Technical information supporting the 2023 Projected sea level environmental trend and condition report card

Department for Environment and Water
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Government of South Australia
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Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present. We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country. We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

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Summary

The 2023 release of South Australia's environmental trend and condition report cards summarises our understanding of the current condition of the South Australian environment, and how it is changing over time.

This document describes the indicators, information sources, analysis methods and results used to develop this report and the associated 2023 Projected sea level report card. The reliability of information sources used in the report card is also described.

The Projected sea level report card sits within the report card Climate theme. Report cards are published by the Department for Environment and Water and can be accessed at www.environment.sa.gov.au.

1 Introduction

1.1 Environmental trend and condition reporting in SA

The Minister for Climate, Environment and Water under the *Landscape South Australia Act 2019* is required to 'monitor, evaluate and audit the state and condition of the State's natural resources, coasts and seas; and to report on the state and condition of the State's natural resources, coasts and seas' (9(1(a-b)). Environmental trend and condition report cards are produced as the primary means for the Minister to undertake this reporting. Trend and condition report cards are also a key input into the State of the Environment Report for South Australia, which must be prepared under the *Environment Protection Act 1993*. This Act states that the State of the Environment Report must:

- include an assessment of the condition of the major environmental resources of South Australia (112(3(a))), and
- include a specific assessment of the state of the River Murray, especially taking into account the Objectives for a Healthy River Murray under the *River Murray Act 2003* (112(3(ab))), and
- identify significant trends in environmental quality based on an analysis of indicators of environmental quality (112(3(b))).

1.2 Purpose and benefits of SA's trend and condition report cards

South Australia's environmental trend and condition report cards focus on the state's priority environmental assets and the pressures that impact on these assets. The report cards present information on trend, condition, and information reliability in a succinct visual summary.

The full suite of report cards captures patterns in trend and condition, generally at a state scale, and gives insight to changes in a particular asset over time. They also highlight gaps in our knowledge on priority assets that prevent us from assessing trend and condition and might impede our ability to make evidence-based decisions.

Although both trend and condition are considered important, the report cards give particular emphasis to trend. Trend shows how the environment has responded to past drivers, decisions, and actions, and is what we seek to influence through future decisions and actions.

The benefits of trend and condition report cards include to:

- provide insight into our environment by tracking its change over time
- interpret complex information in a simple and accessible format
- provide a transparent and open evidence base for decision-making
- provide consistent messages on the trend and condition of the environment in South Australia
- highlight critical knowledge gaps in our understanding of South Australia's environment
- support alignment of environmental reporting, ensuring we 'do once, use many times'.

Environmental trend and condition report cards are designed to align with and inform state of the environment reporting at both the South Australian and national level. The format, design and accessibly of the report cards has been reviewed and improved with each release.

1.3 Climate change in Australia

Climate affects almost every part of our lives. Communities, industries, landscapes and ecosystems all develop with a tolerance for a range of climate variation. If the climate changes beyond that range of tolerance, then they must either adapt, migrate, transform or decline.

According to the Australian Academy of Science (2015), "Earth's climate has changed over the past century. The atmosphere and oceans have warmed, sea levels have risen, and glaciers and ice sheets have decreased in size. The best available evidence indicates that greenhouse gas emissions from human activities are the main cause. Continuing increases in greenhouse gases will produce further warming and other changes in Earth's physical environment and ecosystems."

The primary pressure affecting sea level change in the twenty-first century is the global warming of the atmosphere and oceans due to the enhanced greenhouse effect. Rising temperatures in the atmosphere and oceans result in a global rise in sea levels due to thermal expansion of oceans and melting of continental ice, placing some low-lying coastal assets at an increased risk of seawater inundation (Australian Academy of Science, 2015).

The Bureau of Meteorology maintains an array of monitoring stations which measure sea level very accurately. The Bureau's Australian Baseline Sea Level Monitoring Project monitors sea level around the coastline of Australia to identify long-term changes (Bureau of Meteorology 2023a). A number of other tide gauges are operated in South Australia by Flinders Ports Pty Ltd. Data from these gauges are made available through the Bureau's online resources (Bureau of Meteorology 2023b).

