New climate analysis informs NSW's regional water strategies

With our 12 regional water strategies, the New South Wales Government aims to deliver the right amount and quality of water to meet all our needs, including those of the environment.

The development of the strategies has been informed by a new four-step approach to past and future climate risk. This approach recognises the absolute importance of climate risk to our future water supplies.

In the first step, we look at our past 130 years of recorded climate data and the climate drivers that influence past and present climate. But we recognise that 130 years of records are not enough to understand extreme events, especially long-term droughts.

The next step adds 500 years of climate history to our knowledge by analysing things such as tree rings, river sediments and ice cores that have spent a long time in our landscape and carry tell-tale marks of events and changes in climate.

In the third step, researchers apply stochastic modelling to our 500-year picture of past climate to look at possible climate sequences with 10,000 years of data.

Researchers use the fourth step to incorporate climate-change projections into our water modelling. This is because we recognise that historical patterns we see in the climate record will be altered by climate change.

This new approach has shown us that NSW's surface water supplies are likely to be less secure than we thought. More work is required to apply the new climate data to our understanding of groundwater systems to determine how secure groundwater supplies will be in the future.

With our regional water strategies, we are taking this modelling into account so they will provide a roadmap for the next 20–40 years.

Regional water strategies informed by a new approach to past and future climate risks

The NSW Government is developing 12 regional water strategies to make sure there is the right amount of water, of the right quality, delivered in the right way to meet the needs of our communities, Aboriginal people, industry and the environment.

> **These strategies are being informed by a new approach that brings together our records and investigations of the climate in the past with projected climate change.**

The strategies are a roadmap for the next 20–40 years. In them, we look at how much water a region will need to meet future demand. They reflect the challenges and choices involved in meeting those demands. We look at what we need to do to manage risks to the amount of water available from our surface water and groundwater systems.

Water planning based on modelling climate risk

Climate is the most critical risk in water planning

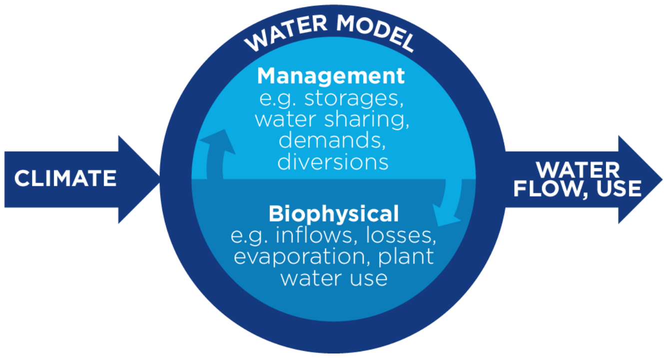
Our climate determines how much water we have available. Australia has a highly variable climate, and rainfall is especially variable. This makes it vital that we understand as much as we can about our climate risks so we can work out how we manage our water supplies.

The 12 strategies will include policy, planning and infrastructure solutions to help meet our current and future water needs. They are built on the best available evidence about climate risk, whether the risk is caused by natural variability or by changes we anticipate. This includes understanding our vulnerability to extreme events such as droughts, which are the largest risk to our water supplies.

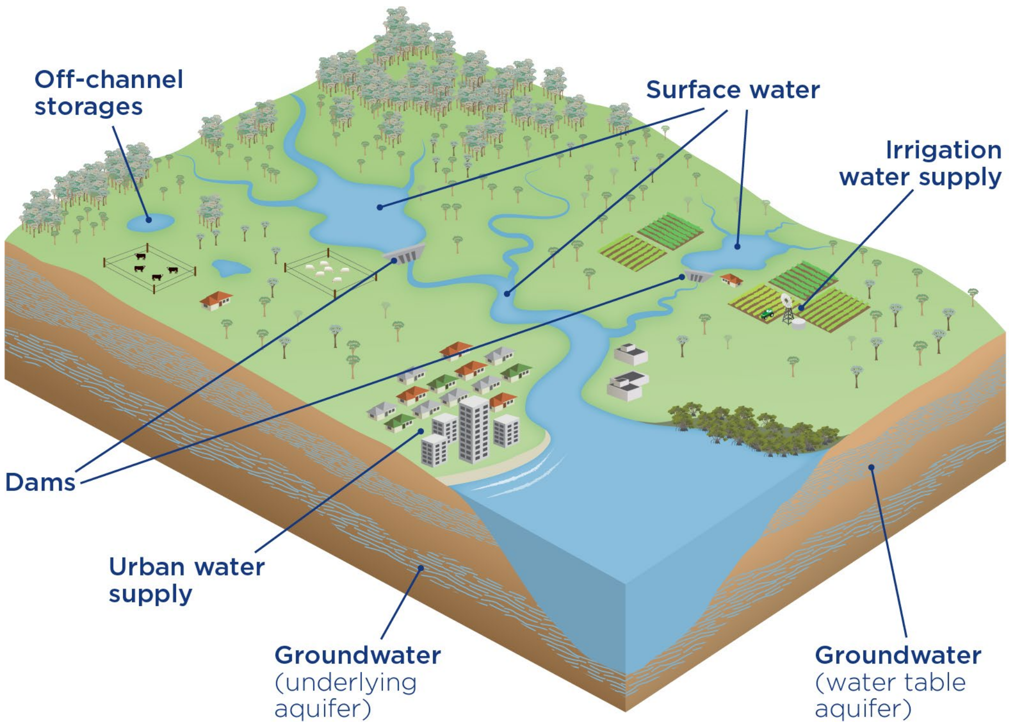
NSW's surface water and groundwater resources are managed by sharing water between different users, including the environment. In determining how our water is shared, we need to consider economic and social risks, although climate is the most critical risk to understand.

