practice modelling principles, improve data/model sharing mechanisms, maintain catalogue of water models used by government.
- **Building Model Capacity and Uptake** – implement programs to accelerate modelling skills/capability, and develop tools to improve data synthesis, communication, and visualisation.
- **Communications and Engagement** – implement strategies to engage universities, research organisations and private providers, develop co-investment opportunities and cross sector initiatives


Model Management
Engagement with collaborators and stakeholders
Model Integration
QWMN
Core Group
Building Model Capacity & Uptake
QWMN Steering Panel
Core Group + Working Group Chairs + User Reps
Model Improvement
Communications & Engagement
Model Integration
Dynamic SedNet improvements
eWater Core Coding
Integrating paddock models and Source
Model Improvement
Source Constituent Analysis
Streambank and gully conceptual model
Model Management
Modelling principles for R&D
Annotated model catalogue
Howleaky model improvements
Scoping model parallelisation
Building Capacity & Uptake
Visualisation to support policy and modellers
Targeted scholarships being explored with universities
Communication & Engagement
QWMN Website
Engagement workshop
QWMN Modelling Fellowship

Community Engagement Workshop

Objective

- Explore opportunities and issues presented by the QWMN engaging with universities and how these may be embraced or mitigated
- 30 participants from AIMS, CSIRO, Queensland and interstate universities and government departments using water modelling

Outcome

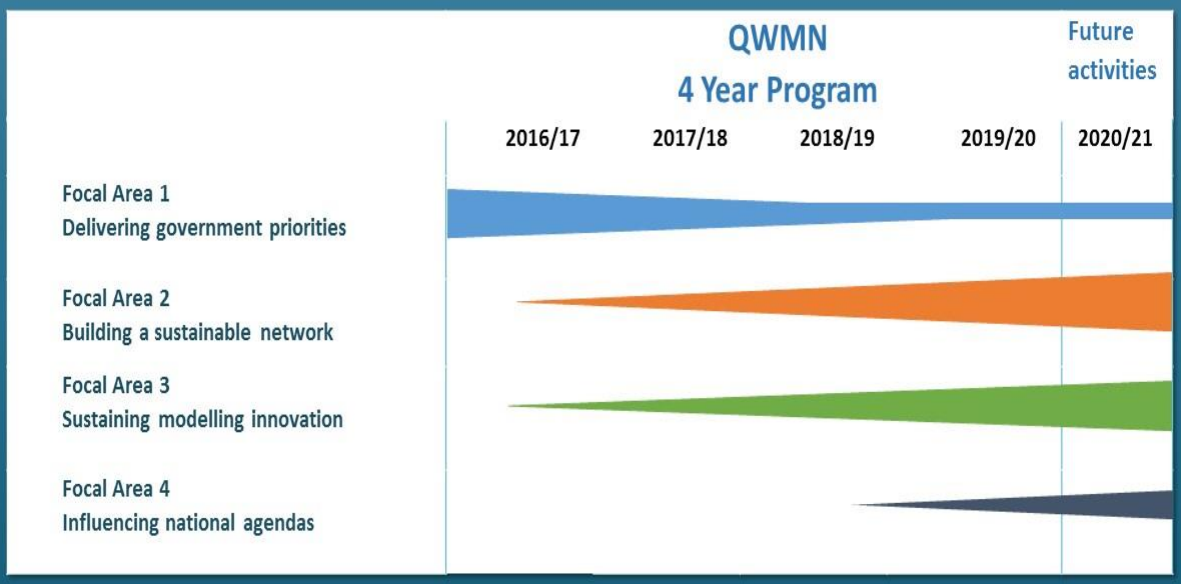
- Strong interest in engagement around scholarships/fellowships and access to models/datasets

Next steps

- Follow-up meetings held on scholarships and data access
- Further dialogue planned after Caretaker period completed