1.4 Future change in sea levels in South Australia

The Climate: Projected sea level report card reports on the projected change in sea levels though the twenty-first century under future climate scenarios, according to the projections of the Inter-governmental Panel on Climate Change (IPCC).

2 Methods

2.1 Indicator

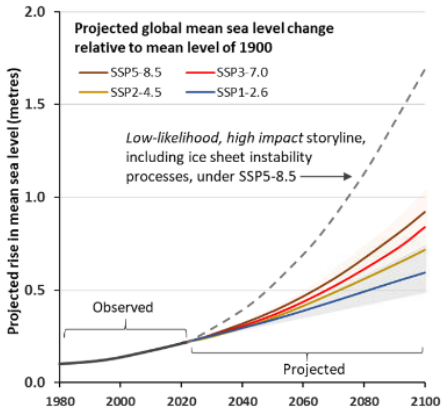
The indicator used for the Projected sea level report card is the projection of the rate of sea level rise reported by the Sixth Assessment Report of Working Group 1 of the IPCC (IPCC 2021) for both the global average sea level and average sea levels at five locations on the coast of South Australia: Port Adelaide, Port Lincoln, Thevenard, Whyalla and Victor Harbor.

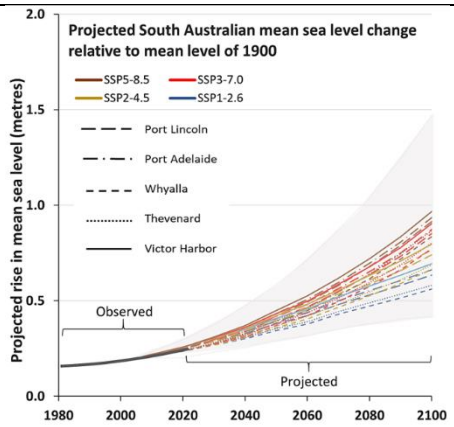
2.2 Data sources, collection and analysis

The content of the Projected sea level report card includes a combination of elements of textual information, graphical figures, trend and condition ratings, and summary statements about the assessed trend and condition of projected sea level in South Australia. The information sources and analyses applied to derive each element of the report card content are summarised in Table 2.1. The method of selection of the trend, condition and information reliability ratings is described in Section 2.3.

Table 2.1. Summary of information sources and analysis

Report card element	Content	Information sources / analysis
Trend quote	Mean sea levels in South Australia are projected to rise approximately in line with global sea levels over the course of this century.	This comment is based on the projected changes in global average sea levels shown in the graph in the top figure and the projected rise in sea levels for five locations in South Australia shown in the graph in the bottom figure.
Trend text	Globally, mean sea levels rose by 15–20 cm from 1900 to 2018. The projections of the Intergovernmental Panel on Climate Change (IPCC) indicate that sea levels will continue to rise and the rate of rise will increase through the 21st century. The projected changes in sea levels at individual South Australian coastal locations (bottom figure) vary by up to 14 cm by 2100 but are generally similar to projected changes in global mean sea levels. The rate of rise is affected by the future greenhouse gas emissions scenario. Under a low emissions scenario (SSP1-2.6), global mean sea level is projected to rise a further 15–23 cm by 2050 and 33–62 cm by 2100, compared to the mean level during 1995 to 2014 (top figure). Changes are greater under a high emissions scenario (SSP5-8.5), with a	The amount of rise in global mean sea levels from 1900–2018 is drawn from the updated mean sea-level analysis of Watson (2020). Projections of the rates of sea level rise for Port Adelaide, Port Lincoln, Thevenard, Whyalla and Victor Harbor are as reported in data from the NASA Sea Level Projection Tool (Sea Level Projection Tool – NASA Sea Level Change Portal) (NASA 2023). Details of the sea level projections data provided by the tool are in Box TS.4 of the Technical Summary report of the Working Group 1 contribution to the Intergovernmental Panel on Climate Change's Sixth Assessment Report (IPCC 2021a). The future greenhouse gas emissions scenarios are defined by Shared Socioeconomic Pathways (SSPs) or emission scenario storylines. These are "illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate change found in the literature. They start in 2015, and include scenarios with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO2 emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO2 emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO2 emissions23 (SSP1-1.9 and SSP1-2.6)" (IPCC 2021b).

