2020–2030

Water Planning Science Plan

November 2020

Queensland Government

CS10119 02/21
Version 1.1 correction made to page 13

This publication has been compiled by Department of Regional Development, Manufacturing and Water and Department of Environment and Science.

Interpreter statement:

The Queensland Government is committed to providing accessible services to Queenslanders from all culturally and linguistically diverse backgrounds. If you have difficulty in understanding this document, you can contact us within Australia on 13QGOV (13 74 68) and we will arrange an interpreter to effectively communicate the report to you.

Contents

Executive summary

Water is an essential part of life. It preserves our environment, sustains our communities and is a vital input for the farming and mining industries which are the backbone of our rural economies.

We have adapted to survive and prosper on the driest continent on Earth by carefully managing water to meet our needs. Queensland has one of the most variable climates in the world, yet the state's water resources are successfully managed to support a range of social, economic, cultural, and environmental outcomes.

To cope with expanding populations and greater water needs, we've installed dams and other water infrastructure along waterways and we extract groundwater using bores. Modifications such as these can have impacts on the animals and plants that rely on these water sources and may also affect social, economic, and cultural values.

Sustainably managing the resource

Science is a crucial aspect that informs the sustainable management of water in Queensland. The Water Planning Science Plan 2020–2030 provides the framework that outlines the key science needs to support water plan development, evaluation, and replacement.

The scope of science needed to inform water management in Queensland has evolved in line with the policy changes of the *Water Act 2000*. The science themes in the previous Water Planning Science Plan 2014–2019 focussed on exploring the linkages of aquatic ecosystems and their critical water needs in surface water systems such as rivers and streams. As water management expanded into groundwater systems, the science themes expanded to groundwater dependent ecosystems.

The scope of the Queensland *Water Act 2000* and associated water plans have now evolved to encompass a broader definition of sustainable management of the water resource and require consideration of other matters such as cultural connections with water and the impact of climate change.

Additional science themes have therefore been developed and included in the Water Planning Science Plan 2020–2030. These updates ensure the Queensland Government is well placed to plan for the science needed to sustainably manage its water resources for future generations of Queenslanders.

Why have a science plan?

As science for water planning is prioritised and delivered across multiple government departments and divisions, the overall impact of the first iteration of the Water Planning Science Plan 2014–2019 was to bring those groups together to focus on priority science and important principles around collection of science. The plan's framework enabled groups across and within government to collectively work on and deliver prioritised science projects focussed solely on water planning needs and outcomes.

The Water Planning Science Plan 2020–2030 is a contemporary science plan that positions the Queensland Government to respond to the current and emerging challenges of sustainable water management. The plan continues to build on its achievements and provides a roadmap for collaboration and engagement with scientists from universities and experts from within the private sector across a broad range of topics (Figure 1).

As a communication tool, it highlights the government's need to collect fit-for-purpose scientific information to inform the decision-making processes in water management. Through the plan, stakeholders can clearly see the importance that the government places on science information to support natural resource management.

The Water Planning Science Plan 2020–2030 demonstrates the relevance and use of the scientific information for decision-making, by having stringent peer review processes. Finally, the Water Planning Science Plan 2020–2030 offers the opportunity to bring together stakeholders, water managers and the scientific community to build capacity, understanding and collaborative networks, and facilitates communication of science in a relatable way.

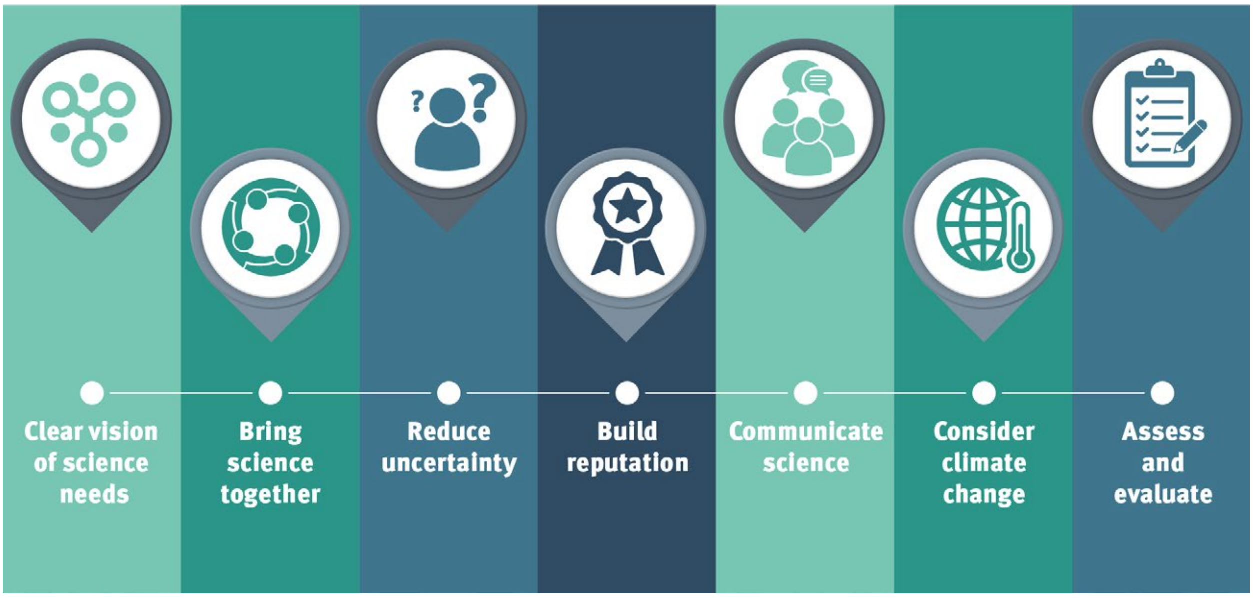

Figure 1 Water Planning Science Plan roadmap.

Structure of the plan

The Water Planning Science Plan 2020–2030 is structured across eight key themes that consider the major scientific areas required for sustainable management and allocation of water resources in Queensland. Within each of these themes are streams that further refine the area of science to be assessed.

Each theme and stream includes a set of specific questions to enable researchers, managers and stakeholders to understand the linkages between science and water management. All themes relate back to sustainable management questions and considerations. They outline the science needed to inform the evaluation of key outcomes in water plans (Figure 2).

Water plan and *Water Act 2000* requirements

- Sustainable management
- Allocation of water
- Health of ecosystems
- Builds confidence in water availability
- Interests of Aboriginal people
- Regulation of water if at risk
- Community understanding
- Climate change impacts

Five yearly Minister's report on each water plan

- Is resource sustainably managed?
- Effectiveness of plan in achieving plan outcomes
- Information about water use and authorisations
- Summary of research and monitoring
- Identified risks to the plan outcomes
- Noncompliance reporting
- Community understanding
- Climate change assessment

Water Planning Science Plan 2020–2030 themes

1. Ecological asset requirements and threats
2. Landscape ecohydrology
3. Understanding groundwater systems
4. Catchment threats
5. Hydrological modelling and monitoring
6. Cultural values
7. Socio-economic values
8. Assessment and evaluation

Figure 2 Overview of the role of the Water Planning Science Plan in water planning.

Science implementation

The Water Planning Science Plan 2020–2030 has been jointly prepared by the Department of Environment and Science (DES) and the Department of Regional Development, Manufacturing and Water (DRDMW). It informs many core science projects conducted each year, within and across these agencies, to deliver on priority science needs across many water plan areas.

These projects aim to deliver science on key questions that relate to water plan outcomes and are implemented with the specific purpose of informing water plan development, review and evaluation. This includes the five-yearly evaluation (Minister's report) required for each water plan.

The timing of projects needs to consider:

- the risks in the water plan area
- the rigour required for each scientific question
- the type of project
- the data that needs to be collected.

Recently, science needs for newly made water plans have been articulated in a Monitoring, Evaluation and Reporting Strategy (MERS) for each plan area.

Opportunities

Water planning science needs are both broad and detailed in many ways. The delivery of these needs is challenging, with some projects taking multiple years to complete. To reduce the uncertainties associated with the science overtime, scientists cannot work in isolation. They need to work together.

Now more than ever, government needs access to the best available science in a timely manner to ensure an appropriate balance is struck in managing water to meet competing water needs and values. The Water Planning Science Plan 2020–2030 establishes the science needed for the upcoming decade to manage Queensland’s water resources in the face of climate change, infrastructure investment and greater scrutiny of decisions.

Collection of the best available science is most effectively achieved in partnership with our stakeholders and by communicating our science challenges. There is now an opportunity for the collective capability of the scientific community, stakeholders, and water managers to work together to meet the science challenges set by the Water Planning Science Plan 2020–2030, and build on the scientific reputation of the framework to date. These networks will lead to the advancement of new tools and technology through innovation and information sharing.

The Queensland Government welcomes partnerships with other science providers and collaborators to meet these challenges.

Githabul Aboriginal people diving for bingh-gingh (fresh water turtles).

Introduction

Vegetation dependent on discharge from Abercorn Springs, Great Artesian Basin.

The Water Planning Science Plan 2020–2030 (WPSP) has been jointly prepared by the Department of Environment and Science (DES) and the Department of Regional Development, Manufacturing and Water (DRDMW). Science is a fundamental part of the water planning and management framework and the WPSP provides an overview of this framework and the science needed to support its successful implementation.

Water plans are developed to sustainably manage Queensland's water resources by balancing the needs of water users and the environment. These plans determine the amount of water that is available and regulate the allocation and management of it in a plan area.

They play an important role in sharing water sustainably across Queensland and between water users in each water plan area.

Water plans are developed in accordance with the *Water Act 2000* (the Act) which sets the requirements for developing, amending and reporting on water plans. The Act outlines that 'sustainable management' must allow for the allocation and use of water resource for the economic, physical, and social wellbeing of the people of Queensland. This includes sustaining:

- the health of ecosystems
- water quality
- water dependent ecological processes
- biological diversity associated with watercourses, lakes, springs, aquifers, and other natural water systems.

In drafting a water plan, the responsible Minister must consider, among other things:

- the water-related effects of climate change on water availability
- the public interest, including the interests of Aboriginal people and Torres Strait Islanders
- the achievement of sustainable management.

Water plans must include arrangements for providing water to support the environment. To do this effectively, we must collect information about the natural ecosystems including their water requirements and how they may be impacted by water management.

Through the consideration of these matters, there is a need to underpin and support the water planning process with the best available, locally relevant science. The WPSP has been developed to guide science collection across the state to ensure it is targeted and meets both water planning science needs and meets stakeholder expectations for rigour and confidence.

This plan replaces a previous version (Water Planning Science Plan 2014–2019). Following a peer review of the previous plan, the scope of this plan has been expanded to include social, economic, and cultural science needs, as well as an increased emphasis on climate science.

Purpose and scope

Isabella Falls, Cape York.

The purpose of the WPSP is to outline the key science needs to support water plan development, evaluation, and replacement by DRDMW. This ensures water management decisions, especially where there are risks to water resources or the values associated with them, are informed by the best available science.

A clear articulation of the themes and streams of scientific information to support water planning is important given the diverse environment, economy, and culture of Queensland. This diversity together with the remote location of many of Queensland's significant water resources (both surface water and groundwater) makes identification and prioritisation of the key information to support water planning particularly important.

The 2020–2030 plan has an expanded scope compared to the previous version, now incorporating science and knowledge relating to cultural, economic, and social values. The WPSP recognises that the status of knowledge and understanding of these newly added themes and their connection to the water planning framework is developing. The holistic approach of the WPSP supports all water policy and planning. By identifying leading-edge science, it informs government decision making to optimise sustainable development outcomes. The priorities in the WPSP are framed across eight themes and 23 streams (Figure 5).

The WPSP provides a framework for delivering the strategic and long-term science objectives to meet the needs of water planning. Where possible, science activities maximise the outcomes and collaborative opportunities provided by other Queensland Government science programs such as Queensland Reef Water Quality Program.

The WPSP also supports other Queensland Government initiatives, including economic recovery initiatives such as the building of new water infrastructure, and improving the way Queensland's water resources are managed, measured and reported through the Rural Water Futures.

In addition to the WPSP themes, DRDMW and DES undertake and support a wide range of collaborative science with stakeholders across government to inform responses to emerging issues and extreme events including disease outbreaks, fire, extreme drought, algal blooms, incursion of exotic pest species, and mass fish deaths. Regional DRDMW scientists are also actively involved in targeted research and monitoring activities to support the development and evaluation of local water management strategies.

Science principles

Abercorn Springs from the air, Great Artesian Basin.

The science is:

- strategic, targeted, adaptive and responsive
- discoverable, communicated, accessible and fit for purpose
- prioritised using a risk framework approach.

There is a commitment to:

- quality, innovation, and continuous improvement
- maximising opportunities arising from local knowledge and regionalisation of staff
- developing expert national and international networks that contribute to science leadership and strategic direction
- inclusive and respectful engagement with stakeholders
- fostering a collaborative approach to science which builds on existing programs and informs external programs
- harnessing digital and new technologies to increase our science impact
- open data management and access consistent with the Queensland Government's open data policy.

Figure 3 Overview of the water planning cycle and the monitoring, evaluation and reporting framework.

