

JOINT SUBMISSION

The Australian Government accepts the science of climate change and is committed to playing its role in global efforts to reduce emissions. Australia has a strong track record of meeting its international emissions reduction commitments. We successfully beat our first Kyoto target by 128 million tonnes and are on track to meet and beat our 2020 target of 5 per cent below 2000 levels by 224 million tonnes.

As part of the Paris Agreement, Australia has committed to reduce emissions by 26 to 28 per cent below 2005 levels by 2030. This will see Australia's emissions per person halve and the emissions intensity of our economy reduce by two-thirds. These reductions are among the largest of any major economy. The Government ratified the Paris Agreement on 10 November 2016 – the earliest opportunity in the new Parliament.

As outlined in the Bureau of Meteorology's analysis of observed data ([Attachment A](#)), Australia's climate has changed. Although not detailed in this submission,¹ further warming is unavoidable, locked into the climate system due to past greenhouse gas emissions.

The departments and agencies contributing to this joint submission provide an illustration of how the policies and programs of the Government help manage climate impacts on the built environment.

Department of the Environment and Energy

The Department of the Environment and Energy plays a role in providing guidance and information needed to ensure that Australian Government operations and activities are resilient to climate change impacts, and that businesses and communities are better placed to manage their own risks. In December 2015, the Australian Government released the *National Climate Resilience and Adaptation Strategy* at the United Nations Framework Convention on Climate Change 21st Conference of Parties in Paris. The Strategy describes how Australia is managing climate risks in priority sectors like cities, water, health and disaster management. The Strategy articulates principles that underpin leading practice adaptation such as shared responsibility, factoring climate risks into decision making and revisiting decisions and outcomes over time. Governments at all levels, businesses, communities and individuals each have complementary roles to play in managing climate risks. The Strategy can be found at <http://www.environment.gov.au/climate-change/adaptation/strategy>.

The Department of the Environment and Energy is working to help build resilience to climate change, including in the housing, building and infrastructure sectors. The Department does this through supporting the provision of climate science, providing information and guidance on best practice adaptation and facilitating consideration of climate risk across the Australian Public Service.

Provision of climate science

The Australian Government plays a major part in providing climate science and information which can be used by decision-makers in government, business and the community to manage their risk. The Government has funded the \$145 million National Environmental Science Program, which is delivered through six research hubs. The Earth Systems and Climate Change Hub supports research to help address the challenges posed by a changing climate across multiple sectors, including the built environment. Other hubs, such as the Clean Air and Urban Landscape hub, are supporting research into climate change adaptation, with a more specific and practical focus on Australia's urban areas.

¹ Projected changes will be covered in depth in a separate submission by CSIRO.

In April 2016, the Australian Government announced a new independent National Climate Science Advisory Committee to inform the future direction of Australia's climate science capability and research priorities.

The Committee is developing a national climate science strategy to assist Australian scientists address research questions including observed and projected changes to climate variables such as sea level and storm surge intensity, air temperature and precipitation and the frequency of extreme weather, including heatwaves, bushfires, floods, and cyclones. The strategy will consider how the presentation of Australian climate science can be tailored to people and businesses making decisions about the risks posed by a changing climate.

The Committee includes senior representatives from across Australian climate science research, investment and policy agencies and institutions. This broad representation is boosting collaboration across agencies and sectors to ensure climate science activities are coordinated and prioritised. Further information about the Committee can be found at:

<http://science.gov.au/scienceGov/CouncilsCommitteesWorkingGroups/CouncilsAndCommittees/Pages/default.aspx#>.

Information and guidance

In the 2017-18 Budget, the Government announced an Adaptation Partnership comprising the National Climate Change Adaptation Research Facility, CSIRO and the Department of the Environment and Energy. The aim of the Partnership is to develop targeted products which allow decision-makers to manage risks from a changing climate.

Since 2007, the Government has invested \$56 million in the National Climate Change Adaptation Research Facility, whose achievements have included delivery of a wealth of research material, with more than 144 adaptation research projects under the first phase, and National Adaptation Research Plans which guide priority research for the adaptation community. The National Climate Change Adaptation Research Facility has begun publishing information products including synthesis summaries, climate change adaptation briefing notes, policy guidance briefs and an adaptation library for policymakers and decision-makers. The material contains relevant and accessible information that synthesises adaptation research for non-science audiences. Themes and content were informed by stakeholder engagement and cover issues such as extreme weather events, community vulnerability and resilience and regional hotspots.

The Facility has developed CoastAdapt, an online coastal risk management tool. CoastAdapt provides access to locally-relevant coastal climate projections data, as well as guidance on how to use that information to manage associated impacts, such as erosion and flooding caused by sea level rise. The tool is of direct relevance to any person or organisation that owns or manages coastal buildings, houses or infrastructure. CoastAdapt received 6,152 visitors within the first quarter of its release. As at May 2017, the overall number of new visitors rose to 14,317, with a monthly average of around 2,000 visits.