Models integrate complex interactions

We use models to integrate complex interactions between the natural environment (labelled biophysical in the diagram below) and human-constructed environment (labelled management).



Water models assess climate risk by integrating the interactions between biophysical and management processes. This diagram shows a simplified model outputting a daily series of water flows and use. Models can produce other outputs, including water storage, allocations and crop area.



A water model provides information to help us understand how the whole water system interacts

Models help us understand likely water security for a region

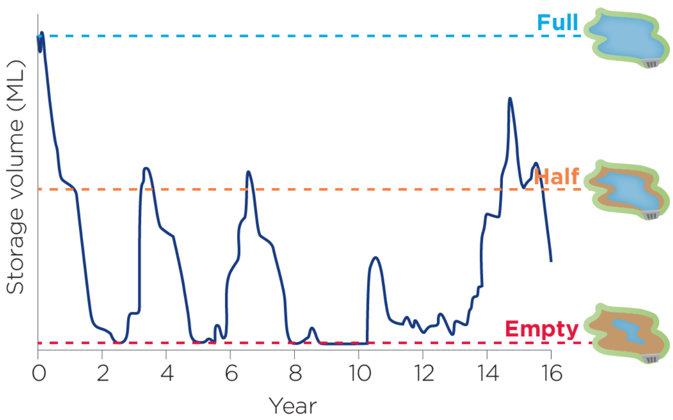
Water models provide information to help us understand the whole waterway system, including headwaters, storages, lakes, groundwater, and flows. They help us understand how the water is used across the landscape.

Water models produce information that helps us understand a region's water security.

For example, if we know the volume of water in a storage at the head of a river, we could determine the:

- frequency and size of water flows that managers could decide to release along a river to benefit the environment
- percentage of time that water cannot meet urban demand
- reliability of supply for industry.

Water models predict the water availability from surface waterways and storages, and in groundwater. Groundwater models look at how much water is likely to be available in underground natural storages (known as groundwater aquifers). The volume in aquifers is affected by how water from rainfall and surface flows naturally percolate underground to recharge aquifers. Climate (especially rainfall and evaporation rates) affect both surface water and groundwater availability.



The modelled volume of water stored in a dam for a 16-year period. The model simulates changes in rainfall, evaporation, and releases of water from the dam to meet downstream human and environmental needs. When the blue line is near the bottom of the chart, it indicates low water security.

Murray Vanderveer/DPIE

John Yurasek/DPIE

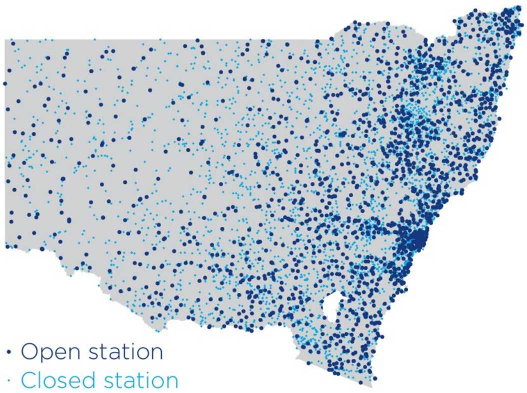
Increasing our knowledge of past and future climate helps us make better-informed decisions

Step 1

130 years of climate history is not long enough to understand climate risks

We have been collecting rainfall records since 1890, and evaporation has been measured since the early 1970s. This historical data shows variation over many years, including periods of wet, dry and average conditions, sometimes lasting several years. Our decisions on river management are based on our understanding of this variability.

But analysing data over such a short period does not tell us how vulnerable we could be to extreme droughts. Looking at the last 130 years doesn't tell us enough about the climate risks we could face, just what we have seen in 130 years. This makes water planning difficult. For example, in the last decade we have seen a raft of climate records broken. Scientists have confirmed it as the hottest decade on record, with 2019 being the second hottest year ever recorded and ocean temperatures the highest they've ever seen.



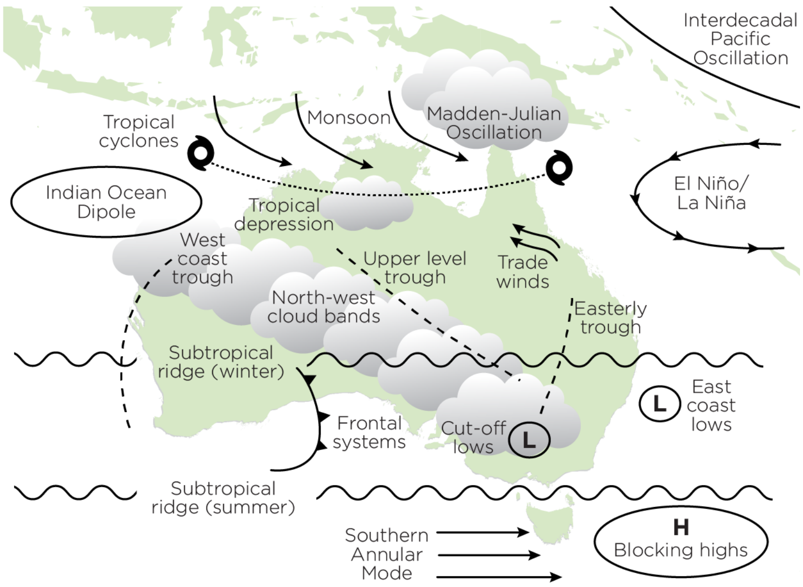
Rainfall data has been collected for 130 years at many rain-gauge stations located across NSW and stored with the Bureau of Meteorology

