Coastal Adaptation Study
for Alexandrina Council

MURRAY ESTUARY SETTLEMENTS

Cell SF 1-2

By Integrated Coasts: Western, Hesp, and Bourman (2019)

Report to be cited as: Western, M, Bourman, R., Hesp, P (2019) Coastal Adaptation Study for Alexandrina Council (Cell SF 1-2 Murray Estuary) prepared by Integrated Coasts, South Australia.

TABLE OF CONTENTS

Cover photograph: SA Coast Protection Board, 2008

Integrated Coasts

markwestern@integratedcoasts.com
www.integratedcoasts.com
1300 767 333 (free call)

Introduction

This document is a partial output for the Coastal Adaptation Study for Alexandrina Council (Murray Estuary Cells SF1 and SF2). This document also represents an output from the coastal adaptation assessment tool designed by Integrated Coast.

This document should be read in conjunction with the main report, *Coastal Adaptation Strategy for Alexandrina,* that explains more fully the underpinning methodology. Definition of terms within this work are adopted from www.coastadapt.com.au (Glossary).

ASSESSMENT FRAMEWORK

This coastal assessment tool adopts a simple and intuitive framework. Coastal hazards experienced along a section of a coastline can be categorised and assessed in three main ways:

- **Coastal Fabric (geology)**

Intuitively we understand that if we are standing on an elevated coastline of granite that the coast is not easily erodible. Conversely, we understand if we are standing on a low sandy dune that erosion may indeed be a factor. It is the geology of the coast upon which our settlements are situated that determines one side of the hazard assessment in terms of elevation (height above sea level), and the nature of the fabric of the coasts (how resistant it is to erosion). This assessment tool categorises coastal geology in four main ways:

(1) Very resistant
(2) Moderately resistant
(3) Moderately erodible
(4) Highly erodible

- **Coastal modifiers (human intervention)**

In some locations there are additional factors that modify this core relationship between fabric and exposure. For example, an extensive rock revetment has been installed from Brighton to Glenelg along the Adelaide coastline. This installation has modified the fabric of the coast from dunes to rock and the erodibility rating from 'very erodible' to 'moderately resistant'.

- **Coastal exposure (eg actions of the sea)**

If we find ourselves on the shore of a protected bay, or in the upper reaches of a gulf, we intuitively know that the impact from the ocean is likely to be limited. On the other hand, if we are standing on a beach on the Southern Ocean and listening to the roar of the waves, we understand that we are far more exposed. This assessment tool categorises coastal exposure in four main ways:

(1) Very sheltered
(2) Moderately sheltered
(3) Moderately exposed
(4) Very exposed

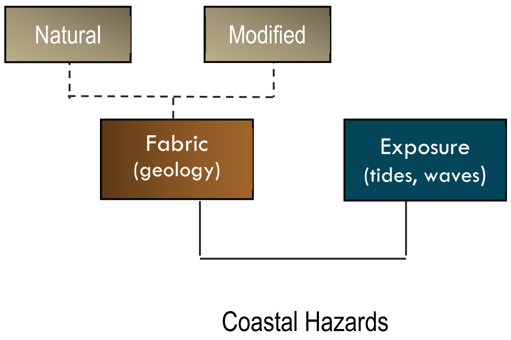
CHANGES IN THE RELATIONSHIP

Finally, in a coastal adaptation study, we are also interested to know how this relationship between ***fabric*** and ***exposure*** may change over time, and what this may mean in the context of our coastal settlements.

Our sea levels have been quite stable for several thousand years. However, in recent times, the rate of sea level rise has escalated. Last century, sea levels rose at ~2-3mm per year. In this century, seas are rising on average at ~5mm per year in our region. The general consensus of the scientific community is that the rate of sea level rise will continue to escalate towards the end of this century (~10-15mm per year). These projections are based on sound physics, but the exact rate is uncertain.

What is certain is that if seas rise as projected then the relationship between fabric and exposure will change significantly in some coastal locations.

Figure 1: Conceptual assessment framework



What we aim to do in this project is to evaluate the relationship between the ***fabric*** of the coastline and its current ***exposure*** to actions of the sea and how this relationship may change over time. We conduct this evaluation within the coastal cells as depicted within Nature Maps (Department of Environment and Water). In this study we review Mundoo and Goolwa Channel settlements within Cell SF1 and SF2.

Introduction

STUDY FOCUS

The River Murray Estuary is a complex series of waterways comprising Lake Alexandrina, Lake Albert, the Murray Mouth, Coorong Lagoon and the coastal barrier systems of Younghusband and Sir Richard Peninsulas. The Murray Estuary is regarded as part of the coast because of its intimate relationship with the sea. The main river channel (Goolwa Channel) flows around Hindmarsh Island, through the Goolwa barrage, and flows south-east to the sea[1]. More direct flows to the Murray Mouth are possible through Mundoo barrage, Mundoo Channel, and around Bird Island.

In the context of this expansive and constantly changing system, the focus of this study is to evaluate the human settlement within Mundoo and Goolwa Channels.

The purpose of this study is not to analyse and make projections about what may happen to this estuarine environment. After the Murray Mouth threatened to close in 1981, the first time since 1839, much scientific research has been applied to the Murray Darling Basin region[2].

In recent times the lower lakes (Lake Alexandrina and Lake Albert) have been the subject of much debate in the context of how to manage the Murray Darling Basin. The purpose of this study is not to analyse these matters apart from how various proposals may impact the settlements within Mundoo and Goolwa Channels.