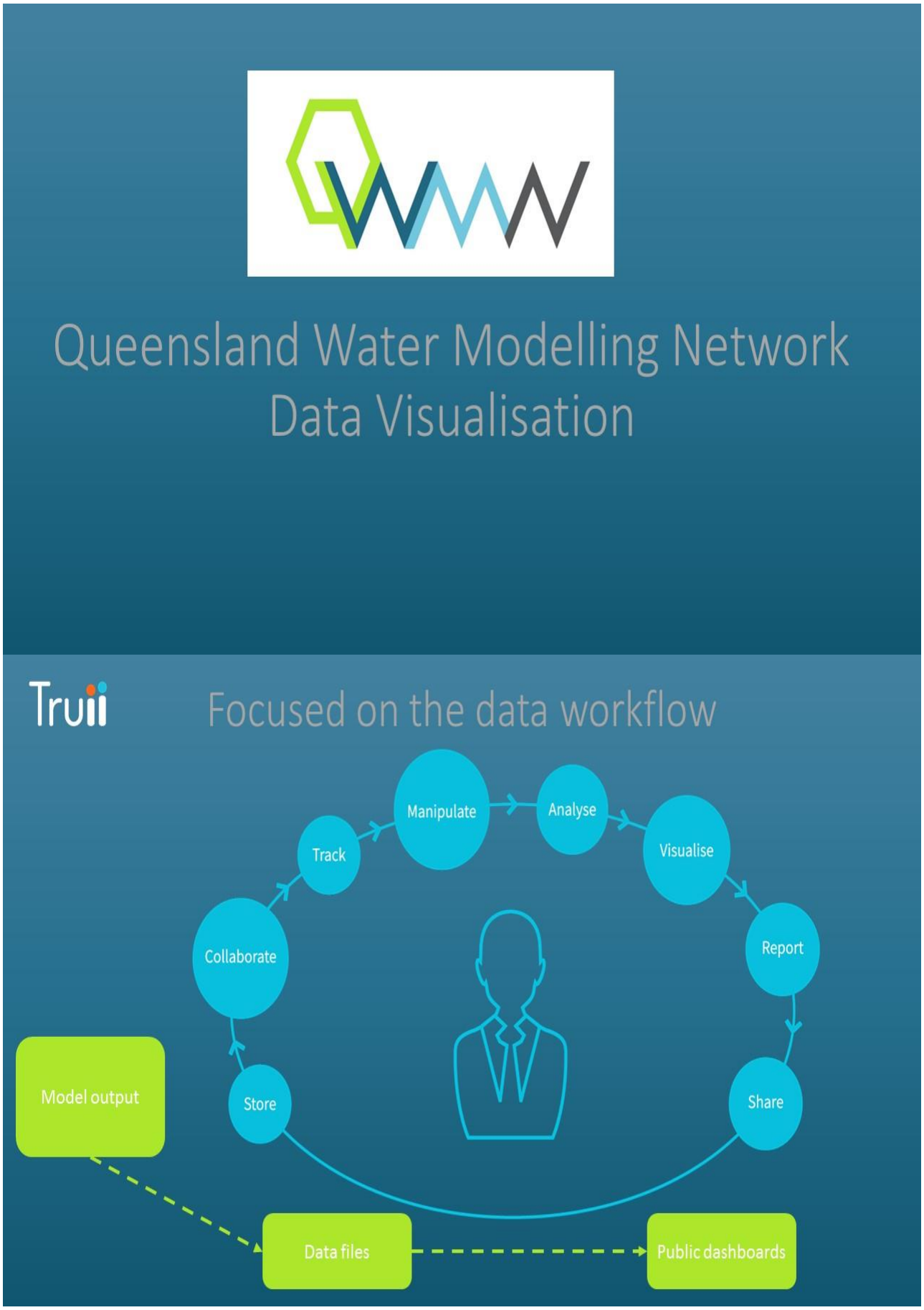
Our partners to date

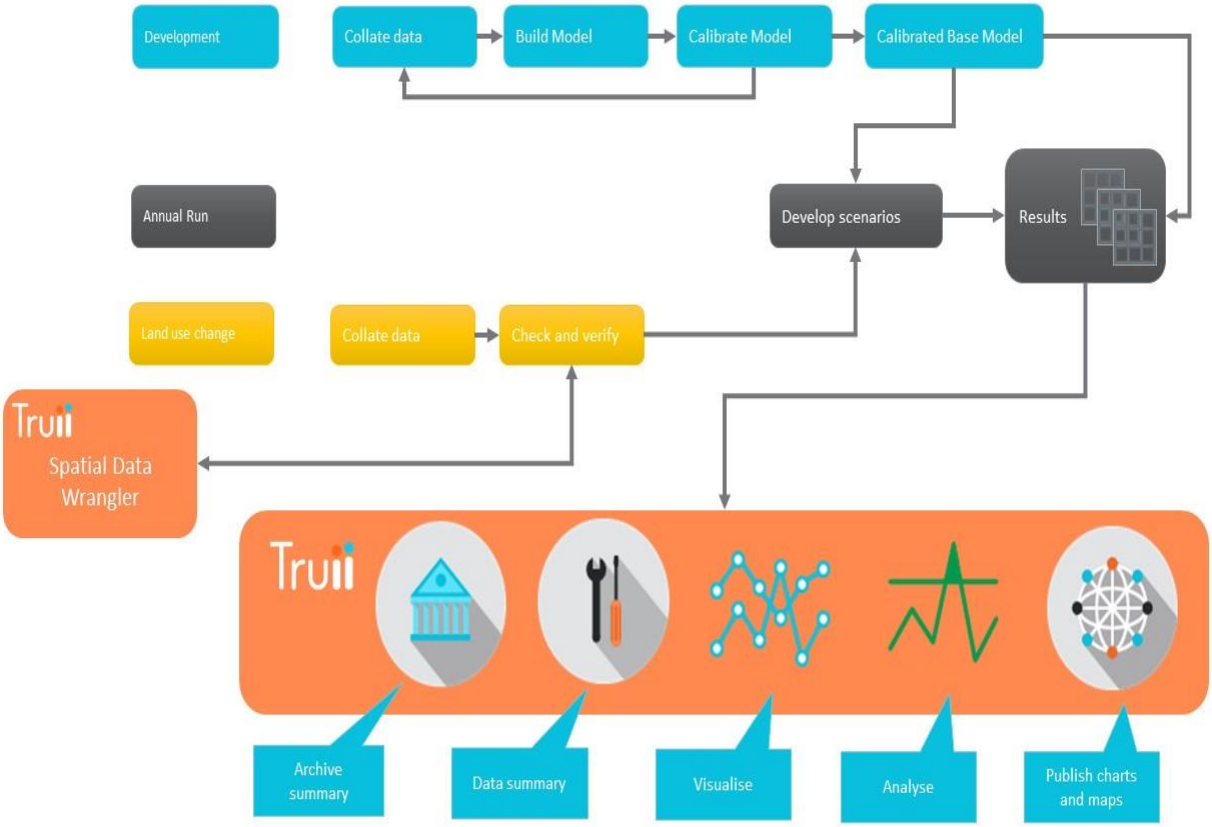
Future directions



Informed by this Forum

Model Visualisation - Dr Nick Marsh, Managing Director, Truii





Truii

Calibration dashboard and templating

Other project activity

- Data Wrangling – transforming and summarising
- Data transferring – zip upload and expand connect to model output

Truii

QWMN eWater Project – Geoff Davis, Executive Manager Software Development, eWater

Upgrades to Source to support QLD modelling

Geoff Davis

Executive Manager Software Development

Goal

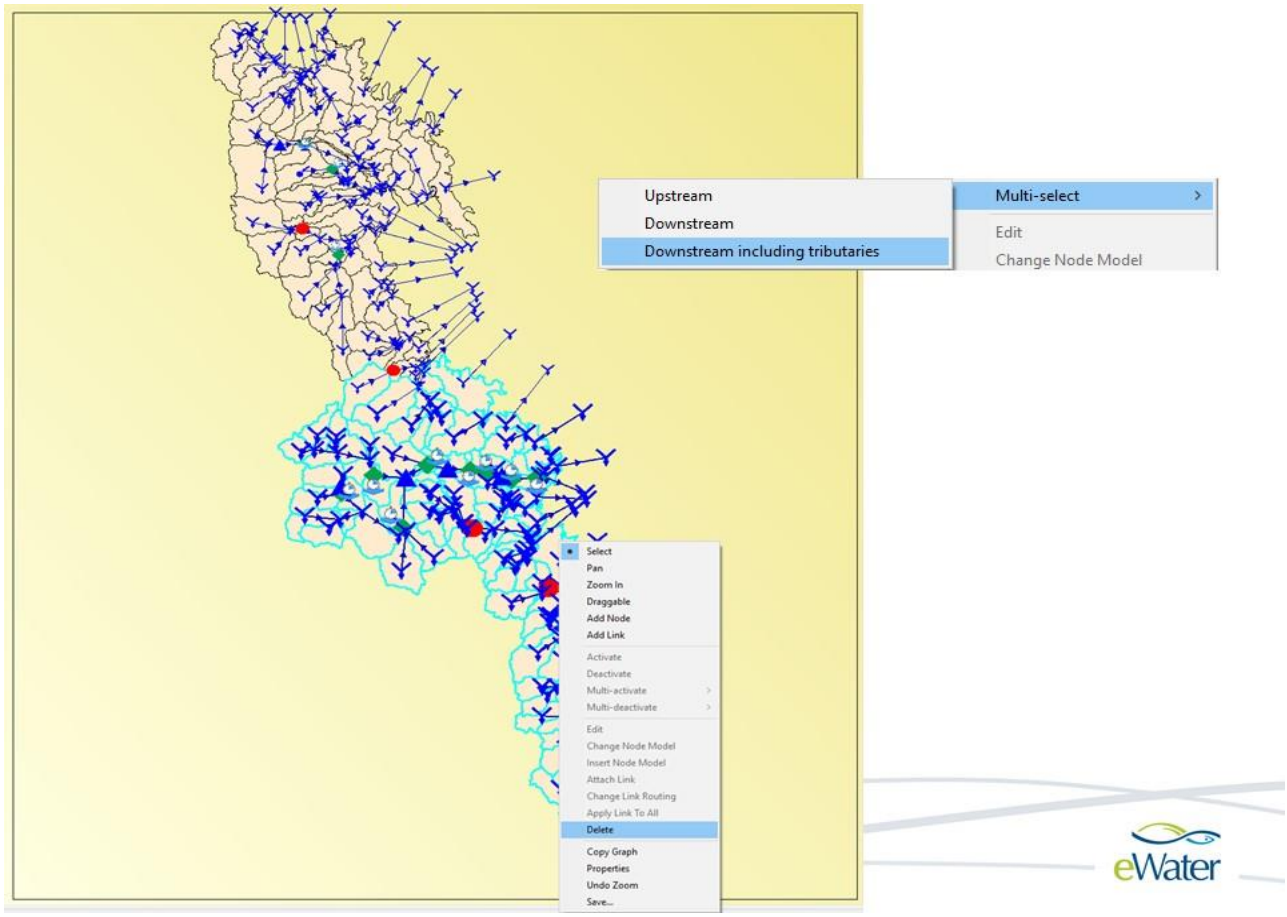
Quality of life improvements for Queensland modellers

- Faster run, load and save times
- Ease of model configuration
- Improved stability for large, complex models

Core changes

User interface improvements:

- Project clipping tool – select sections of the model in bulk to delete or disable. Eg. Select everything upstream from a node.
- Removing time series is faster
- Stability improvements
- Monitoring tools - performance tests for project runtime, load / save times and general user interface performance with large Queensland models



Ongoing work

- Project runtime profiling tool – This will provide information on how each node, feature and phase contributes to the run time of the model
- Further runtime improvements
- Further improvements to load and save times

Model Integration – Joel Stewart, Director, Catchment Research Pty Ltd

Queensland Water Modelling Network

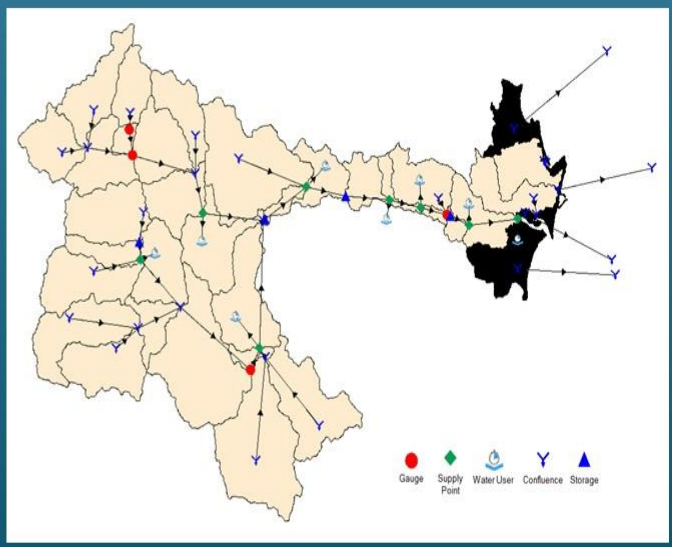
Integration of Paddock Scale Modelling and Source

Dr Joel Stewart

CATCHMENT RESEARCH

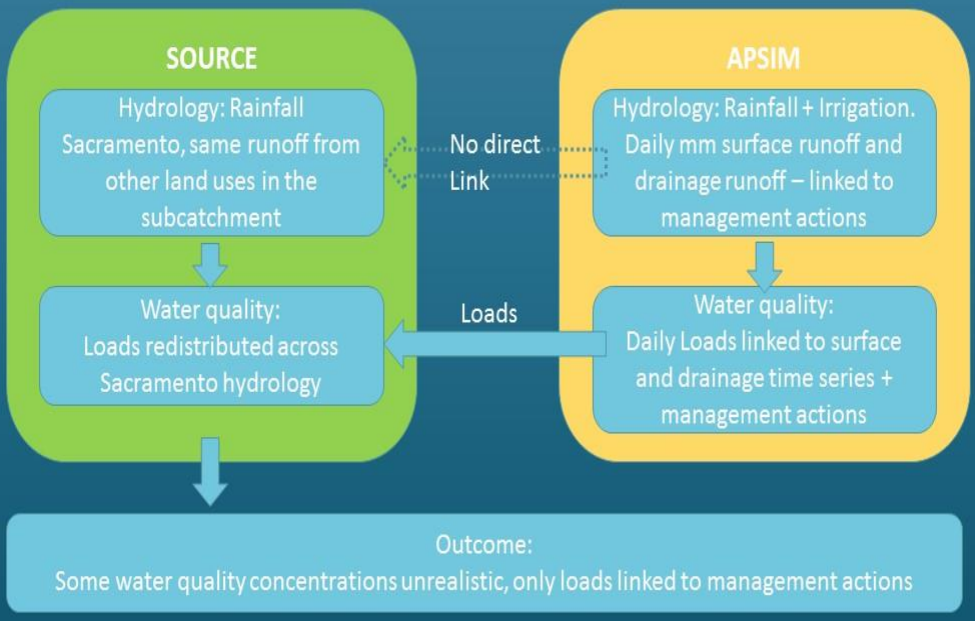
Integration of Paddock Scale Modelling and Source