Monitoring, evaluation and reporting framework

The WPSP is delivered through a monitoring, evaluation and reporting framework. The framework uses a risk-based approach, where risk assessment guides the activities undertaken at each stage of the water planning adaptive management cycle, including science collection (Figure 3). The purpose of having a framework is to ensure targeted collection of science information that is fit for purpose and maximises the information collected using the available resources.

Planning

As part of the development of a water plan, a detailed risk assessment of the risks to sustainable water management is completed. This informs the development of the water plan's outcomes — the desired economic, social, cultural, and environmental outcomes of the management and allocation of water to which the plan applies.

Water plans have a 10-year life, which can be extended to 20 years under provisions in the Act. There are important five yearly reporting requirements, which provide an opportunity to evaluate the water plan's outcomes and consider if they are being achieved. This evaluation and reporting step depends on scientific information, especially in high risk areas, often characterised by high water demand or competing water plan outcomes. With 23 water plans across Queensland, all with different reporting and review timelines, identifying and scheduling the collection of priority scientific information is important.

The WPSP also has a 10-year life and sets out on a theme-by-theme basis the types of science to be collected to support the evaluation of water plans, specifically their outcomes, across the state. Further supporting the collection of priority scientific information is the development of a Monitoring Evaluation and Reporting Strategy (MERS) for each water plan. Guided by the WPSP themes and streams the MERS sets out the evaluation questions, monitoring objectives and information to be collected over the life of a water plan to support its evaluation, including whether the plan's outcomes have been achieved. MERS do not specify how or by who this information is collected. This is an important principle that acknowledges that resourcing, expertise, and methodologies change over time. The mapping of how water plan outcomes will be evaluated provides transparency for stakeholders and sets clear expectations on the information to be collected over the life of the water plan. This supports long-term planning for DRDMW and other responsible stakeholders and provides guidance under which to develop collaborative monitoring partnerships with external science agencies.

The WPSP and the MERS for a plan area are complementary documents and together outline the long term science needs at a statewide and water plan area scale (Figure 4). MERS have only been developed for a few plan areas to date. In the absence of a MERS for a plan area, the WPSP continues to guide the science requirements for a water plan.

Implementation and prioritisation

Most new water plans also have an accompanying internal implementation plan, which sets out all the implementation activities required to support the delivery of the plan. Monitoring is generally considered a sub-activity under implementation. As it is not possible to complete all implementation work straight away due to resourcing, implementation (and monitoring) is generally prioritised and staged over the life of the plan. The priority of implementation activities is guided by risk. The MERS sets out the activities required over the life of the plan to evaluate economic, social, cultural, and environmental outcomes and evaluate the overall effectiveness and success of the plan. An annual work planning process, guided by the risk assessment and a regular evaluation of progress against identified knowledge gaps, is used to prioritise monitoring effort in any given year across the state.

Monitoring and collection of scientific information

Monitoring of a water plan is delivered through a range of government and non-government programs. Neither the WPSP nor the MERS specify who is to deliver the monitoring or how it will be delivered. This is deliberate to ensure maximum flexibility in delivery, to be able to take advantage of new technologies and collaboration opportunities.

Examples of the types of programs currently used to deliver science to support water planning include:

- monitoring of environmental flow requirements
- groundwater and surface water monitoring networks
- measurement of water quantity and quality by Resource Operations Holders
- cultural engagement programs
- external research programs.

Development of a MERS for each water plan ensures that monitoring is undertaken and information is collected in a timely manner to support evaluation and reporting. A hierarchy of documents is in place to guide the science needs from a 10 year to an annual timescale (Figure 4)..

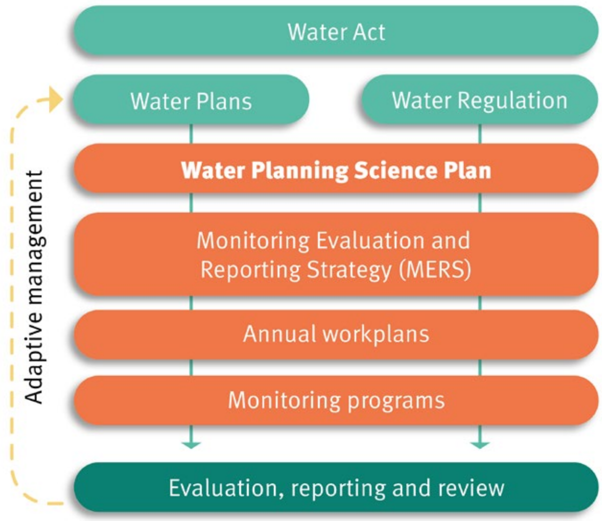

Figure 4 Hierarchy of documents guiding the collection of science for water plans.

Reporting

At a minimum, reports are prepared for all water plans every five years on the matters prescribed by the Water Regulation 2016 (s22). This includes providing a summary of the findings of monitoring and reporting on risks to plan outcomes. Reporting is a component of evaluation, which is covered in more detail below. As well as Minister's reporting, some plans such as those in the Queensland Murray-Darling Basin, have additional evaluation and reporting requirements. Where these exist, these are also captured in the MERS for a plan.

Evaluation and review

Risk assessment informs each stage of the water planning cycle, from plan development, implementation, monitoring, reporting and review (Figure 3).

A risk assessment is completed at least every five years to evaluate the effectiveness of the plan and identify any emerging risks to provision of water for social, economic, cultural, and environmental outcomes. Monitoring across all types of outcomes is an important input to this assessment and informs five yearly statutory water plan reporting as well as the review of the plan.

When undertaking risk assessments, the likelihood, consequence, risk ranking, and associated uncertainty are considered. Reducing uncertainty of underpinning information used to make water planning decisions is a key driver when developing a MERS and prioritising collection of scientific information.

Evaluation of the effectiveness of water plans occurs at least every five years as part of the reporting cycle, and a more intensive evaluation is completed at the 10 year point (the end of plan life), Depending on the outcomes of this evaluation, a plan may be amended, extended, or undergo a full review.

Jardine River Turtle (*Emydura subglobosa*).

Overview of themes and streams

Burnett River from a drone, near Bundaberg.

The science priorities are arranged across eight themes and twenty-four streams including the knowledge and information needed over the life of a water plan to support its evaluation, review, and replacement. The scale of the information needs for a water plan is informed by a risk assessment process and a gap analysis to establish the current state of uncertainty across each information type. The science needs are not listed here by plan area; rather they are specified in each plan's MERS, in annual work plans, and in technical assessments.

Themes one to four cover ecological knowledge with a strong focus on understanding the ecological values in each plan area, their flow or groundwater requirements and threats to these water requirements due to water management. This encompasses both surface water and groundwater dependent ecosystems and includes information on species, ecosystem components and processes. Theme four focusses on the broader range of catchment pressures and threats to aquatic ecosystems and provides contemporary context against which water management actions and environmental strategies can be framed.

Theme five encompasses knowledge of the dominant catchment hydrological processes incorporating surface water and groundwater dynamics and their interactions. It's aim is to collect surface and groundwater data at appropriate scales across the state to support real time water management decisions, longer-term planning and policy drivers and the development of robust hydrological models and assessment tools. Climate change impacts on water availability are relevant across all themes, however, they are emphasised in theme five through the continued development of approaches for the inclusion of climate change projections in hydrological simulations at scales relevant to water planning.

Themes six and seven are new and aim to improve the understanding of cultural, social, and economic values supported by water plans, their water requirements, and the threats to these values. While these values have been considered in the past through technical assessments supporting the development and evaluation of water plans, their recognition as science plan themes provide a focus for continual refinement of assessment approaches through new science and knowledge over time, consistent with the first five themes.

Theme eight aims to develop approaches for integrating information across all other seven themes into risk assessment frameworks and decision support tools for water plan development, evaluation, and replacement. It recognises the challenges of drawing together information from disparate disciplines at different scales and with differing levels of uncertainty with a focus on optimising water management objectives, indicators, and outcome response metrics to support the sustainable management of water.

Some concepts are relevant across all the themes, for example consideration of climate change and uncertainty.

Themes and streams

Waterhole, Moonie River

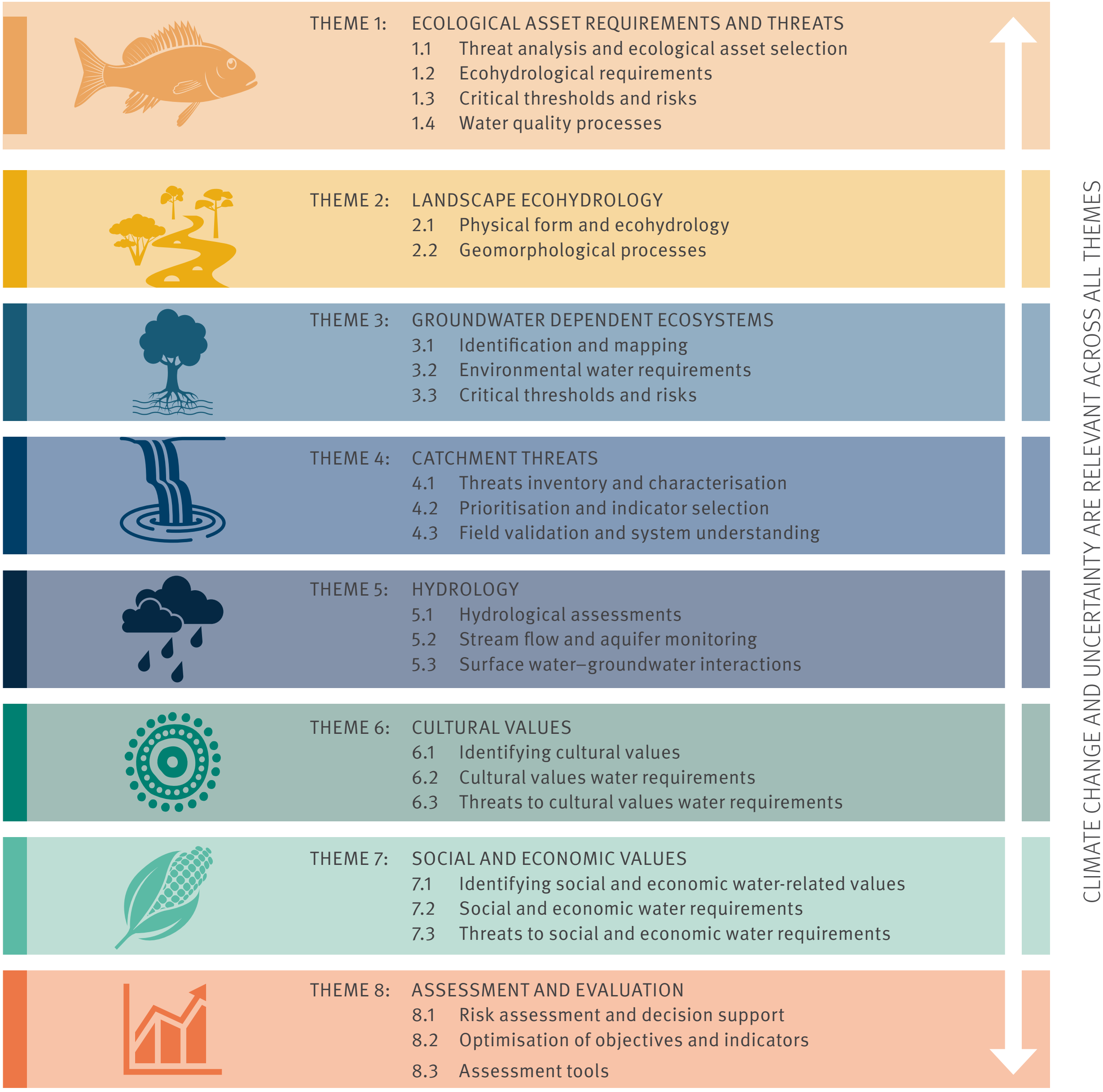

Figure 5 The themes and streams that make up the Water Planning Science Plan 2020–2030.

THEME 1:
ECOLOGICAL ASSET REQUIREMENTS AND THREATS

Theme goal

Identify environmental values supported by the flow regime, characterise current and emerging threats associated with water resource development, and prioritise ecological assets for further research.

Key objectives

- Undertake hydrological threat analyses for priority water plan areas.
- Develop a prioritised suite of ecological assets that are:
  - i. critically linked to aspects of the flow regime,
  - ii. potentially responsive to identified hydrological threats, and
  - iii. representative of plan outcomes.
- Establish ecological asset flow requirements including identification of critical failure thresholds.
- Improve understanding of the interactions between the flow regime, water quality processes and ecological assets, and incorporation of these interactions into a modelling platform.

This theme integrates existing knowledge of how water resource development modifies the flow regime as a potential threat to the ecological values of each water plan area. It incorporates outputs of hydrological threats analyses with information on the flow-dependent ecosystem components, processes and services of the plan area to generate prioritised ecological assets which may be used as indicators to assess the effectiveness of plans in delivering the sustainable management of water.

Electrofishing in the Condamine River for Golden perch and Murray cod.

Stream 1.1 Threats analysis and ecological asset selection

Stream goal

Characterise potential threats to the flow regime and establish a suite of ecological assets as indicators related to each threat in priority water plan areas.

