OFFER OF SERVICES:

CRITICAL REVIEW OF CLIMATE CHANGE AND WATER MODELLING IN QUEENSLAND

January 2019

This offer of service has been prepared by Alluvium Consulting Australia Pty Ltd for the **Department of Environment and Science (DES)** in response to the request for quote titled **'Provision of critical review of climate change and water modelling in Queensland'**.

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Source of cover image: US Geological Survey, NASA. Image of Lake Amadeus, Northern Territory Australia

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1 Introduction

Alluvium Consulting Australia (Alluvium), in partnership with University of Newcastle and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), is very pleased to present this submission to the Department of Environment and Science (DES) to support Queensland in addressing the challenges of climate variability and climate change for water and catchment modelling and management.

We have gathered an experienced team of hydrologists, hydroclimate scientists, water quality scientists and practitioners to undertake a critical review of Queensland's current water modelling ability to incorporate climate variability and climate change projections.

Our value proposition for this project is two-fold:

- A project approach that is geared heavily around understanding the best available science and the context of the range of end-users who are incorporating climate change into hydrological modelling. This will ensure we will develop outputs of maximum utility and impact for the Queensland Government and the broader industry.
- A specialist project team that fulfil and exceed the selection criteria, by drawing together highly experienced staff from industry-leading organisations in water resources modelling, hydrology, climate change projection science, communication of complex technical information and project management.

This offer of services sets out our response to the Request for Quotation (RFQ) in the following sections:

- *Section 3* introduces our project team
- *Section 4* outlines our value proposition and responses to the selection criteria
- *Section 5* documents our appreciation of the project context and drivers
- *Section 6* details our proposed methodology
- *Section 7* provides further details on the project team structure and the team members
- *Section 8* describes the project delivery arrangements, including budget, time assigned to each team member, delivery schedule, project management and risk management
- *Section 9* lists a limited number of our team's past projects that are relevant to this RFQ
- *Section 10* provides a reference list for information cited in this offer.

2 Why this project is important

In the modelling realm, implications of climate change on water resources and water quality have been modelled and discussed in many forums, but the application of consistent approaches in water models has not been forthcoming. Australia has been at the forefront of understanding the science and impacts of climatic change and variability through a number of academic institutions and has had a strong involvement in the Intergovernmental Panel on Climate Change. Through this, Australia has developed a considerable body of science and knowledge, though the application of this in applied hydrology and water resources modelling has been largely through specific projects or through key experts, rather than an industry wide implementation.

What is therefore needed is the integration of this science and knowledge with a better understanding of the modelling contexts where climate change and variability needs to be evaluated. Through thorough recognition of the implications of the modelling contexts and the adaptation of the best available science, we can identify where the potential gains and opportunities for improvement may lie, and therefore provide a clear pathway to consistent, robust modelling approaches for assessing climate change in water modelling and evaluating adaptation options.

We believe that this project is a critical step in improving modelling practice in Queensland, and perhaps also leading the way in a national context, providing an opportunity for the science and modelling experts to discuss ways forward that can help build capacity in the water modelling realm, not only for modellers, but also end users of the modelling.

3 About our partners

3.1 Alluvium

Alluvium is a niche, employee-owned consulting company focused on the sustainable management of catchments, waterways and the communities that rely on them. With offices in Melbourne, Sydney, Canberra, Newcastle, Brisbane and Townsville, we employ more than 55 professional staff. We believe the application of creative thinking, applied economics, robust science and practical engineering can effectively address the complex and interrelated threats to our natural environment. Imagination, originality, and technical rigour form the building blocks of what we do.

We have always walked a path that is different. We are fiercely independent, and our people come together with a shared vision and determination to effect positive change. The value of our work is measured in our capacity to make a difference to the world we live in.

Alluvium is a national leader in catchment, river and water resources science, modelling, engineering and economics. We are known for our ability to deliver the full spectrum of natural resource management (NRM) and water resources related projects, from policy and strategy through to design and implementation. It is our on-ground experience which helps to inform our high level policy, planning and strategy work. Our people include national leaders in water modelling and we have a strong track record in developing, applying and improving water modelling in Queensland and across Australia. We regularly collaborate with key academic institutions and agencies, and are passionate about including and representing the best available science in all that we do.

For this project the Alluvium internal team includes:

- **Tony Weber** who is one of Australia's leading practitioners in the catchment modelling and water quality field.
- **Lisa Walpole** who has a decade of experience in the private and public sector undertaking water resource modelling, statistical analysis, project management, spatial analysis, stakeholder workshop facilitation, organisational change management and emergency response.
- **Danielle Udy*** who has five years' experience in catchment modelling, spatial analysis, hydroclimatology and the application of climate change projections to flow regime changes and economic impact assessments.
- **Andrew John*** who has experience in complex data analysis, hydrologic modelling and design flood estimation in regional and urban environments.

* Both Danielle and Andrew are undertaking PhD research in the areas of climate change, climate variability and hydrologic response and would provide inputs into this project that are based on their latest findings.

3.2 Centre for Water, Climate and Land (University of Newcastle)

The team will also be guided by **Associate Professor Anthony Kiem** - a hydroclimatologist in the Centre for Water, Climate and Land (CWCL) at the University of Newcastle - who will play a technical advisory and review role. Anthony's research focus is on understanding the drivers and impacts of climate variability and change in the Asia-Pacific region. Of particular interest are hydrological extremes and how these may change in the future. Other areas of expertise include: extreme event (e.g. flood, drought, bushfire etc.) risk analysis; water resources management; climate change impact, risk and vulnerability assessment; seasonal/interannual hydroclimatic forecasting; adaptation strategy, planning, monitoring and evaluation; hydrological modelling; stochastic modelling.

Anthony has also been involved in a wide range of consulting projects where insights into the impacts of climate variability and change are used to enable stakeholders from a range of public and private sector organisations to better assess their climate related risk and to develop more informed climate adaptation and mitigation strategies. See here for further details: https://www.newcastle.edu.au/profile/anthony-kiem#grants.

3.3 CSIRO

CSIRO are a recognised national and international leader in hydrological modelling and climate change science, and integrating climate and water science and modelling for applications in the water and related sectors. CSIRO contributes significantly to global forums and leadership in climate change impact assessment, resilience and vulnerability assessment, and risk-based adaptation. CSIRO, together with the Bureau of Meteorology, has been responsible for delivering national climate change projections in line with the global climate modelling in the Intergovernmental Panel on Climate Change reporting cycle. CSIRO are science leaders in landscape hydrology and integrated basin modelling, and has led major hydroclimate and hydrological modelling initiatives and water resources assessments in many key regions across Australia informing water resources management and planning.

The key CSIRO experts in this project are:

- Francis Chiew, who is a global expert in hydroclimate and hydrological modelling, and integrating climate and hydrological science for impact assessment and adaptation and application in the water resources and related sectors. Francis is a Lead Author of the IPCC AR5 and AR6 Assessment Reports. [Please see Section 7 for more detail].
- Michael Grose, who was a key leader in developing the latest climate change projections for Australia (2015), and who currently leads the Earth Systems and Climate Change Hub project doing targeted research and coordinating national effort to develop a consistent framework for developing the next generation climate change projections for Australia.
[Please see Section 7 for more detail].
- Jai Vaze, who has more than 20 years' research and industry experience in catchment processes, landscape hydrological modelling, river systems modelling, and floodplain modelling.
[Please see Section 7 for more detail].

CSIRO can also call upon its expertise across many disciplines, as required for this project.

4 Value proposition and response to selection criteria

As introduced earlier, our value proposition for this project revolves around two key themes:

- A project approach that is geared heavily around understanding the best available science and the context of the range of end-users who are incorporating climate change into numerical modelling. This will ensure we will develop outputs of maximum utility and impact for the Queensland Government and the broader industry.
- A specialist project team that fulfil and exceed the selection criteria, by drawing together key experts from academia and industry in water resources modelling, hydrology, climatology, communication of complex technical information and project management.

Our project team have been at the leading edge of water modelling in Queensland and Australia for more than 20 years and are involved in numerous projects where climate change and climate variability has been considered. We therefore believe we can provide a unique and locally relevant synthesis of how best to improve our assessments of climate change that is completely aligned with the Queensland modelling context.

4.1 Consideration of end-users that guides the approach

This is an important project for DES and the QWMN to improve the understanding of the strengths, weaknesses and critical gaps in the capacity of the Queensland modelling industry's ability to incorporate climate change and climate variability in existing and future modelling projects.

Arguably however, the project is even more important for the broader water resource industry, who will be the end users of the modelling outputs to examine the predicted on-ground changes and implications at local scales, for their particular areas of management interest. To be truly successful, this project therefore needs to give proactive consideration to who these end-users are, and what their needs are and will be into the future.

We have considered this in some detail in preparing this offer of services. Based on our contemplations of the RFQ we see a broad range of potential end-users. The table below lists some examples (that will be further developed through the review and stakeholder engagement) of these end-users and the potential impact from climate change.