- Paddock to Source Integration
- Test catchments
- Hydrology and Water Quality
- Next steps



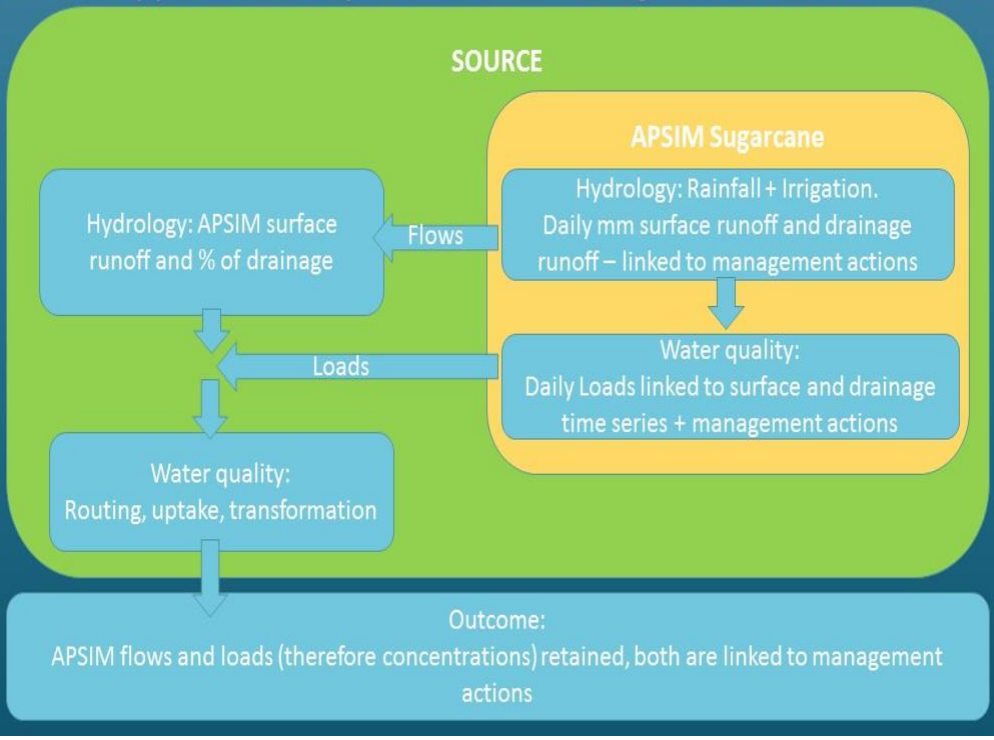
Paddock to Source Linkage – Sugarcane land use

Existing linkage conveys APSIM loads, but flows are not, so conveying water quality concentrations and management actions are difficult.



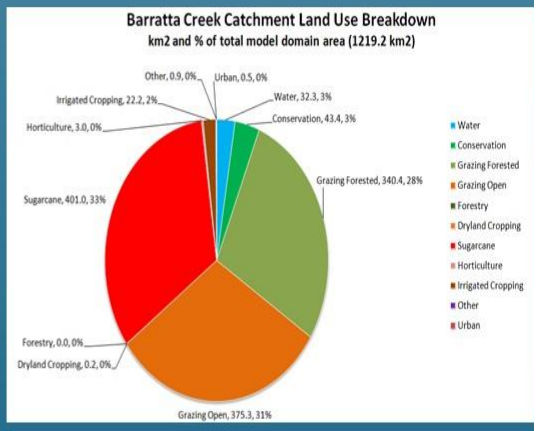
Paddock to Source Linkage – Sugarcane land use

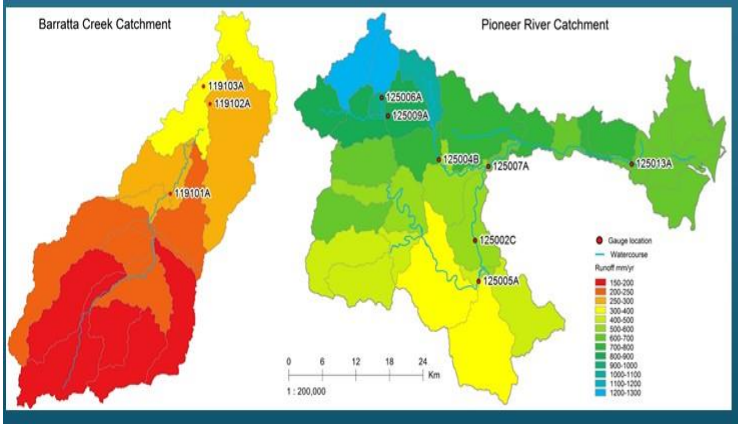
Our new approach incorporates the APSIM generated flows and loads

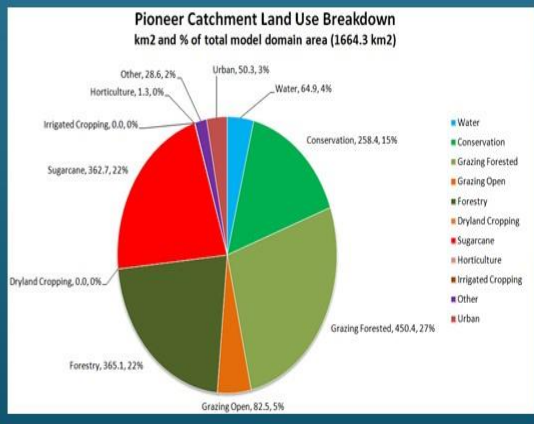


Two test catchments

- Barratta Creek (Burdekin) and Pioneer
- High proportion of sugarcane land use
- Different irrigation regime. Full irrigation in Burdekin, supplementary irrigation in Pioneer







Plugin testing: "Observedpaddockhydrology"

- Baseline model hydrology performance can be maintained with APSIM

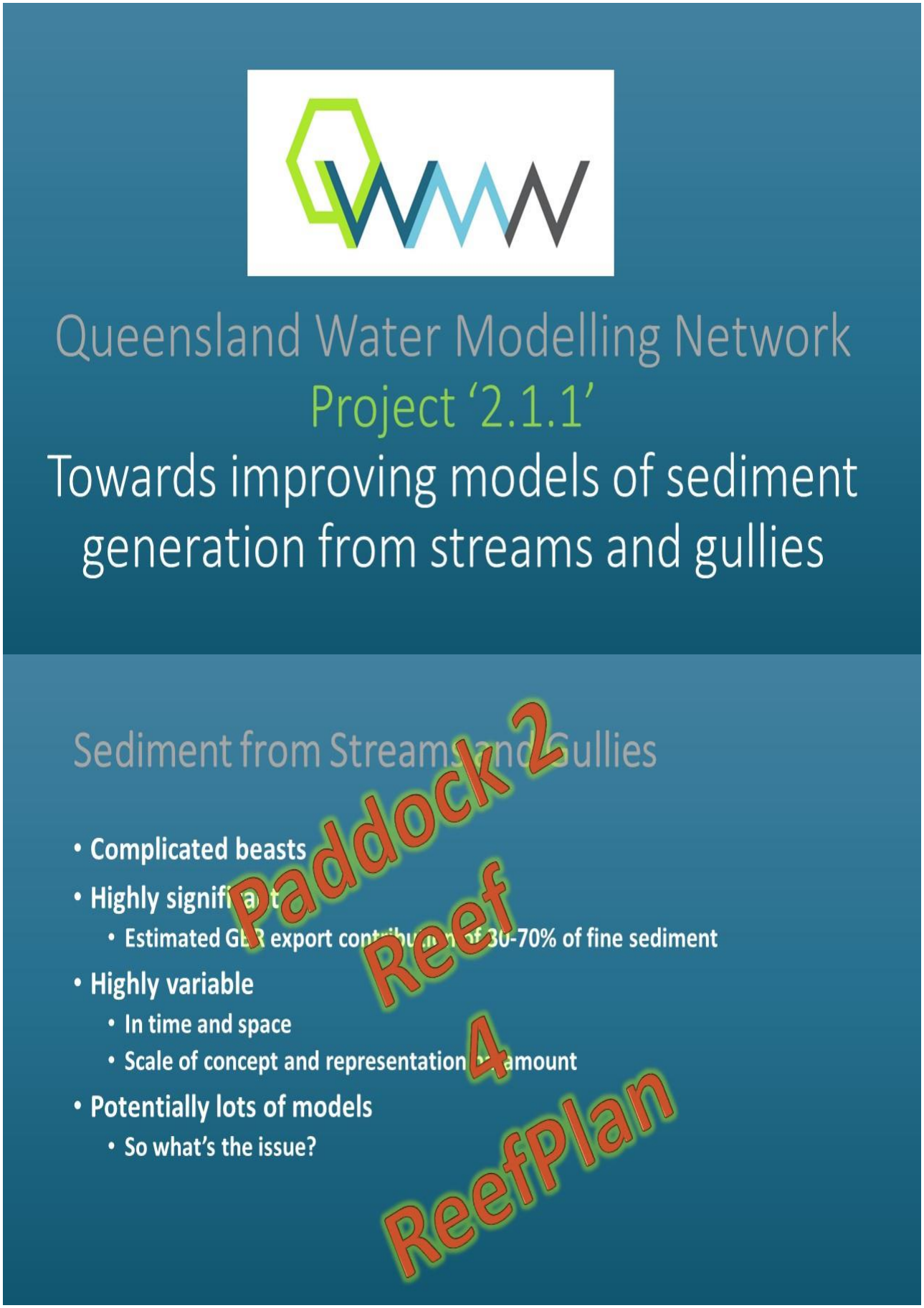
Gauge	Gauge Name	Daily NSE	Monthly NSE	Bias (%)
125004B	Pioneer - Cattle Creek at Gargett	0.703	0.951	-3.7
	With APSIM	0.650	0.928	-5.9
125002C*	Pioneer River at Sarichs	0.800	0.964	-3.3
	With APSIM	0.809	0.969	-3.8
125016A	Pioneer River at Dumbleton Weir Tailwater	0.708	0.978	-1.1
	With APSIM	0.647	0.968	-2.1
119101A	Barratta Creek at Northcote (original model)	0.759	0.864	-16.2
	Barratta Creek at Northcote (Pre-cane runoff)	0.772	0.88	2.1
	Barratta Creek at Northcote (Post cane - APSIM)	0.794	0.97	-11.1