Figure 2: Coast Protection Board, aerial obliques, 2008

[1] Coastal Landscapes p. 109,110,115

[2] Coastal Landscapes, p. 133

Introduction

STUDY ASSUMPTIONS

Some necessary assumptions are required for the purposes of this study and these are listed below.

Assumption: the barrage system continues to operate in accordance with its design purposes.

Whether the barrage system continues to operate under its current parameters to keep seawater out of the lower lakes or is altered to allow seawater into the lower lakes, is likely to have an impact on the human settlements situated within the two channels. Currently there are two main views:

1. Barrages to be opened to allow seawater into the lower lakes[3]

This proposal normally includes the installation of another lock at Wellington to keep freshwater at higher levels at a point further up the river and opening the barrages to allow the lower lakes to become estuarine. The existing barrages would be adapted so that they could operate to keep seawater at higher levels within the lake system. The proposal envisages that periodically the barrages would be opened to allow seawater to flush back to the Murray Mouth in high enough volumes to keep the mouth open without the need for dredging.

[3] Senate Committee of NSW Government which included a review of 'A better way for the Murray Darling Basin', by Ken Jury from Goolwa[3]. The website www.lakesneedwater.org also contains a comprehensive set of articles in support for this proposal.

The Mundoo barrage receives special focus in the proposal because of its proximity to the Murray Mouth. The removal of Bird Island, which came into being after the construction of the barrages, is proposed to increase water flow through the Murray Mouth. The proposal states that 'simple management strategies' of the barrages would ensure that 'marinas should not be affected to where it would be detrimental' (p. 11).

2. Barrages continue to operate to keep seawater out of the lower lakes.

The current position of the Federal Government is best reviewed in *Fact Sheet – All about the barrages.*[4] The Government view is that the lower lakes were predominantly fresh prior to European settlement and that allowing saltwater into these lakes would have significant ecological impacts. The assumption in this study is that the barrages will continue to operate to keep seawater out of the lower lakes.

If the first view was implemented the following likely impacts upon human settlements should be considered:

- Removal of Bird Island and increase 'flushing' through the Mundoo barrage is likely to increase erosion of Mundoo settlement.
- 'Flushing' could increase the likelihood of flooding of Mundoo settlement, especially if it was mis-timed or coincided with a storm event accompanied by increasing sea levels.
- Increased erosion and flooding within Goolwa Channel may be less of a concern in which water flow takes a more direct path to the sea.

The owners of 87 Mundoo Channel Drive informed this writer that within the last few years the Mundoo barrage was opened to allow flows through to the Murray Mouth and 'within a short period of time, water was flooding up to their backdoor'.

Assumption: The Murray Mouth will remain open.

The impact of sea level rise upon the Coorong coastline was evaluated by Short and Cowell in 2009 for South Australian Department of Environment and Heritage. The study found that the narrowest section of barrier is along the Sir Richard Peninsula, and even at the maximum rate of shoreline recession (using 1.5m sea level rise) the barrier would remain at least 100 m wide and not be breached by 2109[5].

In relation to the volume of sea water flows through the Murray Mouth, one view is that flows are likely to increase with sea level rise[6]. However, in the context of the high-energy dissipative beach system that composes Encounter Bay, sea level rise may increase sand levels at the Murray Mouth to such a degree that it closes over[7]. For the purposes of this study, it is assumed that the mouth will remain open and the current layout of internal channels is similar.

[4] www.mdba.gov.au/sites/default/files/pubs/FS_barrages.pdf
[5] Short A, Cowell, P 2009, Coorong Sea Level Rise Vulnerability
[6] Ken Jury, A better way for the Murray Darling Basin
[7] Dr P Hesp, Flinders University

Introduction

STUDY ASSUMPTIONS (CONT)

Assumption: Freshwater flows do not create a confluence of seawater and fresh-water flooding which produces flooding above current risk levels

While recognising the connection of this assumption to the first two assumptions, it is noted that the highest level of seawater experienced at Mundoo and Goolwa barrages occurred in 1953. These flood levels were higher than the 1956 freshwater flood, the effect of which is depicted within the Alexandrina Development Plan (Figure 3). In the context of greater use of freshwater upstream, and in the context of high-level monitoring and controls by various stakeholders, it is deemed unlikely that an increase of freshwater would eventuate and place settlements at increased risk.

Assumption: Tidal characteristics remain similar to those of the last ten years

Seawater flows into Mundoo Channel are dependent on the width and depth of two apertures (Figure 4). Variation to the width and depth of these alters the volume of water into Mundoo Channel which produces differing tidal regimes. For example, lower flows were experienced in 2015 and 2019 (Figure 5). A comparison of the last five years with flows 2010-2014 show flows were generally higher than the previous five years.

Tidal flows into Goolwa Channel tend to be more uniform where flow of water is more directly connected to the sea.