Table 1. *Mapping end-user implications and climate change impacts*

	Industry sector	Potable water supply	Agricultural water use	Water quality	Waterway health	Flood risk	Infrastructure (stormwater/ wastewater)
Examples of potential Climate change driver	*Hydroclimate response*	Impact ☼ - low ☼☼ - moderate, ☼☼☼ - major					
Reduced rainfall, higher evap	Declining water availability	☼☼☼	☼☼☼	☼	☼☼		
Higher temps, higher evap	Increased demand (from higher temp and evap)	☼☼☼	☼☼☼		☼☼		☼☼☼
Increased rainfall extremes (intensity and frequency)	Increased runoff extremes				☼☼☼	☼☼☼	☼☼☼
Increased rainfall extremes (intensity and frequency)	Increased erosion and sediment transport			☼☼☼	☼☼☼	☼☼	☼☼
Reduced rainfall, higher evap	Changed stream low flow characteristics (duration, freq, vol)		☼☼	☼	☼☼☼		
Increased rainfall extremes (intensity and frequency	Changed high flow inundation and response		☼	☼	☼☼	☼☼☼	☼☼☼

4.2 Specialist project team

Our team has been tailored specifically for this project and responds directly to each of the selection criteria for this project as outlined in the RFQ. Details on this are provided below.

Criterion 1: Methodology

Brief overview of how we will address the key points – approach to project and synthesis of information gathered, engagement with key stakeholders, development of case studies

Our detailed methodology is included in the next section, however as a summary, our approach planned over 6 stages in accordance with the following diagram.

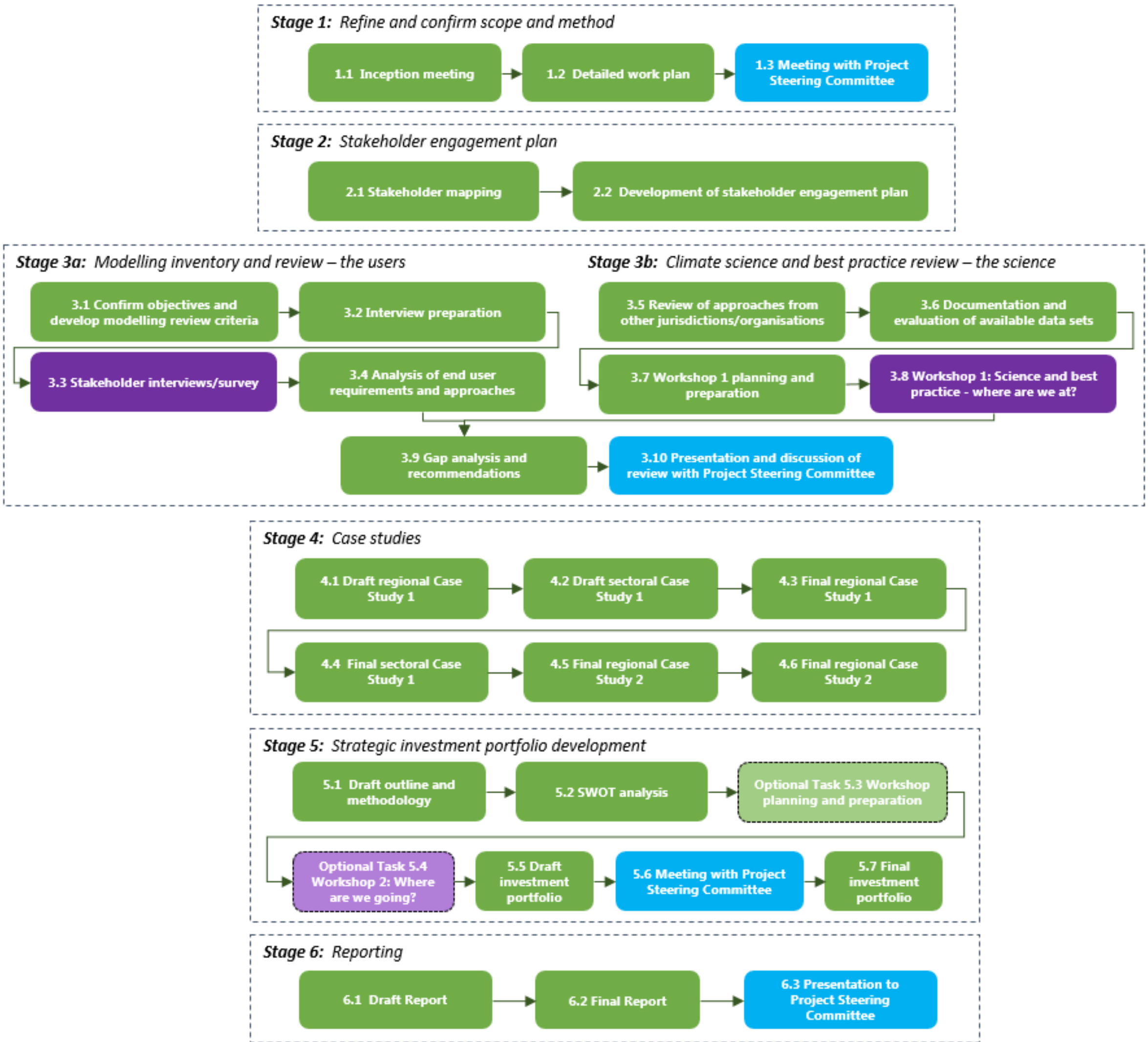

Figure 1. *Project framework*

Criterion 2: Demonstrated suitable experiences

Outlined below are a number of project highlights that indicate typical projects where climate change has been incorporated into hydrologic modelling.

Alluvium project highlights – Our project team members have completed a number of projects that have had to incorporate climate change impacts including:

- Assessing the impacts of changes in system yield in the Wivenhoe and Mid Brisbane catchments for Seqwater, in collaboration with University of Queensland
- Incorporating climate change within hydrologic and water quality models to assess impacts of future land use changes and infrastructure outcomes in the Moreton Bay Council region.
- Simulating and visualising changes in flow seasonality in the Dandenong Creek catchment on behalf of Melbourne Water
- Evaluating impacts of heatwaves under different climatic projections for the whole of Victoria
- Estimating changes in loads to Botany Bay under different climate and land use change scenarios.

University of Newcastle projects – Associate Professor Anthony Kiem leads the Centre for Water, Climate and Land at the University. Their key areas of research are across three interrelated Research Themes:

Water

- Physical and statistical/stochastic hydrological modelling
- Water resources management
- Water supply system modelling, including optimisation of long-term water resource infrastructure plans
- Water isotopes and tracers - water origin, age, and interaction with rocks, soils, sediment, contaminants
- Water-energy-food security

Climate

- Using instrumental data, pre-instrumental (palaeo) data, and climate models to establish what is "normal" and what is "extreme"
- Quantify current and future risk of climate extremes (e.g. flood, drought, bushfire, storms, cyclones, East Coast Lows etc.)
- Quantification and management of climate risks
- Seasonal/interannual climate forecasting and development of climate scenarios for decades into the future
- Climate communication and adaptation, including decision making under uncertainty
- Increasing climate resilience by understanding and managing the relationships between climate and human health (both physical and mental health)

Land

- Using climate insights to ensure sustainable and thriving agriculture
- Climate-smart agriculture
- Mine and disturbed landscape rehabilitation
- Sediment tracing and soil erosion modelling
- Carbon, nutrient and sediment dynamics in semi-arid catchments
- Changes to land use and land cover, and modelling/managing associated environmental impacts
- GIS and Remote Sensing

CSIRO project highlights – CSIRO staff (led by our project team members) have had a long engagement in the climate change and climate hydrology space, including leading a number of research programs in this space over the last 20 years.

Water Resources Assessment and Prediction projects related to hydroclimate and hydrological modelling projects and initiatives (all recent, ongoing or past three years) include:

- Earth System Climate Change Hub (in National Environmental Science Program)
- National NRM Climate Projections for Australia
- Victorian Water and Climate Initiative
- Northern Australia Water Resources Assessments
- Bioregional Assessment
- Geological and Bioregional Assessment
- WIRADA Water Information (water forecasting, landscape and river system modelling for water accounting, hydrological projections)
- CSIRO Groundwater characterisation and management
- CSIRO Water resources assessment, forecasting and prediction
- International (South Asia, Asia Pacific, Latin America) (climate change adaptation, drought management plan, integrated basin management)
- adaptation, drought management plan, integrated basin management).

