Climate risks for the water sector and what it means for making decisions

With application to water resource assessments for Queensland's Water Plans

Queensland Government

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Introduction

- In Queensland, the management of water resources in rivers and groundwater systems is guided by comprehensive water plans.
- Water Plans typically establish the framework for how water in a catchment or an underground aquifer is to be shared. This sharing encompasses town water supplies, irrigators, indigenous communities and the environment.
- To support this framework water resource models have been created to assess long-term performance of that sharing.
- Water resource data and models are used for:
  - Water Plan assessments.
  - Regional Water Supply Security Assessments.
  - Licenced to consultants, agencies, state governments, etc..

Assessments of climate risk

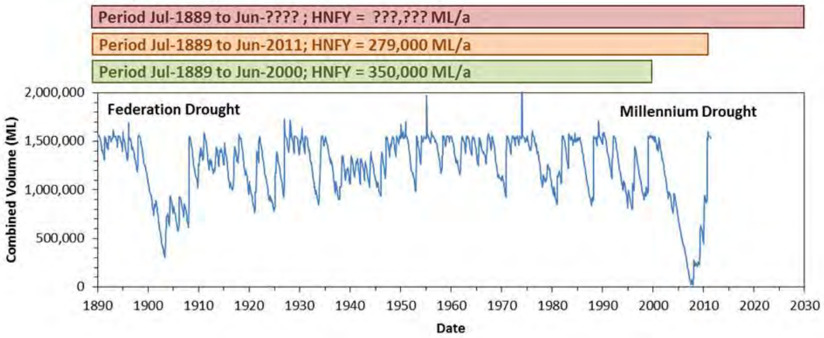
- All analyses utilise calibrated water resource models. They exist for the majority of basins in the state.
- Historical analyses:
  - How might the system perform under historical climate?
- Stochastic analyses:
  - How might the system perform under events that are more extreme than found in the historical record?
- Palaeoclimate analyses:
  - Can we infer longer-term climate variability through more diverse datasets, e.g., tree rings?
- Climate change analyses:
  - How might the system perform under projected climate changes?

Historical analyses

- We gather all gauged rainfall, evaporation and streamflow data across the catchment.
- We extend those data back to 1889 using:
  - Infilling of rainfall data from long-term gauges.
  - Extending streamflow using calibrated rainfall-runoff models.
- A computational water resource model of the river system in created that includes dams, weirs, irrigators, town water demands, water sharing rules, etc..
- The performance of the system is assessed over the historical period 1889 to date.
- The historical data contains a fair amount of variability, typically including a couple of severe droughts and numerous floods.

Issues with historical analyses

- What was the system yield in 2000?
- What was the system yield in 2010?



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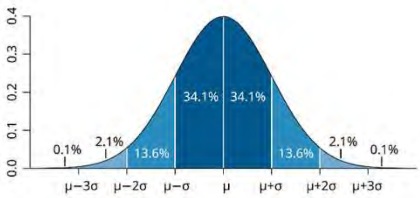
Stochastic analyses

- Probabilistic approach to water resource analysis:
  - Models to represent the variability of the historical climate.
  - The distribution of rainfall, evaporation and streamflows are considered.
- Assessments use the "Level of Service":
  - An attempt to define an acceptable probability on system performance.
  - Quantification of uncertainty in model outputs.
- Issues with stochastic analyses:
  - There is a large degree of uncertainty when assessing rare/infrequent events.
  - Time and computational power required to run analyses.
  - Probabilistic outputs make decision-making and communication more difficult.



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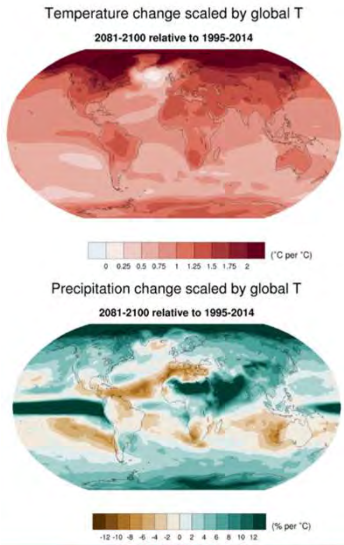
Climate change analyses

- The historical and stochastic analyses are based on a static climate. Predictions are that the climate will change into the future.
- Water Plans now require consideration of climate change.
- The International Panel on Climate Change (IPCC) collates the current science on climate change including impacts and future risks.
- Climate change analyses are driven by projections of:
  - greenhouse gas emissions.
  - technology development.
  - energy generation changes.
  - land use changes.
  - economic circumstances.
  - population growth.