Figure 4: Coast Protection Board, aerial obliques, 2008

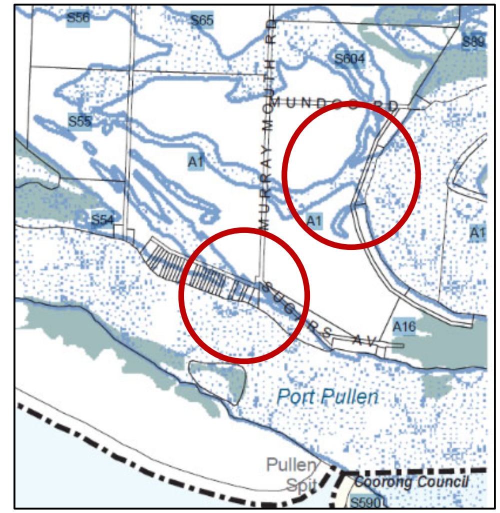


Figure 3: Alexandrina Development Plan, Map 25,

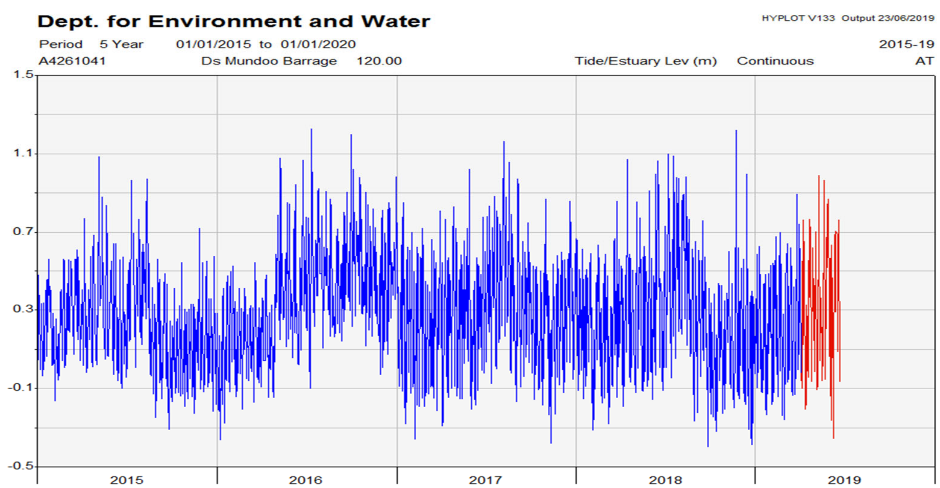


Figure 5: Tidal record 2015 to 2019 from Mundoo Barrage: years 2015 and 2019 have lower tidal flows than the interim years.

A comprehensive study of the various influences on tide levels in the region is contained within report, *The Behaviour and Future of the River Murray Mouth (2002)* by *D.J. Walker*.

1. SETTLEMENT HISTORY

A historical review ensures that the circumstances in which the settlement was founded are understood and key documents and events are identified and reviewed. In this section we:

- Give a brief history of the settlement
- Review archives at Coastal Management Branch
- Identify key studies and plans
- Identify any key storm events (if known).

1. Settlement history

The purpose of this section is three-fold:

- To identify the circumstances of settlement and expansion,
- To report on the archival search at Coastal Management Branch,
- To identify any historical incidents of flooding and erosion.

BRIEF HISTORY

Prior to European settlement the Goolwa region was inhabited by the Ngarrindjeri people. The word 'Goolwa' is a derivative of an aboriginal word meaning, 'elbow'[8].

1840s – 1890s

Goolwa came into being to facilitate transport and trade along the Murray River. However, the mouth of the Murray River was completely unsuitable for navigation and other seaports were utilised nearby, briefly at Port Elliot, and then at Victor Harbor. By 1890 superior rail transport infrastructure had superseded river transport and Goolwa's importance as a transport and trade centre diminished[9].

Farming on Hindmarsh Island began in the 1840s. Mundoo Island Station was established in 1843 with an 'annual occupation licence' issued by the Government.

1914 - 1918

In 1914, the Government's Engineer in Chief recommended a temporary barrage at Mundoo Channel because of its proximity to the Murray Mouth. Work began on the project in 1914. The barrage was severely damaged in a storm on 1st March 1915. It was repaired and topped with 12 inches of stone, and the channel officially closed in March 1915. In 1916 freshwater flooding occurred upstream and many blamed the Mundoo barrage for increased flooding. The Government's view was that the barrage made no difference to flooding but installed automatic gates which would open in times of freshwater flooding[10].

Figures 6 (above): Idealised portrayal of the Murray Mouth circa 1850s viewed from a 'hillock' (Top). SA State Library.

Figures 7 (left): Remains of the first barrage installed in Mundoo Channel in 1914.

---

[8] https://manning.collections.slsa.sa.gov.au/pn/g/g7.htm

[9] Port Elliot and Goolwa Heritage Study, 1981

[10] http://mundooisland.com.au/mundoo-island-station/

1. Settlement history

1935 - 1960

From the period of 1935 to 1940, five barrages were constructed by the River Murray Commission to maintain freshwater in the river to assist irrigation and hold water at a higher level to improve navigation conditions. The changes to the ecology of the region due to the installation of the barrages are well-document and not the focus here[11]. During construction of the barrages, the State Government leased portions of Mundoo Island which became a thriving township for the period of construction.

Aerial photography from 1949 demonstrates that no shack settlement had occurred within Mundoo and Goolwa Channels by this time. No records were available online or from Coast Protection Board archives to inform when Mundoo Channel or Goolwa Channel was settled. A document from 1979 confirms that leasehold was granted to at least some of the shacks in 1964 (19790430). Currently construction dates of original dwellings are given by Department of Planning Transport and Infrastructure as 1960. It is therefore likely that shack settlements in Goolwa and Mundoo Channels began in the latter part of the 1950s.