Strength in water resources modelling and hydrological applications
Alluvium and the rest of our team have been heavily involved at the forefront of hydrologic understanding of waterways and wetlands across Australia, with access to some of the country's leading modellers, hydrologists, climatologists and ecohydrologists. Alluvium's work has involved developing detailed methodologies for examining flow impacts on waterway ecology, developing hydrologic indices to analyse streams and wetlands across the east coast of Australia, and ongoing work in developing hydrologic models for a range of catchments across Australia. Our team members have developed and applied water resource models, hydrologic models, water quality models and spreadsheet tools across Australia using a variety of platforms, including REALM, Source Rivers, Source Catchments, RORB, MUSIC and Rainfall-Runoff Library. Our team also includes expert modellers in catchment processes and water quality who have developed recent and relevant models for Queensland systems.

Breadth and depth of experience in the fields of water resources modelling, climate and hydrological science, and project management
We have sought out and created an exceptional team to deliver this important package of work. We have built a team combining leading hydrologists, climate scientists and water quality scientists. We have significant experience modelling catchment, water resource systems (refer above) and undertaking flood frequency analysis across both rural and urban catchments across Australia and internationally.

One of Alluvium's differentiators in the market-place is the frequency and depth of involvement with external partners for project delivery. We regularly bring in specialist sub-consultants onto our team, as we have a strong belief that no one company, agency or institution has all the knowledge or expertise. That also means our project managers are equipped to successfully manage large, multi-disciplinary projects from both within Alluvium and within our sub-contractor organisations. Our project manager, Tony Weber, has excellent project communication skills and a proven history in managing these kinds of projects

Innovative presentation and communication of complex climate and hydrological data
A recent example of Alluvium's work includes assessing the impact of heatwaves under climate change scenarios on the Victorian economy (a project for DELWP by Alluvium and its subsidiary Natural Capital Economics), which involved presenting the climate analysis of heatwaves and potential implications to key stakeholders.

Increasingly, there is a need to visualise the impact of climate change on system hydrology, for example showing the potential shift in monsoon timing in India using a change in mean-monthly flows (Figure 2) as well as changes to system function and the impact on future development.

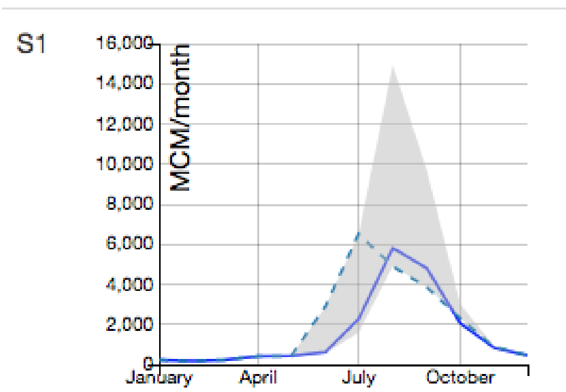

Figure 2. *Shift in monsoon timing in India demonstrated via change in mean monthly flow (example visualisation)*

Similarly, in Victoria, potential reduction in seasonal streamflows were important to visualise to understand implications for environmental flows as shown in Figure 2.

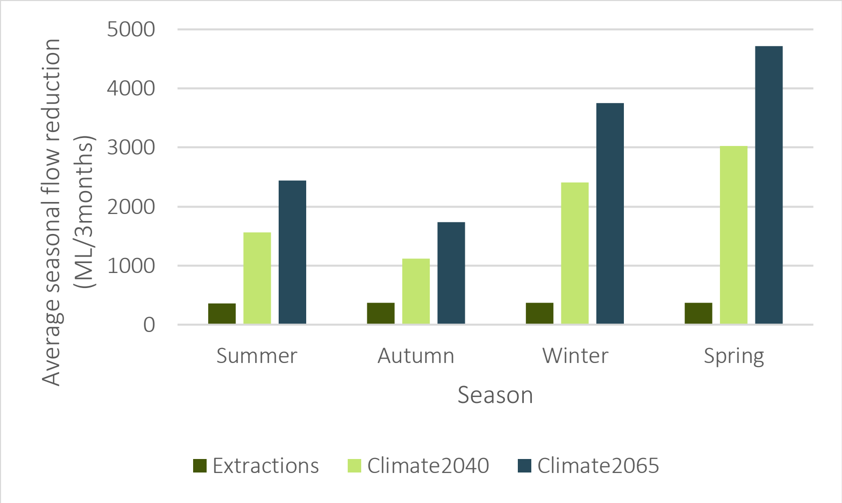

Figure 3. *Changes in seasonal streamflow*

5 Project appreciation

The purpose of the project is "To identify the critical gaps and weaknesses in the treatment of climate change in Queensland's current water quality and quantity models and recommend short and medium term research and development actions to deliver the required improvements".

A key priority action for the QWMN is to consider how climate change is currently incorporated in Queensland catchment and water models, and how this could be improved into the future. The climate information and modelling tools developed for Queensland's water models also needs to consider the pathway for communication, interpretation and utility of information – i.e. climate inputs – catchment models – receiving environment models (e.g. eReefs in GBR, HLW estuary/bay models in SEQ), as well as other end users external to state government (e.g. utility companies, local government, NRM groups).

Climate change is likely to have a number of impacts on natural, managed and human systems and with the scientific understanding of those impacts comes an increased ability to simulate impacts on those systems. In IPCC 2018, a number of "Reasons for Concern" were identified, all of which are strongly related to current modelling activities in Queensland. The following figure from that report provides a good understanding of where the impacts may be realised and this may help to frame the focal areas of model improvements.

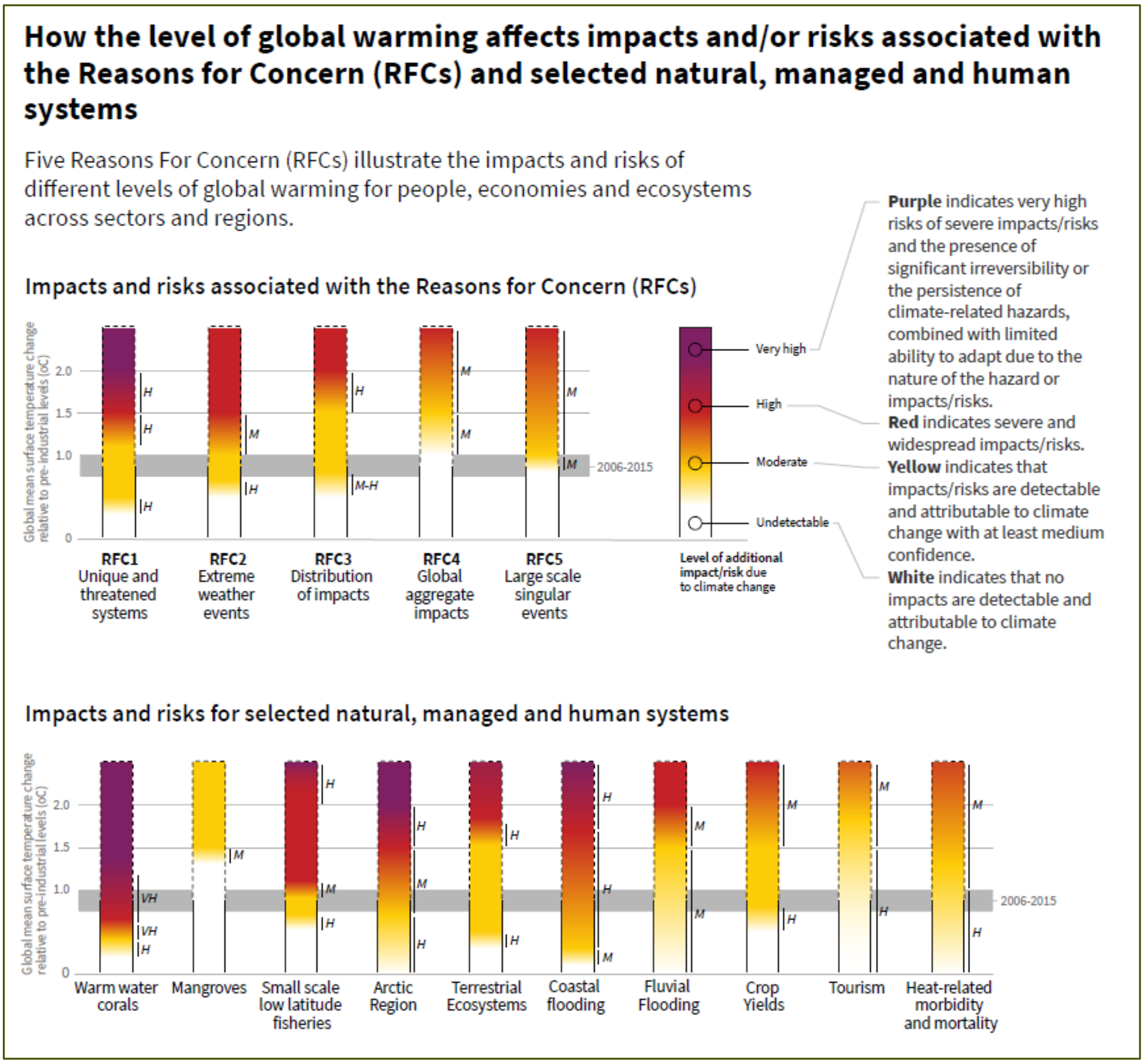

Figure 4. *Reasons for Concern associated with global warming of 1.5°C (IPCC 2018)*

Hydrological modelling is carried out for many different purposes and a key component of this project is to review and engage with modellers (through discussions and workshop) to synthesise the modelling approaches in Queensland and the consideration of climate change in these models. Typical applications of hydrologic models include:

- Water resource management (water security, system yield, system planning)
- Flood risk management
- Agricultural production and optimisation
- Water quality impacts
- Groundwater dependent systems
- Ecosystem health assessments (e.g. environmental flows, habitat protection)
- Urban planning (water supply, flood risk, water quality)
- Integrated Urban Water Management/Total Water Cycle Management
- Infrastructure assessment

With those typical applications are a range of stakeholders associated with framing the modelling problem, understanding and configuring the model platforms to answer the problems and the ability to resolve the problem using the outputs of modelling approaches. These stakeholders will have a corresponding range of understanding of the implications of climate change on model components and data sources. It will therefore be imperative that the project identifies both the stakeholders and their key modelling problems where climate change may have an influence, such that suitable approaches for incorporating the appropriate representation of climate impacts are used.