Report card element	Content	Information sources / analysis
	projected further rise of approximately 16–33 cm by 2050 and 63–101 cm by 2100.	
Condition quote	A condition rating is not applicable as this is an assessment of projected sea level under likely climate scenarios.	The report card condition rating is intended to report on the current status of the reported variable. As the Projected sea level report card reports only on projected future sea level change, it does not provide an assessment of the current condition of sea level.
Condition text	Under the higher emissions scenarios (SSP5-8.5), there is great uncertainty in sea level projections for 2100 and beyond associated with the uncertain responses of continental ice-sheets to warming. In the IPCC's low-likelihood, high-impact storyline under a high emissions scenario (dashed line, top figure), ice-sheet instability processes could drive sea level rise at a much faster rate this century, with a possibility of accelerating to 1.5–2.0 m of rise by 2100 (compared with mean sea level in 1900) and up to 5 m by 2150.	This statement is based on the low-likelihood, high impact storyline shown in the graph in the top figure (dashed line). Further details of the storyline are provided in the Figure SPM 8 of the IPCC AR6 Working Group 1 Summary for Policymakers (IPCC 2021b).
Quote	Sea levels along South Australia's coast are rising, and the rate of rise is projected to increase in the future.	This comment is based on observation of both the observed historic rates of sea level rise reported in the 2023 Climate: Sea level report card and the rates of projected sea level rise shown in the graph in the bottom figure of the report card.
Top figure		The graph in the top figure shows the multi-model average projections of global mean sea level to 2100 under four emission scenario storylines: SSP5-8.5, SSP3-7.0, SSP2-4.5 and SSP1-2.6. This figure is adapted from Figure SPM 8(d) of the IPCC AR6 Working Group 1 Summary for Policymakers (IPCC 2021b). The coloured lines represent the mean sea level change projected by a range of models under each of the four SSPs. The grey shading in the graph represents the range of model uncertainty around the mean of the projected changes in sea level, excluding the uncertainty related to stability of ice sheet processes that is represented by the dashed black line.

Report card element	Content	Information sources / analysis
Bottom figure		The graph in the bottom figure presents projected changes in the average sea level (m) at five locations in South Australia (Port Lincoln, Port Adelaide, Whyalla, Thevenard and Victor Harbor) based on ten year intervals between 2020 and 2100. This was prepared using projection data from the NASA IPCC Sea Level Projection tool Sea Level Projection Tool – NASA Sea Level Change Portal). The NASA data provide a projected change in the local mean sea level at the start of each decade from 2020 to 2100 relative to sea level in 1900. The lines on the graph interpolate the projected change in mean sea level for each of these time points for each location. A projected change is given for each of the five locations and under four different emission scenarios. These scenarios are SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. The values used were those projected with medium confidence in the 50th percentile. Upper and lower projection limits with a confidence interval of 5 and 95% respectively are plotted for the data set and this area is shaded in grey. The data used at timepoints between 1980 and 2020 are based on observed sea level rise since 1900 (0.2 m), and all projected values have been added to this baseline of 0.2 m to reflect a total projected change inclusive of the already observed changes.
Rationale (Why is projected sea level important?)	A sustained and substantial rise in sea levels due to thermal expansion of oceans and melting of continental ice will expose low-lying coastal assets, environments and infrastructure to an increasing risk of coastline erosion and seawater inundation.	This is a general comment on the rationale for providing a report on the trend and condition of projected sea level in South Australia.
What are the drivers?	Most of the sea level rise projected is due to thermal expansion of oceans due to a rise in water temperature, and the melting of glaciers and continental ice sheets, with some additional contributions from changes in the mass of water stored on land. Greenhouse gas emissions from human activities are the main cause of warming atmosphere and oceans. Continuing increases in greenhouse gases will produce further warming and consequent changes in Earth's physical environment.	The attribution of the observed sea level rise to primarily the thermal expansion of the oceans and melting of continental ice is derived from the Sea Level, Waves & Coastal Extremes of CSIRO's Climate Science Centre (https://research.csiro.au/slrwavescoast/sea-level/sea-level-change/#LongerTerm) (CSIRO 2023).