As well as providing information for Australia's coastal regions, CoastAdapt links the user to climate change resources on the NCCARF website and beyond that are relevant to Australia more broadly. CoastAdapt can be found at: <https://coastadapt.com.au/about-coastadapt>.

Since July 2016, the Department of the Environment and Energy has been working with CSIRO to develop a prototype online decision-support tool called the Climate Risk Information and Services Platform. The decision-flow tool brings together expertise on best practice adaptation and climate data and projections. It aims to assist decision-makers consider how to manage implications from a changing climate on their project or program.

The prototype has been developed to inform infrastructure planning and investment in south-east Queensland. It has been designed so it can evolve to help users in other sectors and regions make informed decisions for managing climate risks.

The Adaptation Partnership will build on the CoastAdapt and the Climate Risk Information and Services Platform prototype to continue to meet the needs of end users.

Collaboration across the Australian Public Service

The Department of the Environment and Energy and the Attorney-General's Department have together established the Australian Government Disaster and Climate Resilience Reference Group. The Reference Group considers the risks and opportunities arising from climate change and natural disasters and has senior executive representatives from more than 20 Australian Government departments and agencies. The Reference Group's current activities include developing:

- A set of guiding principles to help Australian Government agencies consider disaster and climate resilience.
- Tools, guidance, and case studies to enable disaster and climate resilience decision-making.
- A map of policies, programs and assets that relate to disaster and climate resilience and identifies linkages and interdependencies.
- Officer-level support for the Resilience Reference Group.
- An agreed approach for further engagement with the private sector on disaster and climate issues.

Energy infrastructure

As well as its broad roles in climate change science and adaptation, the Department of the Environment and Energy has policy responsibility for energy security and energy market reform.

Australia's Chief Scientist, Dr Alan Finkel, together with an expert panel, at the request of the COAG Energy Council, recently completed the Independent Review into the Future Security of the National Electricity Market. The Review's final report, published on 9 June 2017, considered potential risks to the security of the National Electricity Market, including the adaptation required to manage environmental changes, including climate change impacts. The Review found an increase in the frequency and intensity of extreme weather events can increase stress on the power system in several ways:

- Transmission and distribution networks are vulnerable to extreme weather events.
- High ambient temperatures reduce generator efficiency, and can lead to breakdowns and an increase in maintenance costs.
- Many elements in the power system have maximum operating temperatures above which they disconnect to avoid damage. These controls will be triggered more frequently and new investment may be required to make the equipment more resilient to high temperature events.

The Review noted that with increasing and more intense weather events predicted to occur, forecasting and managing the electricity system prior to and during these events will become more difficult.

The COAG Energy Council agreed to develop a strategy by the end of 2018 to improve the integrity of energy infrastructure and the accuracy of supply and demand forecasting, in recognition of the increased severity of extreme weather.

Great Barrier Reef

Climate change is a global issue and the most serious threat to the long-term health of coral reefs worldwide, including the Great Barrier Reef. Details of observed impacts are at [Attachment A](#).

The Reef 2050 Plan was released by the Australian and Queensland governments in March 2015 and is the overarching framework for protecting and managing the Reef until 2050. The Plan sets clear actions, targets, objectives and outcomes to drive and guide the short, medium and long-term management of the Reef through seven key themes, including ecosystem health, water quality, heritage and economic and community benefits. The Reef 2050 Plan is being implemented in partnership with the Queensland Government, industry, scientists and the wider community. In July 2017, the World Heritage Committee welcomed the progress made with the inception and initial implementation of the Reef 2050 Plan since its establishment in 2015.

The Reef 2050 Plan is underpinned by an Investment Framework which establishes current investment in Reef 2050 Plan actions, determines investment priorities for the future and sets out strategies for boosting investment and diversifying its sources. The Australian and Queensland Governments will be spending more than \$2 billion over the coming decade to protect the Reef.

The Reef 2050 Plan is based on an adaptive management approach, with periodic reviews, to ensure it remains consistent with scientific advice and relevant to addressing the pressures on the Reef. As part of the Australian and Queensland governments' response to widespread coral bleaching in 2016 and 2017, the mid-term review of the Reef 2050 Plan has commenced early to ensure that it continues to be effective in addressing the challenges the Reef is facing.

At the 41st World Heritage Committee meeting, which was held in Poland in July 2017, the Committee recognised that Australia's early implementation of the Reef 2050 Plan has been effective and decided that the Great Barrier Reef will not be formally considered by the Committee again until 2020.

Attorney-General's Department

The Attorney-General's Department is committed to enhancing Australia's resilience to disasters, including by reducing disaster risk. Building disaster resilience requires identification of the drivers of disaster, including identification of what the community values, identification of vulnerabilities in the built and social environment, and an appreciation of the nexus between each. Relevantly, the capacity of critical infrastructure, essential public assets, and the broader built environment to withstand natural hazards and other extreme weather events will impact individual and community loss, social and economic disruption, and post-disaster recovery. The Attorney-General's Department provides national leadership to guide the efforts of all Australian governments enabling a whole-of-nation, resilience-based approach to preventing, preparing for, responding to and recovering from disasters.