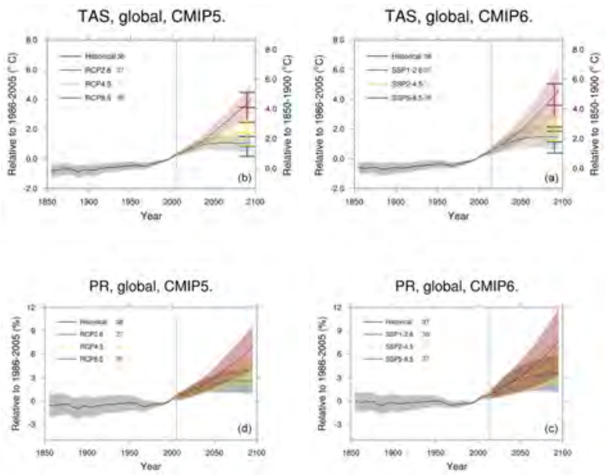
Climate change datasets

- Coupled Model Intercomparison Projects (CMIPs):
  - IPCC project for making multi-model outputs from climate models available.
  - CMIP5 and CMIP6 are collections of model outputs for different IPCC report phases. Phases come out every ~7 years.
- Queensland's downscaled General Circulation Models (GCMs):
  - Improves regional performance (Chapman et al. 2023).
- How do Queensland's datasets fit into Australian and World contexts?
  - Coordinated Regional Climate Downscaling Experiment (CORDEX).
  - National Partnership for Climate Projections (DCCEEW).



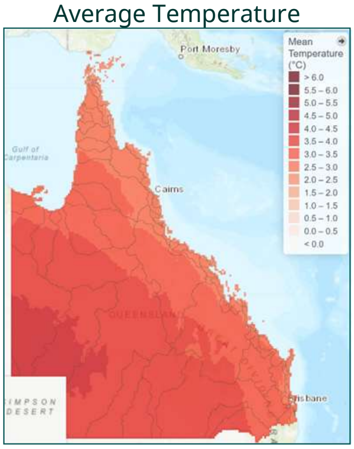
Climate change datasets

- Queensland CMIP5 dataset:
  - Based on AR5 models.
  - 2 emissions scenarios; RCPs 4.5 and 8.5.
  - 11 GCMs (that best replicate Qld's climate).
  - Downscaled to 10km (DES, 2020).
  - Integrated into all Qld Water Plan models.
- Queensland CMIP6 dataset:
  - Based on AR6 models.
  - 3 emissions scenarios; SSPs 1-2.6, 2-4.5, 3-7.0.
  - 15 GCMs (11 atmospheric and 4 ocean-coupled).
  - GCMs downscaled to 10km for Queensland.
  - Will be integrated into Qld Water Plan models.