Report card element	Content	Information sources / analysis
What is being done?	An array of tide gauge stations monitor sea levels around the coastline of Australia to identify long-term changes. Land surface elevation mapping of the South Australian coastline is maintained by the Department for Environment and Water to enable the assessment of risks of rising sea level to coastal communities and infrastructure. This is used to map sea flood hazards along sections of the state's coastline for a range of sea level rise scenarios.	Information on the maintenance of sea level monitoring stations is drawn from the website of the Australia Baseline Sea Level Monitoring Project: http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml (Bureau of Meteorology 2023a), and from the Bureau of Meteorology's State and Territory Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics website: http://www.bom.gov.au/oceanography/projects/ntc/monthly/ (Bureau of Meteorology 2023b).

2.3 Methods to assign trend, condition and reliablity

2.3.1 Trend

Table 2.2. Definition of trend classes used

Trend	Description
Getting better	Over a scale relevant to tracking change in the indicator it is improving in status with good confidence
Stable	Over a scale relevant to tracking change in the indicator it is neither improving nor declining in status
Getting worse	Over a scale relevant to tracking change in the indicator it is declining in status with good confidence
Unknown	Data are not available, or are not available at relevant temporal scales, to determine any trend in the status of this resource
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above trend classes

2.3.2 Condition

Table 2.3. Definition of condition classes used

Condition	Description
Very good	The natural resource is in a state that meets all environmental, economic and social expectations, based on this indicator. Thus, desirable function can be expected for all processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)
Good	The natural resource is in a state that meets most environmental, economic and social expectations, based on this indicator. Thus, desirable function can be expected for only some processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)
Fair	The natural resource is in a state that does not meet some environmental, economic and social expectations, based on this indicator. Thus, desirable function cannot be expected from many processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)
Poor	The natural resource is in a state that does not meet most environmental, economic and social expectations, based on this indicator. Thus, desirable function cannot be expected from most processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)
Unknown	Data are not available to determine the state of this natural resource, based on this indicator
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above condition classes

2.3.3 Reliability

Information is scored for reliability based on the minimum of subjective scores (1 [worst] to 5 [best]) given for information currency, applicability, level of spatial representation and accuracy. Definitions guiding the application of these scores are provided in Table 2.4 for currency, Table 2.5 for applicability, Table 2.6 for spatial representation and Table 2.7 for accuracy.

Table 2.4. Guides for applying information currency

Currency score	Criteria
1	Most recent information >10 years old
2	Most recent information up to 10 years old
3	Most recent information up to 7 years old
4	Most recent information up to 5 years old
5	Most recent information up to 3 years old

Table 2.5. Guides for applying information applicability

Applicability score	Criteria
1	Data are based on expert opinion of the measure
2	All data based on indirect indicators of the measure
3	Most data based on indirect indicators of the measure
4	Most data based on direct indicators of the measure
5	All data based on direct indicators of the measure

Table 2.6. Guides for applying spatial representation of information (sampling design)

Spatial score	Criteria
1	From an area that represents less than 5% the spatial distribution of the asset within the region/state or spatial representation unknown
2	From an area that represents less than 25% the spatial distribution of the asset within the region/state
3	From an area that represents less than half the spatial distribution of the asset within the region/state
4	From across the whole region/state (or whole distribution of asset within the region/state) using a sampling design that is not stratified
5	From across the whole region/state (or whole distribution of asset within the region/state) using a stratified sampling design

Table 2.7. Guides for applying accuracy information

Reliability	Criteria
1	Better than could be expected by chance
2	> 60% better than could be expected by chance
3	> 70 % better than could be expected by chance
4	> 80 % better than could be expected by chance
5	> 90 % better than could be expected by chance

2.4 Data transparency

Data transparency for this report card is represented in the environmental knowledge management chart in Appendix A.

3 Results

3.1 Trend

The trend rating for projected sea level was determined to be 'getting worse'. Under all modelled scenarios, sea levels are projected to continue to rise and the rate of rise is projected to increase in the future in all parts of the South Australian coastline (Figures 3.1 (global) and 3.2 (state)). A rise in sea level is deemed to be a trend that is 'getting worse' due to the increased risk to coastal environmental assets and infrastructure.