The Attorney-General's Department works with the Commonwealth's expert science and research organisations, namely Geoscience Australia, the Bureau of Meteorology, and CSIRO, to understand the risks of a changing climate from a disaster resilience perspective. Such consideration includes increased frequency and intensity of extreme heat events, extreme fire weather and a longer fire season, increased rainfall, rise in sea level amplifying the effects of

high tides and storm surges, and projections suggesting a higher proportion of more intense tropical cyclones in the future.²

Managing disaster risk is a shared responsibility among all levels of government, business and industry, the community and individuals. As noted above, at the Commonwealth level, the Attorney-General's Department co-chairs the Disaster and Climate Resilience Reference Group with the Department of the Environment and Energy.

The Attorney-General's Department works with state, territory and local governments and the New Zealand Government through the Australia-New Zealand Emergency Management Committee, a committee of the Law Crime and Community Safety Council under the Council of Australian Governments. This committee provides strategic leadership on national priorities in disaster resilience policy and supports national capability and capacity development initiatives.

Other initiatives delivered by the Attorney-General's Department's to enhance Australia's disaster resilience include:

- Coordinating Australia's implementation of, and reporting against, the *Sendai Framework for Disaster Risk Reduction 2015-2030*. Agreed by United Nations Member States in 2015, the Framework emphasises management of disaster risk, as opposed to focusing solely on disaster response or recovery. Progress in implementing the Framework also represents progress towards meeting the Sustainable Development Goals, ten of which relate to disaster risk reduction and climate action.
- Maintaining the *National Strategy for Disaster Resilience* which was endorsed by the Council of Australian Governments in 2011 and reviewed in 2015. The National Strategy provides high-level guidance on disaster resilience for all levels of government, business and community leaders and the not for profit sector. The National Strategy establishes priority areas to build disaster resilient communities across Australia, including reducing risks in the built environment. The Strategy can be found at: <https://www.ag.gov.au/EmergencyManagement/Documents/NationalStrategyforDisasterResilience.PDF>
- Supporting the capacity of jurisdictions to mitigate disaster risk and impact. For example, through the *National Partnership Agreement on Natural Disaster Resilience*, the Australian Government supports states and territories to invest in priority disaster resilience projects. The current Agreement provides \$26.1 million in Commonwealth funding each year over the life of the agreement, which is matched by the states and territories through funding or in kind resources. The Government recently agreed to a one-year extension to the Agreement until 30 June 2018.
- Supporting the development of nationally significant hazard information capabilities, such as the next generation National Fire Danger Rating System to improve the quality and accessibility of hazard specific information to the community. A prototype is currently being developed and tested by the New South Wales Rural Fire Service to explore how governments across Australia can best utilise the latest fire science research, along with local weather and topographical data, to deliver a superior, nationally consistent messaging on the potential fire danger to the communities. The work of the prototype will be coupled with social research led by the South Australian Country Fire Service to provide guidance as to how best to convey fire danger information to the public, and in so doing, enable the community to better understand how and when to avoid danger.

² Australian Bureau of Meteorology and CSIRO, 2016, *State of the Climate 2016* (<http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf>)

- Assisting states and territories to manage and deliver public safety communications systems, including the national telephone-based emergency warning system, Emergency Alert, and the location-based mobile telephone emergency warning capability. The Attorney-General's Department operates the Location Based Number Store Emergency Alert's data source for registered service addresses.
- Liaising closely with insurance sector representatives on disaster resilience issues, including through the Australian Business Roundtable for Disaster Resilience and Safer Communities.

Disaster Recovery Programs and Financing

Disaster risk cannot be completely mitigated – natural hazards and other extreme weather events can and do cause significant damage. The Australian Government will always assist communities to recover from disaster. In recognition of the significant cost of natural disasters, the Australian Government established the Natural Disaster Relief and Recovery Arrangements to assist with the financial burden on the states and territories, and to facilitate the early provision of assistance to disaster affected communities. Through these arrangements, the Australian Government provides financial assistance directly to the states and territories to assist with costs associated with certain disaster relief and recovery assistance measures. The Attorney-General's Department is currently working with the states and territories to develop a new disaster recovery funding model which will provide more autonomy to states and local government to enhance the resilience of infrastructure in the long-term.

The Critical Infrastructure Resilience Strategy

The Australian Government encourages critical infrastructure owners and operators to better manage both foreseeable and unforeseen or unexpected risks to the continuity of their operations through the *Critical Infrastructure Resilience Strategy*. Updated in 2015, the Strategy defines critical infrastructure as 'those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact the social or economic wellbeing of the nation or affect Australia's ability to conduct national defence and ensure national security.'