We need to understand what drives climatic patterns so we can better assess climate risks

Even with 130 years of data, it is important to look at what might be driving climatic patterns.

The general circulation of the atmosphere, which is caused by the uneven heating of the Earth's surface, is the driving force behind our weather and climate. Energy from the sun is stronger at the tropics than the poles, and this causes evaporation from tropical oceans. Also, land heats and cools much faster than the sea does, so that land and sea surfaces heat unevenly. The various interactions between the land, sea and atmosphere create a series of climate and weather drivers.

Positioned in the mid latitudes of eastern Australia, NSW is affected by almost all the major weather and climate drivers of Australia at some stage through each year. East coast lows (ECLs) and the major oceanic climate drivers—El Niño–Southern Oscillation (ENSO), the Interdecadal Pacific Oscillation (IPO), the Southern Annular Mode (SAM), and the Indian Ocean Dipole (IOD)—all interact over NSW, producing a highly variable climate from year to year and between seasons.



Australia's climate and weather drivers (Source: Redrawn from Bureau of Meteorology diagram, 2010)

The influence of the climate drivers varies across NSW's regions.

East coast lows (ECLs) affect the south-east coast of Australia, and can build and appear quickly, especially during autumn and winter. They last only a short time (2–5 days) but can cause strong winds, heavy rains and lots of rough weather.

El Niño–Southern Oscillation (ENSO) is a climatic cycle that affects the movement of moisture from the Pacific Ocean. During an El Niño, we see less rainfall in eastern Australia. A La Niña phase results in higher rainfall with greater amounts of moist tropical air across Australia.

Indian Ocean Dipole (IOD) is caused by changes in sea surface temperatures in the Indian Ocean. When the ocean temperature off Western Australia is high, the IOD is negative and more moisture is carried across Australia. This brings more rain in winter and spring. If the Indian Ocean temperature is lower, we see a decrease in winter and spring rainfall across NSW.

Interdecadal Pacific Oscillation (IPO) is related to the movement of warm water around the Pacific Ocean, and occurs over much longer timescales than ENSO. The IPO results in swings in climate over a decade or more. During 'negative phases' of the IPO, the eastern Pacific Ocean tends to be cooler and wetter than average—much like La Niña but operating over years rather than months. During positive phases, the same regions tend to be warmer and drier—much like El Niño, but again on these longer timescales. The IPO influences the frequency of El Niño and La Niña events, and how severe they are.

Southern Annular Mode (SAM) describes the north–south movement of the westerly wind belt that circles Antarctica. During a positive phase of the SAM, the westerly wind belt moves farther south, and winter rainfall in the southern part of the state decreases. A positive SAM may also bring more rainfall to the eastern parts of the state during spring and summer.

Each of these climatic drivers have more or less effect on different regions of NSW. Drivers that have the greatest impact on different parts of the state are:

- **Northern coastal and inland areas**: ENSO and IPO
- **Southern inland areas**: IOD, IPO and SAM
- **Southern coastal areas**: ECL