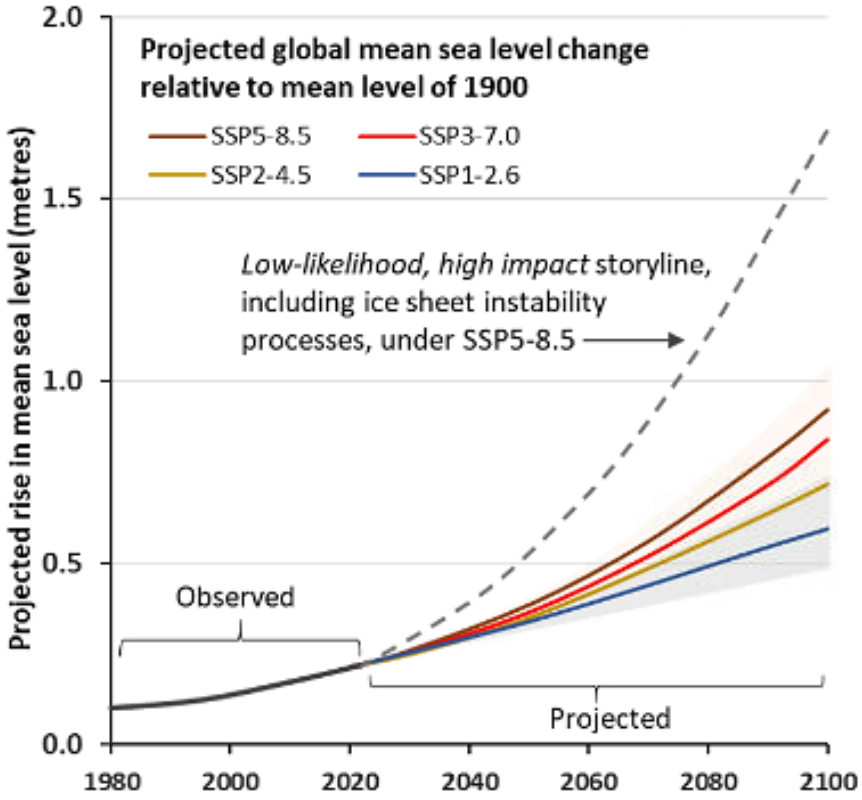


Figure 3.1. **Projected global mean sea level change (metres) relative to mean level of 1900 for four emissions scenarios**