Key research questions

- How has the flow regime changed due to implementation of the water plan?
- What are the ecological values and assets within the plan area that are sensitive to these changes?
- What are the best ecological asset indicators for assessing water plan ecological outcomes?

A clear understanding of the potential threats to the flow regime in a plan area, along with their location and extent, and selection of a relevant suite of ecological asset indicators provides the fundamental basis for developing environmental monitoring and assessment plans. Ecological assets are used as indicators to represent the environmental values of the plan area. An ecological asset is an ecosystem component, process or service that occurs in a plan area, is critically linked to aspects of the flow regime to support its long-term viability or process requirements. As such, ecological assets are the focus of plan evaluations.

Significant progress has been made on species-based ecological assets, notably fish; many have well understood links to the flow regime that support movement, spawning and recruitment. Areas for advancement include understanding the flow-dependencies of plants and invertebrates and ecosystem processes such as river forming processes, nutrient and sediment dynamics, terrestrial and marine food web subsidies, estuarine brackish habitat, freshwater flows to the Great Barrier Reef, the influence of climate change on the distribution and response of ecological assets, habitats such as riffles, and the environmental watering requirements of groundwater dependent ecosystems (see theme 3).

Project Officer, Sharon Marshall, sampling Australian lungfish eggs using a push net.

Stream 1.2 Ecohydrological requirements

Stream goal

Develop explicit, quantitative rule sets that describe the critical requirements of ecological assets as facets of the flow regime.

Key research questions

- What are the environmental conditions provided by the flow regime that are critical to the long-term viability of an ecological asset?
- What are the knowledge constraints to adapting existing ecological models to new water plan settings? (see theme 2).

The approach used to assess risks to ecological assets from water plans considers how their critical water requirements are provided both spatially and over time in the water management arrangements represented in the plan (McGregor *et al.* 2018). Data and information on the life history or process requirements of ecological assets is expressed as discrete aspects of the flow regime (e.g. magnitude, duration frequency, timing, rate of change, habitat features, and associated water quality attributes where relevant), otherwise known as ecohydrological rules.

Mitchell River floodplain wetland.

Ecohydrological rules often begin as flow-dependency conceptualisations, which can take many forms, but commonly are developed as receptor conceptual models that show the flow-related influences on the properties of the assessment endpoints. These can be considered as elements of the conceptualisation representing critical prerequisites for an ecological response. Ecohydrological rules can be simple or have multiple components which all need to be met to constitute an ecological opportunity. Ecohydrological rules invariably include critical facets of the flow regime, but may also include other requirements such as temperature, water depth or flow velocity, etc. When combined with a daily flow time series, ecohydrological rules allow the risk to the asset's long-term viability to be modelled. The use of knowledge from existing scientific literature and relevant experts is maximised to build a body of supporting evidence where possible.

Opportunities for conducting research on aggregates of species with similar life history requirements (guilds) and/or those with similar distributional ranges may provide strategic benefit, particularly when coordinated across regions and with other science providers. Additionally, understanding constraints to the adaptation of existing ecological models into new plan areas is considered an opportunity for further advancement.

CASE STUDY 1:

Establishing ecohydraulic flow requirements of an endemic flow-spawning fish species Fitzroy Golden Perch *(Macquaria ambigua oriens)*

Understanding the flow requirements of aquatic biota is integral to the development of environmental flow strategies in highly regulated river systems. This is particularly important when many species are under continual and increasing pressure from water resource development.

Water temperature and riverine flow requirements for spawning (egg laying) of the golden perch was studied over four years across 22 monitoring locations throughout the Fitzroy River catchment. Eggs, larvae and young-of-year were sampled on a variety of flow events of varying magnitudes to determine the ecological and hydrological flow requirements for spawning. Eggs and larvae were primarily detected during natural flow events, generally with a minimum of 1.5 metre river rise over a duration of seven days. The figure below shows that spawning predominately occurs on the peak and/or fall of the first or second flow event of the season (post-winter flow event) where water temperatures exceeded 24°C.

These results provided the supporting evidence confirming the need for the first post-winter flow management strategy, an environmental flow management strategy developed explicitly with the intent of supporting this species. Importantly, this strategy was initially established when the available literature focussed solely on a similar species, *M. ambigua ambigua*; whose own spawning strategy has been subsequently significantly revised. This study highlighted the importance of confirming and quantifying flow alteration and ecological response relationships with locally relevant information on the species of interest, and the need to consider the key attributes of the natural flow regime in environmental-flow strategies (Cockayne *et al.* 2013).

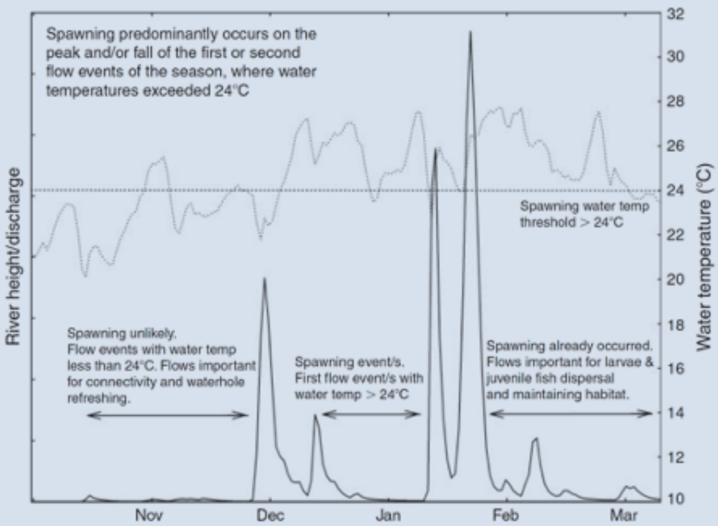

Figure 6 Proposed spawning model for Fitzroy River golden perch (*Macquaria ambigua oriens*).

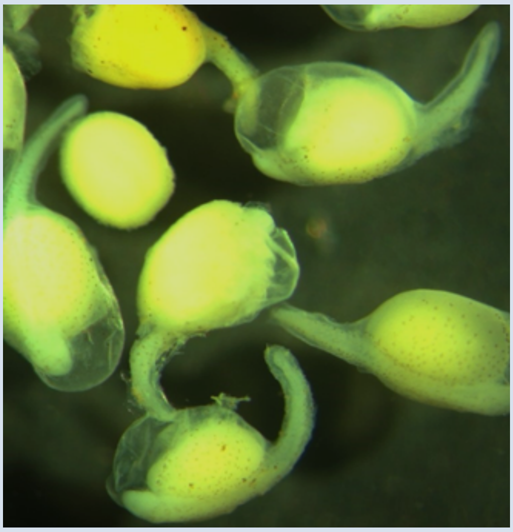

Figure 7 Fitzroy River golden perch (*Macquaria ambigua oriens*).

Stream 1.3 Critical thresholds and risks

Stream goal

Develop measures and thresholds of the consequence of changed flow regimes for the sustainability of ecological assets at relevant spatial scales.

Key research questions

- What change in the provision of flow-mediated ecological responses over time poses a threat to ecological assets?
- What are the temporal and spatial scales at which these dependencies operate?

In the absence of discrete ecological response functions to altered flow regimes for many ecological assets, Thresholds of Concern (ToCs) are used to represent the frequency with which flow-based opportunities are required to sustain ecological asset viability. In many applications, ToCs can be considered as the minimum environmental watering requirements for assets and their associated values. Typically, they represent a threshold at which small changes in environmental conditions produce large, and sometimes abrupt, responses in asset or ecosystem state or function. The probability of achieving a desired ecological outcome is directly related to the flow regime meeting a ToC over time. The ToC needs to relate directly to the relationship between the flow regime and the critical links an asset has to flow. For species assets, this relates to the provision of opportunities within the life span of individuals in a population so, for these, the ToC cannot be expressed as long-term average frequencies or the proportion of years over long periods.

Where possible, ToCs are based on the biology or process knowledge of the asset. In most applications, ToCs have been used to represent:

- the known time species-based ecological assets will survive without experiencing a flow-based opportunity,
- the reproductive longevity of the ecological asset, or
- the minimum number of annual recruitment opportunities that are required to sustain an asset population over time.

Fundamental species information and population parameters for key species including habitat requirements, birth and death rates, minimum population size and genetic structuring, are critical to derive these thresholds. Improved understanding is also required for place-based ecological assets (e.g. specific wetlands, refuge waterholes) and process based ecological assets (e.g. geomorphic and river forming processes, nutrient and sediment dynamics). These asset classes have been underrepresented in quantitative assessments due to the poor understanding of both their ecohydrological requirements over time and what constitutes critical failure thresholds.

CASE STUDY 2:

Using molecular information to measure population viability in response to altered flow regimes and dams

Physical barriers such as dams and weirs impose restrictions to the movement of aquatic biota. Changes to the patterns of longitudinal connectivity over time may alter critical processes such as migration and recolonization of fish species, leading to inbreeding in isolated populations. These impacts may be extreme in systems where the flow regime is significantly modified due to dam releases for hydroelectric power supply.

With critical links to stable low flows, the purple-spotted gudgeon (*Mogurnda adspersa*) was used as an 'indicator species' to assess the impacts that physical barriers and flow changes have had on the population characteristics of individuals in 'natural' (less modified) and impacted environments in the Tully and Barron rivers. Novel molecular techniques were developed and tested to determine levels of population health (genetic diversity) and connectivity (ability to move freely) across populations in the Wet Tropics bioregion. It was hypothesised that the long-term viability of the population, inferred from measures of genetic diversity (Ne), would be affected in the reaches where hydroelectric infrastructure and release regimes were present.

The results indicated that the long-term population viability of purple-spotted gudgeons upstream of impoundments is affected due to the physical isolation and inbreeding in those populations. Furthermore, populations of gudgeons below impoundments, where flow changes are substantial, also show signs of stress from reduced periods of stable low flows during the breeding season. Populations in un-impacted catchments and in side tributaries showed no reduction in population viability. These results provide valuable insights to the flow requirements of this species and will assist in optimising environmental release strategies to enhance their long-term viability. The molecular techniques also show great sensitivity and promise for application to species in other catchments.

Figure 8 Purple-spotted gudgeon (*Mogurnda adspersa*).
Image courtesy Shutterstock.com/Guillermo Guerao Serra.

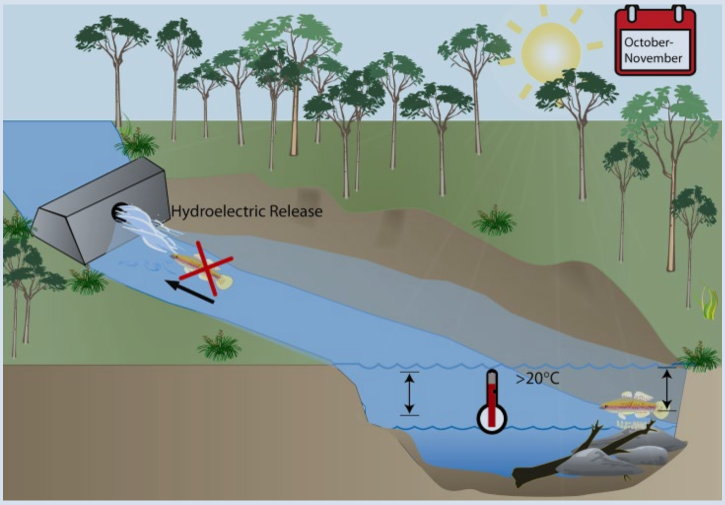

Figure 9 Conceptual model of impacts to population viability from instream barriers and fluctuating flow levels associated with hydroelectric power supply.

Modified flow regimes affected by hydrolelectric releases (often termed 'hydropeaking') disrupt the stable-low flow conditions purple-spotted gudgeons require for successful breeding. Breeding occurs in tropical northern Queensland when water temperature is above 20°C in October-November. Barriers such as dam walls prevent these fish from moving and isolate upstream populations. Genetics studies have demonstrated that both these impacts reduce the viability of populations of this species.

Stream 1.4 Water quality processes

Stream goal

Improve understanding and develop conceptual and quantitative models of the interactions between surface water hydrology, water management, and key water quality attributes and processes.

Key research questions

- How does the flow regime interact with the biophysical habitat to influence key water quality attributes and processes?
- What are the key water quality processes and/or indicators that are sensitive to a managed flow regime?
- What approaches can be used to model water quality processes and/or indicators in relation to a managed flow regime?
- How can the effect of the flow regime on water quality be partitioned from the range of other anthropogenic stressors?

While flow regimes create the hydraulic conditions that support ecological assets, hydrology also influences their physical and chemical environment in terms of a range of water quality conditions and processes. The interacting effects of flow and water quality may be important for facilitating ecosystem responses (e.g. water chemistry and water level stability for the development of fish eggs and larvae, turbidity and velocity for macrophyte recruitment, or conductivity and flow height for sediment transport from waterholes) and plays a significant role in mediating biogeochemical processes such as instream productivity and nutrient and carbon cycling.

Consequently, the importance of water quality to support ecological processes and the environmental values they represent is explicitly recognised as ecological outcomes in nearly all water resource plans. A holistic consideration of water quantity and water quality in supporting environmental outcomes has been recognised as key success factor in understanding the complex responses of ecosystems to anthropogenic threats.