- Water quality loads and concentrations is work in progress

Summary

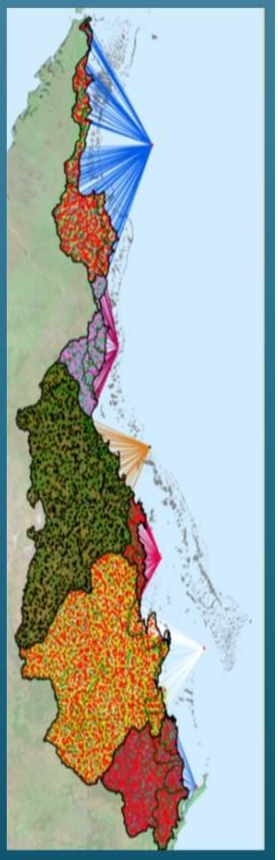
- Project is focussed on making closer link between paddock scale models and catchment models for sugarcane land use
- A source plugin has been constructed to link the paddock hydrology
- With paddock hydrology in Source, hydrologic performance can be maintained, with a small impact on daily correlation
- Work is ongoing for water quality evaluation

Gullies and streambank model workshop – Rob Ellis, Principal Scientist Modelling, Department of Science, Information Technology and Innovation



Streams and Gullies in P2R

- Modelling one of the '5 lines of evidence' of ReefPlan progress
  - Yet estimated load reductions are often interpreted as 'gospel'
  - Driving priority of works funding etc
- Catchment models cover the whole of GBR
  - 423,000 km^2
- Representing erosion from hillslope, gully and streams
  - As well as intensive farm practices
- Scale, Scale, Scale.....



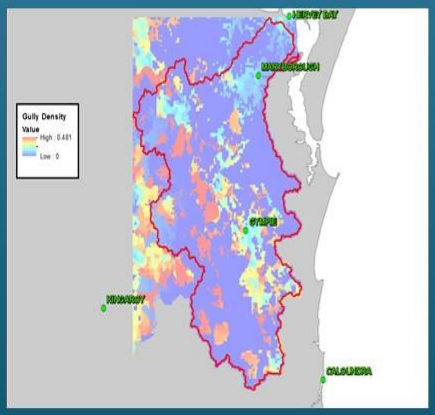
Streams and Gullies in P2R

- What models can be
  - Rapidly deployed
  - At a consistent scale
  - Across the whole of GBR
  - Using available data
  - Allowing management representation
- We chose SEDNET
  - With customisation

Streams and Gullies in P2R

- Gullies, so easy:

Ann. Av. Sed Supply (t/year) = (P_s * α_{xs} * Gully Density * Area) / Age

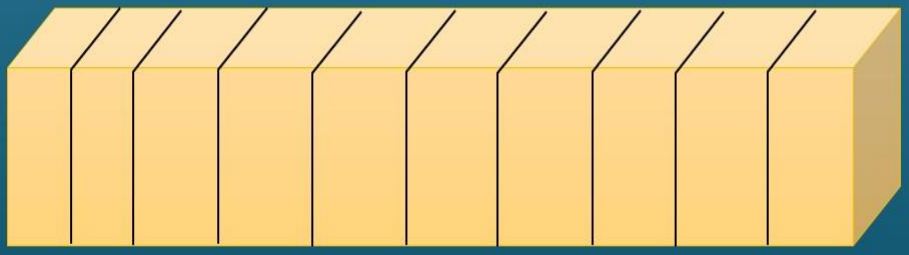


- Gully Density – Continental scale
- Cross Section (α_{xs}) – regionally variable, no source
- Even Bulk Density (Ps) 'patchy'
- Age????

Streams and Gullies in P2R

- Gullies, so easy:
  - Density, Cross Section give a total volume
  - Bulk density gives a mass
  - Age of system gives annual average supply
  - Disaggregate to daily runoff – job done

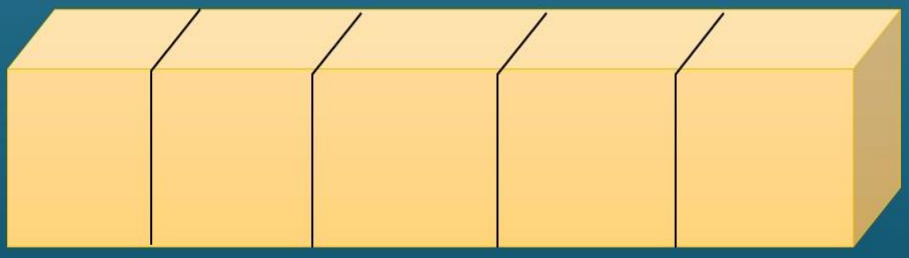
Age of gully = '10'



Streams and Gullies in P2R

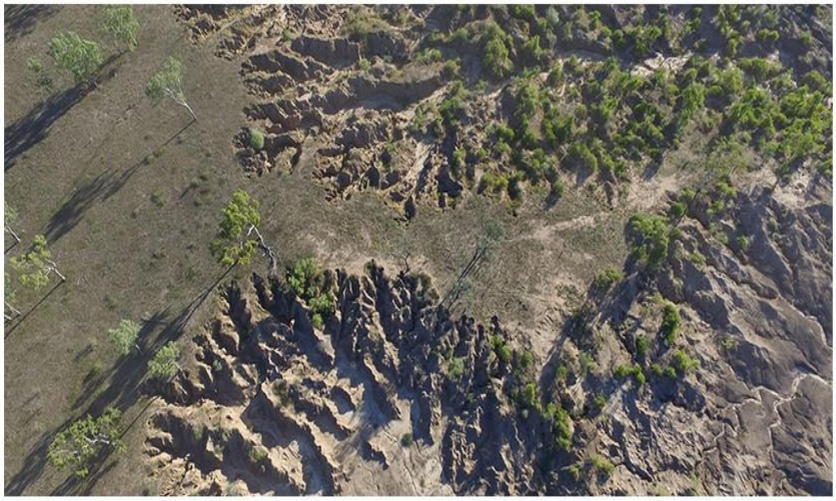
- Gullies, so easy:
  - Density, Cross Section give a total volume
  - Bulk density gives a mass
  - Age of system gives annual average supply
  - Disaggregate to daily runoff – job done

Age of gully = '5'



Streams and Gullies in P2R

Scratching the surface: Uncovering the effects of alluvial gully erosion



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Streams and Gullies in P2R

- Streams much the same
- Box-like geometry in SedNet
  - Plus Stream energy
- But who has ever seen a box-like stream
- What differentiates 'bank' from 'channel' processes?
- What differentiates 'stream' from 'gully'?