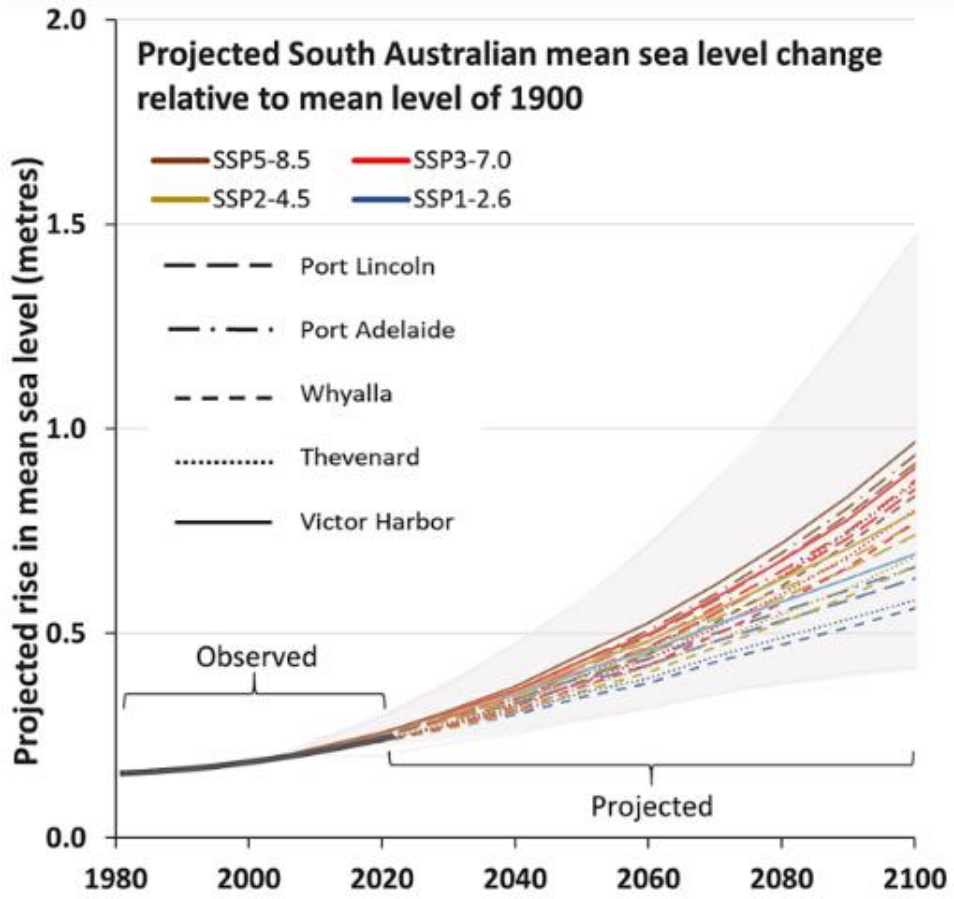


Figure 3.2. **Projected South Australian mean sea level change (metres) relative to mean level of 1900 for four emissions scenarios at five locations (Port Lincoln, Port Adelaide, Whyalla, Thevenard and Victor Harbor). Grey shading shows upper (5% confidence interval) and lower (95% confidence interval) projection limits**

3.2 Condition

As this presents only projected sea levels under future climate scenarios, a condition rating is not considered to be applicable.

3.3 Reliability

The overall reliability score for this report card is 3 out of 5 based on Table 3.1. A reliability rating of 'good' has been assigned.

Table 3.1. **Information reliability scores for projected sea level**

Indicator	Applicability	Currency	Spatial	Accuracy	Reliability
Projected sea level data	3	5	4	NA	3

3.3.1 Notes on reliability

As the IPCC sea level projections datasets, released in 2021, are less than 3 years old, a currency score of 5 is assigned to these data.

The projected changes in sea level are determined from a combination of large scale modelling of climate systems and a complex combination of sea level influences, including thermal expansion, dynamics of the movement and melting of continental ice, changes in large scale ocean currents, and transfers of water between the ocean and land-based stores of water. The projections of future sea level change that result from these modelling processes are all reliant on a combination of direct and indirect indicators of potential future global ocean and atmosphere temperatures, cryospheric, oceanic and hydrological responses, and a range of uncertain greenhouse gas trajectories. An information applicability score of 3 is determined for the resulting sea level projection data.

The report card presents data on projected changes in sea levels locally and globally, which are largely co-dependent. Only five locations on the South Australian coast are represented, however, there is a high degree of dependence between changes in local sea levels and changes in global sea levels. The range of sea level change projected for these five locations are seen as providing a good representation of the likely range of change for in future sea levels along the whole of the South Australian coast. Hence a spatial representation score of 4 has been assigned.

As the projected changes in sea levels are only modelled projections, dependent on a range of scenarios of future greenhouse gas concentrations, the accuracy of the data cannot be compared against measurement. As a result, the accuracy assessment of the projections is considered to be not applicable (N/A).