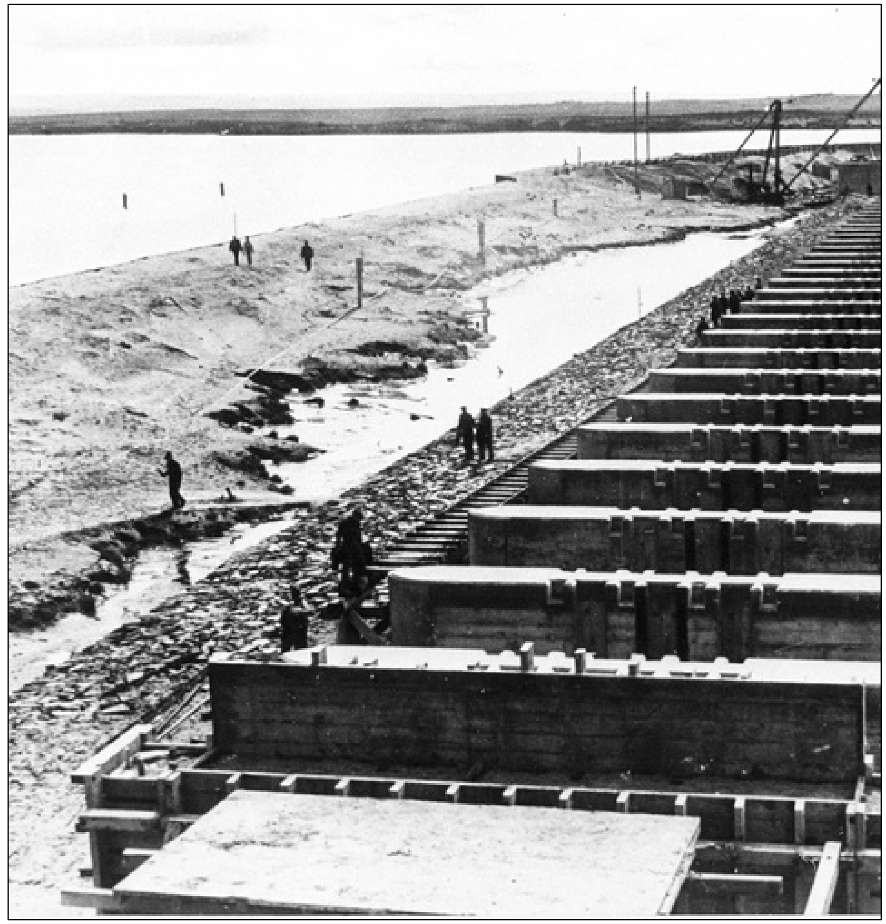


Figure 8: Goolwa Barrage under construction 1935-1940 (SA State Library)

Figure 9: Current day Mundoo barrage constructed in 1930s (Source: mundooisland.com.au)

[11] Coastal Landscapes,p.129

1. Settlement history

ARCHIVAL REVIEW

Coast Protection Board began its work in South Australia in 1972 and therefore the period under review is contained within 1972 to ~2000. This research provides a 'bridge' for coastal activities from a time period when settlements were expanding and/or were beginning to grapple with managing coastal hazards to the time when archives were filed digitally, and therefore accessible in the modern era.

1970s

In 1970s the main areas of concern were the flooding and erosion of Reserve 11 (what is now utilised as road access and carparking in the main carpark at Sugars Beach). The area was extensively filled, including an additional raising of the levels due to increased flooding (19740813, 19750131, 19750609, 19750623). In 1976, land was purchased to ensure that a public roadway 'provides unrestricted access to the adjoining area which is being acquired for the ultimate development as a tourist reserve (ie reference to the 'hillock') (19760119). The road was raised 0.3m above 'flood level' (19760119) and 'sheeted' in 1977 (19770517).

Specifically, in relation to Mundoo Channel settlement, document 19760119 refers to 'placing the Mundoo Road' and it is possible that the land for Mundoo Channel Road was purchased at this time also.

In 1978 The State Planning Authority identified the Murray Mouth as an important area worthy of protection (19790508).

1980s

Land issues around the Murray Mouth dominate the archives in the 1980s for four reasons:

- The State Government proposes a 'conservation area' for the region,
- Assessment of erosion issues,
- Assessment of 1 in 100 ARI storm tide level for development,
- The purchase of land (78 vacant allotments, and other purchases).

<u>Conservation areas:</u>

The State Government proposed a conservation area of 140,500 ha as a Wetland of International Importance under the Ramsar Convention on Wetlands in 1985. The conservation area included Sugars Beach.

This designation seems to increase concern about the human settlements and their impacts on the reserve (19790430), although Doug Fotheringham argued there was no evidence that this was occurring (19790508). There seems to be a push from Cabinet level to reclaim more of the area from housing to create a more conducive environment for the Ramsar designation.

Figure 10: Erosion occurring on Sugars Beach in 1979 (19790000)

Figure 11: Tidal lines on low-set blocks (19790000)

Key documents

Shack site purchase (1979) – conservation zone, Fotheringham and Carpenter (19790508)

Hindmarsh Island Tidal Flooding Study, 1988, Coast Protection Board (19880500).

History of Sir Richard Peninsula (1980) internal report, unknown (19800118)

1. Settlement history

ARCHIVAL REVIEW

Erosion issues

Irrespective of this issue, ongoing erosion and the potential for flooding was the impetus for further study and investigation. A key report (19790430) notes:

- A proposal from the State Government Cabinet to purchase all existing vacant allotments (78) and to purchase other sites as they became available (200k).
- It was reported that 'shack site 4' showed erosion of up to 100 metres since the time of original survey in 1885, and that 'considerable erosion had occurred since 1964 when leasehold was granted'.
- The CPB and Council improved public access to 'an area from which the Murray Mouth can be viewed'.