Water quality is affected by a range of anthropogenic stressors, of which water management is one facet. Understanding the relative contribution of these stressors to any given water quality outcome will require improved knowledge of the range of anthropogenic stressors and their interaction in a given setting, and the ecosystem water quality requirements.

Research to improve our understanding on the dynamics of these water quality requirements over space and time across a range of landscape and water infrastructure settings remains a priority. The effect of surface water and groundwater interactions on water quality outcomes also requires further investigation. Importantly, improved methods are needed for modelling these requirements over time to predict altered water quality regimes in alternative water management scenarios.

Collecting water quality values in the Dumaresq River.

THEME 2:

LANDSCAPE ECOHYDROLOGY

Theme goal

Characterise the landscape setting of managed river systems in terms of their physical form and geomorphological processes and to compile data and knowledge to develop models to represent local system behaviour.

Key objectives

- Collect key physical form and geomorphological process information for priority river reaches and catchments.
- Develop ecohydrologic models for vital geomorphological and river-forming processes.

Ecological assets interact with the flow regime within a landscape context. The physical form of a stream network and its associated floodplain system mediates stream flows to create a range of ecohydrological and habitat conditions. The spatial and temporal creation of these conditions supports a range of critical ecological processes which contribute to the sustainability of aquatic ecosystems. This theme furthers our understanding of the complex landscape setting in which aquatic ecosystems function by characterising key habitat attributes.

Stream 2.1 Physical form and ecohydrology

Stream goal

Characterise the physical form of priority river reaches and catchments and gather information to translate this into time-series of hydrologic/hydraulic conditions relevant to ecological assets at appropriate scales.

Key research questions

- What are the key physical attributes of priority river reaches and catchments which interact with the flow regime to create the hydrologic/hydraulic conditions which support asset responses (i.e. riffle inundation height, shear stress, nest inundation height, floodplain wetland connection, etc.)?
- What are the knowledge constraints to adapting existing landscape attributes to other water plan areas?

Flow interacts with the physical habitat within the stream or across the floodplain, to produce local hydraulic conditions ecological assets experiences and respond to. The conditions required to support an ecological response over time is established as the product of a daily time series of flow produced by a hydrological model, and local habitat information.

For example, to generate a time series of fish movement opportunities, roughness, slope and cross-sectional area data are required to determine the flow volume at which a weir becomes traversable by a migratory fish species. To develop a time series of dispersal and establishment opportunities for mangrove species maintenance, a hydraulic model is required to convert end-of-system flow volume into a time series of estuarine brackish habitat provision. To develop a time series of floodplain wetland connectivity, flow path and river cross-section data are required to identify flow volume thresholds that correlate with wetland filling. This type of information cannot be generalised and must be collected for each location of interest.

Areas for advancement include local measurements of physical form and riverine habitat, in many instances fundamental method development is needed to standardise data collection. The measurements can be carried out in each location or via remote sensing, meaning a coordinated approach across regions may rapidly address several knowledge gaps.

CASE STUDY 3:

Understanding riverine channel and floodplain morphology in the Condamine-Balonne and Border rivers

To better understand the current river channel and floodplain morphology (shape) in the Condamine-Balonne and Border Rivers, a multi-disciplinary project was established to create foundation data layers that would be used to increase the accuracy of outputs from hydrological and ecological models used in water plan evaluations.

Field evaluations were undertaken at gauging stations were updated cross-sectional information was required. Working with ecologists, hydrographers and surveyors, these surveys incorporated information from field measurements, and where this was not possible (e.g. in very long cross-sections of the Lower Balonne floodplain) cross-sections were extracted from digital elevation models.

Aquatic ecologists also worked with hydrologists and hydrographers to identify floodplain extents for the creation of floodplain assessment reaches (FARs). FARs were established which delimit the area of floodplain and the length of the river channel that can be reasonably represented by a stream gauging station, based on local topography, geomorphology, and river network features.

The use of this updated cross-sectional information at gauging stations in the review of the Condamine-Balonne and Border Rivers water plans increased the accuracy of hydrologic model outputs, and subsequent ecological assessments for indicator species, places and processes (ecological assets). FARs defined the spatial scope of ecological assessments by identifying the parts of floodplains and river channels within which confident relationships can be drawn between gauged flow data and the hydrological or hydraulic conditions experienced by ecological assets. These included the eastern snake-necked turtle, flow spawning fish, migratory fish species, floodplain vegetation, floodplain wetlands, and river forming processes.

Figure 10 Using Real Time Kinematic (RTK) technology to collect cross-sectional information to assist in determining drown-out values.

Figure 11 Balonne River cross section.

Stream 2.2 Geomorphological processes

Stream goal

Understand the role of flows in shaping, modifying and maintaining riverine landscapes and physical features.

Key research questions

- What are the key geomorphological processes required to maintain the form and function of riverine landscapes and which aspects of the flow regime are responsible?
- What is the role of infrastructure in modifying geomorphological processes and what is the spatial and temporal extent of the effect?
- What information is required and available to model these events?
- What are the critical risk thresholds for geomorphological processes (i.e. how frequently do flows for geomorphological processes need to occur and what is the consequence of extending the interval between these events)?

Flow regimes play an important role in shaping the physical environments of rivers. Geomorphological processes—often referred to as river forming processes—include scouring of deposited fine sediments to maintain the depth of refuge waterholes, development and maintenance of rocky riffle habitats, and depositing sediments and nutrients on river benches and into estuaries. These processes may be vulnerable to an altered flow regime.

Maintenance of flows to support geomorphic features and processes are ecological outcomes in most water plans. There are also specific infrastructure operational arrangement relating to geomorphological processes focussed on preventing bank slumping.

Physical landscape data to inform risk modelling is still spatially limited (see stream 2.1). Key research priorities to advance these knowledge gaps include: establishing the attributes of the flow regime that drive geomorphological processes in riverine and associated estuarine systems including the spatial and temporal scales at which they interact; understanding the consequence of changing geomorphological processes on sediment and nutrient movement, instream habitat provision and riffle function, terrestrial–aquatic linkages, and waterhole persistence; and determining how frequently flows for geomorphological processes need to occur in a given setting. As many Queensland riverine environments are highly dynamic over short, medium and long-time scales, it is also important to understand the environmental values or management objectives, and the broader geomorphological patterns and range of temporal variability.

CASE STUDY 4:

Establishing flow thresholds to support maintenance of river forming processes

The primary drivers of river channel morphology (shape) are hydrology (river flows), underlying geology and sediment availability. The formation of channel bars and deeper pools, which are essential for healthy aquatic habitat, is dependent on flow driven sediment entrainment and deposition processes. To assess the influence of water management on these processes, bankfull flows are used as a threshold that represents optimum conditions for channel maintenance.

By definition, bankfull flows refer to the flow level above which water spills onto the floodplain. In regular alluvial channels with one floodplain (Figure 12), the bankfull flow typically occurs every 1.5 to 2 years. This also referred to as the effective flow that transports most sediments for channel maintenance. In these regular channels, bankfull flow height can be identified, amongst other features, by the sudden widening of the channel and the lower limit of permanent vegetation line.

However, in incised (eroded) channels (Figure 13), the definition of bankfull flows based on regular channel conditions may not apply. During subsequent incisions, floodplains are abandoned, and benches, terraces and hydrological floodplains develop and flows may never reach the topographic floodplain as they did in the past. Therefore in incised channels the bankfull flow and the effective flow might be different.

Since many rivers in Queensland are incised, to improve the modelling of bankfull flows, this project aimed to develop a standardised approach for defining bankfull flows, by conducting a pilot study for the Burdekin River catchment. Using remote aerial photography, the channel width where permanent woody vegetation starts was identified and transposed to channel cross sectional data to identify the corresponding bankfull height. Modelled flow data of 120 years was used to define the return interval of the identified bankfull height, and sediment load frequency curves were constructed to identify effective flows.

It was found that the height at which permanent vegetation starts coincided with the lowest bench, with a flow return interval of 1.5 to 2 years, and generally with the first peak in sediment load frequency curve. This study verified that permanent vegetation thresholds and flow heights with 1.5 to 2 year return interval are appropriate indicators of the top of the active channel and 'bankfull' flow height for incised channels. This study greatly improved our confidence in using flow statistics to establish bankfull flows for ecological assessments. Regional relationships between physical parameters and bankfull flows are currently being investigated, which will enable estimation of bankfull flows where flow statistics are not available.

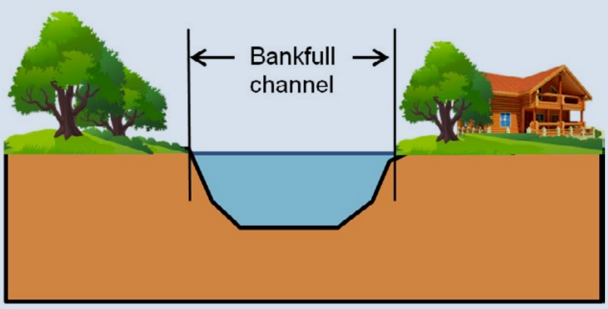

Figure 12 Conceptual diagram of a regular channel and associated floodplain.

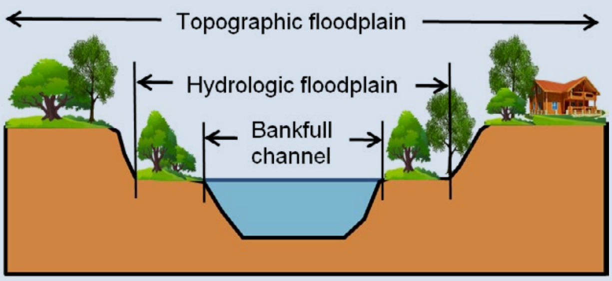

Figure 13 Conceptual diagram of an incised channel and associated floodplain.

THEME 3:
GROUNDWATER DEPENDENT ECOSYSTEMS

Theme goal

Identify groundwater dependent ecosystems (GDEs) and improve the understanding of their environmental water requirements and responses to potential threats.

Key objectives

- GDE identification and mapping for each water plan area.
- Establish environmental watering requirements for key GDEs across a range of aquifer types and dependencies.
- Improve the understanding of surface water–groundwater interactions and how these may alter the provision of critical water requirements for GDE assets.

This theme highlights GDEs as a class of ecological asset which remain poorly characterised in terms of their location and the nature of their water dependency. They are potentially vulnerable to the management and allocation of both groundwater and surface water, particularly in those areas where surface and groundwaters closely interact.

Groundwater dependent ecosystems require access to groundwater to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes, and ecosystem services (Clifton *et al.* 2007). In many systems groundwater dependence is either subtle or cryptic, extending beyond the ephemeral or permanent expressions of groundwater at the surface which we might characterise as wetlands (Hatton and Evans 1998).

Groundwater resources are managed for consumptive uses including agriculture, mining, urban and commercial developments. The water regimes experienced by GDEs are therefore altered by these demands as well as other stressors such as land use management practices. GDEs may be threatened by water allocation and management that alters groundwater regime attributes such as depth, pressure, and quality. To date, the nature, extent, and water requirements of GDEs in Australia have been poorly characterised, however studies have shown that they are widespread yet often cryptic, and vulnerable to water extraction activities. Understanding these requirements is an interdisciplinary endeavour; termed ecohydrogeology (after Cantonati *et al.* 2020), it integrates ecology, hydrogeology, and groundwater-surface water (GW-SW) interactions.

Stream 3.1 Identification and mapping

Stream goal

To identify the types and spatial and temporal extents of GDEs in each water plan area.

Key research questions

- What types of GDEs are present in water plan areas (i.e. GDEs that reside within groundwater (e.g. karsts; stygofauna), GDEs requiring the surface expression of groundwater (e.g. springs; wetlands); and GDEs dependent upon sub-surface availability of groundwater within the vegetation rooting depth (e.g. woodlands; riparian forests) and what existing information is available to characterise their spatial extent and characteristics?
- What hydrogeological and water balance information is required to develop robust conceptualisations and typologies across all GDE types to support modelling and decision making?

Coastal wallum wetland.

GDE mapping has been undertaken across many water plan areas, however gaps still exist. Completing GDE mapping remains a priority, as does field validation of their nature and extent. A fundamental understanding of GDE distribution and water needs for all three GDE categories across Queensland is a key area for advancement, particularly in those areas where the water regime is under current and anticipated future demand. Groundwater ecology is a multidisciplinary field that combines methods, concepts and data from hydrogeology, geochemistry, microbiology, and aquatic ecology. This is reflected in the range of tools and approaches available to develop this understanding ranging from desktop remote sensing to field based physiological and hydrogeological studies. Reliable estimates of GDE aquifer source attribution, groundwater level and quality dynamics at a scale which matches the distribution and dependence of GDEs, robust conceptualisations and agreed typologies are all pre-requisite to support these studies and water allocation decisions.

Stream 3.2 Environmental water requirements

Stream goal

Characterise the environmental water requirements (EWRs) of GDEs.

Key research questions

- What are the environmental water requirements–in terms of depth, pressure, and quality–required to maintain GDEs?
- What hydrogeological attributes are required to parameterise ecohydrologic models to predict GDE responses to an altered groundwater regime?
- What is the landscape setting relevant to the water requirements and how is environmental variability structured across this setting (i.e. complex of springs, local vs regional scale, multiple source aquifers)?