Sediment from Streams and Gullies

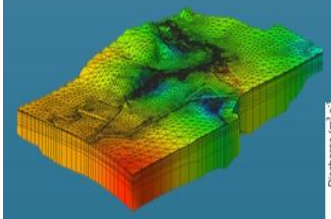
- **P2R needs to 'reset'**
- **Modelling and data at many scales need improvement**
- **Need to start looking beyond GBR**
- **Coordinated approach to model and data improvement**
  - **QWMN project '2.1.1'**
- **Facilitated review and workshops**
- **Inventory of all relevant models (Aus. With Qld focus)**
- **Consensus and collaboration to infinity and beyond**
  - **Or at least as far as we can spatially predict infinity**

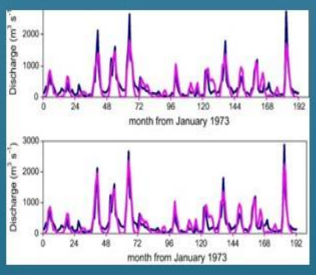
Model parallelization – John Doherty, Watermark Computing

Queensland Water Modelling Network

Expediting Non-Intrusive Parallelization of Model Runs for Improved Model-Based Decision Support

Model-Based Decision-Support (traditional)





1. Build
2. Calibrate
3. Predict
4. Decide

Problems

- What are the post-calibration uncertainties of decision-critical predictions?
- Have we reduced those uncertainties as much as we can given all available data?
- What extra data can be most effective in reducing these uncertainties?
- What can go wrong if we take a particular management option?
- Does a proposed management strategy minimize costs subject to constraints of
  - achieving design objectives
  - the uncertainties associated with decision-critical predictions

Model-Based Decision-Support

(ideal)

Global sensitivity analysis

Calibration-constrained Monte Carlo

Optimisation under uncertainty

All of these require:

- Hundreds/thousands of parallelized model runs
- A flexible, non-intrusive partner-to-model interface

Direct predictive hypothesis testing

Inversion

etc

We are half way there already.

BEOPEST, PEST_HP and supporting software

John Doherty (WNC, Qld), Willem Shreuder (Principia Mathematica, USA)

- Highly parallelized inversion and calibration constrained uncertainty analysis
- Global optimization
- Advanced run management for difficult, long-running and numerically problematical models

PEST++ and supporting software

Dave Welter (SFWMD, FL), Jeremy White (USGS, TX), Mike Fienen (USGS, WI), Willem Shreuder (PM, CO), Adam Saide (Univ .of WA, Australia)

- Includes modular parallel run manager (YAMR)
- Inversion
- Global sensitivity analysis
- Global optimisation (DE and PSO)
- Optimisation under uncertainty using linear/nonlinear programming and FOSM

Destination

Highly parameterized inversion

Global sensitivity analysis

Markov chain Monte Carlo

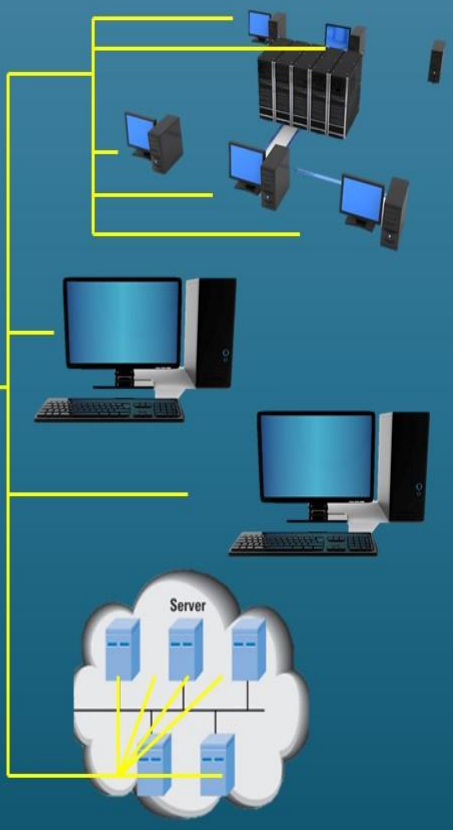
Geostatistical Monte Carlo

Global Optimization

Optimization under uncertainty

Written in any language

Parallel run manager (an improved version of the PEST++ YAMR manager)



The Proposed Project

1. Expand capabilities of the YAMR model-non-intrusive, public-domain, parallel run manager
   - callable from C, C++, FORTRAN, Python, R and Matlab
   - upgraded from the existing PEST++ modular run manager which, in turn, is based on the BEOPEST run manager
   - **anyone** can then use this manager to write model dancing partners

2. Provide a cohesive, inter-operable set of initial dancing partners based on PEST/PEST++ software
   - inversion
   - calibration-constrained linear/nonlinear uncertainty analysis
   - global optimisation – CMAES, SCE, PSO, DE
   - global sensitivity analysis using methods of Saltelli and Morris
   - Monte-Carlo analysis
   - optimisation under uncertainty using linear/nonlinear programming

The Proposed Project

3. Demonstration of Software and Concepts at DSITI sites
   - groundwater issues
   - surface water issues

4. Web Presence
   - download all software
   - discussions and support

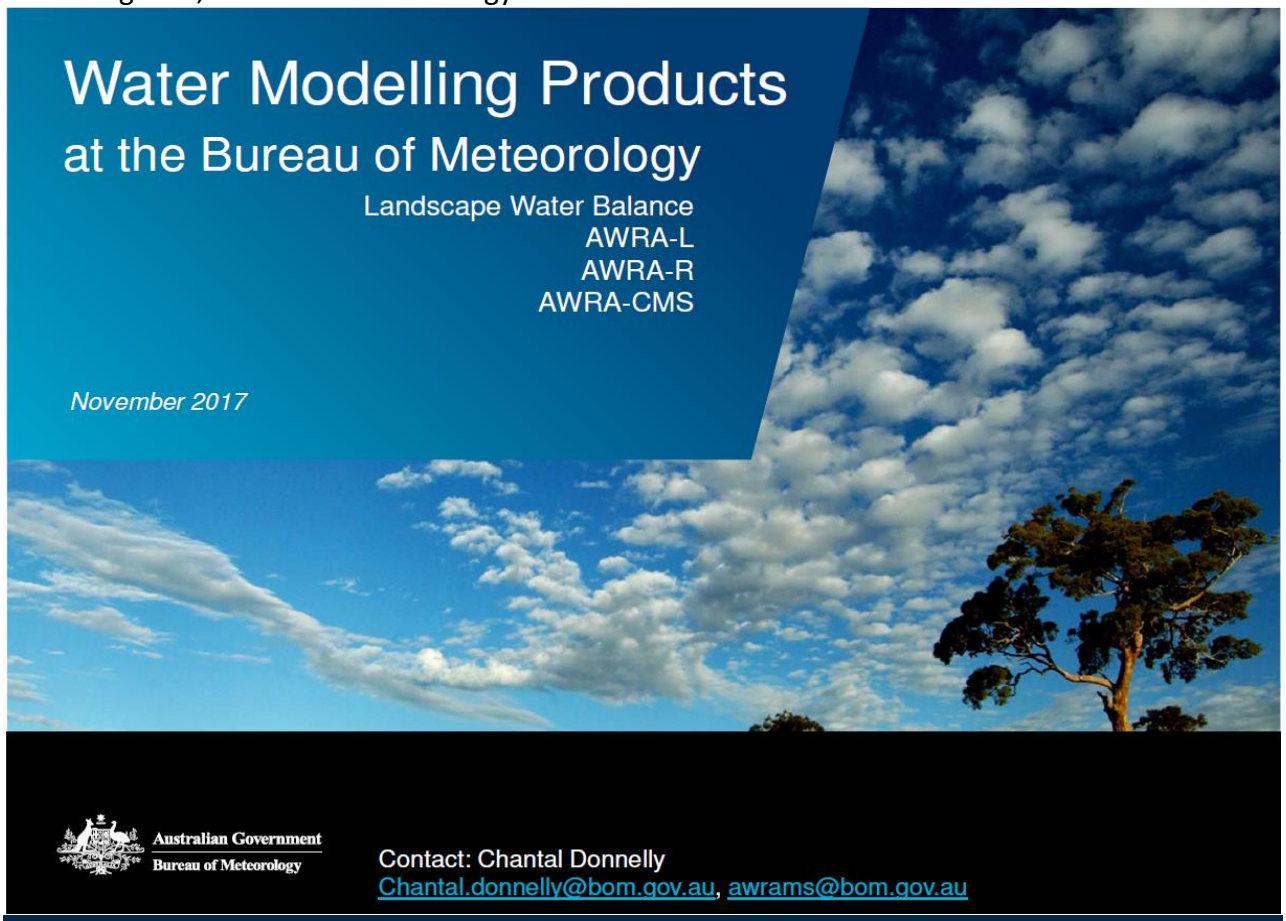
5. Lay groundwork for next stage
   - migration of run manager to the cloud
   - make use of off-peak low-rate cloud possibilities
   - seek government/industry/university support for continuation of the project