Accompanying the Strategy, the Critical Infrastructure Resilience Strategy Plan outlines the activities that will be undertaken at a national level in pursuit of these outcomes. To facilitate the priorities of the Strategy and the Plan, the Australian Government maintains a business-government partnership with the owners and operators of critical infrastructure through the Trusted Information Sharing Network. The Network provides a secure environment for businesses and government to share information on emerging risks, including those posed by climate change, and best practice resilience building initiatives.

Department of Agriculture and Water Resources

The Department of Agriculture and Water Resources is committed to working with farmers, communities, industry and governments to enhance the sustainable, efficient and productive management and use of water resources and to help irrigators overcome the challenges of the 21st century including climate variability, drought and water scarcity.

The Australian Government's approach to water management is set out in the National Water Initiative, the blueprint for water reform. The implementation of the blueprint helped facilitate the development of Australia's water markets by creating incentives for water to move to higher value use thereby encouraging more efficient water use. Markets facilitate the reallocation of water during drought periods and help adjust to seasonal variations.

Activities in the Murray-Darling Basin, Northern Australia and Tasmania are informed by sustainable (water) yields studies undertaken on behalf of the Department of Agriculture and Water Resources by CSIRO. These studies factor in long-term climate projections to ensure that new water infrastructure activities supported by the Department are sustainable over at least a 30 year period.

The Department leads the Australian Government's contribution to the Murray-Darling Basin Plan which is working towards providing responsible, long-term management of Murray-Darling Basin water resources for farmers, communities and the environment.

To meet the challenge of future demand for water, key programs in the Basin, such as the Sustainable Rural Water Use and Infrastructure Program, commit \$10 billion to help secure a long-term sustainable future for irrigated agriculture and communities, deliver substantial and lasting returns to the environment and improve the health of rivers, wetlands and freshwater ecosystems.

The majority of infrastructure funds are committed to projects in the Murray-Darling Basin, investing in the management and efficiency of water use through on and off farm infrastructure upgrades. These programs deliver water savings by reducing the loss of water from irrigation networks and farms through seepage, evaporation and escape. Projects incorporate a requirement to demonstrate proposed water efficient infrastructure improvements are sustainable in the context of current and forecast climatic conditions for the area.

Australian Government investment has funded activities which aim to enhance the water security and resilience to meet challenges such as climate variability and drought associated with system and flow variability. These programs include Strengthening Basin Communities which assisted in planning for a future with less water and to support projects that improve water security by reducing demand on potable water supplies.

In the context of the millennium drought and pressing community concerns around water security, the Australian Government has invested over \$2.4 billion in multiple urban water program to improve water security in cities and towns across Australia, including remote and regional communities. These program reduced the demand on potable supplies by reducing water usage, loss from distribution systems and accelerating the development and uptake of smart water technologies and alternate water supplies including funding of cooperative research centres.

Water supply and sewage treatment systems

Understanding the impacts of climate change on water supply is essential for water planners and managers to ensure resources are best able to meet future demand for water. If climate change risks are not sufficiently incorporated into planning and management, this increases the possibility of water systems becoming over-allocated, and water security concerns and environmental degradation worsening. There is also the potential for increased cost in adapting and updating water infrastructure to cope with more rainfall variability. Recent climate events such as the Millennium Drought that affected southeast Australia, and the observed decline in rainfall in southwest Australia, have highlighted the need for water plans and management approaches to be flexible and able to respond to climate risks.

The Considering Climate Change and Extreme Events in Water Planning and Management (2017) module³ is a supporting document to the National Water Initiative Policy Guidelines for Water Planning and Management (2010).⁴ Its purpose is to provide guidance to jurisdictions on

³ <http://www.agriculture.gov.au/SiteCollectionDocuments/water/climate-change.pdf>

⁴ <http://webarchive.nla.gov.au/gov/20160105002803/http://www.coag.gov.au/node/461>

how to consider and incorporate possible impacts from climate change and extreme events in water planning and management.

The module outlines a range of approaches that may assist water planners to respond to reduced water availability during a planning period, while also positioning water planners to manage longer-term impacts. By providing a suite of options for managing climate risks, water planners can develop a tailored approach that suits their local circumstances such as the type of water resource, the level of demand from water and expected climate risks.

National Water Infrastructure Development Fund

The Department of Agriculture and Water Resources has portfolio responsibility for the roll out of the Australian Government's water infrastructure policy and program through the \$500 million National Water Infrastructure Development Fund and the \$2 billion National Water Infrastructure Loan Facility. The primary aim of these initiatives is to accelerate and co-fund the construction of water infrastructure including dams, weirs and pipelines to stimulate regional economic development.

With regard to the terms of reference for this Senate Inquiry, the states and territories are responsible for water planning for new water infrastructure to enhance current water supply and meet future demand. This includes deliberations regarding the type and location of new water infrastructure to meet water supply challenges based on future climate scenarios and assessing the resilience of current water infrastructure.

