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

Department for Environment and Water
August, 2023

DEW Technical note 2023/49

Government of South Australia
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August 2023

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Preferred way to cite this publication

Department for Environment and Water (2023). *Technical information supporting the 2023 Sea level environmental trend and condition report card*, DEW Technical report 2023/49, Government of South Australia, Department for Environment and Water, Adelaide.

Download this document at https://data.environment.sa.gov.au

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.

Acknowledgements

This document was prepared by Graham Green (DEW) and Susan Sweeney (DEW), and technically reviewed by Sharie Detmar (DEW). Brady Stead (DEW) provided mapping support. Improvements were made to this report and associated report card based on reviews by Amy Ide (DEW), Murray Townsend (DEW), and Fi Taylor (DEW).

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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 Sea level report card. The reliability of information sources used in the report card is also described.

The 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 Sea levels in South Australia

The Climate: Sea level report card reports on the observed variations in sea level at tide gauges on the South Australian coastline over the 57 years to 2022.

2 Methods

2.1 Indicator

The indicator used for the Sea level report card is the monthly mean sea level recorded at three tide gauge stations on the coast of South Australia, at Port Adelaide, Thevenard and Victor Harbor (Figure 2.1).

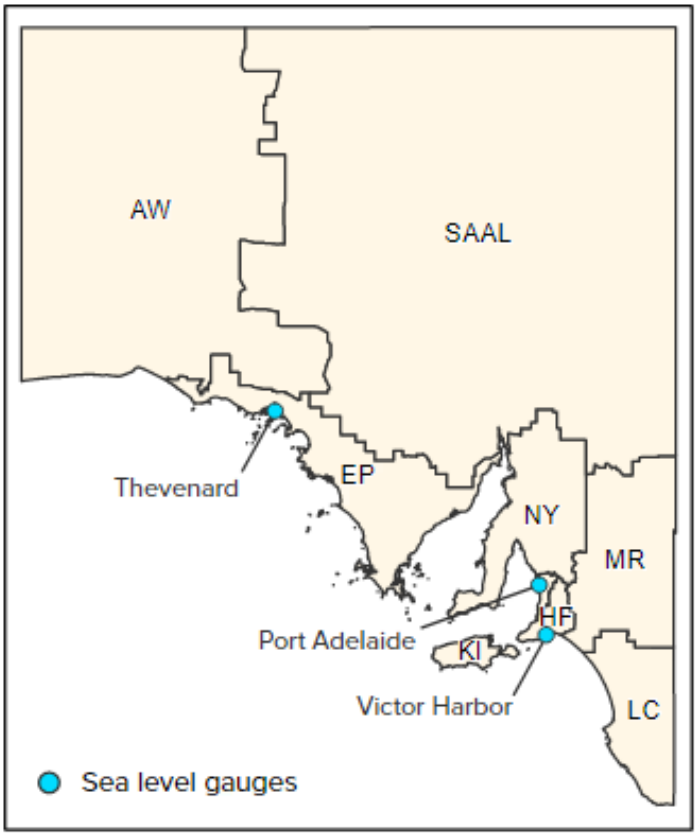


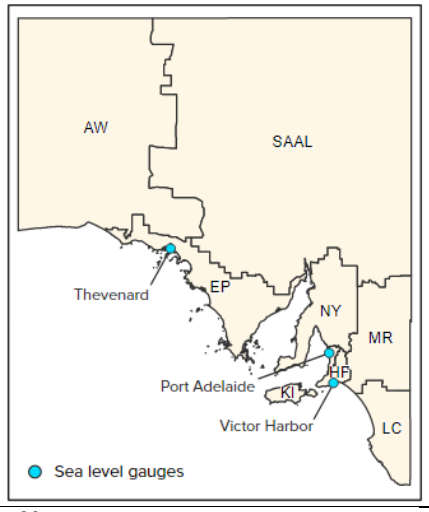
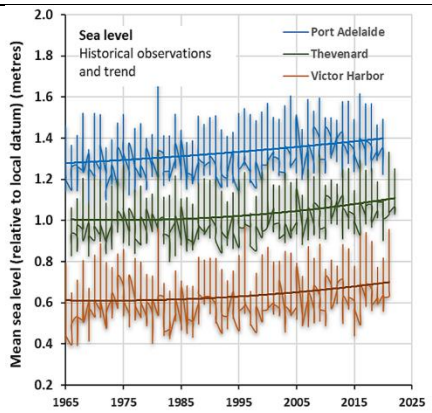
Figure 2.1. Long-term sea level gauge stations in South Australia used for the Sea level report card