4 Discussion

4.1 Trend

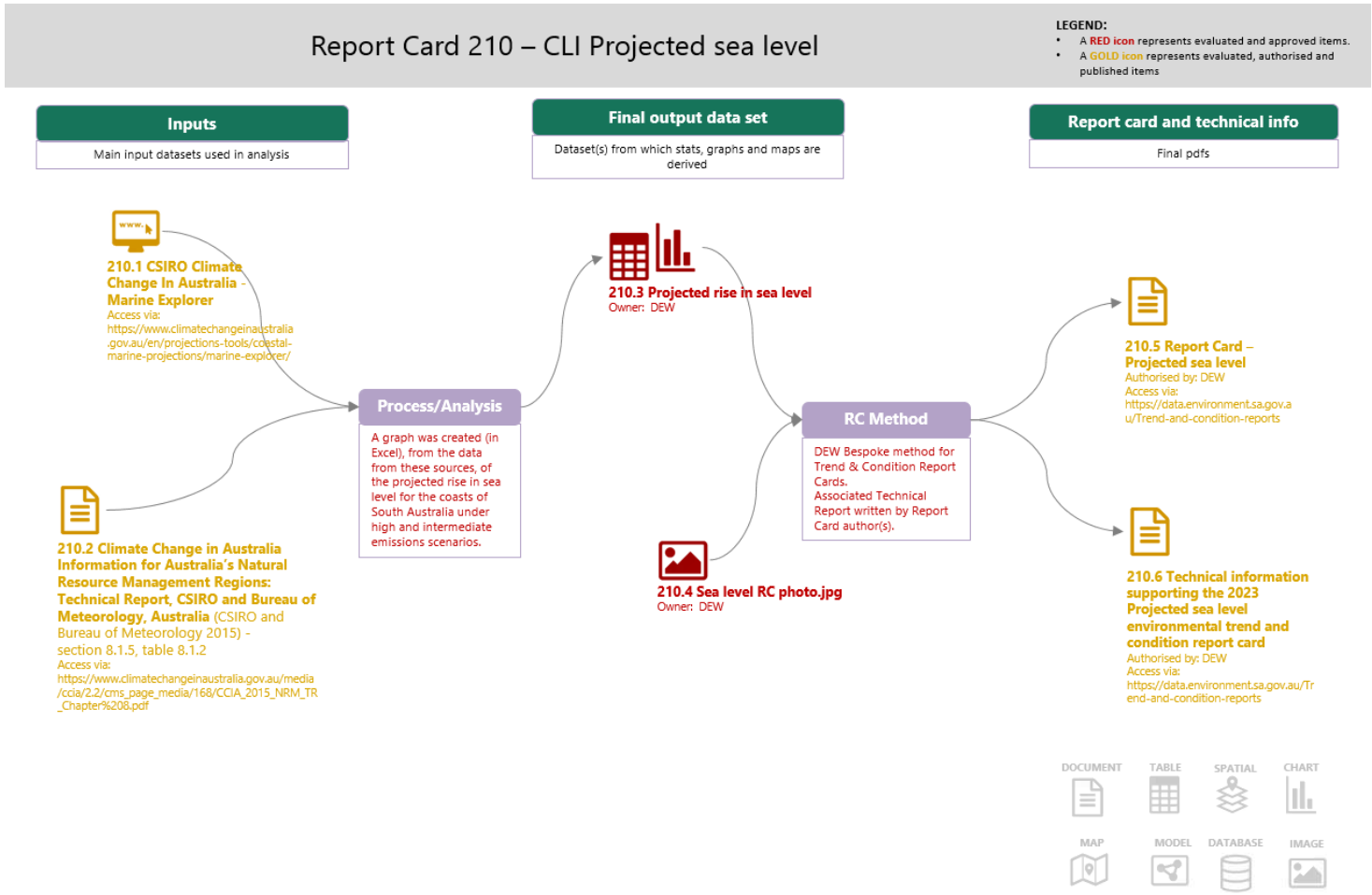
A trend of 'getting worse' was assigned for projected sea level. Under all modelled scenarios sea levels are projected to continue to rise and the rate of rise is projected to increase in the future in all parts of the South Australian coastline. Sea level rise is rated as a trend of declining condition because higher sea levels cause an increase in the risks to coastal assets and infrastructure.

Projections of sea level rise this century are unlikely to change significantly in coming years, however, it will become more apparent over time which of the projected emissions storylines is being realised. A low-likelihood, high impact scenario provided among the IPCC sea level rise projections presents a much higher rate of sea level rise than is projected under the four SSP emissions scenarios (dashed line in Figure 3.1). This low-likelihood scenario is subject to a number of highly uncertain processes related to Arctic and Antarctic ice sheet dynamics. Beyond a certain degree of global temperature rise, irreversible ice sheet movements may be triggered that will accelerate the rate of sea level rise. If this occurs, future projections of sea level rise will cease to be tied to greenhouse gas emissions scenarios alone.