Existing water infrastructure, including dams, were designed and constructed to meet the relevant engineering and construction standards of the time. However, since that time engineering design standards have been revised to reflect changes in engineering practice, safety requirements and the ability to forecast the impact of adverse weather events on catchments. For example, with regard to the resilience of infrastructure in Queensland, SunWater has a dam safety management program that includes annual and five yearly comprehensive inspections and risk assessments. This process of continual review and assessment will minimise and mitigate the impact of changing conditions on water infrastructure.

As part of its dam safety management program, SunWater infrastructure assets undergo a process of continuous assessment against statutory requirements outlined in the Australian National Committee of Large Dams guidelines, and Australian and international standards.

All states and territories have agreed to implement the principles of the National Water Initiative, which aims to drive the efficient and economic use of water. Among other things, the National Water Initiative requires that each infrastructure project funded by the Australian Government complies with the state's water resource plan for that particular catchment. This water resource plan is a legislative instrument for water management that takes into account the current and future impacts of climate change. All funding provided by the Australian Government is contingent on the implementation of principles of the National Water Initiative. The National Water Initiative underpins private sector investment as it provides for legally secure access to water through water entitlements that can be traded on an open trading market.

Water markets

Water markets provide the mechanism for participants to adjust to changes in water availability. This enables Australia to be responsive to changes in water availability caused by climate change, noting many factors contribute to water scarcity.

The last El Nino event from May 2015 to May 2016 demonstrates the correlation between water scarcity and water prices as well as water scarcity and structural changes in the agriculture sector.

The data in the table below shows the link between storage levels and prices for the Goulburn and Murray catchments in Victoria and New South Wales. The draw-down in storage levels in these catchments progressively tightened the supply and demand balance for water, placing an upward pressure on water allocation and entitlement prices. The data shows storage levels almost halved and prices more than doubled.

The pressure on Australian water markets to facilitate the supply of diminishing water resources to a diverse source of demands also increased expectations of open access to the market and transparency in prices and trading activity.

In terms of drivers for structural adjustment, the increase in prices following a reduction in water availability during dry years produced a shift in the allocation of water resources from low to higher value producers. This shift occurred as the opportunity cost/benefit from selling allocations and entitlements became greater than on-farm revenue, typically for lower value, labour intensive operations, including dairy. Conversely, higher value, capital-intensive operations with a greater capacity and willingness to pay, acquired allocations and entitlements for crops, such as permanent tree nut plantings, that needed the water to survive.

Table: Storage and price information for the Goulburn and Murray catchments

	Storage (%)	Allocation price (\$/ML)	Entitlement price (\$/ML)
2013/14	60%	\$75	\$1,500
2014/15	47%	\$130	\$1,900
2015/16	32%	\$250	\$3,000

Source: ABARES and Marsden Jacob and Associates

Geoscience Australia

Geoscience Australia acknowledges the relevance of considering impacts of climate change on the broader infrastructure that will support our future communities, ranging from the buildings to the physical networks that support a functioning society. Addressing these considerations can draw on existing and developing capabilities in the Australian Government, in conjunction with the academic and private sectors. This submission will highlight a few relevant areas in which existing capability in Geoscience Australia can help Australia meet those challenges.

Impacts on the built environment

A changing climate will alter the nature of 'extreme' events. Geoscience Australia has established capabilities in assessment of the impacts of many climate-related hazards on the built environment. This work integrates Geoscience Australia's national spatially-enabled collections of information on the built environment, along with expertise in engineering vulnerability and hazard modelling. This capability integrates various streams of information that are also essential to address the key questions around the impacts of recent and projected climate changes, for example from sea level rise, storm surge, and extreme wind and -rainfall events.

Future climate and sea level projections are an essential input to understanding potential impacts of climate change, but in isolation are insufficiently detailed to base policy or adaptation decisions on. Geoscience Australia has worked on a range of projects that translate large-scale climate projections into localised changes and/or the associated impact and risk from extreme

events, such as tropical cyclones and storm surge. This work built on the climate projections undertaken by CSIRO and the Bureau of Meteorology and internationally.

Geoscience Australia's capability for assessment of risk/impact of natural hazards can further inform adaptation policy and planning priorities at state/territory and Commonwealth levels.

Geoscience Australia's natural hazard impact and risk modelling capability already supports resilience to current climate conditions. For example, Geoscience Australia is leading and collaborating on research into the factors contributing to built environment vulnerability to wind and riverine flooding, with the aim to identify opportunities to mitigate these impacts. This work is particularly relevant for the present inquiry, as buildings and critical infrastructure that are already susceptible to present hazard may be further compromised as local hazard is exacerbated by climate change.

Impacts on the groundwater

Geoscience Australia provides the Australian Government with understanding and advice of the vulnerability of groundwater resources. In recent years, Geoscience Australia has undertaken a national vulnerability assessment of sea water intrusion into coastal aquifers, which is relevant in the context of sea level rise.