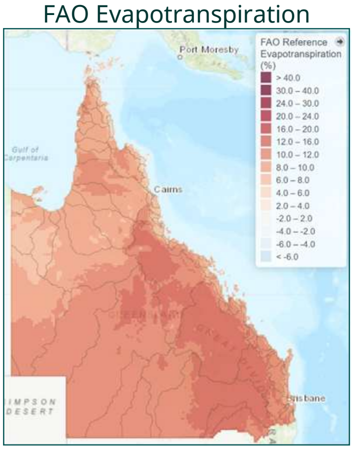


Climate change across Queensland

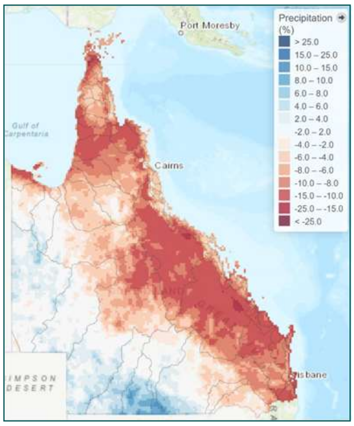
Average Temperature



FAO Evapotranspiration

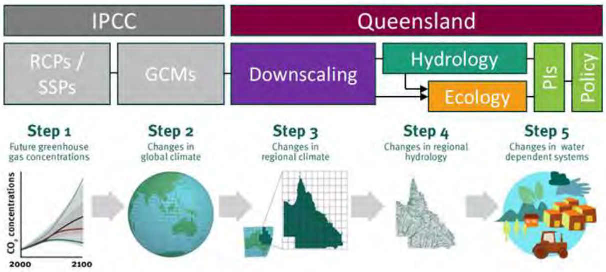


Rainfall



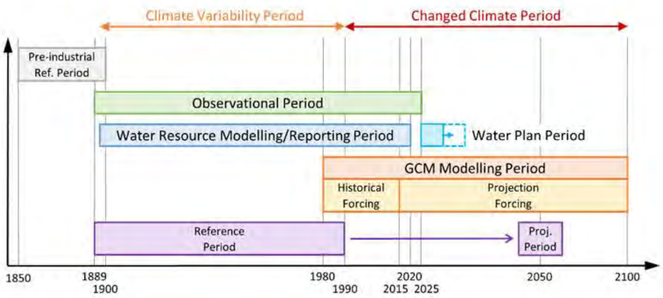
Climate change modelling approach

- Climate-change has been incorporated into almost all river system models (IQQM/Source) in Queensland since the mid-2000s.
- Currently a “top-down” approach is used. This is a common approach used across Australia.
- Not the only approach out there. Other governments, agencies and consultants use:
  - Bottom-up approach.
  - Non-stationary approach.
- Integrated with how we currently assess Water Plan outcomes.



Climate change modelling approach

- Varying data and modelling time periods affect how we apply climate change, e.g., observation, simulation, GCM-modelling and GCM-projection periods.
- Changes in climate are applied to the modelling period based on “windowed” differences between a reference period (or climate variability period) and a target projected period.
- An ensemble of GCMs are used to create an ensemble of datasets, that then produce an ensemble of outputs.



Case study: Barron Water Plan

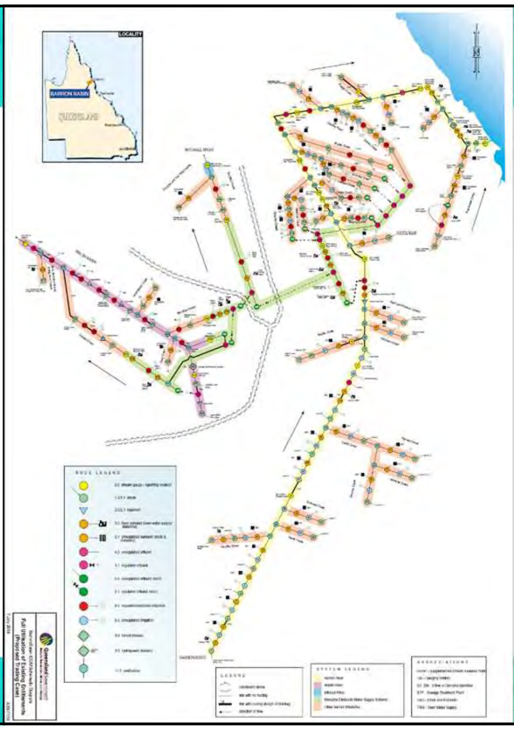
- Consider the Barron Water Plan as a case study.
- Recently it had its Water Plan updated which included:
  - A recalibration of its rainfall-runoff models.
  - A recalibration of its water resource model.
  - Revision of model components.
- Revision of WASOs and EFOs.
- The effects of climate change are assessed at 2050 for all emissions scenarios.
- CMIP5 RCPs 4.5 and 8.5 used.