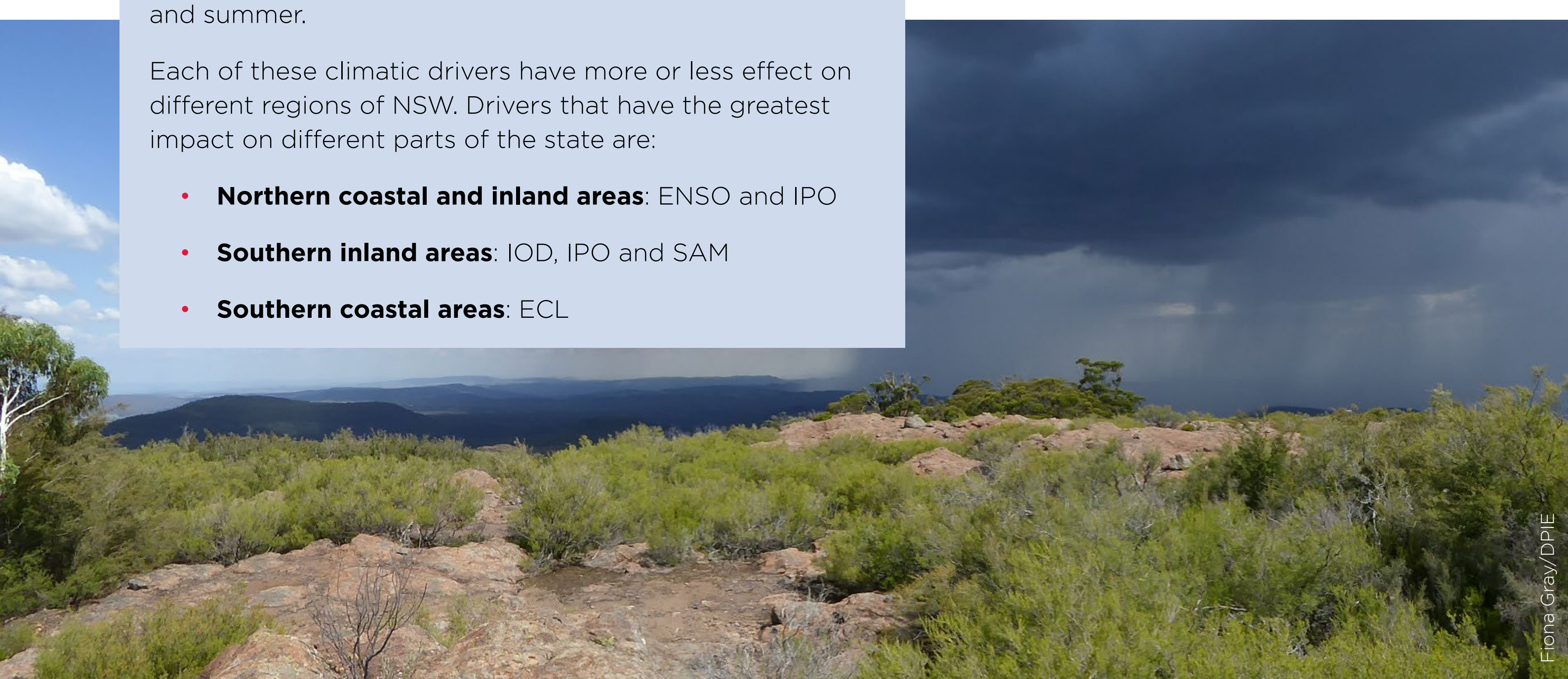
Once we identify patterns in historical climate records, we can look at what climate drivers might have caused them. For example, ENSO and the IPO were thought to be the primary drivers of the Federation drought from 1895 to 1903. East coast lows are often responsible for the big rainfall events that fill our dams across the eastern seaboard, as occurred in February 2020.

If we understand past climate patterns and what drives those patterns, this can help us predict what might happen in the future. But to describe how climate patterns might change and vary in the future, we need to understand the characteristics of climate variability and change.

Typical questions might be: how quickly might the climate change, how long will it stay dry or wet, and what are the chances it will happen again? We need lots of data about climate variability and change to help us answer these questions.

However, our changing climate as well as Australia's high natural climate variability make predicting our future climate very uncertain. We need a better understanding of NSW's longer-term climate past (hundreds and thousands of years).

> **We need to know more about possible future climates so we can make better-informed decisions in our water planning.**



Fiona Gray/DPIE

Step 2

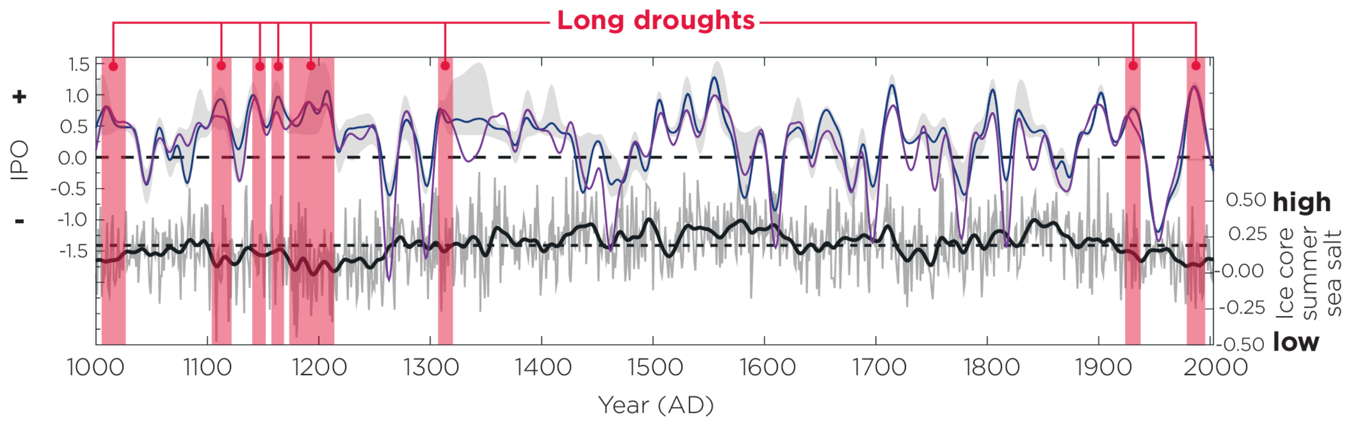
Adding 500 years of paleoclimatic climate data

To go beyond 130 years and find out more about past climate, we need to investigate things that have spent a long time in our landscape: tree rings, cave stalactites and stalagmites, river sediments, soil patterns, and ice cores.

When we study the data discovered in these longer records of time, we can detect past patterns of wet and dry that go back 500 to 1,000 years. For example, we can see there were a number of droughts that went for several decades between the 11th and 14th centuries.