Environmental water requirements (EWRs) are defined as the water regime which maintains the composition, structure, and level of ecological function and/or ecosystem service provision. Often, the water regime which supports GDEs will comprise a combination of one or more of groundwater, surface water and soil water (Clifton *et al.* 2007). EWRs include elements of flow, level (or depth to water table), pressure and quality which apply both spatially and temporally; ideally these are defined at the spatial scale of the dependency (e.g. individual spring vent, versus spring complex).

The prediction of ecological responses to altered groundwater regimes is typically compromised by both confounding stressors and by the complex nature of the relationships between the groundwater regime, geology, surface water interactions and the ecology. Development of system response functions requires knowledge of these relationships with respect to both the resistance and resilience of various ecosystem components in relation to their total water requirements.

Progressing the development of hydro-ecological conceptualisations which describe relationship between GDE assets, functions and values, and groundwater management objectives is a key activity to advance this understanding. Aspects such as the timing, magnitude, frequency, and duration of water level alterations should also be considered where possible. This ensures that water management scenarios are evaluated to account for the seasonal aspects of groundwater use by dependent ecosystems.

Work undertaken to date in Australia to develop EWRs for GDEs has generally been limited to the identification stage, very few studies have progressed through to establishing quantitative water regimes. To progress this understanding, site-specific studies based on ecophysiological measurements of representative biota, as well as complementary water sourcing techniques which can identify connections between aquifer systems and dependent biota need to be undertaken.

CASE STUDY 5:

Use of water by floodplain vegetation in the Queensland Murray-Darling Basin

In the Lower-Balonne floodplain, a 3-year project investigated the water sources of key floodplain vegetation species and the influence of rainfall, overbank floods and shallow groundwater on vegetation condition and structure. The project also investigated shallow groundwater recharge processes to understand where floodplain vegetation was getting its water from.

Using a combination of detailed, site-based measurements of tree water use and characterisation of the underlying soils and hydrogeology, as well as vegetation patch/landscape scale assessments using remote sensing, the project illuminated ecological relationships between different levels of flow, flood and groundwater dependence and vegetation communities across the landscape. Research found coolibah and river red gum species accessed different water sources. Some patches of floodplain coolibah trees maintained condition through dry times by accessing shallow groundwater, while over the majority of the floodplain coolibah were dependent on rainfall, with no obvious reliance on river flooding.

The only species with evident reliance on flooding was lignum, but available vegetation mapping is not precise enough to use it as a water plan asset for this region at present. See Figure 14 for an example of vegetation distribution in relation to water sources.

Key project findings included a new conceptual understanding of groundwater/surface water connectivity in riparian zones within meander bends, and improved confidence in the identification and mapping of groundwater dependent ecosystems (GDEs). It also provided new insights into the importance of rainfall to sustain vegetation communities on back plain environments.

This new information fundamentally changed our understanding of the assumed dependencies of these vegetation communities on overbank flow events. Consequently, the suitability of flow metrics related to the inundation regime of terrestrial floodplain vegetation species used in modelling risks from water management were re-evaluated.

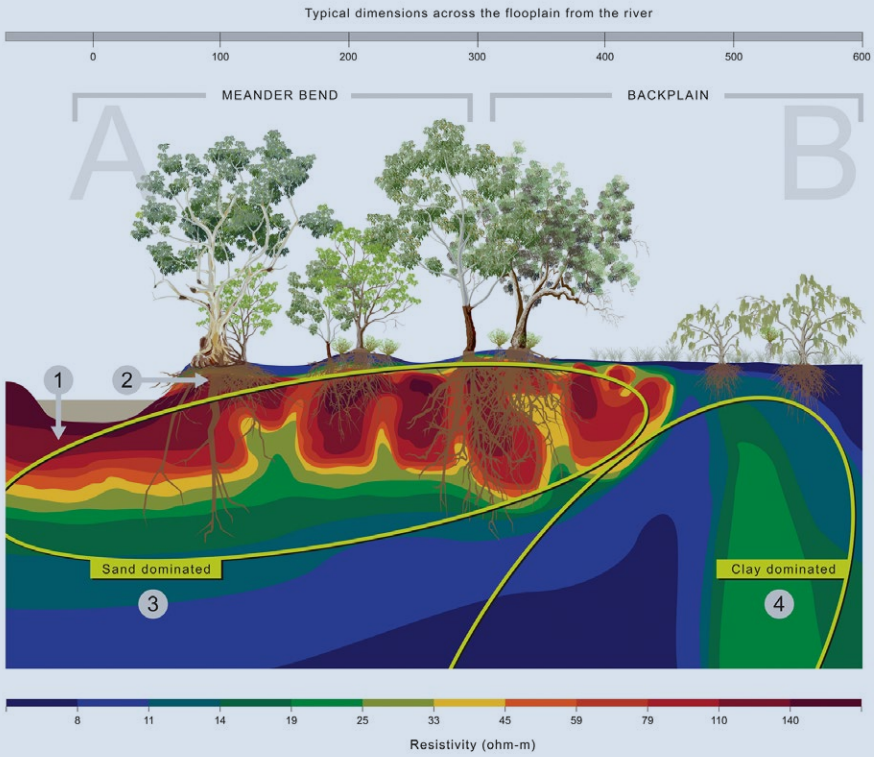

Figure 14 Conceptual model of groundwater/surface water connectivity through paleochannels within meander bends developed as a project output.

This figure shows both vegetation structure above ground and interpreted sub-ground geophysics.
1) channel-fringing river redgums directly access river water and maintain good condition over long periods;
2) meander bends are underlaid with sandy paleo-channels which transmit flow from the channel and retain water and thus support river redgum forests in good condition over long periods;
3) clay of the broader floodplain is largely impermeable to water and
4) supports coolibah dominated vegetation communities which obtain their water from local rainfall and undergo fluctuations in condition in response to rainfall patterns.

Stream 3.3 Critical thresholds and risks

Stream goal

Understand the ecosystem response to threats and develop groundwater thresholds protective of the environmental values representative of GDE assets.

Key research questions

- What changes in the groundwater regime over time pose a threat to the GDE asset?
- How do these thresholds relate to the structuring of environmental variability across the landscape (e.g. the spatial scale at which the GDE responds to change)?

Critical thresholds are used as measures of consequence in the current ecological risk assessment framework. As such, in GDE assessments, ToCs define the minimum environmental watering requirements (in terms of depth, temperature, etc.) for assets and their associated values. Science to support the development of these thresholds is still in its infancy and few studies quantitative studies have been undertaken in Queensland. To support the sustainability of these ecosystems, developing critical thresholds remain a priority, particularly in areas where significant groundwater take and high value GDEs are in close proximity. Science undertaken by the Office of Groundwater Impact Assessment (OGIA) to assess impacts of groundwater extraction from resource operations in the Surat cumulative management area provides a useful foundation to our understanding of this cryptic class of water dependent ecosystem.

The application of emerging technologies such as remote sensing, geophysics, sap flow meters to directly measure tree water uptake, and analysis of stable isotope concentrations in vegetation, for comparison to isotope signatures from surface and groundwater sources provide opportunities for advancing these knowledge gaps. Along with phenological studies, and controlled greenhouse growth studies, this information can be combined to derive critical water thresholds to support recruitment, and condition maintenance.

CASE STUDY 6:

Understanding the impact of groundwater extraction on the hydrological behaviour and values of Abercorn Springs

Abercorn Springs, situated approx. 27 km south of Monto, are one of the six springs listed as key monitoring sites for the Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017. In the Mulgildie section of the Great Artesian Basin, a six-year monitoring program has been investigating whether extraction of groundwater from a recharge area of the basin affects the flow and pressure of water at the springs. The project aims to improve understanding of the hydrological impacts of groundwater extraction on the springs.

The first phase of the study has focussed on confirming the source aquifer providing for the springs and measuring water level changes both at the springs and from nearby groundwater monitoring bores in the aquifer to understand linkages. Since 2015, there have been two key periods of water level extraction from the source aquifer and both times, there have been measurable impacts on water levels at the springs, nearly 22 km away. The team has mapped the wetted extent of the springs over time and used groundwater chemistry to determine sources of water.

The next phase of the project aims to understand the impact of groundwater extraction on ecosystem response by identifying the vegetation species that may be particularly vulnerable to water level fluctuations. The springs contain 82 native floral species, including one vulnerable species, Hairy-jointed grass (*Arthraxon hispidus*) listed under the *Nature Conservation Act 1999*.

Additionally, sediment cores have been extracted to investigate the long-term history of hydrology and floral colonisation at the site. This complements the shorter-term monitoring and is working towards understanding thresholds in groundwater behaviour that influence this GDE spring.

Figure 15 Aerial view of Abercorn Springs highlights the vegetation gradient.

Figure 16 Hairy-jointed grass (*Arthraxon hispidus*) is seasonally observed at the site in areas of moist substrate.

Figure 17 Contrast in the vegetation of the spring at the extent of the wetted area caused by groundwater flow.

THEME 4:

CATCHMENT THREATS

Theme goal

Understand the relative importance of catchment threats, the relationships between these threats, ecosystem responses and the human pressures and natural drivers of the aquatic ecosystem in priority water planning regions.

Key objectives

- Develop an inventory and characterisation of all catchment threats to aquatic ecosystems.
- Undertake risk ranking and prioritisation of all catchment threats in priority water plan areas.
- Validate the current system understanding and priority threats through targeted field programs.

To advance the development of water management interventions which aim to improve environmental outcomes, aquatic ecosystem assessments need to produce metrics of ecosystem health, diagnose threats, the causes of degradation, and identifying priorities for mitigation. The DES Q-catchments program assesses the health of Queensland's riverine ecosystems and diagnoses the relative impact of the multiple stressors impacting upon them (Marshall & Negus 2018). The legislative driver is the *Water Act 2000* and the policy driver is to provide support for water planning decisions by placing risks to river health resulting from water resource development in the context of risks from other stressors. These assessments are undertaken at large spatial scales ranging from river catchments to bioregions.

Stream 4.1 Threats inventory and characterisation

Stream goal

Identify and characterise the potential threats to aquatic ecosystems across Queensland.

Key research questions

- What are the potential threats to Queensland's aquatic ecosystems?
- What are the ecosystem components and functions sensitive to these potential threats in each water plan area?

Threats to freshwater ecosystems can be broadly categorized into five types of stressors: (i) overexploitation, (ii) pollution, (iii) flow regime modification, (iv) removal or disturbance of habitat, and (v) invasion of exotic species (Dudgeon *et al.* 2006). These threats have been expanded for application in risk assessments for Queensland river ecosystems (Negus *et al.* 2020). For each of these generic stressors, Pressure-Stressor-Response models have been developed for Queensland rivers by consolidation of scientific literature and incorporation of local knowledge. These represent the best current understanding of the cause-effect pathways linking human activities (i.e. pressures) to ecosystem responses via the effects that they have on the intensity of stressors. They indicate how the changing intensity of a stressor may threaten or influence river health.

CASE STUDY 7:

The threat of climate extremes to Queensland's threatened coldwater fish populations

The Earth's climate is rapidly changing. The year 2019 was both the hottest and driest on record for large parts of Queensland and many extreme records were broken. Climate projections predict a greater than 99% probability that most of the years between 2019 and 2028 will be in the top ten warmest years on record for the planet. For many parts of Queensland, climate change will bring higher extreme temperatures, more hot days and increasing frequency and severity of drought. This is a threat to many species, but none more so than Queensland's cold stenotherm aquatic species.

***Figure 18 Gadopsis marmoratus*, the river blackfish. The only Queensland population of this species was threatened by extreme climate conditions over the summer of 2019–2020 triggering a rescue operation.**

These species are very sensitive to increases in water temperature, tend to be specialised, and often have distributions that are highly fragmented and very limited. They are already 'climate refugees', having been restricted to cool refuge areas by the increase in Australia's temperature and aridity over the last few million years. As climate warms further their available habitat will shrink as narrow, suitable climatic envelopes move or disappear completely. Possibilities for these species include adaptation to higher temperatures or migration to cooler areas. Both are unlikely, with the greatest possibility being extinction.

With interventions, these species can be saved. In the summer of 2019–2020 extreme heat and drought threatened Queensland's cold stenotherm river blackfish (*Gadopsis marmoratus*). Currently this species is restricted to small headwater tributary streams of the Condamine River. Emergency funding allowed individuals to be held in captivity as an 'ark' or insurance population for potential recolonization if the wild ones went locally extinct. These fish were able to be restocked into part of their former range to increase the chances of the species in Queensland surviving into the future. Following a successful trial, eDNA sampling is being used to track the success of the reintroduction. This non-invasive technique detects the presence of DNA in water samples collected from streams as a means of confirming the presence of the species at a site. More such actions are likely to be needed over future severe summers to save this and other such cold adapted species.

Figure 19 Perennially flowing, cold, groundwater-fed streams are climate refuges for Queensland's cold stenotherm aquatic species.

Stream 4.2 Prioritisation and indicator selection

Stream goal

Undertake risk assessments of threats to aquatic ecosystems across Queensland

Key research questions

- What are the significant threats to aquatic ecosystems?
- What are the knowledge gaps relating to these threats?
- What are the most sensitive indicators for assessing these threats at a catchment scale?