2.2 Data sources, collection and analysis

The content of the Sea level report card includes a combination of elements of textual information, graphical figures, trand and condition ratings, and summary statements about the assessed trend and condition of 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	Sea levels along South Australia's coast rose by an average rate of around 2 mm per year between 1966 and 2022. The rate of sea level rise is increasing and from 1993 to 2022 was between 3 mm and 5 mm per year in some locations.	The average rate of sea level rise of around 2 mm per year is determined from the difference between average sea levels in 2017–2021 and average sea levels in 1965–1969, divided by the 53 years between those two periods. Average sea levels in each of the two periods are derived from the average of the monitored mean monthly sea levels relative to the local datum elevation over the 5-year period 1965–1969 compared to the average over the 5-year period 2017–2021 at the three gauge locations at Port Adelaide, Thevenard and Victor Harbor. The data were drawn from individual tide gauge datasets and associated metadata maintained on behalf of Ports Australia and provided by 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). The increase of the sea level rise trend to 3–5 mm per year over the period 1993–2022 in some locations was determined from the slope of the trend lines over that period of the mean monthly sea levels relative to the local datum elevation at the Bureau's SEAFRAME sea level monitoring gauge at Thevenard and the Flinders Ports operated tide gauge located at Victor Harbor.
Trend text	Trends of gradual rise in sea level have been observed in all long-term sea level gauge records in South Australia (top figure). Measurements are stated relative to a local fixed reference height, which in some cases may be changing over time due to slow changes in the elevation of the land level at the location. Hence, in some locations, the vertical movement of the local reference point is a component of the observed rise. Consistent satellite records since 1993 have enabled comparison with sea levels from long-term tide gauge records and improved estimates of the rates of change of sea level.	This comment is based on observation of the rates of rise in the graph in the bottom figure of the report card. The effect of vertical land movement on the elevation of local datum points is drawn from the Australian Baseline Sea Level Monitoring Project Annual Sea Level Data Summary Report (July 2010 – June 2011) (Bureau of Meteorology 2012) http://www.bom.gov.au/ntc/IDO60202/IDO60202.2011.pdf The impacts of vertical land movement on the elevation of local datum points and consequent effects on measurements of sea level change over time is discussed and quantified in an updated mean sea level analysis for Australia published in the Journal of Coastal Research in 2020 (Watson 2020). The improvements in sea level monitoring resulting from satellite measurements from 1993 are discussed in a paper by Hague et al. in the journal Earth's Future in 2022 (Hague et al. 2022)
Condition quote	The condition is rated as fair as the observed changes in sea level do not currently impact on most social, economic and environmental values.	The condition rating was applied according to the criteria for a 'fair' condition: '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).'