Monitoring impacts

Digital Earth Australia is an analysis platform for satellite imagery and other Earth observations developed and maintained by Geoscience Australia. When fully operational, Digital Earth Australia will provide a series of structures and tools that calibrate and standardise datasets, enabling the application of time series and the rapid development of quantitative information products. It uses high-performance computing and open source standards and is designed to help both government and private industry make informed decisions. In the 2017-18 Budget, the Government announced that it would invest \$15.3 million in Digital Earth Australia over the next two years to apply satellite data to streamline government business.

Digital Earth Australia is already producing products such as the Intertidal Extents Model which has applications in environmental monitoring, habitat mapping in coastal regions, and can also identify coastal instability. The related Digital Elevation Model can provide a seamless model from the deep oceans through the coastal zone to the land. Other products such as Fractional Cover and Water Observations from Space provide characterisations of the landscape and identify the presence or absence of surface water. These products, and the underlying high-performance analytical capability of the Digital Earth Australia, are ideally suited to applications such as environmental monitoring and modelling the projected changes and impact resulting from climate change.

Fundamental data

Geoscience Australia develops, manages and distributes a range of national fundamental data products to underpin climate impact monitoring and adaptation by stakeholders. For example:

- National geodetic datasets that support sea level rise measurements and the production of elevation models
- National, regional and high resolution local digital elevation and bathymetry datasets, which are essential for modelling inundation or fire spread, among many other things.
- The National Coastal Geomorphological database, and the National Coastal Compartment datasets, which underpin the assessment of coastline response to future sea levels.

- Information on the built environment, in the form of the National Exposure Information System, which contains information on buildings, infrastructure and population. This information is essential for any type of impact study in either current or future climate.

Further information

The departments and agencies represented in this joint submission would be happy to provide more detail regarding the above information. The appropriate contacts are outlined below:

Agency	Contact name	Contact details
Department of the Environment and Energy	Chris Johnston Assistant Secretary Climate Change Policy Branch	
Attorney-General's Department	Elizabeth Quinn, Assistant Secretary Disaster Resilience Strategy Branch	
Department of Agriculture and Water	Paul Morris, First Assistant Secretary Water Division	
Bureau of Meteorology	Neil Plummer, General Manager Community Forecasts	
Great Barrier Reef Marine Park Authority	Bruce Eliot, General Manager Biodiversity, Conservation and Sustainable Use	
Geoscience Australia	Andy Barnicoat Chief of Division Community Safety and Earth Monitoring Division	

ATTACHMENT A

Contextual information from the Bureau of Meteorology and the Great Barrier Reef Marine Park Authority, against the relevant Terms of Reference.

a. Recent and projected changes in sea level rises, and storm surge intensity

Global sea levels have increased between 1993 and 2016 at an average rate of 2.6 to 2.9 millimetres per year, amounting to a total increase in the order of 7 centimetres over that period. Superimposed on this overall trend is variability on seasonal to interannual timescales, of which El Niño and La Niña events are a major driver. A strong event, such as the 2015-16 El Niño or the 2010-11 La Niña, can result in fluctuations of 5 to 10 millimetres in global sea level over periods of 6 to 12 months, with larger shifts on individual coastlines. (Sea levels in the western Pacific, including eastern and northern Australia, are generally lower during El Niño events and higher during La Niña events).

The sea level at any particular point in time will be the sum of the astronomical tide, the baseline sea level, interannual fluctuations and any surge component arising from short-term weather events. Even in the absence of any change of the severity of storm surges, rising sea levels will result in an increased frequency of flooding from storm surge events. This is because an increase in the baseline sea level component will lead to an increase in sea levels at any specific time even if all other components are constant.

The most extreme storm surges are normally associated with severe tropical cyclones and hence their risk will be a function of changes in the occurrence of severe tropical cyclones. However, substantial storm surges can occur outside the tropics as a result of east coast lows and other mid-latitude storms. Further discussion of these cyclones and other storms is found under term of reference (c).

b. Recent and projected changes in temperature and precipitation

Mean temperatures have increased throughout Australia over the last century. Averaged over Australia as a whole, temperatures have increased by about 1°C since reliable national records began in 1910, with most of the warming occurring after 1950. The highest rates of warming have occurred in central Australia, but all parts of Australia have warmed over the last century. Warming has occurred in all seasons, with the strongest warming in spring.

The hottest year on record in Australia was 2013, with temperatures 1.2°C above the 1961-1990 average. Each of the four years from 2013 to 2016 ranked amongst the six warmest years on record for the continent.

Changes in rainfall over recent decades show large variations between different parts of Australia. Much of southern Australia, especially southwestern Western Australia and Victoria, has shown a substantial decline over the last 20 years in rainfall during the cooler months (May to October), as the subtropical high pressure ridge has strengthened and frontal systems increasingly pass south of the continent. In Western Australia, this decline extends back to the 1970s.