An essential step in developing a monitoring program is indicator selection. Ideally, indicators are chosen via a prioritisation process which identifies sensitive aquatic ecosystem components that can be sampled in the field to assess impacts. This process is informed by robust stressor-receptor conceptualisations which are explicit about the mode of stressor action and the receptor response. Where possible, these conceptualisations give recognition to the presence of multiple stressors and the potential for cumulative effects which can be difficult to disentangle. Issues such as the potential spatial and temporal variation, measurement methods and associated errors, required resources and applicability to an assessment area are also essential considerations.

Stream 4.3 Validation and system understanding

Stream goal

Validate risk assessments and improve system understanding of threatening processes by undertaking targeted monitoring using sensitive aquatic ecosystem indicators.

Key research questions

- What is the optimum sampling design to detect impacts from priority threats to aquatic ecosystems at the catchment-scale?
- Does the risk prioritisation process capture the most important aquatic ecosystem threats?
- How can targeted monitoring inform aquatic ecosystem responses to key threatening processes?

Sampling design is a critical aspect of developing a monitoring program to detect ecosystem responses to anthropogenic threats. As such, there is a substantial body of scientific literature devoted to this. A suitable design is prerequisite for collecting monitoring data that can be used to make reliable, credible, and valid inferences for assessing river health (Dobbie & Negus 2013). Advances in the following areas will contribute to improvements in achieving robust assessments of ecosystem health considering known stressors: (i) better definitions of target populations through improved understanding of demographics and distribution, (ii) statistically balanced site selection incorporating key landscape attributes relevant to populations, (iii) alternative reference site definitions to account for degraded catchments and alternative climate futures, (iv) improved understanding of species-stressor interactions across multiple life stages and generations to support the establishment of robust effect estimates, and (v) better understanding of how the interactions between stressors influence ecosystems in multistressor systems.

CASE STUDY 8:

Studying the potential impacts of climate change using extreme environments

Increased water temperatures are predicted to occur due to climate change, thus impacting riverine biota. To date, there have been very few field studies testing these temperature-related effects. The ecology of thermal spring systems has been assessed as an example to understand how altered thermal regimes due to climate change might impact riverine biota.

Thermal springs are defined as those which have water temperatures above 36.7°C. Temperature generally decreases as water flows away from spring vents until it reaches the ambient air temperature. Springs have a high biodiversity with many containing unique and endemic biota but also many generalist aquatic species. The natural gradient of water temperature in spring flows combined with high biodiversity provides a unique opportunity to investigate the influence of water temperature on aquatic biota.

Recent work has focussed on Talaroo Springs in the Einasleigh River catchment of the Gulf of Carpentaria. They are the only hot terraced springs in Australia with recorded water temperatures exceeding 70°C. Aquatic invertebrates and diatoms were surveyed along a water temperature gradient to identify critical thresholds.

The results show a decrease in invertebrate and diatom diversity as water temperatures increase. Additionally, the number of invertebrates markedly decrease at 40°C, a critical threshold. The nearby Einasleigh River has experienced contemporary peaks in water temperature over 40°C, which corresponds to this threshold level. The information contributes to the understanding of how even small fluctuations in water temperature can influence aquatic biota and highlights the importance of instream refugia for long term resilience.

Figure 20 An outflow of hot water on Talaroo Springs mound.

Figure 21 A flowing watercourse from Talaroo Springs.

Figure 22 An aquatic beetle larvae and dragonfly nymph sampled from a watercourse at Talaroo Springs.

THEME 5:
HYDROLOGY

Theme goal

Develop an understanding of the dominant catchment hydrological processes incorporating surface water and groundwater dynamics and their interactions.

Key objectives

- Monitor and simulate stream flow at key locations in water plan areas.
- Monitor and simulate groundwater dynamics across key aquifers.
- Improve hydrological conceptualisations incorporating surface water and groundwater interactions to support water management decisions and the development of hydrological models .
- Develop additional model input data sets for modelling to assess climate change and climate variability .
- Utilise process understanding and modelling approaches to optimise measurement of water resources for management decisions.
- Evaluate innovative approaches to incorporation of multi-source data of varying qualities and frequencies to improve process understanding and simulation of critical hydrological processes (e.g. remote sensing, distributed sensor networks, contactless water flow monitoring, citizen science).

Hydrological models and process understanding underpin the development and implementation of Water Plans. Daily flow or groundwater depth simulations which represent water entitlements and their use, are the principal input to environmental assessments, design of plan objectives and water management strategies, and evaluation of water trades. These models incorporate all available data from the water usage, groundwater and surface water monitoring sites, water storages and operational rules to provide a strong scientific platform to provide the basis of defensible decisions to stakeholders.

Fyke netting, sampling fish populations in the Cooper Creek catchment.

Stream 5.1 Hydrological modelling

Stream goal

Develop and maintain a suite of hydrological models and assessment tools for characterising stream flow regimes, and groundwater dynamics to support water plan development and implementation.

Key research questions

- What is the most efficient and robust hydrological modelling platform (or approach) for simulating daily stream flow at the catchment scale?
- What is the most efficient and robust hydrological modelling platform (or approach) for simulating groundwater dynamics across a range of aquifer types?
- What is the most efficient and robust assessment and/or modelling platform for simulating groundwater-surface water interactions?
- What are the likely changes to hydrological drivers from climate change projections?

Integrated Quantity Quality Model was developed in the early 1990s and has underpinned several generations of legislative plans for Queensland catchments. This model platform has reached the end of its developmental life. A new generation modelling platform (SOURCE) has been developed collaboratively with Queensland, New South Wales, Victoria, South Australia, Western Australia, and the Murray-Darling Basin Authority. This model is now operational, and all the partners are implementing or already implemented.

Somerset Dam.

Significant advancement has been made on implementing SOURCE models in priority catchments across the state. Opportunities exist for further enhancement of hydrological modelling to support operational decision-making within the life cycle of the Water Plan. For example, assessment of unallocated water releases and changes to scheme operations have very localised impacts on entitlements and environmental flows that may not be reflected due to the scale of models used for Water Plan development and review. In addition, the time-scale of modelling outputs for decision-making should ideally be flexible in response to process understanding. Daily time-steps may have limited value when looking at aquifer responses in the Great Artesian Basin. Other priorities for further advancement include:

- Expanding the access and utility of hydrology simulations for external stakeholders, and socio-economic, cultural, and ecological assessments.
- Improving linkages between Water Planning and GBR hydrological modelling domains.
- Improving model and workflow management to achieve automation of resource intensive process such as rainfall runoff calibrations, and better management of large data sets.
- Improving methodologies for rainfall and stream flow matching.
- Modernisation of key software and data analysis methods consistent with evolving data science standards.
- Use of 2D hydraulic approaches to improve high flow ratings at stream gauges where high flow ratings are not available.
- Continuing development of approaches for the inclusion of climate change projections in hydrological simulations. Recent releases of downscaled global climate model outputs for both high and low emission scenarios provide opportunities for climate projections at temporal and spatial scales relevant to water planning. Complementary information on climate change influences on landscape processes, land use, and vegetation and crop water use patterns will also be required.
- Better representation of salinity and water quality processes within hydrological models.
- Incorporation of paleoclimates for the better representation of long-term hydro-climate variability.
- Incorporation of uncertainty analysis in hydrological simulations.
- Improvement of data and model visualisation and communication tools to enhance policy and planning outcomes.
- Ability to inform short-term management decisions (e.g. water permits, announced entitlements, seasonal restrictions) as well as longer-term security objectives.

Stream 5.2 Stream flow and aquifer monitoring

Stream goal

To collect surface and groundwater data at appropriate scales across the state to support the real time water management decisions, longer-term planning and policy drivers and the development of robust hydrological models and assessment tools.

Key research questions

- How can the state-wide water monitoring network be optimised to provide the pre-requisite measurement of stream flow and groundwater levels required to support robust hydrological modelling and/or assessment tools?
- What are the key areas of monitoring technology in which Government should be investing to support the network?
- How can small-scale, project specific monitoring be incorporated into the statewide network data repository to create a meta-network to enhance technical assessments and modelling?
- How can external data sources of varying quality and frequency be better integrated?

The state invests significant resources into the statewide surface water and groundwater monitoring networks to achieve multiple objectives, including informing real time water management decisions and the development of robust hydrological models to underpin water plans. The network also supports other priorities including reef water quality program, through the provision of timely, reliable flow data which underpins modelling and reporting on catchment sediment, nutrients, and pesticide loads. The networks are reviewed at a regular basis, most recently in 2020, to assess its efficiency and identify improvement opportunities.

Advancement has been made in the application of alternative hydrological measurement and observation technologies. These include the use of remote sensing products, drone-based and fixed cameras (image velocimetry) and mobile water quality sensors (use of remotely controlled boats). Opportunities provided by improvements in the cost and reliability of telemetry are also being trialled via integration of sensors and gauges with the CATN1 narrow-band network.

Futures challenges include data management, access, and visualisation to a broad range of stakeholders and end users. Adoption of cloud-based approaches and unified data quality assurance coding are critical to deliver a more open-source approach to hydrological data collection and sharing to support improved water resource management.

The use of remote or contactless measurement technologies will continue to be driven by cost-effectiveness, coverage and work place safety needs, acknowledging there will remain a role for traditional direct measurement techniques to provide higher data quality for validation of new technologies and where required for critical decision-making.

Stream 5.3 Surface water–groundwater interactions

Stream goal

To improve the understanding of water flow between surface water and groundwater systems to support hydrological and ecological assessments.

Key research questions

- How do surface water and groundwater systems, including marine influences, interact over space and time?
- What methods are appropriate to measure the water flow between surface and groundwater systems across a range of aquifer types?
- What information is required to develop robust hydrogeological conceptualisations across the state to support hydrological and ecological modelling and assessments?

The interaction of surface water and groundwater involves many physical, chemical, and biological processes that take place in a variety of physiographic and climatic settings. While surface water and groundwater regimes are often considered, measured and modelled separately for simplicity and due to limited system understanding and data availability, the interactions between water sources and their spatial and temporal dynamics are likely to affect the provision and quality of water. To ensure that consequences of changed flow and groundwater regimes are appropriately assessed, hydrological and ecological models need to realistically describe the interactions of and ecosystem requirements for different sources of water.

Hydrochemical methods including analyses of stable (e.g. O and H) and cosmogenic (e.g. tritium, 14C) isotopes, major and trace ions, radon, and strontium isotopes, together with measurements of stream flow and groundwater levels, and geophysical methods such as seismic and ground penetrating radar can be used to reveal the spatial and temporal variations in connections between surface water and groundwater systems.


Lawn Hill Creek, Boodjamulla (Lawn Hill) National Park.

THEME 6:
CULTURAL VALUES

Aboriginal people and Torres Strait Islanders have valuable insights and perspectives on water management in Queensland. To date, our science and planning frameworks have not fully incorporated, comprehended, or conceptualise this traditional knowledge. As such, the WPSP has been expanded to include this theme, which aims to guide the extent to which a water plan can identify, maintain, and protect cultural values that are water-related through the water planning framework in the *Water Act 2000*.

Cultural values and uses of natural resources including riparian areas, plants and animals, springs, lakes, rivers, creeks are potentially represented by environmental assets and functions already understood through environmental assessments and risk assessments that underpin water planning. This provides a foundation from which cultural knowledge can be incorporated into water plans. Building an understanding and capacity of how environmental assets and functions are valued and used in a cultural sense will enable new knowledge to be gathered and build that into the development, evaluation, and review of water plans. This will place government in a better position to recognise and protect cultural values and uses in water plans as having distinct water needs.

Theme goal

Identify water related cultural values supported by the flow regime across priority water plan areas, characterise current and emerging threats associated with water resource development, understand water requirements for cultural values and prioritise cultural values and assets for further research.

Key objectives

- Undertake hydrological threat analyses for priority water plan areas.
- Undertake consultation with Aboriginal and Torres Strait Islander people across the state to identify water related cultural values.
- Develop an inventory of water related cultural values that are supported by the flow regime and potentially responsive to identified hydrological threats.
- Improve understanding of the interactions between the flow regime and cultural values, and incorporation of these interactions into a quantitative assessment process.

Cultural outcomes are required in water plans under the *Water Act 2000*. There will be measures in plans to support these outcomes that may relate to understanding flow requirements of values and uses of water identified by Aboriginal people in the water planning process.

Effective engagement throughout the water planning process is needed to ensure water-related Aboriginal science is given the platform and support it needs to be understood alongside Western water management. Water Policy in DRDMW is currently developing a state-wide approach to cultural engagement to ensure that water plans are underpinned by effective partnerships with Aboriginal people and Torres Strait Islanders to strengthen their participation in the water planning process.

Stream 6.1 Identifying cultural values

Stream goal

1) Develop an inventory of cultural values, and 2) identify which of these values have critical links to the flow regime in water plan areas.

Key research questions

- What are cultural values in the plan area?
- Which of these cultural values are flow dependent?
- What are the water requirements for the flow related cultural values within the plan area?
- What are the cultural values that are sensitive to changes in flow?

A comprehensive understanding of how water is valued and used for water-related cultural purposes is needed. This can be used to build knowledge of how these values relate to assets and functions and what the associated risks and sensitivities are to flow. The case study below describes an example of this process that was completed for the Water Plan (Condamine and Balonne) 2019.