Report card element	Content	Information sources / analysis
Condition text	Mean sea levels at tide gauges at Thevenard, Port Adelaide and Victor Harbor were 10–12 cm higher in 2017–2021 compared to sea levels in 1965–1969 (bottom figure).	The range of change in sea levels in 2017–2021 compared to levels in 1965–1969 was determined from an average of the monitored mean monthly sea levels relative to the local datum elevation over the 5-year period 1965–1969 compared to the average over the 5-year period 2017–2021 at the three tide gauge locations at Port Adelaide, Thevenard and Victor Harbor. These data are illustrated in the graph shown in the bottom figure of the report card.
Quote	Sea levels along South Australia's coast are rising, and the rate of rise is increasing.	This comment is based on observation of the rates of rise in the graph in the bottom figure of the report card.
Top figure		The top figure uses spatial data held by DEW, including: 1. Landscape region boundaries 2. South Australia's coastline The locations of the Australian Baseline Sea Level Monitoring site at Thevenard, and Flinders Ports tide gauge sites at Port Adelaide and Victor Harbor are as reported in metadata provided by 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).
Bottom figure		The graph in the bottom figure shows monitored sea levels relative to the local datum elevation at three sea level monitoring gauge locations along the South Australian coast for the period 1965 to 2022. These data were drawn from the individual tide gauge datasets provided by by 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). Monthly mean sea levels are plotted, together with a polynomial function trend line that reveals slight increase in the rate of sea level over time.
Rationale (Why is sea level important?)	Coastal environments and infrastructure are typically resilient to only the natural variations in sea levels that occur due to tides and occasional storm surges. Climate change is causing a rise in sea levels globally, this subjects low-lying coastal environments and infrastructure to an increased vulnerability to erosion and seawater inundation. Relatively small changes in mean sea level can result in	This is a general comment on the rationale for providing a report on the trend and condition of sea level in South Australia.

Report card element	Content	Information sources / analysis
	major increases in the frequency and extent of seawater flooding events.	
Drivers	Most of the observed sea level rise is due to thermal expansion of oceans due to a rise in water temperature and the melting of glaciers and continental ice sheets due to global climate change, 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 website of CSIRO's Climate Science Centre (CSIRO 2023): https://research.csiro.au/slrwavescoast/sea-level/sea-level-change/#LongerTerm
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 provided in the environmental knowledge management chart in Appendix A.

3 Results

3.1 Trend

The trend rating for sea level was determined to be 'getting worse' as there are high quality observational data indicating that sea levels are rising at all three of the continuously monitored locations on the South Australian coastline (Figure 3.1). A rise in sea level is assessed to be a trend that is 'getting worse' due to the increased risk to coastal environmental assets and infrastructure.