Conversely, rainfall has increased substantially since the 1970s in many parts of northern Australia, especially northern and interior Western Australia and the northern half of the Northern Territory, largely associated with more active monsoon conditions.

Climate model projections indicate that increases in temperatures across Australia are expected to continue over the coming decades. Projections also indicate likely continued cool-season rainfall decline over southern Australia.

c. Recent and projected changes in extreme weather, including heatwaves, bushfires, floods, and cyclones

Consistent with the observed increase in temperatures, the occurrence of extreme high temperatures is also increasing over most of Australia. The duration, intensity and frequency of heatwaves has increased, and there have been a number of historically significant heatwaves in the last decade, including those of January-February 2009 (Black Saturday), January 2013, December 2013-January 2014, and February 2017.

There has been a particularly strong increase in heatwaves affecting large areas. In 2013, there were 28 days on which the Australian area-average mean temperature exceeded the 99th percentile for the month in question. This is a greater number of such days in a single year than the number (26) which occurred in the 30-year period between 1911 and 1940. Very warm monthly mean daytime temperatures at a level which occurred 2.2 per cent of the time between 1951 and 1980 occurred 11.5 per cent of the time between 2001 and 2015, an approximately fivefold increase. Individual extreme high temperatures have also become more prevalent; one illustration is that there were 24 days in the 16 years from 2001 to 2016 on which it has reached 45°C somewhere in Victoria, whereas there was only one such day in the 16 years from 1985 to 2000.

In general, the occurrence of extreme low temperatures has decreased, although the decrease has not been as sharp as the increase in extreme high temperatures. Some parts of southern Australia which have experienced substantial decreases in cool season rainfall have also experienced stable or increasing frost frequency over the last 20 years after a long-term decline up until the 1990s. This is mostly likely associated with reduced cloud cover and lower soil moisture.

There has been an increase in extreme fire weather (as indicated by the Forest Fire Danger Index), and an increase in the length of the fire season, over many parts of Australia since the 1970s. This increase is especially pronounced in southern and eastern Australia, driven both by higher temperatures and reductions in cool-season rainfall. There is substantial variability from year to year, with generally lower fire danger in major La Niña years such as 2010-11.

Evidence for significant observed changes in extreme high rainfall is mostly inconclusive, although some parts of Australia do show a tendency over the post-1950 period towards a higher proportion of rainfall falling from extreme events. It should be noted that extreme rainfall events are highly variable in time and in space, and any underlying trend would need to be large in order to be detectable with a high level of statistical significance. Climate model projections generally indicate a higher proportion of total rainfall coming from extreme events, with more extreme rainfall events projected even in those regions where total rainfall is expected to decrease.

Parts of southern Australia, including southwestern Western Australia and southern Victoria, have experienced multi-year droughts at times in the last 20 years which have been without precedent in the observed historical records (for example, Victoria had rainfall below the 1961-1990 average in nine consecutive years from 2001 to 2009, whereas prior to 2001 the longest such sequence was four years). The reduction in rainfall is amplified in streamflow, with declines of 50 per cent or more in both south-eastern and southwestern Australia since the mid-1990s.

The Murray-Darling Basin experienced significant drought in the 2001-2009 period, although droughts of comparable length and severity had previously occurred from 1937-1945 and 1895-1903. Similarly, the 2012-2016 drought in inland Queensland and northern New South Wales

was generally the most significant in those regions since the 1960s, but longer and more severe droughts did occur over most of this region in the 1920s and 1930s.

The number of tropical cyclones in the Australian region varies with El Niño and La Niña events. Observations show that when this variability is accounted for since 1982 (when consistent satellite records begin) there is a statistically significant downward trend in the number of tropical cyclones in the Australian region of responsibility for observing tropical cyclones (i.e. the ocean and land areas from 90°E to 160°E in the southern hemisphere). There is no clear trend over this time in tropical cyclone intensity, with large uncertainties in observed trends due to the small number of intense cyclones and high interannual variability. Climate model projections generally indicate a likely decrease in tropical cyclone numbers but an increase in the intensity of those cyclones which do occur.

d. Recent and projected changes in natural coastal defence systems including coral reefs, kelp and mangrove forests

The Great Barrier Reef Outlook Report 2014 is the most comprehensive assessment of the state of the reef, published every five years. The 2014 Report found that, while the system as a whole retains the qualities contributing to its Outstanding Universal Value as a world heritage property, the overall outlook for the reef ecosystem is poor and worsening. This assessment was reached after taking into account 150 years of human impacts such as poor water quality and Crown-of-Thorns starfish outbreaks, and the poor forward outlook for the reef under present pressures, including the increasing levels of greenhouse gases in the atmosphere.

Climate change may affect the Great Barrier Reef in a number of ways, including increased frequency of severe weather events, ocean acidification, rising sea temperatures and rising sea levels. The extent and persistence of these impacts depends to a large degree on how effectively nations, globally, implement their commitments under the Paris Agreement.