Case study: Barron Water Plan

- The Barron River basin is located in North Queensland, draining into the Coral Sea just north of Cairns.
- The Barron Water Plan encompasses the Barron River (2,000 km2) as well as parts of the Walsh River (2,800 km2), Mitchell River (170 km2) and Freshwater Creek (70 km2).
- Average rainfall across the basin varies widely (from 800 to 3,200 mm/a) and is very seasonal. Large rainfall events are associated with cyclones and monsoon events occurring between November and April.
- Tinaroo Falls Dam supplies the Mareeba Dimbulah Water Supply Scheme, which supports a vast number of irrigated agricultural crops, mainly including sugar cane, bananas, mangoes and avocadoes.

Simulation model

- The water resource model uses nodes and links to represent inflows, reservoirs, weirs, demands and operations.
- Previously Queensland Hydrology used IQQM models, now Source models.



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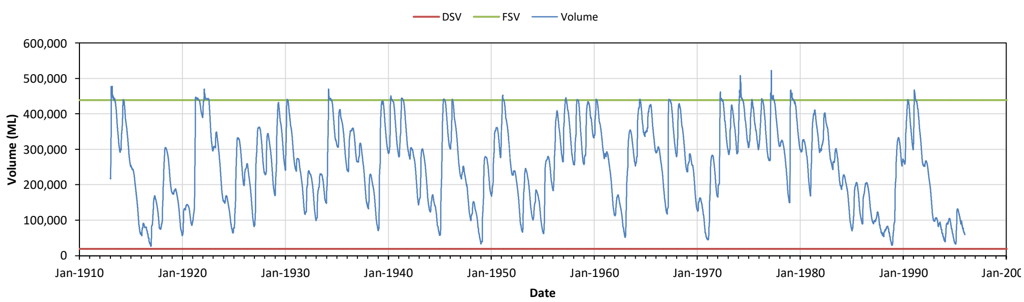
Historical analysis

- Tinaroo Falls Dam.
- Historical no-failure yield.



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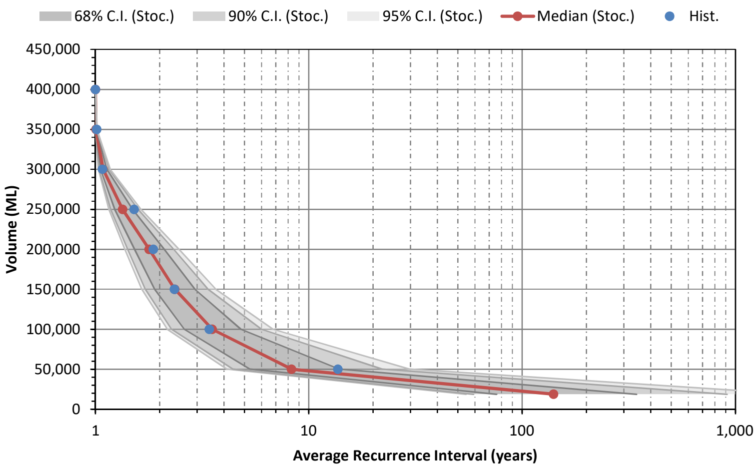
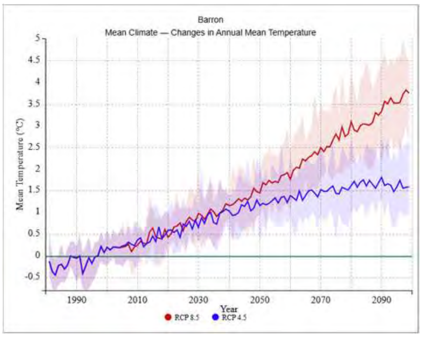
Stochastic analysis

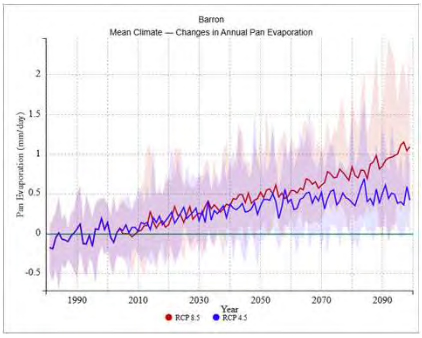
- Tinaroo Falls Dam
- Probabilistic change of being below some trigger level

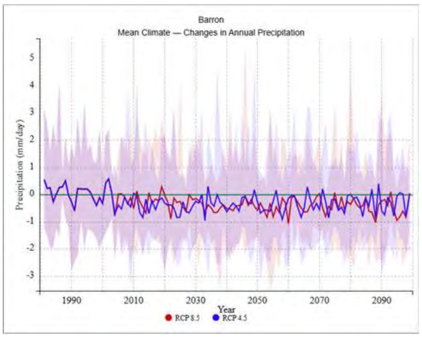


Climate change analysis: Catchment projections

- Climate change projections across the catchment predict an increase in temperature, evaporation and a small decrease in rainfall.