This research provides us with a much more extensive picture of past climates. We can investigate this picture to see how climate patterns and drivers, especially the IPO, have changed over a very long time. This helps us to see what might happen in the future under similar circumstances as in the past.

Ice sheets and glaciers at the earth's poles formed from many hundreds of years of accumulated snow. Each year's snow compresses previous layers, until eventually they form glacial ice, which may end up several kilometres thick. Researchers may drill more than 1.5 km deep into the ice to collect an ice core. Studying the salinity of ice cores reveals what eastern Australia's rainfall was like hundreds of years ago.



With a much longer history of climate available to us through paleoclimatic analysis, we can identify periods (highlighted as red shading) centuries ago that were consistently drier for decades. This helps us understand the risk of more severe droughts in the future (Redrawn from Vance et. al., 2015).

Step 3

Looking at the past to understand 10,000 years of climate data

After collecting a 500-year history of climate data, we worked with researchers to extend the past record of climate into a 10,000-year record of the possible future climates. We were especially interested in the periods of wet and dry.

We extend the past data into longer periods of climate through stochastic modelling, which we use to look at how observed data varies. We use that to make a number of datasets for long periods. For example, if we look at the minimum, maximum and average rainfall for a region, we can investigate questions such as: how likely is one wet year to follow another; or what are the chances of multiple days of rainfall? Once we understand these characteristics of past climate, we can then construct extended datasets that show similar patterns of wet and dry climate periods to those seen in the paleoclimate record. At the same time, we introduce a random component to model the range of possible future patterns.

We splice together many different patterns of climatic variation at a number of different locations across NSW. This gives us a wealth of climate data that we can use in our water models to test how resilient our water resources and waterways are likely to be under all possible combinations of droughts and flooding rains.

In particular, this type of modelling tells us much more about possible climatic extremes. We now have a much better understanding of the probability of long-term droughts in the future.

Once we have set up our stochastic models, we can look at how different sequences of climate might affect the availability of water to NSW's water resources.

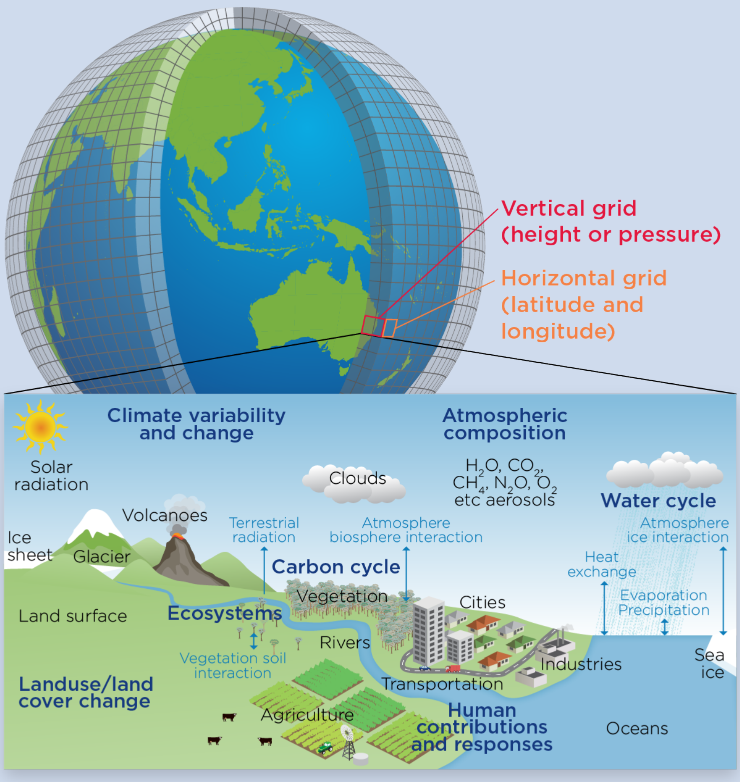
However, this modelling is still based on our knowledge of the past climate. It doesn't tell us what might happen under a changing climate.

Sharon Bowen/DPIE

Global climate models (GCMs) seek to represent the different physical processes of weather and climate. Building and running a climate model means representing physical processes using complex mathematical equations. Variables are then set to represent initial conditions and subsequent changes in climate. Powerful supercomputers then repeatedly solve the equations.

We can tell how good a GCM might be by seeing how well it describes historical and current weather and climate. They have proven to be effective at predicting temperature, and therefore evaporation, but there is much more uncertainty in predicting rainfall.

Global climate models predict the whole world, which means their predictions for regional and local climate is less precise.



In a global climate model, each of the thousands of three-dimensional grid cells has a mathematical equation that represents how energy and matter interact between the ocean, atmosphere and land at each location. To run a model, scientists specify how climatic factors (for example, an increase in the percentage of greenhouse gases) might change over time. They use powerful computers to solve the equations in each cell to discover the effects of a change.

Step 4

Using climate-change projections to improve our understanding of future risks

Using historical climate data, even 500 years' worth of it, assumes that everything will stay the same. But climate scientists say this is very unlikely. Moving from a fixed point in history to a changing future means that climate processes and patterns that happened in the past won't necessarily occur in the future.