Figure 5 shows a schematic of components in climate change projection data sources and considerations for robust hydrological modelling applications. The project will adopt an integrative and consultative approach where leading hydroclimate and hydrological modelling experts and Queensland water modellers will engage to guide best practice climate change treatment in hydrological modelling to inform planning and adaptation in Queensland in the water and related sectors. Approaches adopted in other regions in Australia will also help provide guidance.

There are many climate change projection data sources (and even more will become available in the near future)[5,7,9,10,11,12,16] and practically all of them needs to be adapted (through empirical scaling, downscaling or bias correction) for realistic application in hydrological modelling[2,3,6,17,19,21,22] (see 'climate projection' in Figure 5). This project will summarise and present the data and methods, and through a workshop between hydroclimate experts and modelling practitioners and water managers, will synthesise and provide guidance on climate change treatment in the different types of hydrological modelling (a 'horses for courses' approach to complexity depending on climate change knowledge and hydrological modelling objectives).

An equally important consideration is whether existing models can be extrapolated to predict a future beyond the range of past observations, e.g. changed precipitation/hydrologic patterns, higher temperature and PET, and vegetation feedbacks under enhanced atmospheric carbon dioxide concentration[1,4,8,13,18,20,23] (see 'hydrological modelling under change' in Figure 5). Hydrological models may need to be adapted and conceptualised to account for these changes. This will also be reviewed and discussed in the project.

Ultimately, the key focus needs to be the purpose for climate change consideration in the water and hydrological modelling, e.g. why is there a need for climate change treatment, climate change in the context of other drivers (land use, development, policies, etc…) (see 'hydrological impact modelling' in Figure 5). This will guide the complexity of modelling required. For example, a decision scaling or sensitivity approach may be useful to assess catchment and water system resilience and adaptation options to changes in different climate characteristics prior to a detailed climate change impact assessment. For the nearer term (next 5-10 years), it is possible that the stochasticity/variability in plausible climate may dominate (paleaodata[14,15,24,25,26] can be useful here providing indication of variability over longer time scales). Climate change could dominate further into the future but there is still uncertainty that the likelihood of that is greater or less than the likelihood of other shifts in climate caused by something other than anthropogenic climate change such as long duration drought. This is why there is so much uncertainty in Global Climate Models, especially with respect to precipitation and other water-related variables.

The project will review the above, and engage with hydroclimate experts and practitioners through two workshops, to (i) synthesise and identify the critical gaps and weaknesses in the treatment of climate change in Queensland's current water quality and quantity models, (ii) provide guidance on "best practice" methods which can be adopted with existing projection data sources and hydrological models, and (iii) recommend short and medium term research and development actions to deliver improvement in climate change treatment in water modelling.

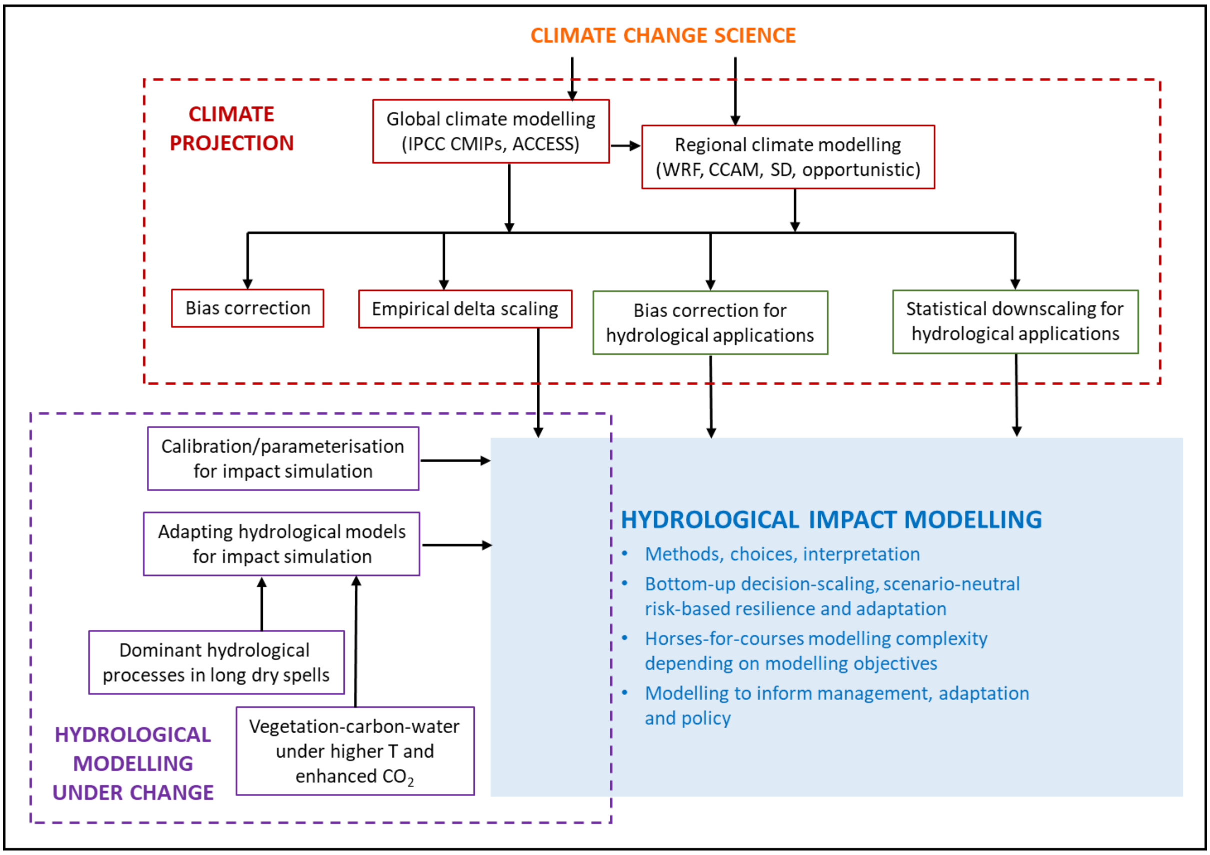

Figure 5. *Climate change projection data sources and consideration and approaches for robust hydrological modelling to guide management, adaptation and policy*

<u>Key references on climate change projection data sources and considerations and applications in hydrology and water modelling (most of the references are led by, or involve collaborations with, the project team)</u>

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[26]Tozer, C. R., Vance, T. R., Roberts, J. L., Kiem, A. S., Curran, M. a. J. & Moy, A. D. 2016. An ice core derived 1013-year catchment-scale annual rainfall reconstruction in subtropical eastern Australia. Hydrology and Earth System Sciences, 20, 1703-1717.

6 Method

We propose to undertake this project in six stages, building on the outputs and delivery timeline in the statement of work. The following describes each of the tasks in our six stages in detail.

Stage 1 Project inception

Objective/s	Agree on the project objectives and work plan for delivery and discuss any contractual matters
Outputs	Agreed work plan Inception meeting minutes
Inputs	Request for Quote Statement of Work Alluvium Offer of services
Resourcing	Tony Weber, Lisa Walpole, Anthony Kiem and Francis Chiew

Task 1.1 Inception meeting

We will initiate the project by meeting with DES to discuss the project in detail, specifically:

- our method, work plan and the key outputs and communication touch points
- key stakeholders and engagement strategy
- potential case study locations and models for Stage 4
- dates for workshops and other meetings as required

An important part of this task will be discussing our proposed approach, timeframes and structure of the project, to discuss and agree on any changes.

We will undertake the inception meeting at the DES offices.