Since the 2014 Outlook Report, the effects of climate change have become increasingly apparent. Approximately two thirds of the Reef has been affected by an unprecedented two consecutive years (2016 and 2017) of mass coral bleaching, which has significantly impacted the Reef. While the full effects of the 2017 bleaching event are yet to be confirmed, the 2016 bleaching event resulted in an estimated 29 per cent loss of shallow-water corals from the Marine Park⁵.

The Australian Government is working closely with scientists, including the Independent Expert Panel, to better understand these bleaching events and respond accordingly. The major coral bleaching events of 2016 and 2017 in the Great Barrier Reef are well known, with 2016 also seeing bleaching on some coral reef systems off northern Western Australia. A major contributor to these bleaching events is high sea surface temperature. In March 2016, mean sea surface temperature for the region was the highest on record, at 29.1°C, or 1.3°C above the long-term (1961-1990) average, while March 2017 (at 28.7°C) ranked second. Sea surface temperatures in the Great Barrier Reef region have warmed at an average rate of 0.09°C per decade since 1900, or about 1°C over the full period.

In conjunction with the 2017 mass bleaching event, severe tropical cyclone Debbie crossed the Reef in the Whitsunday region in March 2017, causing widespread regional wave damage to coral combined with heavy rainfall and flooding. It is estimated that approximately 28 per cent of the total reef area of the Marine Park was in the 'catastrophic damage zone' of the cyclone's path. Initial in-water surveys of reefs in the cyclone's path found extensive, severe coral reef damage around the popular Whitsunday Islands, while damage to mid and outer-reefs was

⁵ Great Barrier Reef Marine Park Authority 2017, Final report: 2016 coral bleaching event on the Great Barrier Reef, GBRMPA, Townsville

more variable and patchy. Debbie was the tenth severe tropical cyclone to cause significant impact to the Reef in 13 years.

In recent years, reefs in the northern two-thirds of the Great Barrier Reef Marine Park have been experiencing ongoing severe outbreaks of crown-of-thorns starfish. In some areas where coral reef health was compromised by the multiple impacts of bleaching and crown-of-thorns starfish, there was a notable increase in outbreaks of coral disease. It is estimated that at least 75 per cent of the Marine Park has now been affected by one or more of these impacts (either individually, simultaneously or cumulatively) between January 2016 and May 2017.

The Great Barrier Reef provides physical security for the Queensland coast by buffering the coast from the majority of wave energy. On reaching the shallower water of reef areas, incoming waves break, thereby dissipating much of their energy before they can reach the coast. It has been estimated that coral reefs reduce wave energy by an average of 97 per cent⁶. This effect is most beneficial during cyclones which produce large and damaging waves. For example, during tropical cyclone Aivu, which struck North Queensland in 1989, wave heights of 10 metres were reduced to 6 metres after passage over the Great Barrier Reef⁷.

The presence of reefs as “natural breakwaters” is therefore of considerable benefit to coastal communities, most obviously in the form of reduced erosion. Additional benefits may arise from the reduction in wave generated damage to fishing fleets and recreational boats⁸.

Under a regime of sea-level rise, the wave-buffering function of the Great Barrier Reef is dependent on the Reef’s ability to grow vertically at a pace that ‘keeps up’ with the rising sea level – if the Reef ‘falls behind’ rising sea-level, then reef waters will become progressively deeper, incoming waves will be less likely to break, and ultimately the Queensland coast will be subject to more wave energy. In the long-term, this would put coastal buildings and infrastructure at significantly higher risk from major weather events.

The Australian Government continues to invest heavily in actions that support the resilience of the reef and consider new actions that may enhance reef rebuilding. While it is too early to tell whether the Reef will be able to ‘keep-up’ with sea level rise, increasing sea temperature and ocean acidification due to climate change are likely to be already contributing to a reduction in reef-building processes on the Great Barrier Reef. Researchers⁹ have found that between 1990 and 2005, reef-building processes on the Great Barrier Reef underwent the fastest and most severe decline in at least 400 years.

⁶ Ferrario, F., Beck, M.W., Storlazzi, C.D., Micheli, F., Shepard, C.C. and Airolidi, L. 2014, The effectiveness of coral reefs for coastal hazard risk reduction and adaptation, *Nature Communications* 5(3794): 1-9.

⁷ Young I & Hardy T (1993) “Measurement and modelling of tropical cyclone waves in the Great Barrier Reef”, *Coral Reefs*, Vol.12, No.2

⁸ Oxford Economics 2009, *Valuing the effects of Great Barrier Reef bleaching*, Great Barrier Reef Foundation, Newstead

⁹ De'ath, G., Lough, J.M. and Fabricius, K.E. 2009, Declining coral calcification on the Great Barrier Reef, *Science* 323(5910): 116-119