The two main climate features that are important for water modelling are rainfall and evaporation of water (from the surface of water and through plants). For rainfall, which is highly variable, we need to know characteristics of daily, seasonal, yearly and decadal changes. These characteristics, in particular, affect how much water is available.

Global climate models are useful for providing broad predictions of likely variations and changes in rainfall, rather than providing specific regional details. For NSW, they indicate that there is unlikely to be much change in rainfall in the north of the state. But in the south, winter and spring rains are likely to be less. Along the south coast, changes in the patterns of east coast lows are likely, with an increase in the intensity of rainfall.

Global climate models are much more accurate at predicting future temperatures, which drive evaporation rates, as there is less variability in evaporation rates compared to rainfall. All models predict increases across the state.

However, global climate models are unable to predict the future climate in any detail at a regional scale. This means we need to use our historical knowledge of climate variability across NSW to produce climate information that is useful in water models. Modellers use a process called downscaling, which overlays our historical knowledge of how rainfall varies across the state with the broad predictions about rainfall change. The best way to downscale is to use regional climate models such as the NSW

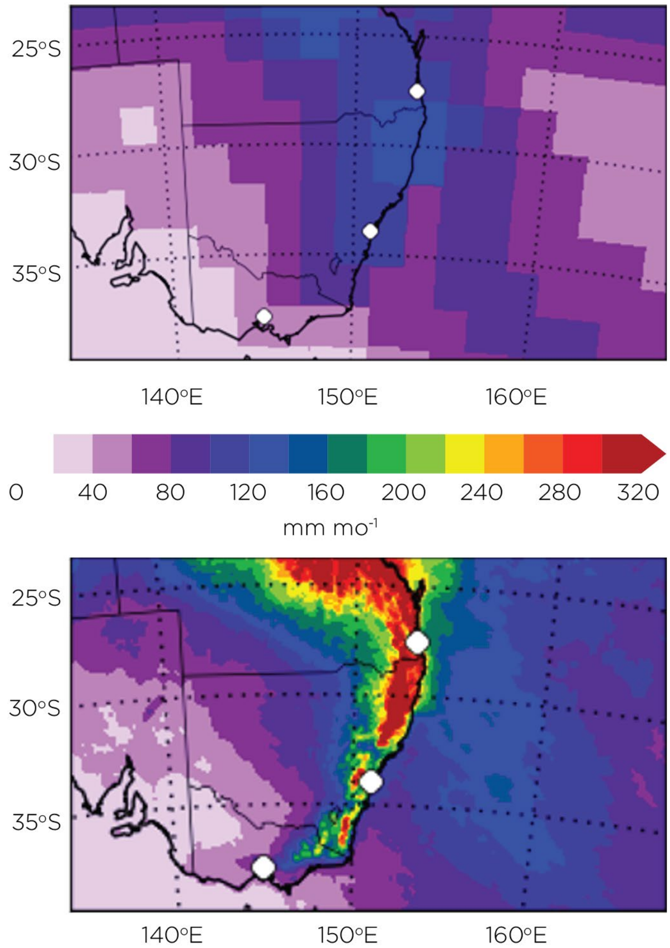
Government's NARCliM (NSW and ACT Regional Climate Modelling), which provides more detailed estimates of rain across NSW.

Combining historical data with climate modelling has generated data that is informing the latest NSW regional water strategies.

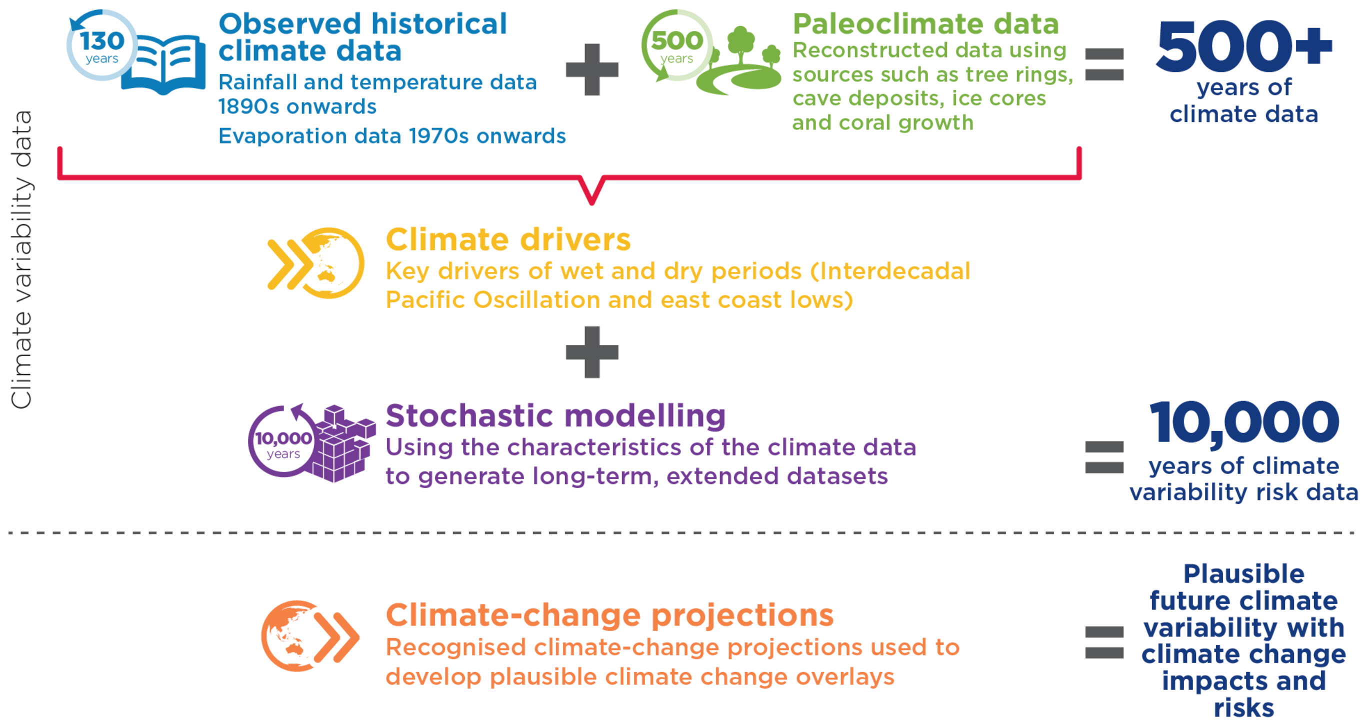
We use the knowledge gained from the long-term paleoclimatic analysis and factor in what we predict might happen in the future to give us a better indication of what they may mean for water availability and security.