Report 19790508 by Fotheringham and Carpenter reviewed the various areas under threat and made recommendation as to which areas should have highest priority to purchase. The report noted that parts of the coast have eroded 40-60m between 1941 and 1981. By the time of writing this report, it was noted that 49 allotments had been purchased of the proposed 78 and that no more funds were available to purchase the remainder at that time. The report contained a plan that designated areas in accordance with priority of risk.

This report designated areas A and B within **Mundoo Channel** settlement as Level 3 priority for purchase, and elsewhere in the report noted these as 'low priority'. It is more difficult to ascertain how settlements within Goolwa Channel were prioritised and which allotments were purchased by the SA Government.

The *Hindmarsh Island Tidal Flooding Study* completed in 1988 by Coast Protection Board noted that, 'erosion is set to continue and increase with sea level rise' but also noted that containing erosion should not be seen as 'insurmountable' given the sheltered position and shallowness of water (19880500).

Tidal and storm surge analysis

The Hindmarsh Island Tidal Flooding Study utilised records from Mundoo and Goolwa barrages for statistical analysis and construction of a probability curve. The study found that there was very little difference in outcomes between the two gauges. The study also noted that allowances for freshwater flooding and the effect of wind and waves were included in the data, and so therefore taken into account in the analysis.

CPB assigned flood risk levels taking into account 0.15 of sea level rise. However, the possible coincidence of river flooding and storm tide was not taken into account, and something the report considered a 'low probability' (19870623). The highest event on record at the Mundoo barrage was 1.59m on 18 May 1953 (19870000).

Storm surge	1.55m AHD
Wave set-up	0.20m
Sea level rise	0.15m
Site level	1.90m AHD
Floor levels	2.10m AHD

Purchase of shack sites.

The decade closed with purchases of a significant number of allotments, some of which also contained dwellings (19900327). However, no sites were purchased from Mundoo Channel settlement.

Key points

Mundoo Channel was first closed with a barrage in 1915. This means that only seawater flows have impacted land formation in the Mundoo Channel for over 100 years.

The current Goolwa and Mundoo barrages were constructed in the 1930s.

No residential infrastructure existed adjacent Goolwa and Mundoo Channels to ~1950.

Shack settlements are likely to have been settled in the latter part of the 1950s.

Erosion in the Sugars Beach area was extensive from 1949 to 1988, but no record of erosion at Mundoo.

Tidal analysis showed highest recorded event at the barrage was 1.596m on 18 May 1953.

A tidal study conducted in 1988 took into account freshwater flooding and wind effects and recommended floor levels at 2.10m AHD, including and allowance for sea level rise of 0.15m.

2. GEOMORPHOLOGY

How the geology of the coast was formed and has changed over time.

2. Geomorphological context

How the geology of the coast was formed and has changed over time.

By Dr Robert Bourman
See full version in Part 1 of the report

COASTAL FORMATION

Today we live in an interglacial period, the most equitable time for human beings. The previous time in Earth history was about 125,000 years ago during what is called the Last Interglacial when locally it was warmer and wetter than at present with sea level being 2-5m higher than present.

Tectonic Movement

Relicts of the geological history of the area are preserved in places along the Alexandrina Coastline. Ancient metamorphic and granitic rocks at Middleton and Port Elliot bring stability to the shoreline at those locations. Permian glacial sediments and alluvium of the last interglacial age form the back shore of easily eroded coastlines, while offsets of limestones of various ages record the tectonic behaviour of the area. In particular, offsets of the last interglacial shoreline (125,000 years old), which originally stood at ~2m above present sea level confirm the ongoing tectonic uplift of the Mount Lofty Range and the South East Coastal Plain, with subsidence occurring in the Murray Estuary. Consequently, most of the study area is undergoing subsidence at an approximate rate of 0.02mm/yr.

Modern coastline

The modern coastline developed after sea level rose between 17,000 and 7000 years ago at a rate of ~10mm /year at the end of the Last Glacial Maximum. With sea level rise, large reserves of sand, including the last glacial maximum desert dunes on the exposed continental shelf, were carried landward, providing source material for the modern beaches and dunes. The coastline east of Middleton Creek is very dynamic, changing with variations in sea level, wind, storm waves and tidal conditions. A prominent feature of this section of coastline has been recent coastal erosion, which as been particularly marked in the softer rocks of the Middleton to Goolwa Section of the coastline.

KEY POINTS

- Land areas to the east of Watson Gap (including Cell 7) are subsiding, but at a very low rate of 0.02mm/ yr.
- The coastline from Middleton to Goolwa is very dynamic and has undergone significant erosion in times before the 1950s.