Task 1.2 Detailed work plan and risk register

A detailed work plan based on the outline provided in this proposal will be developed incorporating any feedback provided. In particular, timelines will be adjusted to account for the project kick off date. In terms of risk registers, we commonly prepare these across all of our projects and have suitable templates and major risks identified (e.g. timeliness, access to data, stakeholder engagement, political sensitivity, staff changes, client satisfaction). We propose to develop the register collaboratively with DES and agree on rectification actions.

Task 1.3 Meeting with Project Steering Committee

The initial meeting with the Project Steering Committee will enable a shared understanding of the strategic direction of the project. The meeting will give the committee a chance to review and discuss the work plan and to contribute any other strategic considerations which may benefit the project.

Stage 2 Stakeholder engagement plan

Objective/s	Identify key stakeholders
Outputs	Stakeholder engagement plan
Inputs	Stakeholder lists from RFQ, inception meeting and Steering Committee meeting
Resourcing	Lisa Walpole, Tony Weber

It is understood that this project is to be a collaborative review process, facilitating the cooperation and contribution of a range of stakeholders who work within the modelling space or use the information produced by modellers to aid decision making. We will give considerable thought to who, when, why and how we engage with different organisations at the very beginning of the project to ensure best results. We wish to establish early in the project who all the stakeholders are, what their interests and concerns might be, how they will be involved and what information they hold that might be useful throughout the project. We have proposed several stakeholder engagement activities in this proposed methodology, including interviews and workshops, but would be happy to discuss alternative approaches with DES. We acknowledge the importance of building momentum and early relationships in encouraging collaboration and the acceptance and uptake of any recommendations emerging from the project.

Task 2.1 Stakeholder mapping

We will review and build on the QWMN model catalogue and contact list of selected stakeholders (e.g. CSIRO, universities, state government agencies, utilities, local government) to develop a broad assessment of potential model developers, modellers and end-users from across the Queensland water modelling realm. We understand that these stakeholders will likely cover many modelling aspects, including numerical assessments, policy development, managerial and review roles, and it will be important to ensure we have reasonable representation from as many areas as possible. We will also explore who are the “key players” in this space so that their knowledge and input can be used in the most influential ways.

Task 2.2 Development of a stakeholder engagement plan

Using the outcomes of the inception meeting, meeting with the Project Steering Committee and the stakeholder mapping in Task 2.1, we will outline who, when, why and how given organisations will be involved, based on the IAP2 public participation framework (see Figure 6). Where possible, the strategy will be prepared to closely align with other engagement processes conducted by DES and the QWMN.

INCREASING IMPACT ON THE DECISION

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

Figure 6 *IAP2 public participation framework (IAP2 2014)*

Stage 3a Modelling inventory and review - the users

Objective/s	To identify and document models and modellers actively engaged in climate hydrologic modelling and/or with interests in modelling climate change
Outputs	Analysis of end user requirements
Inputs	Stakeholder engagement plan, project team knowledge
Resourcing	Lisa Walpole, Tony Weber, Danielle Udy, Andrew John

Task 3.1 Confirm review objectives and develop modelling evaluation criteria

The review objectives as outlined in the project scope are:

- Assess whether the models are fit for purpose in the short term and medium term
- Identify investment opportunities to drive future strategic improvement in the modelling of scenarios and responses.
- Identify potentially relevant current, new and emerging modelling approaches worthy of consideration in future climate proofing actions.
- Documentation of major relevant parameters

The objectives of the review as outlined in the project scope will be clarified and confirmed through consultation with the project steering committee. The clarification of objectives will assist in the development of specific modelling evaluation criteria to elucidate the critical gaps and weaknesses in the treatment of climate change in current water quality and quantity models.

Task 3.2 Interview preparation

In accordance with the established modelling evaluation criteria, interviews will be prepared for the stakeholders identified in the stakeholder engagement plan. At a minimum the interview questions will cover the key requirements as outlined in the RFQ:

- the models/software
- need for climate change analysis (if any)

- current climate change approach (if any)
- climatic inputs required to drive models (e.g. rainfall, evaporation, temperature, water quality, daily, monthly, intensities, averages, at-point, grid based, etc.).

Task 3.3 Stakeholder interviews/survey

The stakeholder interviews will be conducted within one month of project inception. Interviewees will be contacted personally by phone at a scheduled time to ensure there is sufficient time to draw out the necessary information.

Task 3.4 Analysis of end user requirements

The data collected will be analysed using the established evaluation criteria. The findings will be tabulated to provide a clear understanding of how end user requirements are or are not being met and how these needs can be strategically met.

Stage 3b: Climate Science and best practice review – the science

Objective/s	To bring together experts, users and stakeholders to outline the latest science and best practice in climate change and hydrologic modelling
Outputs	A synthesis of science and modelling approaches for incorporating climate change and a gap analysis of where improvements may be required
Inputs	Stakeholder engagement plan, Modelling inventory and review
Resourcing	All project team members

Task 3.5 Review and documentation of approaches from other jurisdictions/organisations

Our collaborative approach draws together leading practitioners, organisations and their networks across the national and international water and climate modelling space. This pool of information will be utilised to draw out and document the most useful and relevant water and climate modelling approaches from other jurisdictions and organisations. These approaches will also be evaluated against the set criteria to provide perspective on how modelling in QLD compares with the broader scientific community.

Task 3.6 Documentation and evaluation of available data sets

All available climate datasets currently utilised by QLD water/climate models will be documented and evaluated against best practice standards.

Task 3.7 Workshop planning and preparation

Careful design and consideration of desired workshop outcomes and audience requires a significant investment of time to ensure success. The effort invested into alignment of the objectives, methods and outcomes is a key success factor in workshop success.

As part of the workshop design we would like to discuss with DES, either at the inception meeting or at a later date, the following:

- the purpose and desired outcomes, including defining the measure of success
- prioritisation of the objectives of DES and other stakeholders
- confirm the audience, their views and key motivating factors
- facilitation techniques, and workshop design and approaches including roles and responsibilities
- the roles DES project team members wish to play in the workshop (e.g. active participants, observers, facilitation support for group processes?)
- participant management, workshop venue, room layout, equipment and material needs.

We always tailor the workshop to the target audience and to meet the specific needs of the client's objectives, but regardless of the engagement approach, our behaviours and actions are underpinned by some basic elements. These basic elements include:

Context clarity: We always work through the background of the project and why the client has initiated it. We seek consensus in understanding the needs and reasons to help justify participants investment of time.

Relationship to the issues: We seek understanding that there are different views and perspectives on issues and that they may not align initially. It is important for us to set the need for a collaborative process at the start. We will focus on promoting issues-based negotiation of enduring solutions. To this end, we will include a step to identify all the key issues for all parties, and cross check later that issues have been effectively addressed.

Boundaries: We make it clear what is on the table for discussion, what is negotiable and what is not. Too often facilitators don't make it clear what is not up for negotiation and ultimately leaves stakeholders feeling frustrated when they don't appear to get traction on an issue.

Restraint: We understand our role is not to provide technical advice, lecture or take over conversations, but to thoughtfully guide dialogue to ensure objectives are met, ensure timely and effective discussions and deliberations, and to ensure the voices of all participants are heard equally.

We will use a range of workshop processes in a fit for purpose way. We are experienced in managing the following workshop processes:

Plenary style sessions with panel discussions – We use this technique when we wish to share information and ensuring all participants are on the same page and / or have the opportunity to openly discuss any conflicting views or concepts. We are also experienced in capturing issues/feedback interactively during these discussions and creating group alignment and agreement on key issues.

Table based group dialogue and discussion – this technique allows for comprehensive dialogue between a small number of stakeholders and may suit conversations with regards to a very specific topic or objective. We commonly use this where a large number of themes or issues need to be discussed quickly and efficiently and/or where participants wish to focus their time and input on a specific topic.

Break out focus groups and sub-task discussion – breakout sessions allow for multiple streams and lines of enquiry at the same time.

Review and reflection on progress – reflection is an essential facilitation technique used to ensure the workshop is on track to deliver the desired and agreed objectives, provides an opportunity to assess engagement levels of participants, and enables any changes to the agenda to be made in a collaborative, iterative manner.

We intend to develop a pre-workshop discussion paper to prime the audience. The discussion paper is not meant to be a detailed report but will be a concise overview of the issues and provides the reader with the objectives of the project and poses a number of questions to generate some low level tension and to get people thinking. The discussion paper will help to create the right mind space to talk about issues. The discussion paper will specifically prompt participants to consider issues around the incorporation of climate change influences into hydrologic and water system models.

At the conclusion of the workshop, we will document the outcomes and combine that with other data we have collected. We are very happy to talk to DES in more detail to understand the expectations of the review workshops and to adjust our method as needed.

Task 3.8 Workshop: Science and best practice - where are we at?

Outcomes from the review tasks 3a and 3b will be compiled in preparation for the Workshop. Key representatives from the major modelling groups within the Queensland government will form the bulk of the attendees at the workshop, which will also host members of our consortium. Our members will facilitate collaborative discussion, where workshop attendees will have the opportunity to expand upon the review and to identify knowledge gaps and strategic improvements. Our project team members includes those who have attended other QWMN workshops and are familiar with the structure and typical audience involved in these.