In particular, we look at the predicted extremes of climate—droughts and flooding rains—to investigate how and where our regional water resources and waterways may be vulnerable to such climate risks.

The four-step approach to predicting our future climate risk means our water models are more realistic in predicting the likely water available in our waterways and storages.



A comparison of the level of detail for summer rainfall from a GCM (top) and the NARCliM regional model (bottom). The benefits of using a regional climate model to downscale rainfall from a global climate model is that it can represent local climatic differences, as determined by physical influences such as proximity to the coast and topography. This provides more detail of rainfall patterns compared to the global climate model.



The new climate-risk modelling approach combines historical data with our knowledge of climate drivers and climate-change forecasts

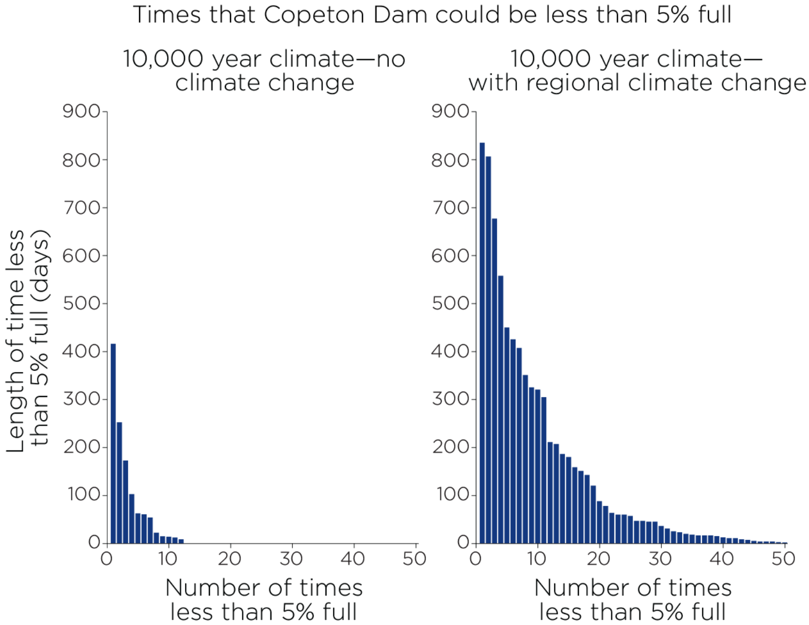
Applying the new method to the Gwydir River system: An example

Copeton Dam is on the Gwydir River in north-west NSW, and part of the Murray–Darling Basin. The dam supplies water to towns such as Bingara, to agricultural industries, and to environmental assets such as the Gwydir wetlands. Using climate data from the new methods, we investigated how storage levels in Copeton Dam could change under different climate scenarios.

Our observed records tell us that Copeton Dam has never fallen below 5% capacity. Even in this current drought, Copeton Dam was sitting at 9% in February 2020. However, our new modelling painted a different picture: the results show that Copeton Dam could fall below 5% capacity for longer periods than previously understood:

- In the longer-term data beyond the observed records (that is stochastic data), Copeton Dam falls below 5% capacity 12 times in 10,000 years, with the longest duration below 5% being over 400 days.
- In the climate-projection scenario, Copeton Dam could fall below 5% capacity 50 times in 10,000 years. The worst of these scenarios would see the dam remain below this level for up to 800 days.

The probability of this occurring is small. These estimates are based on the driest, or a worst case, climate-projection scenarios. These scenarios will not necessarily eventuate, but they give us an idea of the possible climate risks.



Our new stochastic modelling (left-hand graph), which extends historical climate data for 10,000 years, shows Copeton Dam falling below 5% capacity (85,660 ML) 12 times, with the longest event being just over 400 days. When regional climate modelling projection is added (right-hand graph), the risk increases almost four-fold, with the longest event doubling to more than 800 days.

The message from the new modelling to date is that our water supplies in NSW could be less secure than we thought. This is because we have factored in that droughts longer than those of the last 130 years are likely at some point, and that we could see higher temperatures and less rainfall.