Stream 6.2 Cultural values water requirements

Stream goal

Develop explicit, quantitative rule sets that describe cultural watering requirements as facets of the flow regime to inform the development of a quantitative assessment process.

Key research questions

- What are the environmental conditions provided by the flow regime that support cultural values within a given plan area?
- Can existing knowledge on the flow requirements of ecological assets be used as a surrogate for cultural values?

There will be crossover with environmental water requirements to achieve cultural water requirements in a given water plan area but what we don't know is whether there are other cultural values that are not currently provided for in the flow regime. This will need to be determined through engagement.

Stream 6.3 Threats to cultural values water requirements

Stream goal

Identify and characterise the potential flow related threats to cultural values across Queensland.

Key research questions

- What are the potential threats to cultural values?
- What are the environmental and related values sensitive to these potential threats in each water plan area?

We are at the start of the journey of understanding flow requirements of cultural values, so it is important to have an inventory of potential threats. This will need to be underpinned by engagement and updated as more information becomes available.

CASE STUDY 9:

Linking cultural values and uses to outcomes for water management

A process to understand and connect cultural values and uses was undertaken for the development of the Water Plan (Condamine and Balonne) 2019. Yellowbelly was identified as important species, valued and used by Aboriginal people in the Murray Darling Basin. The link between yellowbelly's values and uses and Aboriginal people's objectives and outcomes for water management is shown in Figure 23 below. This is a process that could be undertaken for other values and uses identified by Aboriginal people and Torres Strait Islanders across Queensland.

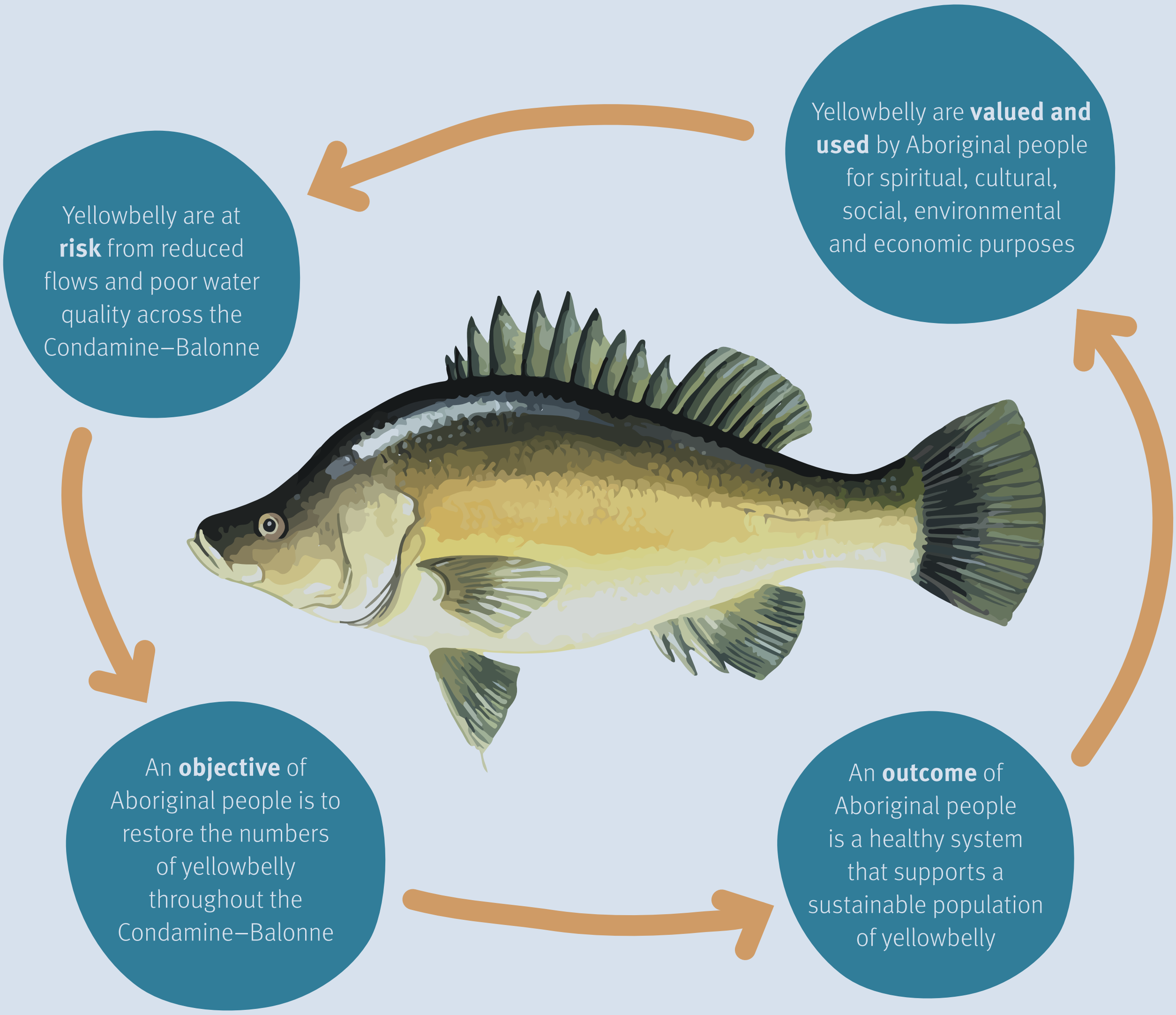

Figure 23 Link between the yellowbelly's value and uses and Aboriginal people, and risks, objectives and outcomes for water management.

Source: Water Connections: Aboriginal people's water needs in the Queensland Murray-Darling Basin 2019.

THEME 7: SOCIO-ECONOMIC VALUES

Theme Goal

Identify social and economic (i.e. socio-economic) values supported by the flow regime, characterise current and emerging threats associated with water resource development, and prioritise socio-economic values and assets for further research.

Key objectives

- Develop a profile of socio-economic values that are supported by the flow regime and potentially responsive to identified hydrological threats.
- Improve understanding of the interactions between the flow regime and socio-economic values, and incorporation of these interactions into a quantitative assessment process.

Sustainable management of water resources under the *Water Act 2000* requires the consideration and balancing of competing needs of different water users, including the environment. Social and economic assessment or socio-economic assessment (SEA) is the process of analysing, monitoring, and managing the intended and unintended social and economic consequences, both positive and negative, of policy decisions to all major stakeholders.

SEAs play a key role in informing policy decisions about the management of Queensland's water resources under water plans and the socio-economic benefits resulting from implementing these plans.

In water planning, SEA is used as a tool to assist in realising the effects of policy decisions upon people and economy through:

- identification of core water related social and economic values and the analysis of conditions and trends of such values to inform on demand for water and the implications for water planning
- assessment of social and economic benefits of a water plan and impacts of policy options
- identification of risks that could affect achievement of the stated social and economic outcomes of a water plan, and the associated mitigation measures; and
- ensuring decisions are transparent, equitable and consistent with the principles of sustainable water management.

A process is currently underway to enhance the existing social and economic assessment process to ensure consistency in approach statewide. The enhanced approach will:

- establish when SEAs could be used and their scope, with reference to the planning cycle
- establish a standard approach to:
  - document the socio-economic profile for a plan area including what information sources could be used and how they can be used; and
  - report analyses of condition and trends of social and economic values documented in the profile.
- align the socio-economic risk assessment approach with the approach used for environmental risk assessments as far as possible
- inform the Monitoring Evaluation and Reporting Framework on how achievement of plan outcomes can be evaluated. This includes what measures (metrics) should be collected and at what frequency to inform ongoing evaluation of social and economic outcomes of a water plan
- provide guidance on how risks to social and economic outcomes will be considered, including risks from climate change
- inform on appropriate social and economic analysis that can be undertaken to assess policy options and the water related socio-economic benefits of water plans.

Under the planning framework, water plans are routinely reviewed and potentially amended or replaced to ensure they meet requirements of the *Water Act 2000*. A SEA comprises several components (socio-economic profile, risk assessment, social and economic analysis) and some or all components are applied at different stages (Figure 24).

Significant opportunities exist into the future to improve the quality of the data used for SEAs and water plan evaluation including:

- more systematic collection of water use data
- the use of targeted water user/community surveys with the potential to collect information synergistically with other sections of the water business; and
- adopting new technologies such as collecting, collating, and presenting data and analysis of water use in a timely manner to facilitate management and water user decisions.
  - Use of on-line platforms for water user/community surveys.
  - Accessibility of water use data, availability, and pricing information to enable more effective functioning of water trading markets.
  - Remote sensing to inform land use and cropping changes.

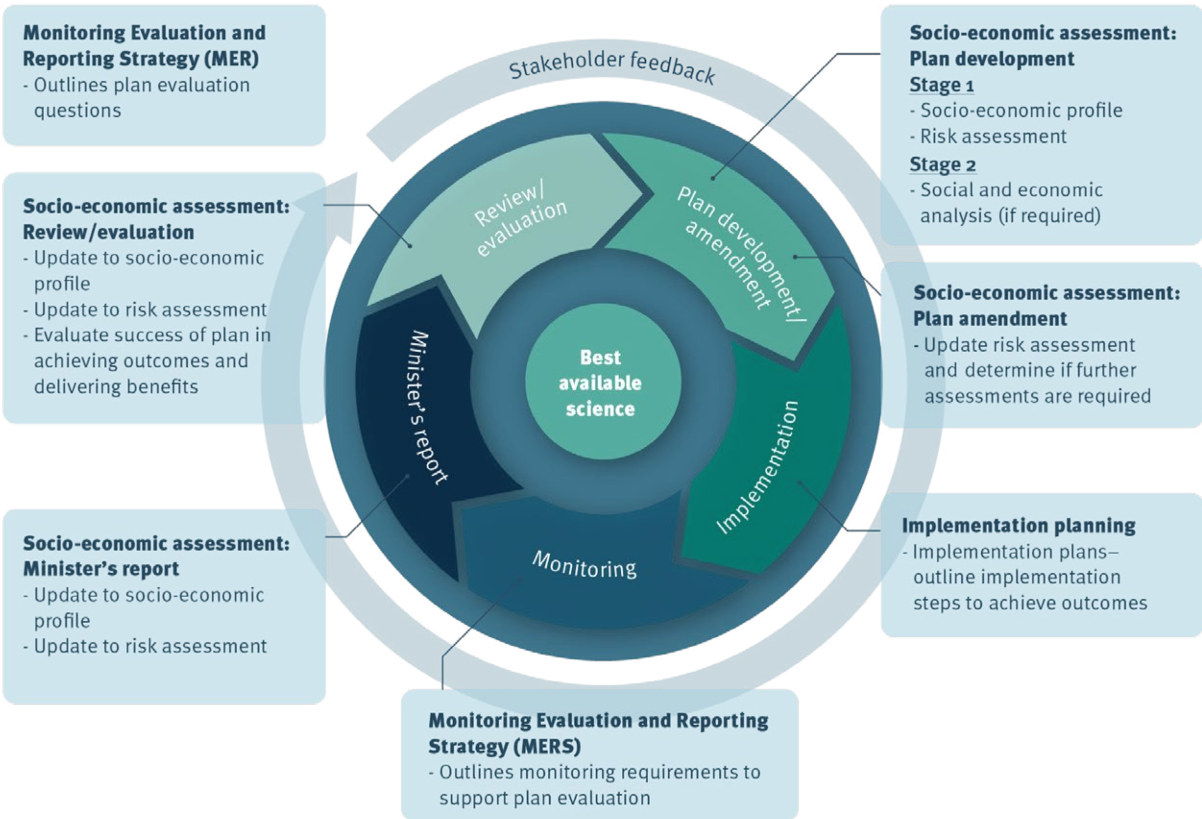

Figure 24 The planning cycle indicating where social-economic assessments may be required and their scope.

Stream 7.1 Identification of social and economic values and indicators

Stream goal

Develop an inventory of socio-economic values supported by the flow regime in all water plan areas and identify suitable indicators.

Key research questions

- What are the socio-economic values within the plan area that are sensitive to changes in water availability and water management under the plan?
- What are the best indicators of socio-economic values for assessing water plan ecological outcomes?

The socio-economic profile for a plan area informs the identification of water related values by documenting water uses and users in the plan area and realised or emerging socio-economic value changes and associated water use demands. Examples of water related social and economic values are shown in the table 1 below.

Table 1 Economic and social values and metrics

Economic values	Economic metrics	Social values	Social metrics
Water for irrigation, agriculture etc	• Water usage • Industry growth • Price and market functionality	Town and community essential drinking water supply	• Access to water • Reliability of supply • Community satisfaction
Stock and domestic water use		Primary and secondary recreation, visual amenity	
Water to support industry and economic development			


Great Artesian Basin water bore.


Tully River looking downstream from Kareeya Hydro gondola.

Stream 7.2 Socio-economic water requirements

Stream goal

Develop explicit metrics that describe socio-economic watering requirements as facets of the flow regime to inform the development of a quantitative assessment process. Socio-economic watering requirement are the water requirements to support and achieve the stated economic outcomes in a water plan.

Key research questions

- What are the water requirements of socio-economic values within a given plan area?