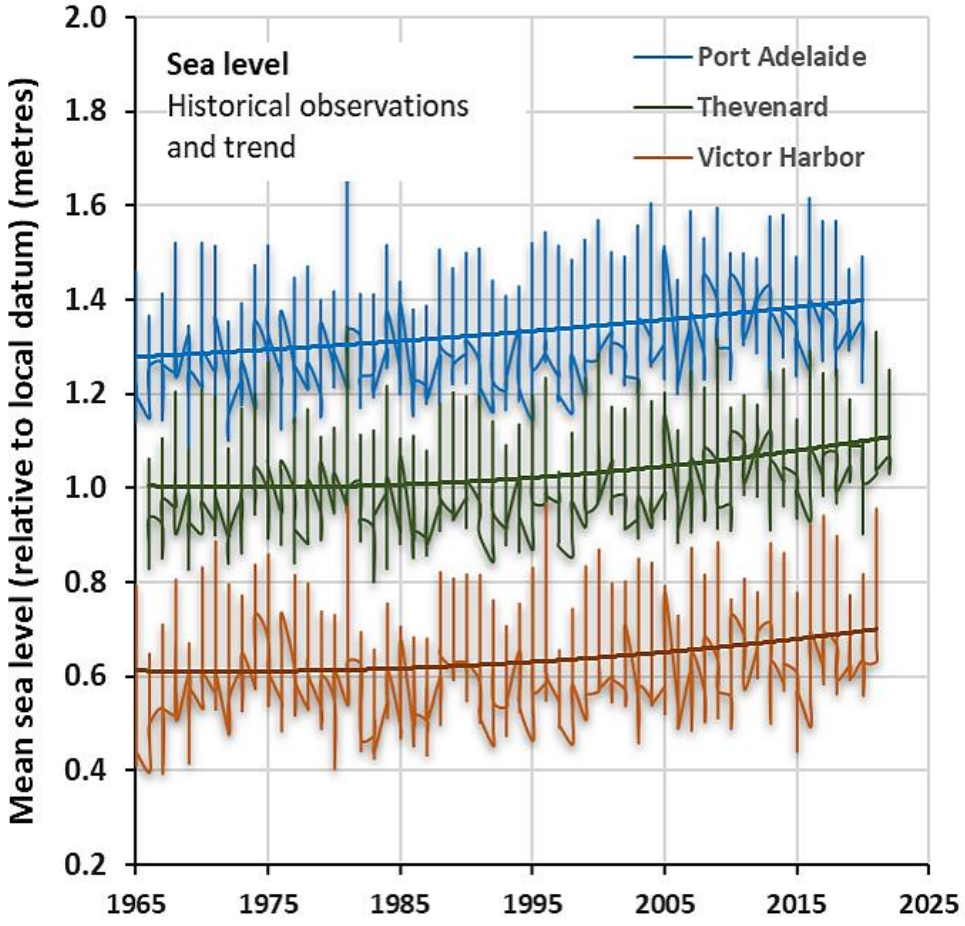


Figure 3.1. Observed mean sea level (relative to local datum, in metres) for three sea level gauge stations in South Australia and associated polynomial function trendlines

3.2 Condition

The condition rating for sea level was determined to be 'fair' as levels currently meet most social, economic and environmental requirements, however some undesirable outcomes (such as periodic flooding) for coastal assets and infrastructure may result from the change in sea levels, now and into the future, particularly at times of stress such as during particularly high tides and storm conditions.

3.3 Reliability

The overall reliability score for this report card is 3 out of 5 based Table 2.7. A reliability rating of 'good' has been assigned.

Table 3.1. Information reliability scores for sea level

Indicator	Applicability	Currency	Spatial	Accuracy	Reliability
Sea level data	5	5	3	5	3

3.3.1 Notes on reliability

The information has a currency score of 5 as measured sea level data up to 2022 have been presented in the graph of sea level variation in the bottom figure.

The information has an applicability rating score of 5 because the data are based on monthly averages of tide gauge measurements, which are direct indicators of mean sea level at each of the three locations.

A spatial representation score of 3 has been assigned because the data are from tide gauges that are sparsely distributed across the coastline of the state and each one is representative of sea level variations in a limited area. Although the sea levels across the extent of the state's coastline can be inferred from the locations represented by these tide gauges, the measurements represent less than half the spatial variation of the sea levels along the state's coastline.

The observed changes in sea level are based on direct measurements at calibrated tide gauge stations. The accuracy of measurements of average monthly sea level at these locations is more than 90% better than could be expected by chance (Table 2.7). As a result, the accuracy of the data, for the purpose of the report card, has been ascribed a score of 5.