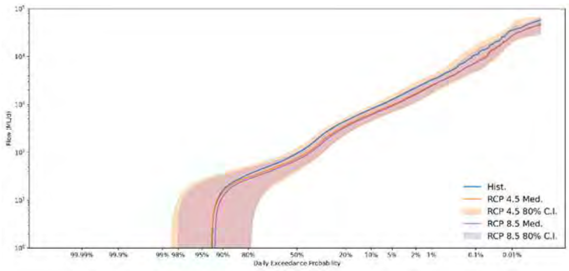


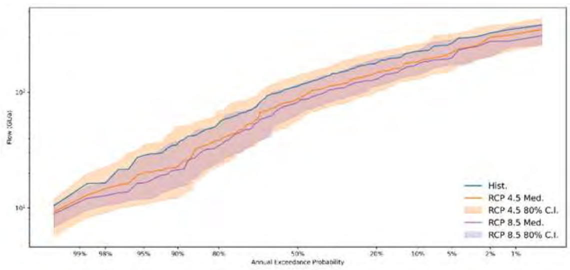




Climate change analysis: Streamflow

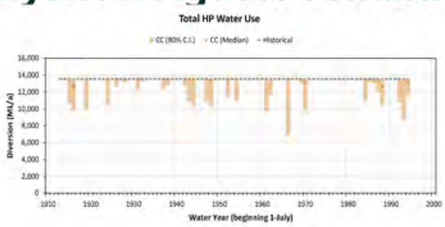
- Simulated streamflow at Picnic Crossing gauge:
  - Daily exceedance curve.
  - Annual exceedance curve.

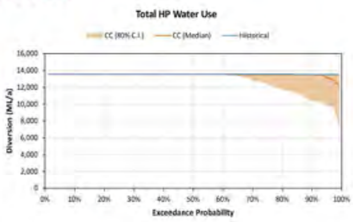


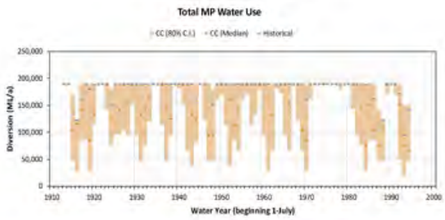


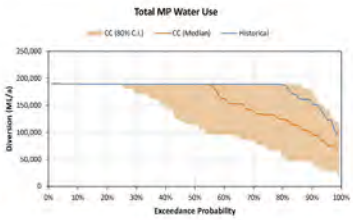
Climate change analysis: Irrigator reliabilities

- Irrigator reliabilities are calculated based on water availability and rules-of-take.
- Medium-priority users potentially impacted more than high-priority users.









Climate change analysis: WASOs

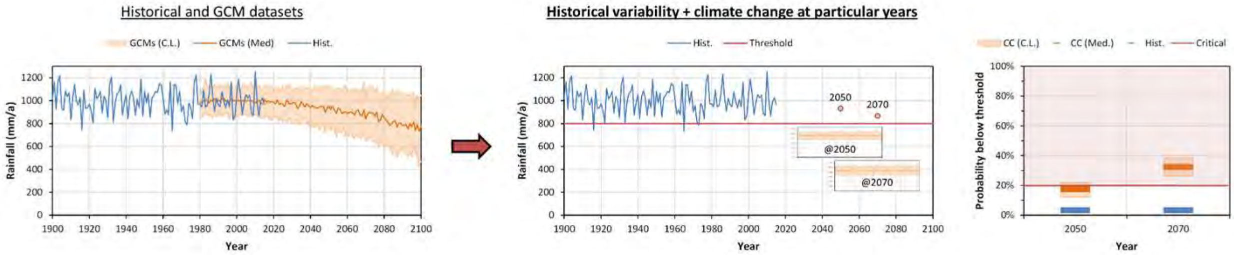
- Water Allocation Security Objectives (WASOs) provide a minimum performance indicator for water users' reliabilities.
- New Water Plans use a MAD/NV measure, "mean annual diversion / nominal volume".
- Different types of water users are potentially affected by climate differently. In particular, medium-priority users are affected more than high-priority users due to the rules of their water access.
- A similar reporting is done for WASOs.