We have assumed that a suitable workshop venue and catering will be provided by DES/QWMN.

Task 3.9 Gap analysis and recommendations

Key data and modelling gaps/weaknesses, limitations and assumptions and strategic improvements identified through the part of the workshop and review process will be analysed to inform the development of recommendations for DES. These key recommendations/actions will be identified for delivery over 2, 5 and 10 year timelines for DES and critical partners. This would also form part of the inputs for Stage 5.

Task 3.10 Presentation and discussion of review with Project Steering Committee

At the end of each stage, Alluvium will present interim products for discussion with the Steering Committee in person or via teleconferencing depending on what is more convenient for both parties. The draft final documents/findings will be presented for review prior to the final presentation. The final review will be presented by Alluvium in a meeting with the Steering Committee and the wider stakeholder group.

Stage 4 Case Studies

Objective/s	Evaluate existing approaches for accounting for climate change and outline how models could be improved
Outputs	Recommendations for model improvements and strategic investment
Inputs	Case study models, reports and discussions with model developers and users
Resourcing	All project team members

General approach

Our proposed approach to Stage 4 will be to review modelling approaches in two key geospatial regions and two industries/sectors, including within the Great Barrier Reef region. Our general approach is consistent with a model audit and review process, rather than a rebuild or rerunning of the model. We intend to review each model in terms of several key model process steps, as indicated in the illustration below (Figure 7). Each of these tasks is described in detail below.

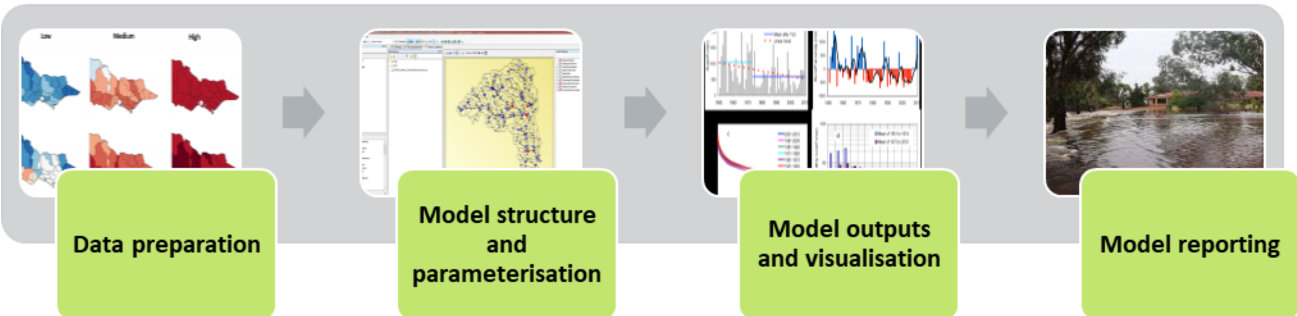

Figure 7. *Four tasks involved in each of the Stage 4 case studies*

Approach to case study selection

An important element underpinning the implementation of these four tasks is the appropriate selection of case study locations. When considering potential case studies for inclusion in this project, we propose the following selection criteria are applied:

- *Modelling platform*
  Our team has experience in the development and application of hydrological models using Source Catchments, Source Rivers, IQQM, REALM, eWater MUSIC, Rainfall Runoff Library (RRL), URBS, RORB, as well as in-house spreadsheet tools. There are advantages and disadvantages to using a consistent

platform across multiple geographical locations or demonstrating application using a variety of approaches.

- *Team experience in specific system model development and application*
  While our team has experience in the use of the platforms described above, there are certain models and regions for which we have intimate knowledge and recent experience, including in model development and application. The selection of these models will reduce the time required to get 'up to speed' with the nuances of specific models and the risks of encountering challenges such as model versions and additional processing, but we also realise that these models may or may not be suitably representative.

- *Relevance for meeting project objectives*
  As has been highlighted previously, success in this project is contingent not just on fulfilling DES needs but also those of a range of end-users. The case studies selected will therefore need to be relevant to the needs of DES and key end-users.

Recommended case studies
Based on the considerations above, we will develop a list of suitable case studies for use in this stage of the project to be discussed with DES and the project steering group.

Case study tasks
The four tasks to be applied to each of the selected case study locations are described below.

Task 4.1 Data preparation review
The first task within this stage will be to evaluate the climate and streamflow data used in developing the model to understand the basis of the climatic inputs and how these may have been perturbed to account for climate change influences. We will also evaluate the processes used to develop climate data replicates or other representations of past, current and future climates and how this compares to the latest science and best practice in this area. This is a critical component of this project, as there are a number of "standardised" approaches to perturbing existing climate sequences to represent altered climate patterns and each have benefits and constraints in terms of how they impact modelling structure and outputs.

Depending on the model requirements, this may include rainfall, evaporation and/or streamflow data. For Water Resource models, any streamflow inputs that are developed externally using rainfall runoff models will also be evaluated for suitability. For Source Catchments and rainfall-runoff models, only the climate data inputs will need to be prepared for each of the climate change scenarios.

Task 4.2 Model structure and parameterisation assessment
In this task we will examine the chosen models within the case studies to assess their ability to represent climate change responses. It is likely that most models have a static structure to represent different climatic periods, though we know that the hydrologic responses due soil moisture changes, hydrophobicity, cover changes etc are likely to significantly alter under different climatic regimes.

We will review the model structures to evaluate how they may be best adapted or improved for climate change assessments and whether other component models (e.g. for hydrology, cover etc) may be suitable as supplementary or replacement models. The intent is to assess what is currently used and identify improvements, not to point out flaws or errors, though obviously if these are identified we will discuss them with DES. In identifying potential improvements, we will also document advantages and disadvantages of these as we realise that any change in structure and parameterisation will have other implications for consistency and legacy models.

Task 4.3 Model outputs and visualisation critique
Representations of climate change outputs from models often suffer from a lack of suitable presentation of the variability and/or certainty of the results, especially where there are multiple replicates or equally plausible results from multiple scenarios. We will evaluate outputs from existing models and use outputs from the workshop to compare them against best practice approaches and how the case study models may be modified

or output reassessed to better indicate climate change characteristics. We will also use our experience in presenting these in other jurisdictions across Australia and overseas to highlight a range of potential result visualisations that can best inform users of the “story” that the model outputs are indicating.

Task 4.4 Model reporting evaluation

While similar to the previous task, model outputs are typically incorporated into detailed reports. We will evaluate the reports from the case studies to identify how climate change could be represented (if it isn’t already) or to examine how the reporting may be improved in comparison to other climate change model reports and modelling best practice. This again is not intended to be a detailed critique of the reports, but an evaluation of improvements and methods for reporting that are able to best represent climate change in hydroclimate, hydrologic and water resource assessments.

Stage 5 Strategic investment portfolio development

Objective/s	To compile the outputs of the previous tasks that identify key tasks or projects for improving the assessment of climate change in water modelling
Outputs	A strategic investment plan for improving climate change assessments in hydrologic and water resource modelling in Queensland
Inputs	All previous tasks, but specifically Task 3.9
Resourcing	All project team members

Task 5.1 Draft investment outline and methodology

As the project progresses, it is highly likely that key gaps and improvements will be identified early in the project. In this task we will document those and also a proposed method for evaluating priorities and resource requirements that may be needed. The intent is to develop a “strawman” early in the project (so this task is not necessarily sequential to the others), and build on this as the project progresses.

Task 5.2 SWOT analysis

SWOT (Strengths, Weaknesses, Opportunities and Threats) is used to analyse a situation or issue and provides a consistent framework to work through a number of issues or activities that may need to be prioritised or evaluated in a qualitative sense. A SWOT analysis creates a picture of the environment in which the activities may apply and provides an opportunity to discuss and compare strengths and weaknesses and see whether these may be opportunities or threats, and also whether the weaknesses or threats can be turned into strengths or opportunities.

We will use this process to evaluate the gaps and use this to develop the best investment pathways to address them.

Optional - Task 5.3 Workshop planning and preparation and Optional - Task 5.4 Stakeholder workshop

Initially we were considering a second workshop to consider and discuss the identified gaps and provide opportunities to socialise these and suggest ways of either integrating these with existing initiatives or setting frameworks for future initiatives. Our involvement in existing QWMN activities such as the EEP may already provide these opportunities and hence a second workshop may not be required, but we still believe that there may be value in having a platform in which the gaps and suggested investment pathways can be debated before they are finalized.

If a second workshop is desired, it would require both a planning and preparation task and a delivery task, plus synthesis of the workshop outcomes. This would be of a similar nature to the initial Science and Modelling workshop.