4 Discussion

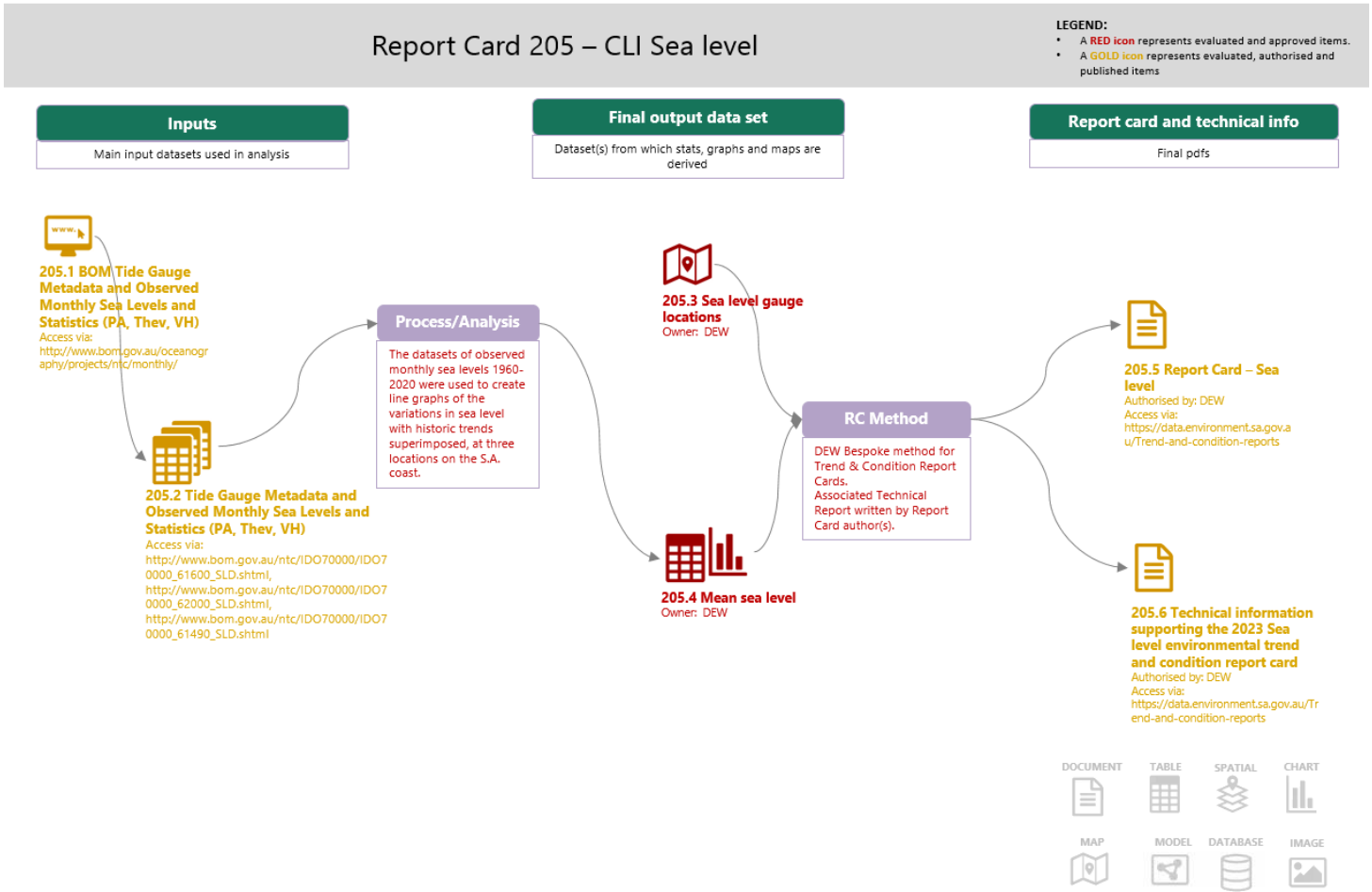
4.1 Trend

The sea level trend at all observation gauges on the South Australian coast has been rising between 1965 and 2022. A trend of observed, sustained rise in sea levels is classified as 'getting worse' according to the trend class definitions applied in the report cards (Table 2.2). 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.

4.2 Condition

The condition of sea level on the South Australian coast is considered to be 'fair' overall for this assessment. There have been moderate changes to sea levels compared to historic baseline levels. The observed rise in sea level results in a moderate increase to the risks of flooding and inundation of coastal assets and infrastructure in some locations, generally only at times of particular stress, such as during exceptionally high tides or storms, or a combination of the two. However, current sea levels are not problematic for most coastal locations for the majority of the time.