Making decisions

- *Risk ~ Likelihood x Consequence*
- Historical analyses are used for high likelihood, but low consequence events:
  - Typically not presented as probabilistic outputs.
- Stochastic analyses are use for low likelihood, but high consequence events:
  - Typically presented as probabilistic outputs.
- Climate change analyses can be used:
  - Typically presented as multi-projection probabilistic outputs.
- Currently considering:
  - Static "at target date" assessments.
  - Dynamic forecast-like assessment.
  - Multi Criteria Analysis.

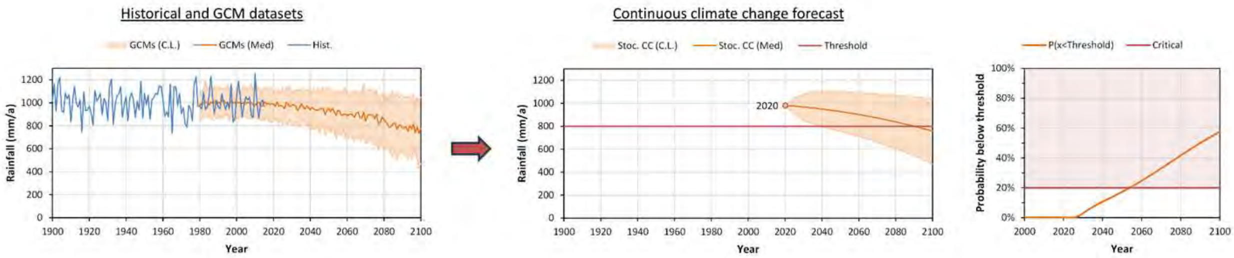
Making decisions

- Analysis applied at discrete years into the future.
- Historical variability with projected climate change at particular years.
- Our current method.



Making decisions

- Continuous stochastic projection into the future.
- Can deal with non-stationarities.



Making decisions

- Multiple Criteria Analysis.
- A risk matrix can be formed for historical, stochastic and/or climate-change based on likelihood and consequence classes.