Task 5.5 Draft investment portfolio

The outcomes of these tasks will help develop the draft investment portfolio with recommended actions over a number of timeframes and modelling areas. Obviously this will develop as the project progresses and may not necessarily be solely constrained to a specific point in the timeframe (i.e. it may develop from an initial "strawman" iteratively over the project) but will be finalised in this task.

Task 5.6 Meeting with Project Steering Committee

The investment portfolio will be presented to the project steering committee for consideration. This may be either face to face or by teleconference, whatever is the most efficient process.

Task 5.7 Final investment portfolio

Once comments are received from the steering committee, these will be incorporated into a final portfolio ready for inclusion in the project report.

Stage 6 Reporting

Objective/s	Describe the process and outcomes of the project
Outputs	Draft report Final report Presentation
Inputs	Outputs from Stages 1-5
Resourcing	All project team members.

Task 6.1 Draft report

We will produce a complete draft report for DES to review. Alluvium requests that one set of consolidated comments is provided on behalf of DES and any other stakeholders. We assume that these will be provided within approximately 2 weeks of submission of the draft report. Alluvium will discuss with DES the preferred report format and the intended audience to ensure that the language and level of technical detail meets DES expectations.

Task 6.2 Final report

A final report will be prepared incorporating comments provided by DES.

Task 6.3 Presentation to Project Steering Committee

The project outcomes and deliverables will be summarised and presented to the project steering committee. It may be better to deliver this as part of the draft reporting stage as this may assist in providing the committee with an informed project understanding to help with providing more incisive comments and suggestions.

7 Team structure and overview

We have structured our team as illustrated in Figure 8.

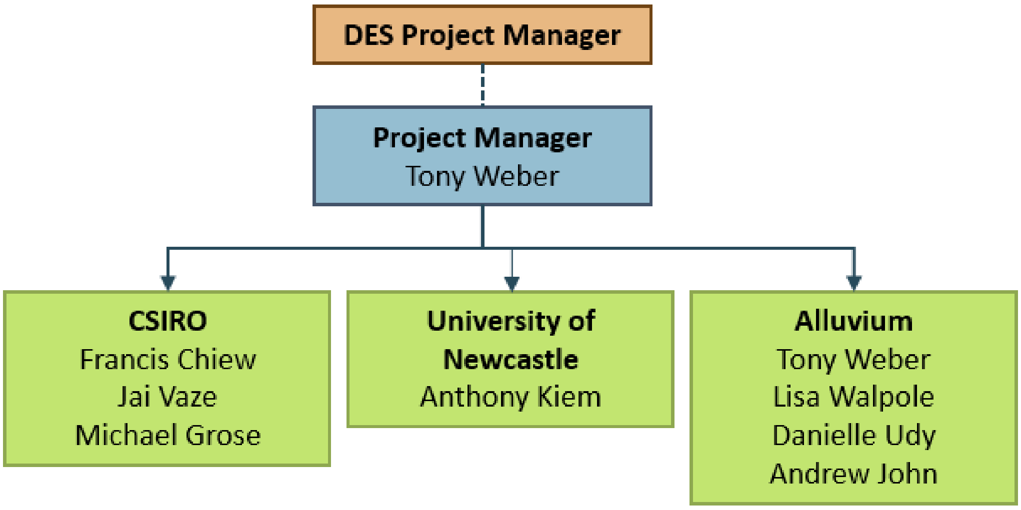

Figure 8. *Team structure*

A brief description of our project team members is provided below, with detailed CVs provided as an attachment to this offer of services.

Tony Weber *Project Manager*	Tony is one of Australia's leading practitioners in the catchment modelling and water quality field. He has over 30 years' experience in the water industry delivering a range of catchment modelling, water sensitive urban design, integrated water management, water quality and stormwater management projects. He was also a member of the MUSIC urban stormwater model development team and is a leading proponent of the Source modelling framework in Australia and internationally.
Lisa Walpole	Lisa has a decade of experience in the private and public sector undertaking water resource modelling, statistical analysis, project management, spatial analysis, stakeholder workshop facilitation, organisational change management and emergency response. Lisa has developed and applied catchment and water quality models across Australia to determine priority management issues and multi-disciplinary actions. Lisa is currently completing a Master of Integrated Water Management with the International Water Centre which seeks to balance the environmental, social and economic aspects of water resource management. Lisa will be undertaking her Masters thesis project in 2019, evaluating the consideration of climate change and climate variability in strategic and operational response to threats to the Great Barrier Reef.
Danielle Udy	Danielle has five years' experience in catchment modelling, spatial analysis, hydroclimatology and the application of climate change projections to flow regime changes and economic impact assessments. She has played a key role in a range of climate and hydrology projects under current and future climate conditions, involving vulnerability assessments of Victorian economy to heatwaves, strategic and model reviews of water policy and infrastructure in the Hunter region and identifying climate refuge areas across the Murray Darling Basin under future climate change scenarios. Danielle has also been involved in streamflow analysis (seasonal to decadal variability) and developed multiple catchment models across Australia to assess the impact of future climate change on streamflow.

	Danielle is currently undertaking a PhD at the University of Tasmania/University of Newcastle to improve understanding of Eastern Australia's hydroclimate risk to water resource sector through the analysis of high resolution Antarctic ice cores and atmospheric circulation patterns.
Andrew John	Andrew completed a Master of Engineering (Environmental) at the University of Melbourne in 2016 specialising in waterway engineering and hydrology, where his research looked at hydrologic resilience and recovery after the severe Millennium Drought (1997-2009) in south-east Australia. Andrew has experience in private and public sector roles as an engineering hydrologist and consultant. His PhD research contributes to understanding the vulnerability of Australia's environmental water outcomes in the face of natural variability and a changing climate, with a specific focus on consideration of non-stationarity in future rainfall regimes and in environmental and ecological response, and how different levels of complexity interact in informing our understanding of climate change impact. Environmental water represents a multi-billion dollar investment by the state and federal government in promoting significant environmental objectives with intertwined economic, social and cultural considerations.
Anthony Kiem	Anthony is an associate professor of hydroclimatology at the University of Newcastle. His research focus is on understanding the drivers and impacts of climate variability and change in the Asia-Pacific region. Of particular interest are hydrological extremes and how these may change in the future. Anthony has been involved in a wide range of consulting projects where insights into the impacts of climate variability and change are used to enable stakeholders from a range of public and private sector organisations to better assess their climate related risk and to develop more informed climate adaptation and mitigation strategies.
Francis Chiew	Francis has more than 25 years' experience in research, teaching and consulting in hydroclimate and water resources, and in research and project management. Francis is a CSIRO Science Leader and currently leads a group of about 30 hydrologists working on water resources assessment, forecasting and prediction, climate change adaptation and integrated basin management. Francis and his team are active in converting research outcomes into modelling tools and guidelines for the water industry, and engage and partner widely with the industry to guide water resources planning and adaptation in Australia and overseas. Francis' research is published widely (more than 11,000 citations and h-index of 56), he is a member of several global and national water expert committees, and is a lead author of the IPCC AR5 and AR6 Assessment Reports.
Michael Grose	Michael is a research scientist whose work focusses on climate change processes, understanding climate changes we have seen to date, and how we can produce future climate projections that are useful for a range of stakeholders. Michael was a key leader in developing the latest climate change projections for Australia (completed in 2015). Michael currently leads the Earth Systems and Climate Change Hub project doing targeted research and coordinating national effort to develop a consistent framework for developing the next generation climate change projections for Australia.
Jai Vaze	Dr Vaze is an internationally recognised hydrologist developing methods to estimate runoff in ungauged catchments and studying the impacts of land use and climate change on catchment, regional and continental scale water balance and floodplain inundation modelling. He is currently a Research Team Leader within Land and Water Business unit. He also leads two major externally funded projects, Australian Water Resource Assessment (AWRA) and MDBA floodplain inundation modelling to support Basin Plan. He collaborates widely with leading scientists from Australian Universities and State Government Departments, and from France, UK, USA, Ireland, South Africa, China, Nepal, and India. He has worked (and continues to work) on and led many high

	impact projects that contribute to key national initiatives including the CSIRO Sustainable Yields projects, the AWRA project, the MDBA floodplain inundation modelling project, the eWater Source, SEACI, the Bioregional Assessments project and the Northern Australian Water Resources Assessment project.

8 Project delivery arrangements

8.1 Delivery

A Gantt chart outlining our proposed delivery schedule (Figure 9) plans out final project completion by the June 2019.