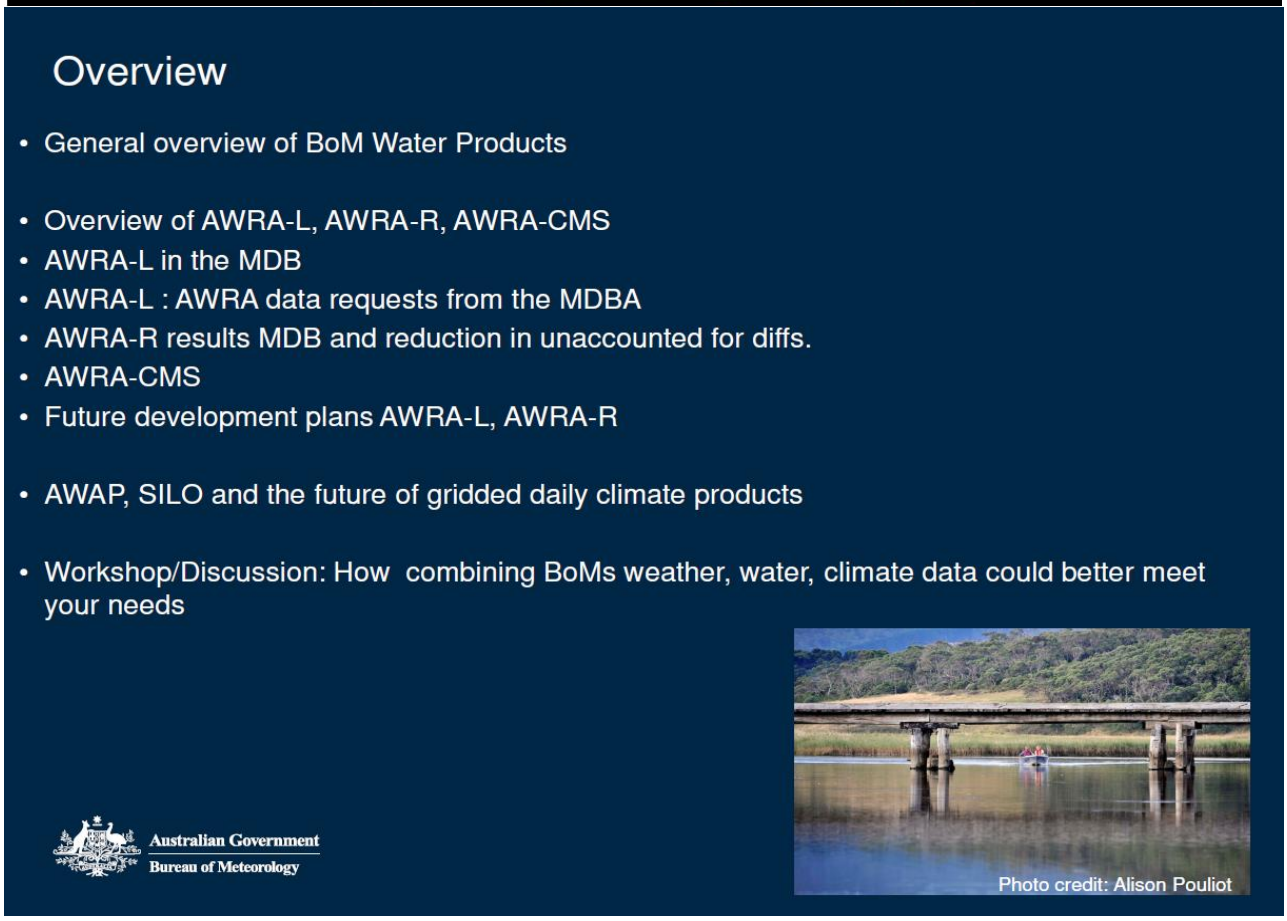
Really Important...

Technology transfer to this side of the Pacific requires involvement of smart young local people who wish to get good at:

- programming for parallel run management on networks and clouds
- programming of model dancing partners
- construction, calibration, deployment of models in important decision-support contexts

Water Modelling Products at the Bureau of Meteorology – Chantal Donnelly, Water Resource Modelling Unit, Bureau of Meteorology





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Our mission

To provide trusted, reliable and responsive weather, water, climate and ocean services for Australia – all day, every day.

Customer Focus – *We listen to our customers, understand their needs and are invested in their success. We strive to provide them with an outstanding experience. We are a pleasure to work with and can be relied upon to deliver.*

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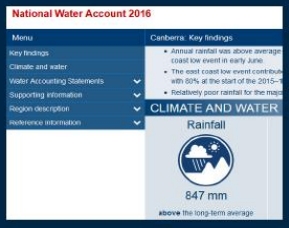
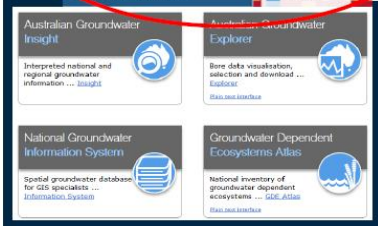
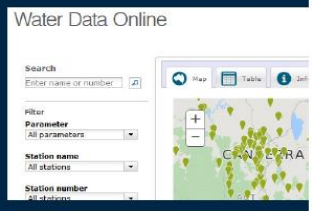




Water Restrictions



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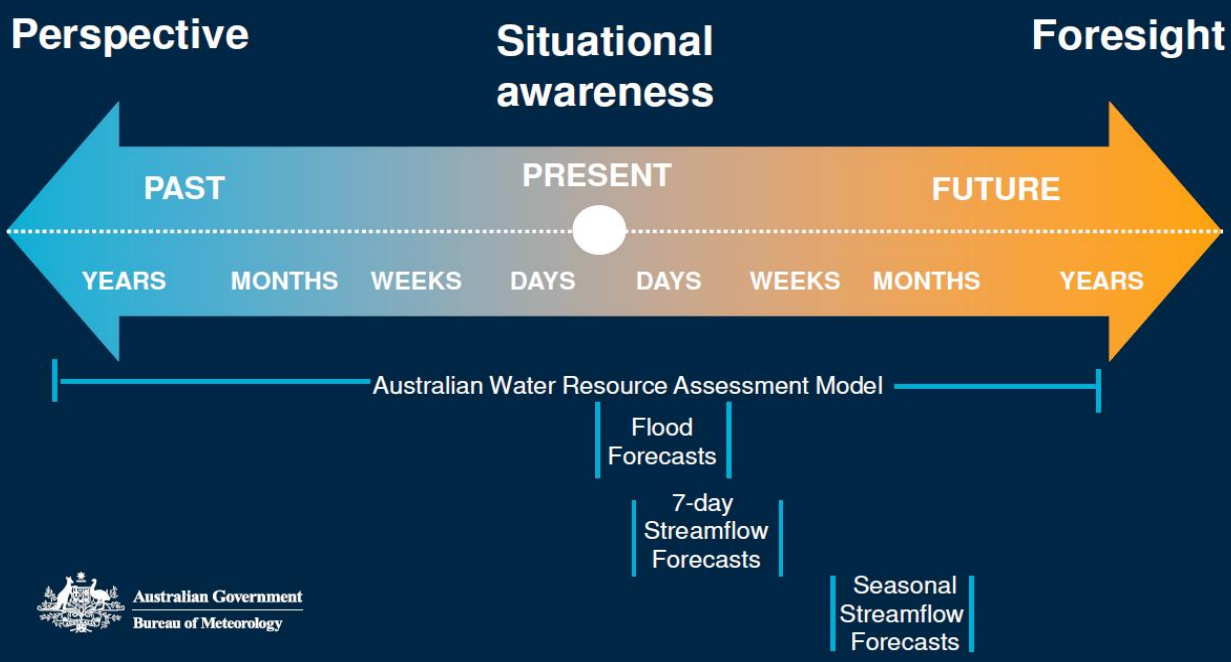
2016 Rainfall IFD Data System

River Water Balances

Hydrologic modelling capability
For re-analysis and forecasting



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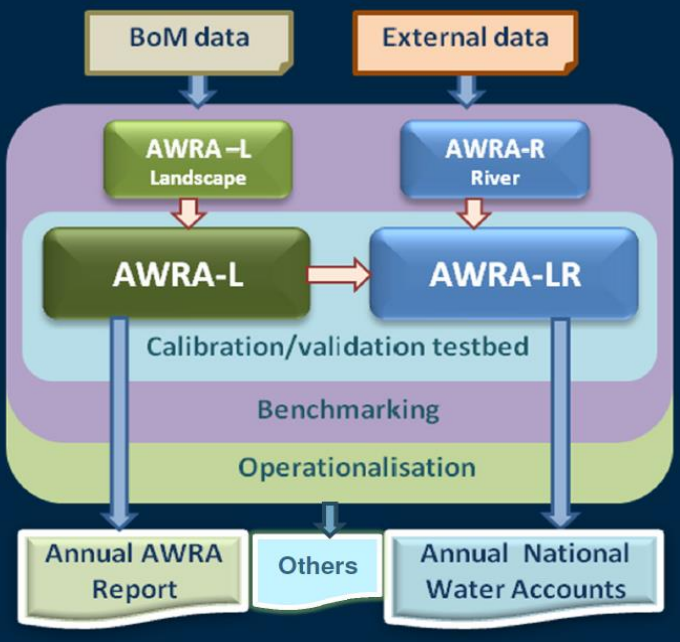
Overview AWRA-L, AWRA-R, AWRA-CMS