The degree of security varies across regions, and in our regional water strategies we are seeking to address areas where water resources and waterways are most vulnerable.

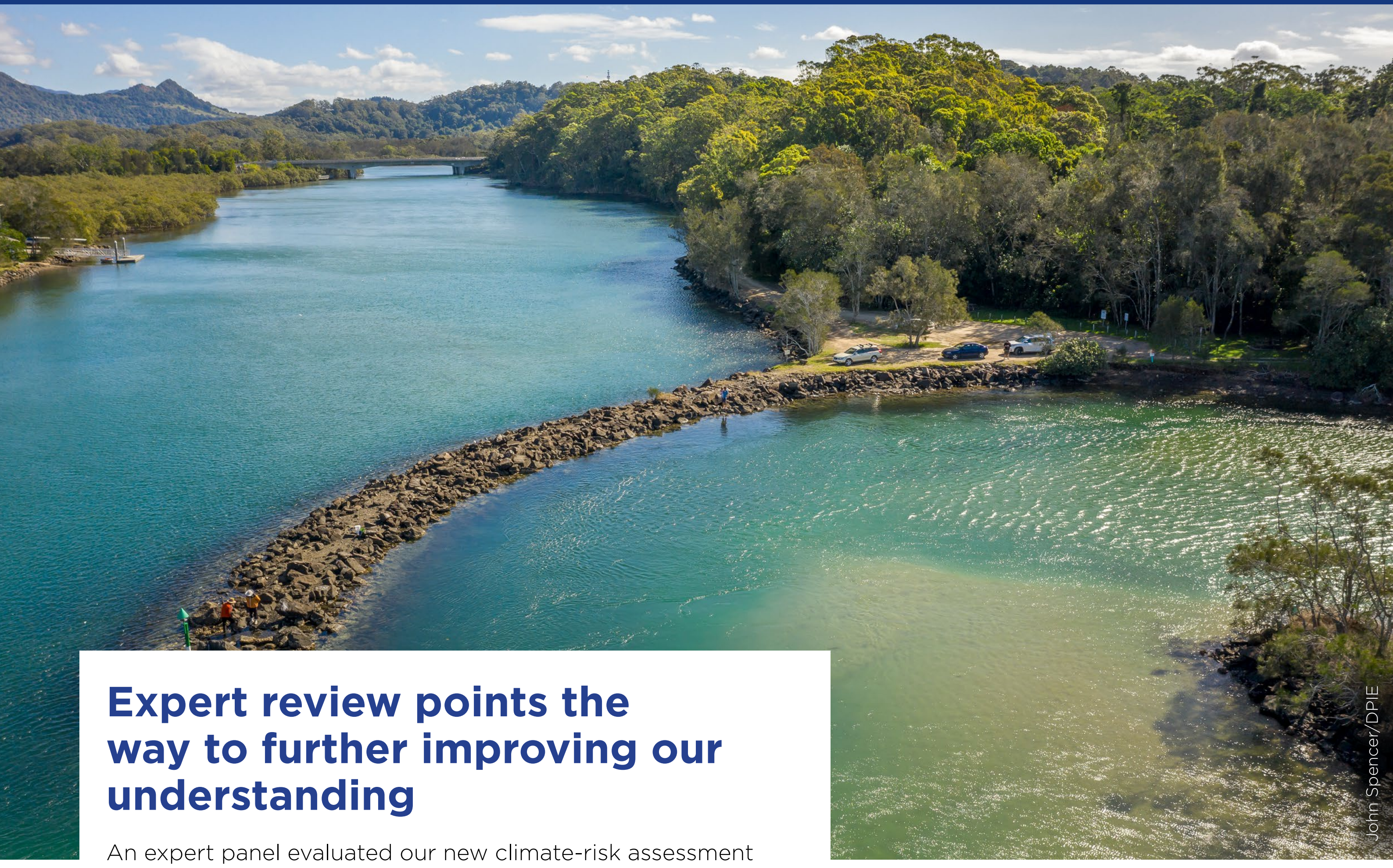
This is compared to when we used only 130 years of climate records for our assessments. These assessments could not look at the range of possible future climates based on our new knowledge of long-term climate historical variability and possible future climate changes.

A note of caution: There is always a level of uncertainty with this type of modelling, which needs to be taken into account as part of any decision-making and planning for water security.

In some instances, this may mean managing risks to our water security by being prepared and resilient, rather than relying on firm predictions.

As the science develops further, we will be able to reduce or quantify some of these uncertainties.

Jane Humphries/DPIE



Expert review points the way to further improving our understanding

An expert panel evaluated our new climate-risk assessment method. The NSW Office of the Chief Scientist and Engineer convened the panel, which was commissioned by the NSW Minister for Water, Property and Housing to ensure the method's rigour and validity.

The panel found that the method is 'fit for purpose' in providing the best available knowledge of climate risk to inform NSW's regional water strategies. They found that the method was consistent with best practice in the field and a major advance over using only historical records or only climate models.

The expert panel noted that this is an area where the science is still developing. They recommended ongoing work to continuously improve the method and keep up to date with the latest scientific findings.

The NSW Government is considering all of the recommendations made by the panel and is preparing a response to show how these may be addressed.

For more information

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