4.2 Condition

As this report card presents only projected sea levels under future climate scenarios, a condition rating is not considered to be applicable.

5 Appendix A: Managing environmental knowledge chart for Projected sea level



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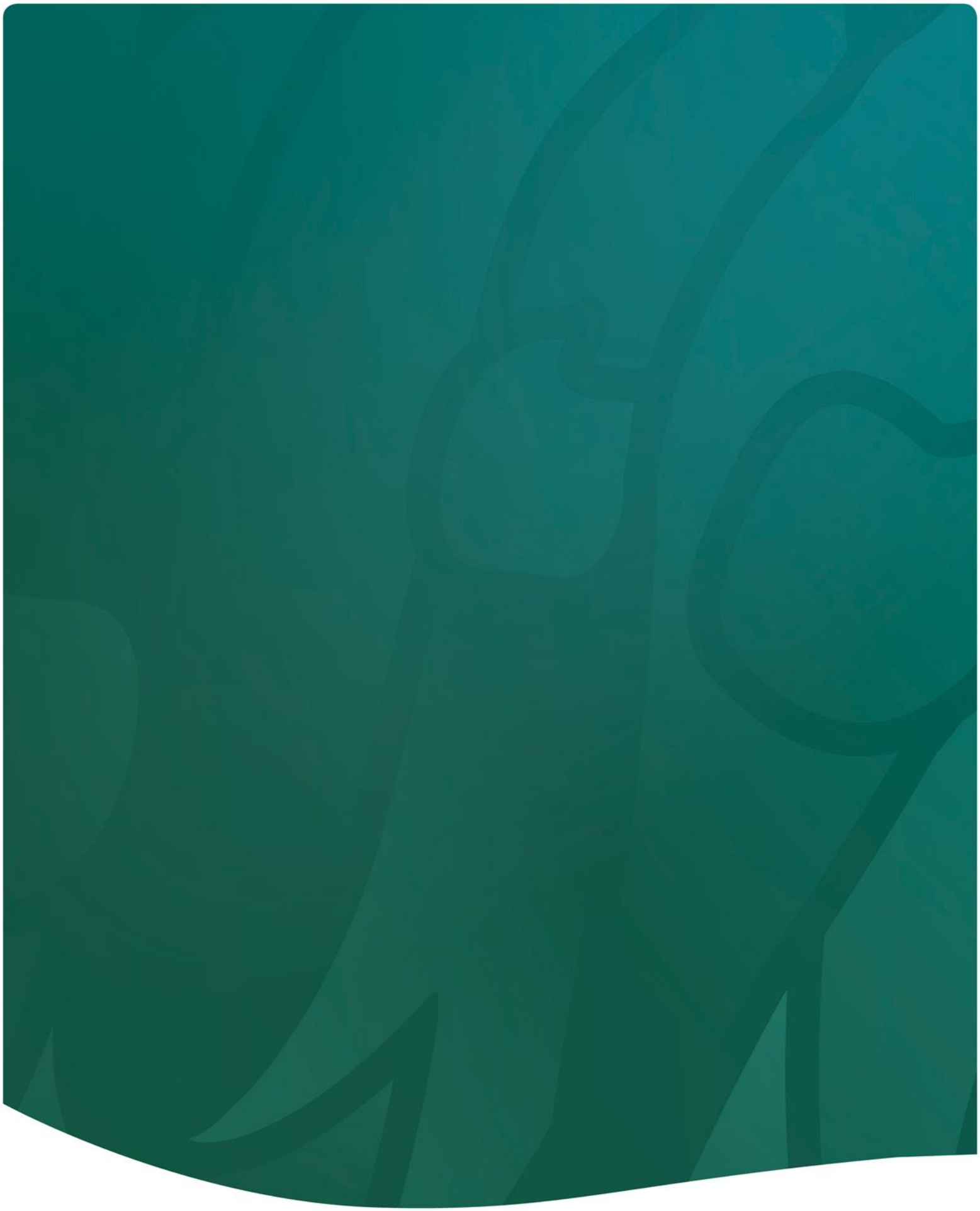

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