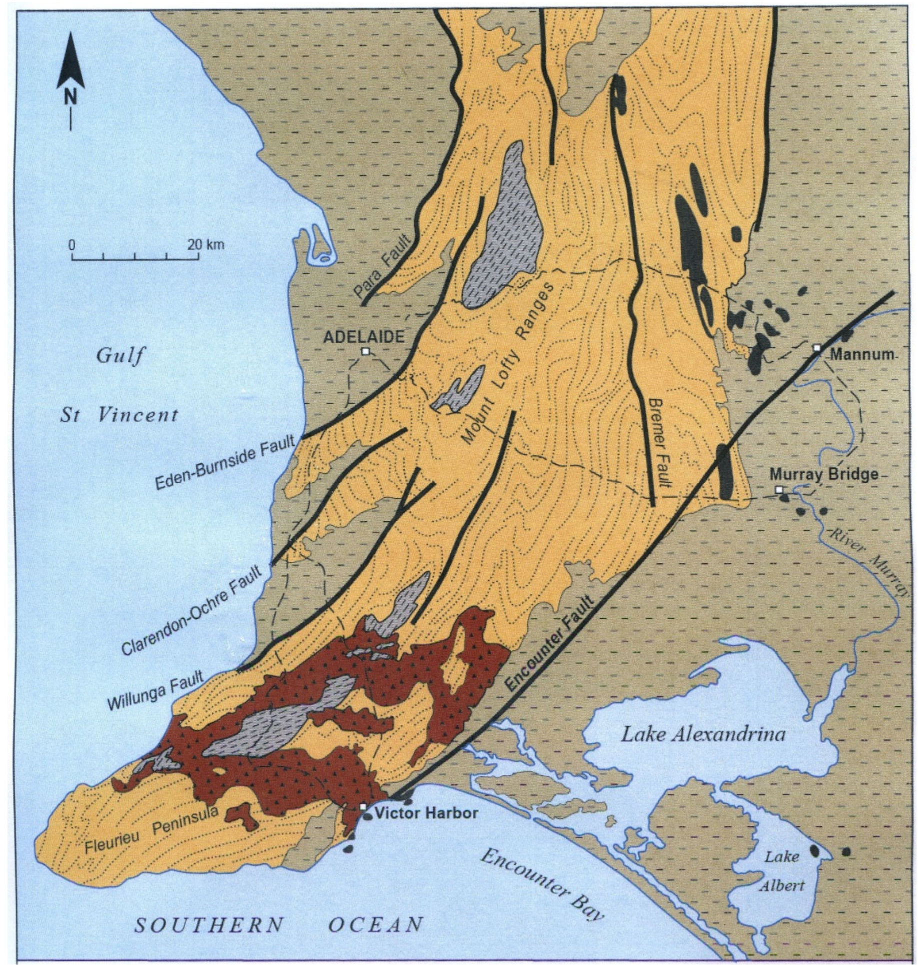


Figure 12: The location of the Encounter Fault, which runs out to sea near Watson Gap. This fault separates the uplifting Mount Lofty Ranges, on which sits the Chiton to Watson Gap coastal sector, from the subsiding Murray Basin, the setting for the remainder of the Alexandrina Coast.

2. Geomorphological context

How the geology of the coast was formed and has changed over time.

Editorial note: Pages 13 -14 rely on *Coastal Landscapes of South Australia*, Chapter 4, by Bourman, Murray-Wallace, Harvey and review by Dr Patrick Hesp.

The key focus of this section is to provide a framework to understand how Goolwa and Mundoo Channels have been formed and their current physical setting.

Physical Setting:

The Goolwa and Mundoo Channels are separated from the ocean by Sir Richard Peninsula, a long narrow coastal barrier that extends from Goolwa to the Murray Mouth. The shoreline on the other side of Sir Richard Peninsula is part of the sweeping shoreline that extends from Middleton towards the southeast and includes the longest beach in Australia (194kms).

Because unconsolidated sand dominates the shoreline, it is the processes of waves, winds and tides which dictate the morphology (or shape) of the coastline and determines the character of the beaches. Two main types of waves influence the shape of the coastline: swell waves and storm waves. Constructive, open ocean swell waves, approaching the curved coast from the southwest, have moulded the regular, curved shape of the Encounter Bay coastline.

These wave patterns on the southern part of the Encounter Bay impinge at an angle that causes longshore drift to the northwest but also cause drift to the east on the northern part of the coast. These opposed sand drift directions help to explain the general position of the Murray Mouth as well as the huge accumulation of sand towards the northern extremity of Younghusband Peninsula.

The Murray Estuary

The Murray Estuary is regarded as a part of the coast because of its intimate association with the sea. Although aided by wind-assisted ebb tides, river flows are essential for the long-term maintenance of the Murray Mouth, through which estuarine-dependent fish migrate and sediments are transported. The coastline is thus closely connected with the estuary and with the greater hinterland from which freshwater runoff is produced.

Sources: Coastal Landscapes of SA (top) and Coast Protection Board 1997 (below)

Figures 13-14: Top: The Goolwa estuary is separated from the Southern Ocean by Sir Richard Peninsula. Bottom: Sediment tends to drift east from Sir Richard Peninsula, and west from the other side of the Murray Mouth and is one of the factors that influences its position.

2. Geomorphological context

How the geology of the coast was formed and has changed over time.

Hindmarsh Island sandflat

Much of the southern half of Hindmarsh Island consists of an extensive sandflat ranging up to 2 m above present sea level. First, when the sandflat formed, relative sea level may have been up to 1 m higher than at present. Under these conditions, the Murray Mouth would have been much wider than today, even perhaps 1 to 2 km wide, so that active flood tides and wave action could transport large volumes of sand through it to construct the sandflat. The quiet water conditions landward of the developing barrier system would have favoured deposition of the sandflat. A network of natural spillways criss-crosses the Hindmarsh Island mid-Holocene sandflat as distributary channels, effectively dispersing flood waters, as was clearly demonstrated during the 1956 flood (Figure 15).

A dynamic estuarine setting

A distinctive characteristic of the Murray Estuary coast is that it is an extremely dynamic environment: the coastline is eroding, the coastal sand barriers are migrating landward, new sand islands are forming and the shorelines of the former estuarine lakes are eroding.

Since its position was first surveyed in 1839, the Murray Mouth has migrated over a range of at least 1.6 km, reflecting the impacts of river flows, tidal fluxes, wave action and storms on the unconsolidated sandy coastal sediments.