- Landscape
- River
- Calibration and validation
- Benchmarking
- Operational system
- Supports Bureau Products (such as NWA, Water Assessment suite, flood forecasting)
- Community Modelling System (CMS)



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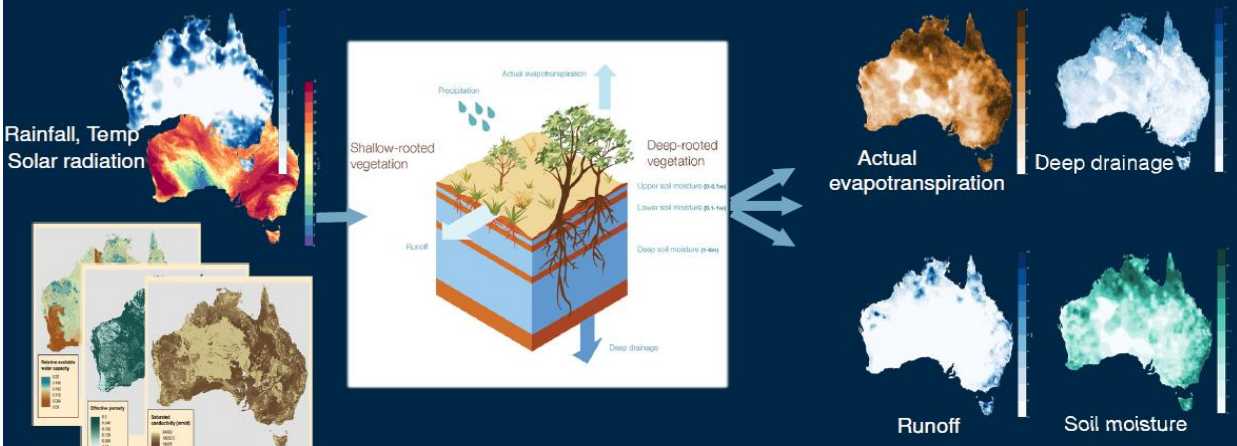
Operational continental landscape water balance model

AWRA-L: national, daily time-step, 5 km resolution

Inputs **Model analysis** **Outputs**



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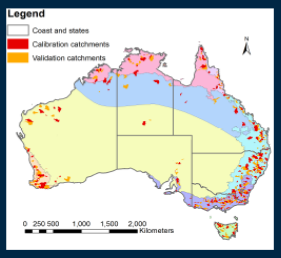
Calibration and Validation

Calibration: multi-objective optimisation to

(a) streamflow (295 small, unimpaired catchments, daily data),
(b) catchment averaged soil-moisture (satellite derived from ASCAT and AMSR-E)
(c) catchment evapotranspiration (satellite derived from CRMSET, 8 day)



Validation:

(a) streamflow (291 small, unimpaired catchments, daily data),
(b) volumetric point soil moisture (38+13 sites, calibrated reflectometers, Murrumbidgee+Hunter valley only, monthly data),
(c) grid averaged soil-moisture (satellite derived from ASCAT and AMSR-E)
(d) Point evapotranspiration (25 flux towers, daily)
(e) Gridded evapotranspiration (satellite derived from CRMSET, 8 day)
(f) Recharge, point, long-term mean (Crosbie et al.)

The AWRA-L model uses a global parameter set, calibrated simultaneously to the runoff, soil moisture and evapotranspiration across 295 calibration catchments.

It sacrifices local performance at individual gauges/catchments and for individual variables for the best possible performance Australia wide.

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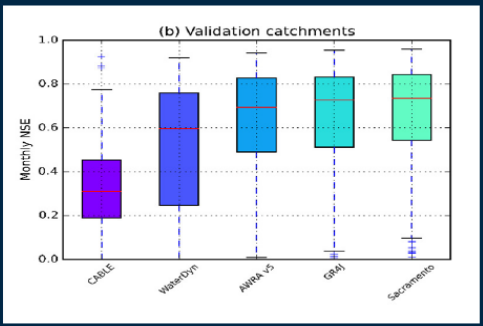
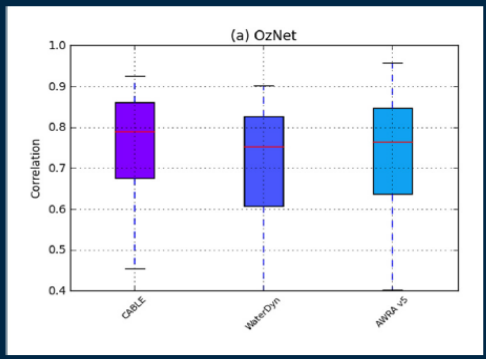
AWRA-L model performance,



Validation Streamflow,
Australia wide

Validation Soil moisture,
Murrumbidgee



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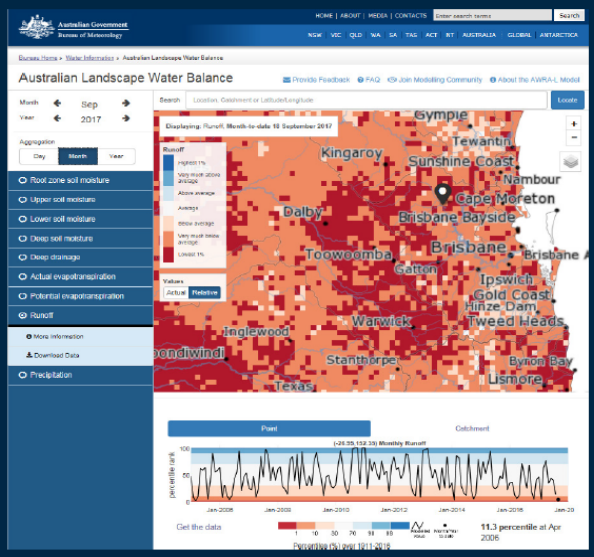
Australian Landscape Water Balance website

- A unique service!
- Updated daily
- See all variables at daily, monthly or annual time slices
- Download the grids at a resolution of 5km x 5km
- Past 10 years data available to all
- Registered users access >100 years and tailored products



http://www.bom.gov.au/water/landscape

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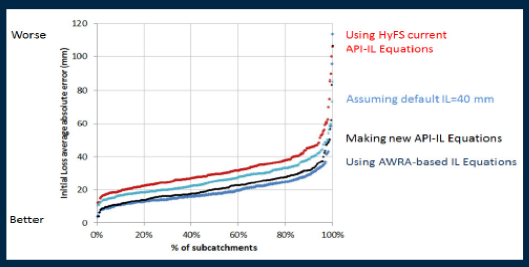
How is AWRA-L data used by our Customers?



Initial Loss estimation for Flood/runoff forecasting
- SEQWater
- BoM flood forecasting
- MDBA

Other data requested by water utilities
- Daily feeds of evapotranspiration and soil moisture over dam catchments
- Seasonal forecasting of evapotranspiration to forecast urban water demand
-Seasonal forecasting of soil moisture to forecast pipe cracking

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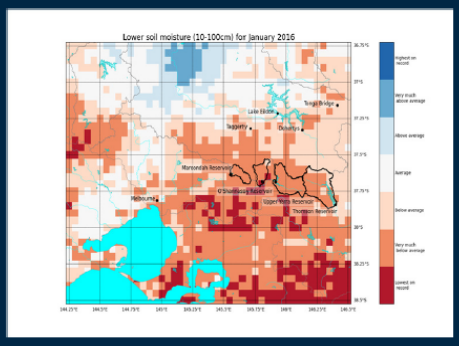
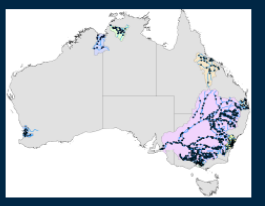


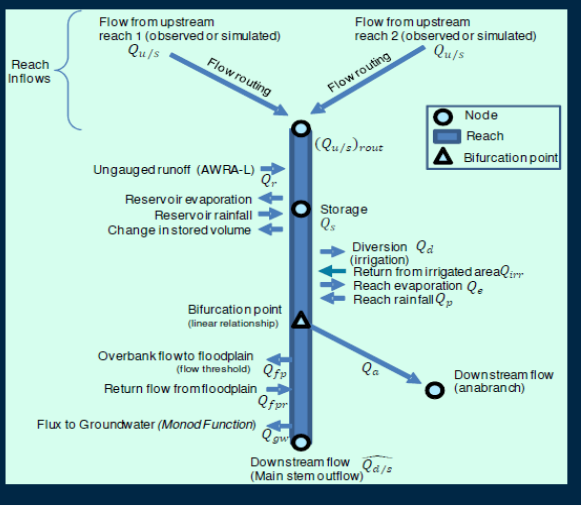
MDBA:
- Contextual data for RAS
- Initial loss data for runoff forecasting
- Contextual data for flow attenuation studies
- An SDL level water balance

Others who use AWRA data:
- ABARES, MDB, DPIs (states), EH & NR deps (states), consultants, researchers
- Inform irrigation planning, inform pastoral management, flood forecasting, water resource management