A fundamental component of a socio-economic assessment is the documentation of a socio-economic profile at the pre-planning phase to provide an overview of the key communities and industry structures in a catchment area both at the snapshot and trend level and ensures the ability of the community to absorb change is appreciated.

The socio-economic profile:

- documents key water related social and economic values for consideration in a water plan
- develops an understanding of changing water demands by water users and the drivers of future consumptive demand over the life of the water plan; and
- informs commentary on the economic implications of the estimated future patterns of water use relative to water supply.

Main types of socio-economic information that inform the baseline profile include:

- social and demographic information
- economy and market statistics; and
- water use statistics, including water supply and demand and the water market.

The profiles aim to identify key historical trends in the community and industry that would be expected to impact on water demand. Where possible, future projections are also identified to enable a better understanding of the implications of the likely future patterns of water use. This is generally achieved through assessment of factors such as identifying consumptive water users and how much water they use, how water resources are used, and the contribution of those water resources to economic output and employment, and future economic trends and market outlook of key industries. An overall assessment seeks to focus on two key aspects: whether demand for water equates to supply and whether the market is functioning effectively.

The use of socio-economic assessments has been well established and used to inform water planning in Queensland. While the approach to these assessments has been applied in an ad hoc manner, the implementation of the framework will provide a consistent methodology to apply across different water plan areas. A key challenge for application of the framework will be understanding the reasons underlying trends identified in the socio-economic profiles, for example how on-farm investment decisions and other drivers affect cropping practices and consequently water use and demand. Opportunities exist to incorporate water user surveys as part of the assessment to understand and ground truth trends.


Centre pivot irrigation of soybeans near Emerald.

Stream 7.3 Threats to social and economic water requirements

Stream goal

Characterise potential threats to the flow regime and develop measures and indices of the consequence of changed flow regimes for socio-economic values at relevant spatial scales.

Key research questions

- How has the flow regime changed due to implementation of the water plan?
- What are the socio-economic values within the plan area that are sensitive to these changes?

A key challenge is quantifying the impacts on socio-economic values because of changed flow regimes. At present, most analysis are limited to qualitative methods due to insufficient data particularly on socio-economic values that are non-consumptive, have an indirect use or have a non-use value. Significant opportunities exist to develop methodologies to address this.

Pelicans at a refuge waterhole.

THEME 8:
ASSESSMENT AND EVALUATION

Theme goal

Develop tools and approaches for the evaluation of water plan performance against its stated outcomes.

Key objectives

- Develop risk assessment and decision support tools to facilitate appropriate, timely reporting and advice in line with decision-making priorities and timeframes.
- Implement appropriate monitoring, modelling, and assessment strategies to evaluate the effectiveness of current water management strategies.
- Develop, maintain, and disseminate methods, models and assessment tools for decision making.

Water plan development and performance evaluation is informed by the best available science, using a range of technical information, data, and modelling outputs. This is achieved through technical assessments which investigate environmental and ecological factors, hydrology, and climate risks; as well as social, economic, and cultural needs and values. Outcomes from these assessments are incorporated into water plans to ensure the needs of water users and the environment are met.

Stream 8.1 Decision support and risk assessment

Stream goal

Translate data and information from Queensland government research and monitoring projects and other information sources into knowledge to inform water planning decisions.

Key research questions

- How should information from disparate science disciplines, activities and qualities be integrated to provide an effective knowledge platform to support water planning decision making?
- What constitutes current best practice in translating knowledge on the watering requirements of socio-economic, cultural, and ecological values into improved planning outcomes?

Effective decision making to support the allocation and management of water must be based on a sound scientific understanding of the implications of these decisions on the water dependent values of the plan area. The water regime required to meet these objectives can be tested via an understanding of how values may respond under a range of allocation and management scenarios. Scenario evaluation may be based upon quantified relationships developed from a range of sources from expert opinion to information gathered through targeted research and monitoring programs, and the broader scientific literature. Where possible, science undertaken by DES and DRDMW under the plan is published in the peer reviewed scientific literature. This provides confidence and improves its discoverability.

This stream focusses on:

- developing systems to capture information and knowledge relating to socio-economic, cultural, and ecological water dependencies from the full range of scientific sources relevant to Queensland's catchments
- developing robust system conceptualisations of their responses to flow/groundwater regimes and water allocation and management arrangements based on a synthesis of current scientific knowledge and the outcomes of research and monitoring programs
- using this information to inform modelling, management, and monitoring priorities.

CASE STUDY 10:

Water resource risk register

Risks to water resources and water plan outcomes are regularly assessed to support five yearly Minister's performance reporting on water plans, to gain an understanding of the effectiveness of management actions and prioritise activities across the water business. Historically the results of these assessments were stored in archived spreadsheets which were not widely accessible by water business staff.

One of the recommendations of the 'Independent Audit of non-urban measurement and compliance' in 2018 was to "Implement a documented, formalised and systematic catchment risk assessment process and apply the outcomes to decision-making on water measurement and monitoring."

Consequently, a central digital repository, the 'water resource risk register', has been developed to store all risk assessments of water resources completed to date to ensure they are documented in a systematic and comprehensive way. The register will enhance discoverability of this information across the water business to inform decision making. Having a central repository of information makes reporting easier, which provides greater transparency for our stakeholders on the risks to water resources that have been identified and how they are being managed.

Collaboration in action at the Water Planning Science Forum 2019.

Stream 8.2 Optimisation of water management objectives and indicators

Stream goal

Optimise water management objectives, indicators, and outcome response metrics to support plan implementation and evaluation.

Key research questions

- What is the most effective way to specify plan flow objectives incorporating relevant aspects of the flow regime, values, threats, and management objectives?
- Does the range of current performance indicators (PIs) respond to water allocation scenarios as expected based on the current system understanding?
- What are acceptable limits of change in a PI while still supporting plan outcomes?
- How can plan outcomes be made more specific and measurable?
- How can flow objectives be better specified to reflect the intent of the flows being provided?

A key driver for the ongoing refinement of PIs, Environmental Flow Objectives (EFOs) and Water Allocation Security Objectives (WASOs) is to ensure they are specific and behave in a predictable manner. Some current challenges for further refinement include:

Choosing metrics which behave in a predictable manner under a range of water trading scenarios avoiding issues such as inconsistent, non-linear behaviour.

Establishing clear levels of protection provided to ecological assets by outcomes and strategies in the plan. For a range of PIs a water plan may allow for decisions to be approved as long as the EFO is between percentage ranges of the value in the predevelopment case. To date there has been limited assessment of whether this range is suitable for the ecological assets identified in the plan area based on improved knowledge.

Establishing clear links between EFOs and the ecological outcomes they support.

Backpack electrofishing in the Wet Tropics.

CASE STUDY 11:

Optimising environmental management rules to reduce the risk of turtle nest inundation

The critically endangered white-throated snapping turtle (*Elseya albagula*) is an ecological asset for the Burnett Basin water plan. Nesting activity is triggered by rainfall between May and July, with hatchlings emerging from December onwards. Ben Anderson Barrage on the Burnett River is an important nesting site for this freshwater turtle and research has shown that females nest on the riverbank relative to the standing water level at the time of nesting. Inundation of eggs is lethal; therefore, nests are at risk from May to December due to their extended incubation period.

Previous operating rules for the barrage allowed drawdown to 1 m AHD from its 3.97 m AHD full supply level. Collaborative research by DRDMW and DES showed that nests laid when barrage water levels are low are at high risk as subsequent inflows can cause inundation (Espinoza *et al.* 2018). The review of the water plan in 2013 highlighted these risks. The science revealed that water level fluctuations within the barrage could inundate a significant proportion of turtle nests, causing clutch failure and reduced recruitment. The review further identified operational changes to the barrage which resulted in reduced rates of nest inundation. In summary, raising the Nominal Operating Level (NOL) during the nesting season (May–July) as a solution forced turtles to nest higher up the bank, and allowed drawdown at the end of the nesting season, an air space is created for natural inflows.

Whilst the main objective of changes to storage level management in Ben Anderson Barrage was designed to reduce nest inundation of *E. albagula*, the provision of more stable water levels benefit other vulnerable species such as the Australian lungfish (*Neoceratodus forsteri*) and improves fish passage by increasing fishway operation, without compromising water security and reliability for existing users. Additionally, as the barrage levels are kept closer to full supply under the new operational rules, smaller riverine flows overtop the barrage more frequently providing increased freshwater flows to the estuary. As such, providing more movement cues and creating brackish habitat for critical life stages of a variety of estuarine species, including barramundi, prawns and mangroves. Finally, as part of a holistic review of the ecological requirements of aquatic species and operational rules in the Burnett, there were a number of other changes proposed at this time to promote a transfer of natural flows down the river through several storages.

Figure 25 Female *Elseya albagula* nest on the riverbank relative to the standing water level at the time of nesting between May and July. Nest inundation can be reduced by effective water management.

Figure 26 Female white-throated snapping turtle (*Elseya albagula*).

Stream 8.3 Assessment tools

Stream goal

To develop and manage conceptual and quantitative models, risk assessment methods and decision support tools that enable increasingly efficient plan assessments and decision making.

Key research questions

- What modelling capacities are required to effectively support the range of values identified as indicators across the state?
- What is the best approach for storing, sharing, maintaining, and updating them?
- What reporting is required at each level of the information hierarchy to be informative for assessments and statutory reporting?

Observing change and understanding the vulnerabilities of values supported by the water plan are important foundations for the sustainable management of water; benefits to these values come from specific actions to prevent, mitigate, or remediate potential impacts. Water management strategies to mitigate risks to these values are assessed by monitoring and modelling the viability of sensitive indicators. This model-based assessment process is knowledge demanding.

A weight-of-evidence risk-based approach, bringing together multiple lines of evidence and considering the strengths and weaknesses of each and their level of uncertainty, is the basis for the framework used to date. Sources of information used include the broader scientific literature, expert elicitation and targeted monitoring conducted by DES and DRDMW scientists. Hydrological models of priority surface water and groundwater systems have been developed across Queensland and are maintained and extended to support the development and implementation of Water Plans (see theme 5). A library of ecological models and assessment tools have been developed over the past ten years which provides a platform for further enhancement and adaptation to ecological assets with similar life history or process requirements and across regions.

Challenges for ongoing refinement of this capacity include:

- improving the predictive capacity by developing and implementing targeted research to test assumptions and model parameters
- making tools available to potential users within the Queensland Government, and more widely
- maintaining currency by updating assumptions as new information becomes available
- ensuring model uncertainties are communicated to staff to inform research and monitoring prioritisation
- developing standard methods and approaches to collect data for model integration
- improving model outputs to streamline reporting and assessment activities
- explicit inclusion of future climate predictions.

References

Cantonati, M., Stevens, L.E., Segadelli, S., Springer, A.E., Goldscheider, N., Celico, F., Filippini, M., Ogata, K. and Gargini, A., 2020. Ecohydrogeology: The interdisciplinary convergence needed to improve the study and stewardship of springs and other groundwater-dependent habitats, biota, and ecosystems. Ecological Indicators, 110, p.105803.

Clifton, C., Cossens, B., McAuley, C., Evans, R., Cook, P., Howe, P. and Boulton, A., 2007. A framework for assessing the environmental water requirements of groundwater dependent ecosystems. Report 1: Assessment Toolbox. Prepared for Land and Water Australia.

Cockayne, B.J., McDougall, A.J., Espinoza, T., Burndred, K.R., Thrupp, C.L., Broadfoot, C.D. and Finn, M.A., 2013. Riverine flow and spawning requirements of Macquaria ambigua oriens: implications for conservation and management. Marine and Freshwater Research, 64(1), pp.42–53.

Dobbie, M.J. and Negus, P., 2013. Addressing statistical and operational challenges in designing large-scale stream condition surveys. Environmental monitoring and assessment, 185(9), pp.7231–7243.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D., Stiassny, M.L. and Sullivan, C.A., 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological reviews, 81(2), pp.163–182.

Espinoza, T., Connell, M., Marshall, S., Beukeboom, R. and McDougall, A., 2018. Nesting behaviour of the endangered Mary River turtle: monitoring and modelling to inform e-flow strategies. Australian Journal of Zoology, 66(1), pp.15–26.

Hatton, T.J. and Evans, R., 1998. Dependence of Australian ecosystems on groundwater. Water, 25, pp.40–43.

Marshall, J.C. and Negus, P.M., 2019. Application of a Multistressor Risk Framework to the Monitoring, Assessment, and Diagnosis of River Health. In Multiple stressors in river ecosystems (pp. 255-280). Elsevier.

McGregor, G.B., Marshall, J.C., Lobegeiger, J.S., Holloway, D., Menke, N. and Coysh, J., 2018. A risk-based ecohydrological approach to assessing environmental flow regimes. Environmental management, 61(3), pp.358–374.

Negus, P., Blessing, J., Clifford, S. and Marshall, J., 2020. Adaptive monitoring using causative conceptual models: assessment of ecological integrity of aquatic ecosystems. Australasian Journal of Environmental Management, pp.1–17.

Mitchell River.

Contact us

If you would like further information on current projects or how you can collaborate with us, please email us at waterplanningscience@DNRME.qld.gov.au

13 QGOV (13 74 68)

www.DNRME.qld.gov.au
www.des.qld.gov.au

Follow Water Queensland on FaceBook or LinkedIn