		Week ending																										
		01-Feb	08-Feb	15-Feb	22-Feb	01-Mar	08-Mar	15-Mar	22-Mar	29-Mar	05-Apr	12-Apr	19-Apr	26-Apr	03-May	10-May	17-May	24-May	31-May	07-Jun	14-Jun	21-Jun	28-Jun	05-Jul	12-Jul	19-Jul	26-Jul	02-Aug
Stage 1	**Project inception**																											
1.1	Inception meeting																											
1.2	Detailed work plan and risk register																											
1.3	Meeting with Project Steering Committee																											
Stage 2	**Stakeholder engagement plan**																											
2.1	Stakeholder mapping																											
2.2	Development of stakeholder engagement plan																											
Stage 3a	**Modelling inventory and review - the users**																											
3.1	Confirm objectives and develop modelling review criteria																											
3.2	Interview preparation																											
3.3	Stakeholder interviews/survey																											
3.4	Analysis of end user requirements and approaches																											
Stage 3b	**Climate science and best practice review - the science**																											
3.5	Review of approaches from other jurisdictions/organisations																											
3.6	Documentation and evaluation of available data sets																											
3.7	Workshop 1 planning and preparation																											
3.8	Workshop 1 - where is the science at?																											
3.9	Gap analysis and recommendations																											

3.10	Presentation and discussion of review with Project Steering Committee
Stage 4	**Case studies**
4.1	Draft regional case study 1
4.2	Draft sectoral case study 1
4.3	Final regional case study 1
4.4	Final sectoral case study 1
4.5	Final regional case study 2
4.6	Final sectoral case study 2
Stage 5	**Strategic investment portfolio development**
5.1	Draft outline and methodology (this may occur earlier in the project)
5.2	SWOT analysis
5.3	Optional - Workshop 2 planning and preparation
5.4	Optional Stakeholder workshop 2
5.5	Draft investment portfolio (this may occur earlier in the project)
5.6	Meeting with Project Steering Committee
5.7	Final investment portfolio
Stage 6	**Reporting**
6.1	Draft report
6.2	Final report
6.3	Presentation to Project Steering Committee

Milestone

Workshop

Progress meeting

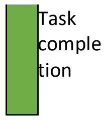

Figure 9. *Project timeline*

9 Experience

As demonstrated above, our project team brings together a purpose-built team to provide the necessary technical and project management skills. The following sections showcase our experience in each of the areas raised as selection criteria in the RFQ.

Water resources modelling and analysis

Over recent years, Alluvium has formed a strong team of water resource and catchment modellers. Across the company, our work has involved developing detailed methodologies for examining flow impacts on waterway ecology, our involvement in the development of hydrologic indices and analyses of coastal streams and wetlands across the east coast of Australia and our ongoing work in developing hydrologic models for a range of catchments across Australia. We have experience developing and applying various modelling platforms to support water resource management decision-making for clients across Australia. The below projects demonstrate the team's experience in their current Alluvium roles and previous roles. In addition to these projects, please also refer to the CVs of our project collaboration team for project examples in CSIRO and the University of Newcastle.

Project title	Description	Client	Year	System(s)
Report Card Modelling	Development, calibration and improvements of a range of hydrologic and water quality catchment models for South East Queensland to provide summaries and inputs for developing Report Card assessments for all of the region's waterways	Healthy Land and Water	2016-2021	Brisbane, Bremer, Logan, Albert, Lockyer, Stanley, Caboolture, Pumicestone, Maroochy, Mooloolah, Noos
Local Government Infrastructure Planning	Development and peer review of catchment models for the City of Gold Coast to evaluate stormwater infrastructure demands across the whole of the city. This became instrumental in identifying infrastructure requirements to feed into a whole of city infrastructure plan.	City of Gold Coast	2016-2019	City of Gold Coast waterways
Total Water Cycle Management Plan	Development and upgrade of catchment models for evaluating changing land use and climate impacts across the Moreton Bay Council region.	Moreton Bay Regional Council	2010-2019	Moreton Bay Council region waterways
Regional water security and strategic policy review	Project involved a strategic review of significant water policy, planning, infrastructure and water market options, including developing innovative options to reconfigure water policy and management under historical and future climate conditions. The review informed analysis of distribution of benefits, followed by a preliminary economic appraisal of the options.	Department of Water NSW	2017-2018	Hunter region of NSW

Project title	Description	Client	Year	System(s)
NSW Floodplain Harvesting Policy – Implementation Review	Assessment and independent review of floodplain modelling across 5 regulated and unregulated systems across NSW.	Department of Industry NSW, MDBA	2018-2019	Border Rivers, Namoi, Gwydir, Macquarie, Barwon-Darling
Sunbury Source modelling	An assessment of hydrologic responses of Emu and Jacksons Creeks to future urban development including daily climate and streamflow input development, rainfall-runoff calibration, and scenario modelling	Melbourne Water	2017	Maribyrnong
Development of the Dandenong Creek Source model	In conjunction with hydrogeologists, Alluvium developed an hourly timestep Source model that linked key groundwater systems with surface water through a detailed understanding of the hydrogeology of the Dandenong Creek catchment. This model is to be used in detailed ecological flow assessments for the catchment into the future.	Melbourne Water	2017	Dandenong
Daily Source model for the ACT	Development of a daily Source model for the ACT, including derivation of daily inputs from January 1891 to December 2016.	ACT Government	2017	ACT
Lower Werribee River eco-hydraulic modelling	We completed an investigation of environmental water use in the lower Werribee River to manage water quality for amenity values and improve habitat condition for fish and platypus values. This involved detailed 2D and 3D hydraulic modelling to test assumptions embedded in previous environmental water recommendations regarding pool turnover for blue green algae management and velocities for to prevent build-up of aquatic weeds.	Melbourne Water	2016	Werribee
Development of the South East Queensland catchment models	Numerous catchment models have been constructed by Alluvium staff members in a range of frameworks including EMSS, E2, WaterCAST, SedNET, Source Catchments and Source to derive a whole of catchment understanding of the processes driving hydrology and pollutant export across the SEQ region.	Healthy Waterways, Seqwater, SEQ local governments	2002-2016	SEQ
Review of the Diamond Creek and Olinda Creek Streamflow Management Plan	Applied the Diamond Creek and Olinda Creek REALM models to determine sustainable licence volumes for desired reliability and environmental compliance and review passing flow requirements	Melbourne Water	2014	Yarra

Project title	Description	Client	Year	System(s)
Goulburn River Multi Year Flow Planning	Development of a Source Rivers model to review of water allocation, storage operation, demand, inflows, inter-valley trade and carryover rules for the Goulburn River and environmental water delivery scenario modelling.	Goulburn Broken CMA	2014	Goulburn
Whole of water cycle management options for delivering environmental flows in the Maribyrnong	We undertook a high-level assessment of Whole of Water Cycle Management and reviewed the environment flow requirements for the Maribyrnong catchment. This involved the development of a daily-timestep Source model for the Maribyrnong catchment. The model was then used to consider various scenarios for Jacksons Creek looking at how management of potable water supply, stormwater, and treated waste water in surrounding urban areas influence the environmental outcomes for the area.	Melbourne Water	2014	Maribyrnong
National Inventory of Stressed Catchments	Combination of individual hydrological stress indicators to one overall score including sensitivity testing, development of flow stress categorisation method for surface water and groundwater, compilation of basin description and jurisdictional stakeholder consultation	National water Commission	2011	Australia
Review and update of Kerang Lakes REALM model	Review and update of the Kerang Lakes REALM model, applying existing methods and developing new regressions and rainfall-runoff models to update and extend model inputs	DELWP (DSE)	2009-2010	Loddon

Project management

Given the importance we place on technical quality and timelines of project delivery, Alluvium has been collecting post completion feedback for randomised projects, for over 10 years of project delivery. Our performance over the entire data collected is provided below.

Sub-contractor management

Effective sub-contractor management has been central to the business model of Alluvium since we were founded. There are a number of elements to our demonstrated success in sub-contractor management.

Strong relationships: We have developed strong existing relationships with our sub-contractors. It is inevitable that some projects at some stage have problems, and there will be different perspectives on the cause of the issues. Sound relationship, built on honesty, trust and mutual respect will enable issues to be resolved in a co-operational, mature and sensible way.

Clear lines of responsibility and accountability: Our project management structure is clear and straightforward, and has been designed to provide clarity on workflow, delivery and reporting.

Highly skilled project managers: We have allocated our most capable and experienced staff to our team. Our project managers are skilled and experienced in effectively managing sub-contractors as part of larger project teams. We recruit staff with the attitude and aptitude for collaborative working, and provide a comprehensive professional development program to support them.

Processes: Our quality management processes and project management approach are designed for effectively managing sub-consultants. As examples, we hold internal inception meetings for project team members to ensure there is a clear understanding across all parties of the scope, timing, deliverables, roles etc. All sub-contractors will be inducted into our quality management system.

Alluvium is the lead agency and will hold the contractual relationship with QWMN and sub consultant agreements with sub-consultants. The sub-consultant agreements will provide 'Back-to-back' arrangements which will pass through the obligations as defined in the Alluvium – QWMN contract. The sub-consultant agreements will define requirements for dispute resolution, communication, knowledge of the main contract, and Suspension and termination. These agreements will also contain key clauses aligned with our internal governance, safety and quality systems. This will include the requirement to ensure all qualifications, registration and licences are in place and staff have appropriate levels of training.

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See also (from Section 5)

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Attachment A: CVs