Australian Water Resources Assessment-River Model AWRA-R

- Catchment/Reach water balance model
- Developed to support the NWA and provide an estimate of all the fluxes affecting a catchment
- Runs for river basins on a node-link network: MDB, capital city regions, Ord, Daly and Burdekin
- Accounts for in-stream processes including river attenuation and delay, spilling on to floodplains, groundwater recharge and diversions and return flows (including transfers)
- Uses observations as far as possible and infills these with simulated data (e.g. AWRA-L for ungauged runoff) to best estimate the different fluxes affecting the reach





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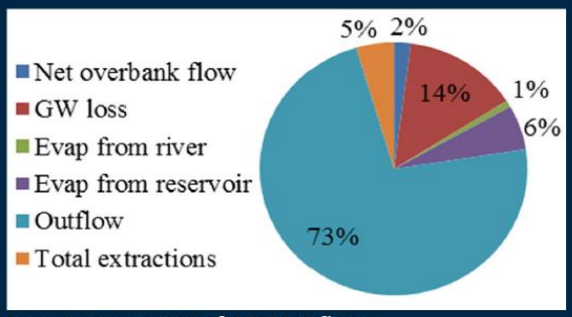
AWRA-R application SE Queensland

No. reaches	65
Median RE	0 %
Median daily/monthly NSE	0.68/92



Long-term average of AWRA-R fluxes

Change in unaccounted differences NWA (GL/year)

Region	2011	2012	2013	2014	2015	2016
Without*	226	1365	531	388	547	85
With*	100	211	279	26	575	82
SEQ	56 %	85 %	47 %	93 %	-5 %	3 %

**with and without AWRA-R estimated fluxes*

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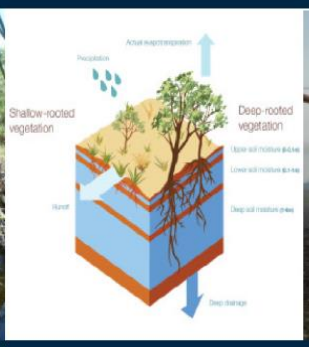
unaccounted for difference = closing storage + outflows - opening storage – inflows

AWRA Community Modelling System

- Guided by the CABLE, APSIM and other National Weather Program community development model approaches
- Make the model freely available for use and co-development by universities, CSIRO, agencies and consultancies

- Did you know the AWRA-L model is freely available for you to run locally (in the CMS)?
- Could potentially be improved by regional calibration over Canberra catchments with local input data

- https://github.com/awracms/awra_cms
- Free training course: Hobart, Wed Dec 6th (full, please register interest for future courses)



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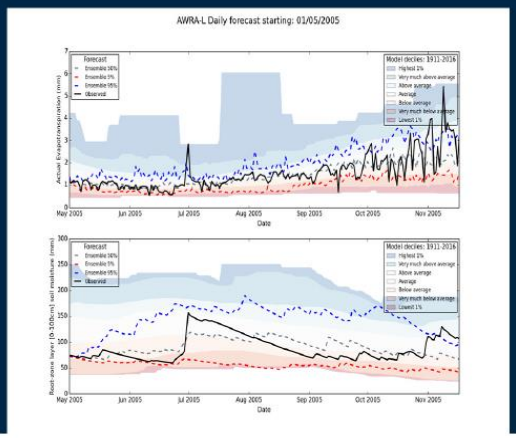
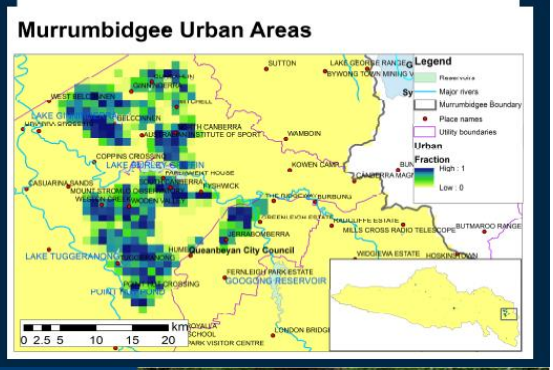
Coming Developments

- Operational evaporation products, gridded 5 km (Mortons areal and shallow lake, FAO56, synthetic pan, penman)
- Finescaling AWRA-L to 1 km and accounting for urban areas, irrigated areas and water bodies
- Farm dam interception in AWRA-L and R
- Forecasting and Seasonal forecasting with AWRA-L (soil moisture, evapotranspiration, runoff)
- Operationalisation of AWRA-R (i.e. updated daily to today's conditions), possibly forecasting
- Future Water Climate Service (projections of water to 2100)





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Thanks for your attention

Chantal Donnelly
Head of Water Resource Modelling Unit
Bureau of Meteorology
Chantal.donnelly@bom.gov.au
07 3239 8767

BoM are committed to working together with our customers, either through user engagement (like today) or partnering to accelerate product development. Please let us know what you would like to see available to support your work.

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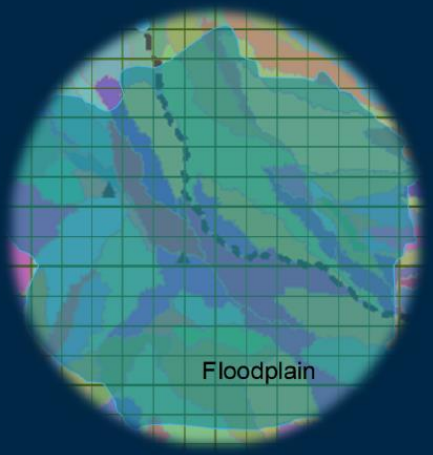
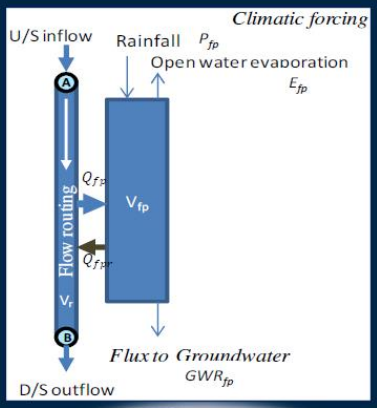
AWRA-R floodplain inundation model

Digital Elevation Model



Floodplain Concept



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*, 504:12-28.

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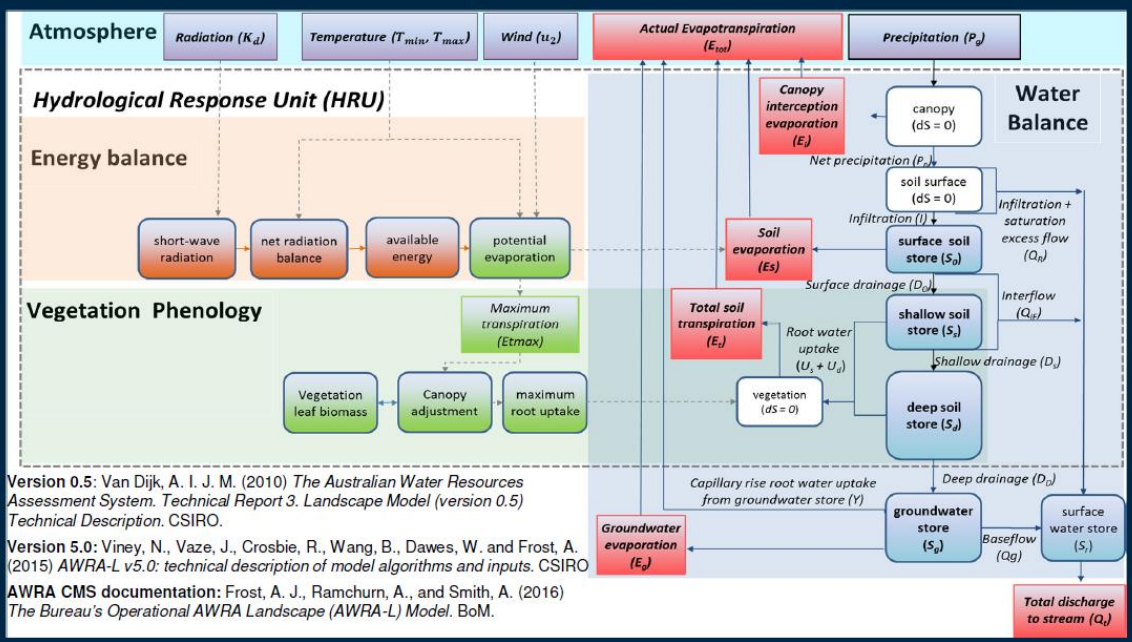
AWRA-L
Australian Water Resource Assessment Landscape model



Version 0.5: Van Dijk, A. I. J. M. (2010) *The Australian Water Resources Assessment System. Technical Report 3. Landscape Model (version 0.5) Technical Description.* CSIRO.

Version 5.0: Viney, N., Vaze, J., Crosbie, R., Wang, B., Dawes, W. and Frost, A. (2015) *AWRA-L v5.0: technical description of model algorithms and inputs.* CSIRO

AWRA CMS documentation: Frost, A. J., Ramchurn, A., and Smith, A. (2016) *The Bureau's Operational AWRA Landscape (AWRA-L) Model.* BoM.

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