In pre-historic times, mouth migration has been even more extreme, perhaps as much as 6 km in 3000 years. Aboriginal middens only occur on the western half of Sir Richard Peninsula, suggesting that mouth migration towards the west partly destroyed the barrier, which later reformed as the mouth migrated back to the east. End points of migration are marked by abandoned flood tidal deltas at Mulloway Point on Mundoo Island and Swan Point on Hindmarsh Island. A jumbled mass of sand dunes up to 4000 years old fringes much of the south coast of Hindmarsh Island. The dunes formed from coastal sands delivered through the river mouth during mouth migrations.

Editorial note: Pages 12 -14 rely on *Coastal Landscapes of South Australia*, Chapter 4, by Bourman, Murray-Wallace, Harvey and review by Dr Patrick Hesp.

Figure 15: The southern half of Hindmarsh island is an extensive sandflat with natural spillways that were formed when the Murray Mouth was wider (Coastal Landscapes of SA)

Geomorphological context

Key points

- The area on which settlements on Goolwa and Mundoo Channels is situated is part of a large sandflat that forms the southern part of Hindmarsh Island.
- The coastal environment is extremely dynamic with eroding coastline and coastal sand barriers migrating landward (ie Sir Richard Peninsula)
- Since 1839, the Mouth of the Murray has migrated over a range of at least 1.6 km. The position of the Murray Mouth is partially determined by the longshore drift regime on the coast of the Southern Ocean.

2. Geomorphological context

MEDIUM TERM CHANGES

Map SF1-2

Goolwa and Mundoo Channels

Changes 1949 to 2018

Assessment

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

Note the location of Murray Mouth and the position Goolwa Channel.

Technical note: the metadata states that 1949 image should be within + or – 2m of actual position.

(It is very difficult to georeferenced this area with no human land markers).

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

2. Geomorphological context

MEDIUM TERM CHANGES

Map SF1-2

Goolwa and Mundoo Channels

Changes 1949 to 2014

Assessment

Comparison with 2016 aerial photograph shows that the Murray Mouth has moved westwards by ~1km. The change in location of the mouth has altered the location of the main channel which is now situated further to the north. This movement of the channel explains the rapid erosion of Sugars Beach in the 1960s and 1970s.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

2. Geomorphological context

MEDIUM TERM CHANGES

Map SF1-2

Goolwa and Mundoo Channels

Changes 1949 to 2014

Assessment

The contour map from 2016 has been superimposed over the 1949 image.

The western side of Sugars Beach area has eroded by up to 60m. The eastern side of Sugars Beach has accreted. The land area appears to have translated eastwards as the channel moved westwards and altered the location of the main channel.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

2. Geomorphological context

MEDIUM TERM CHANGES

Map SF1

Goolwa and Mundoo Channels

Changes 1949 to 2014

Assessment

The contour map from 2016 has been superimposed over the 1949 image.

The western side of Sugars Beach area has eroded by up to 60m. The eastern side of Sugars Beach has accreted. The land area appears to have translated eastwards as the channel moved westwards and altered the location of the main channel.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

MUNDOO CHANNEL

3. COASTAL FABRIC

The nature of the coastal fabric is a combination of natural geology and human intervention (where applicable).

In this section we evaluate coastal fabric in more detail:

- Overview of the current coastal fabric
- Changes to shoreline over seventy years
- Human intervention (coastal modifiers)

3. Coastal Fabric - natural

Overview

Map: SF1 and SF2

Secondary Cell: Coorong

Tertiary Cell: SF1 and SF2

Minor cell: Mundoo Channel

Form

Beach

No beach – river estuary

Backshores

Sand flat, predominantly at elevations less than 2m AHD.

Bathymetry

Not applicable

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com
1300 767 333 (free call)

3. Coastal Fabric - natural

Overview

Map: SF1 and SF2
Secondary Cell: Coorong
Tertiary Cell: SF1 and SF2
Minor cell: Mundoo Channel
Geology

Geology

Predominantly semaphore sand from Holocene period.

Some areas underpinned by undifferentiated quaternary rocks
Age: Pleistocene – Holocene

3. Coastal fabric - natural

How the geology (fabric) of the coast has changed over time.

MEDIUM TERM CHANGES

Map SF1 and SF2
Mundoo Channel
Changes 1949 to 2018
Event: 1949

Assessment

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

The dotted line represents the best indication of current shoreline position.

Informal interview with the owner of Number 99 Mundoo Channel Road stated then when he first moved into the area in the 1960s, Mundoo Channel had a sandy beach. The photograph from 1949 tends to support this recollection.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

MEDIUM TERM CHANGES

Map SF1and SF2
Mundoo Channel

Changes 1949 to 2018

Event: 2009

Assessment

Aerial Photograph from 1949 provides the basis for comparison of change over the last seventy years.

The north-western portion of the shoreline appears to have undergone very little change.

The southern portion of the residential section appears to have accreted. This appearance may be accretion, or it may that residents have pushed their land holdings seaward (see inset photograph)

The south-eastern portion appears to have eroded by 15m.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

MEDIUM TERM CHANGES

Map SF1 and SF2
Mundoo Channel

Changes 1949 to 2018

Event: 2018

Assessment

All sections of the shoreline appear in the same location as 2009.