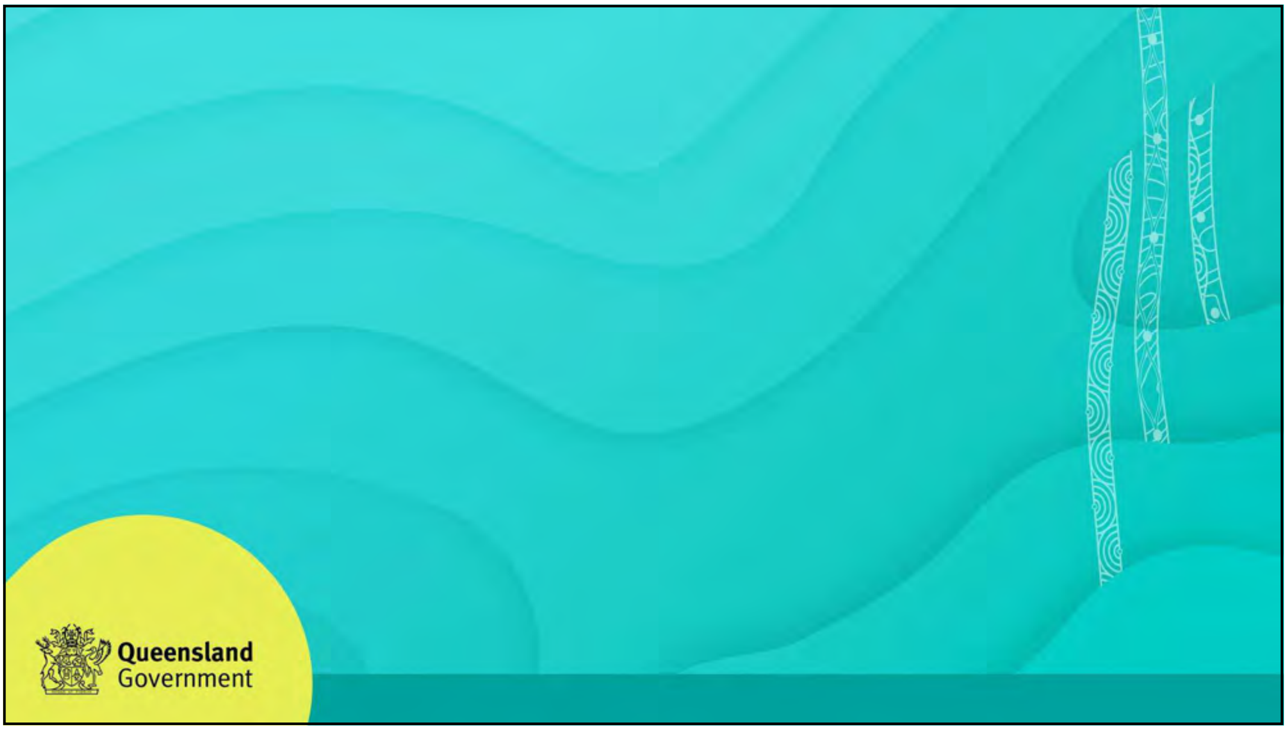
Resilience Matrix			Sensitivity Criteria (e.g., change from baseline)				
			Low	Moderate	High	Very high	Extreme
			< 5%	5% to 15%	15% to 25%	25% to 50%	> 50%
Trend Criteria (e.g., No. GCMs)	Strongly positive	10 - 11 positve	Very high	Very high	High	Moderate	Moderate
	Positve	7 - 9 positive	Very high	High	Moderate	Moderate	Low
	Neutral	5 - 6	High	Moderate	Moderate	Low	Low
	Negative	7 - 9 negative	Moderate	Moderate	Low	Low	Very low
	Strongly negative	10 - 11 negative	Moderate	Low	Low	Very low	Very low

Absolute Risk Matrix			Absolute Consequence (e.g., WASO failure rate)				
			Negligible	Minor	Moderate	Significant	Severe
			<2%	2% to 5%	5% to 15%	25% to 50%	>50%
Likelihood (e.g., probability under CC)	Very likely	10 - 11 GCMs	Medium	Medium	High	Very high	Very high
	Likely	8 - 9 GCMs	Medium	Medium	Medium	High	Very high
	Possible	4 - 7 GCMs	Low	Medium	Medium	Medium	High
	Unlikely	2 - 3 GCMs	Very low	Low	Medium	Medium	Medium
	Very unlikely	0 - 1 GCMs	Very low	Very low	Low	Medium	Medium

Relative Risk Matrix			Relative Consequence (e.g., change in EFO from baseline)				
			Large Decrease	Decreased	Negligible	Increased	Large Increase
			< -10%	-2% to -10%	-2% to +2%	+2% to +10%	> +10%
Likelihood (e.g., probability under CC)	Very likely	10 - 11 GCMs	Highly improved	Improved	Neutral	Impacted	Highly impacted
	Likely	8 - 9 GCMs	Highly improved	Improved	Neutral	Impacted	Highly impacted
	Possible	4 - 7 GCMs	Improved	Neutral	Neutral	Neutral	Impacted
	Unlikely	2 - 3 GCMs	Improved	Neutral	Neutral	Neutral	Impacted
	Very unlikely	0 - 1 GCMs	Neutral	Neutral	Neutral	Neutral	Neutral

Conclusions

- Consideration of climate-variability and climate-change risks on water availability are required for Queensland Water Plans.
- Approaches have been developed for incorporating and assessing climate risks in our water resource modelling and providing Water Plan outputs. We continue to further improve our methods when (we have time).
- Palaeoclimate analysis is another source of information to inform climate risks. A pilot study was done for the Brisbane system but has yet to be applied elsewhere.
- Finally, and arguably the most important, it is the translation of modelled risks to decision-making, then policy and ultimately to the user where more work is required.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