5 Appendix A: Managing environmental knowledge chart for Sea level



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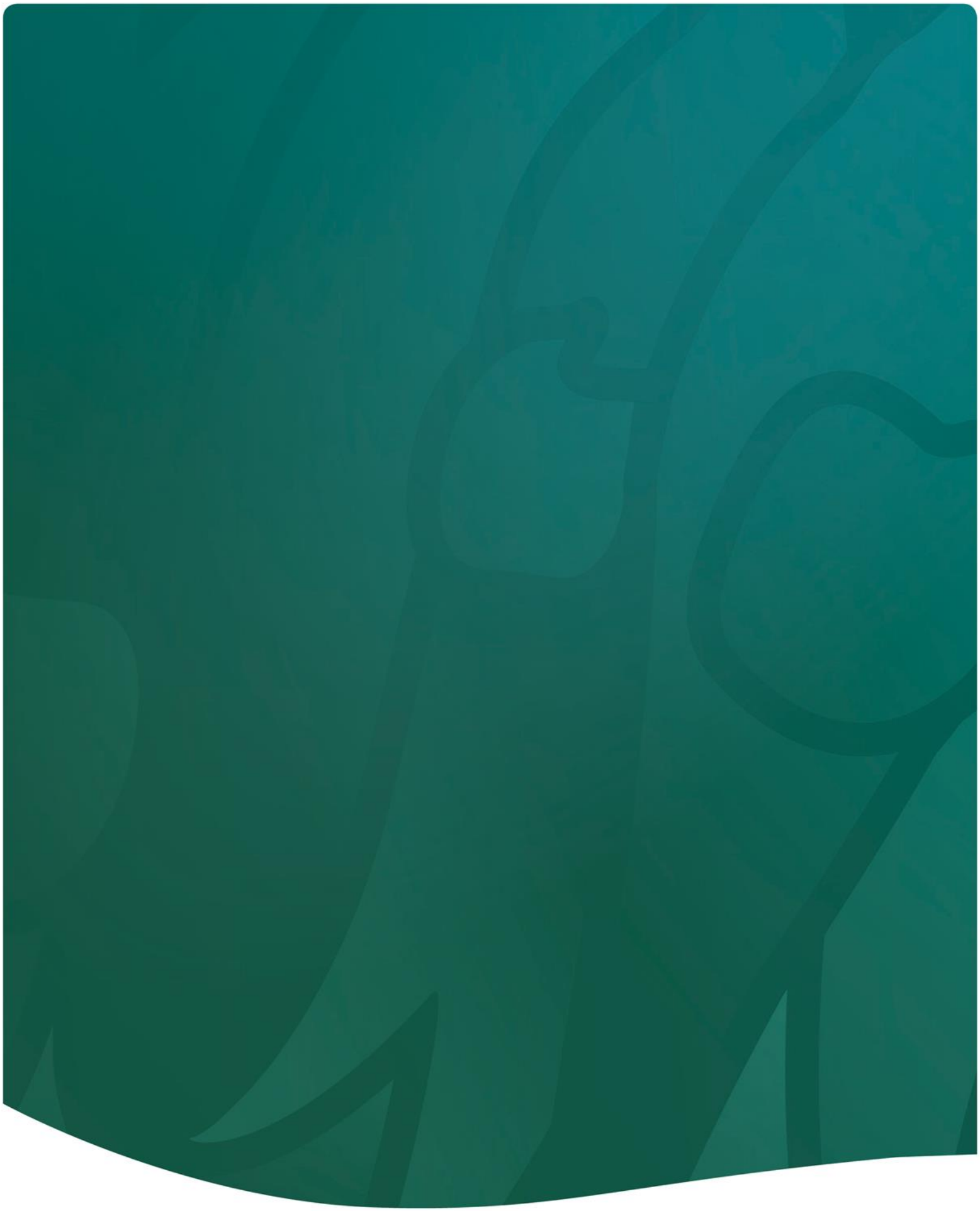

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