The southern portion of the residential section appears to have accreted since 1949. This appearance may be accretion, or it may that residents have pushed their land holdings seaward (see inset photograph)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

MEDIUM TERM CHANGES

Map SF1 and SF2 Mundoo Channel

Historical comparison

Event: 1949

Assessment

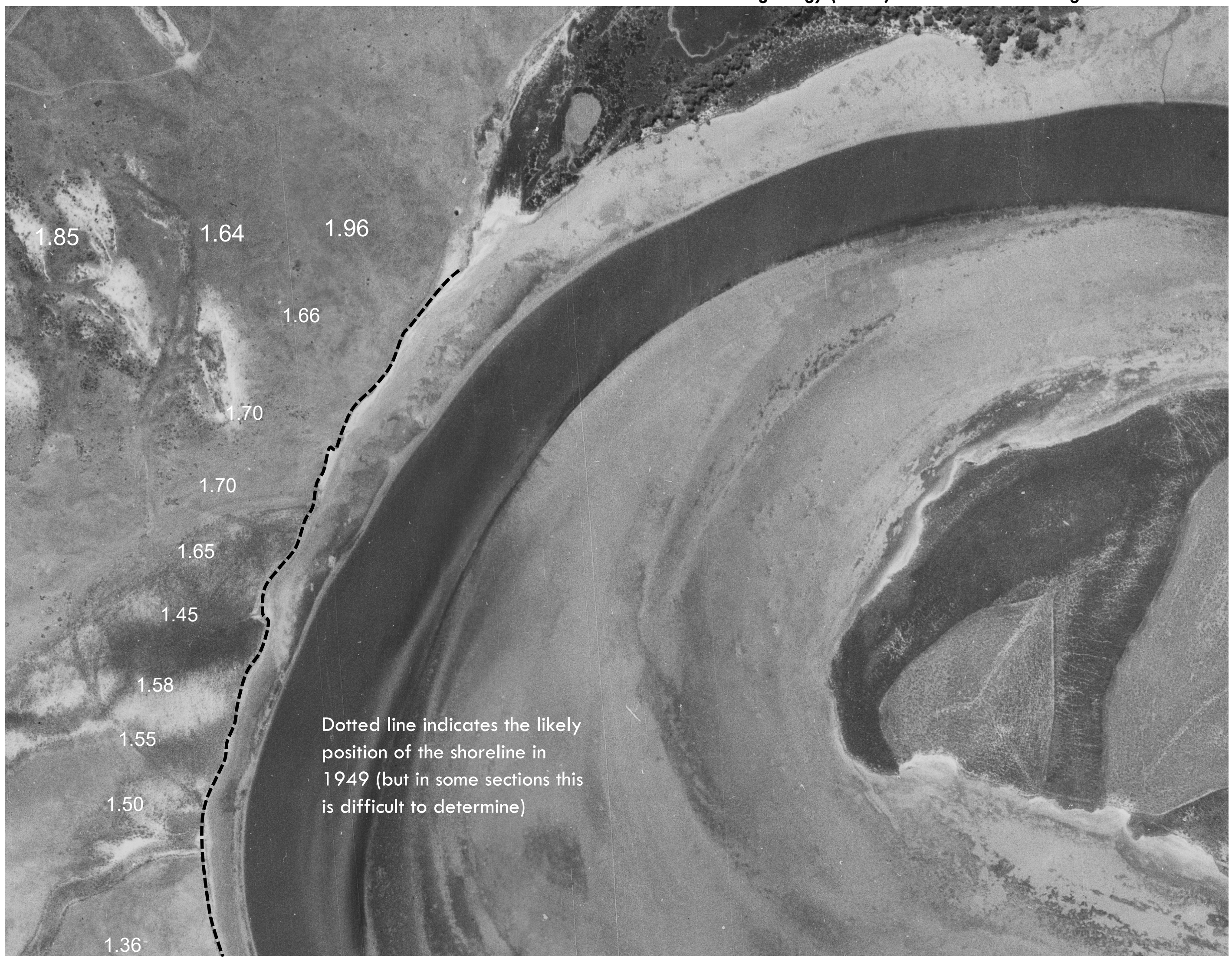
Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

The dotted line represents the best indication of current shoreline position.

Informal interview with the owner of Number 99 Mundoo Channel Road stated then when he first moved into the area in the 1960s, Mundoo Channel had a sandy beach. The photograph from 1949 tends to support this recollection.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

How the geology (fabric) of the coast has changed over time.



3. Coastal fabric - natural

MEDIUM TERM CHANGES

Map SF1 and SF2
Mundoo Channel

Historical comparison

Event: 1949 - 2009

Assessment

Aerial Photograph from 1949 provides the basis for comparison of change over the last seventy years.

Areas within the flood plain (likely remaining from 1953 sea flooding, and 1956 freshwater flooding) have eroded the most (~15-20m).

Other areas near the boat ramp appear to have eroded 5-10m.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

MEDIUM TERM CHANGES

Map SF1 and SF2
Mundoo Channel

Historical comparison

Event: 1949 - 2018

Assessment

All sections of the coast appear in the same location as 2009.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4. Coastal modifiers – human intervention

MACRO MODIFICATION – THE BARRAGES

The dynamic system described above was transformed by barrage construction of the 1930s, which reduced the tidal flow through the mouth by up to 90%. Increasing amounts of fresh water (75%) were diverted from the river, further aggravating the situation, so that by the mid-1950s lobes of the flood tidal delta were becoming more permanent, allowing colonisation by vegetation.

Surrounded by bare sand, a circular dune initially formed around a small patch of vegetation, which became the core of Bird Island. Wing-like dunes attached to the central dune developed, and their migration was blocked by samphire (salt marsh) vegetation, which colonised the northern half of the island.

A combination of salt marsh expansion and sand supply sourced from bare flood tidal shoals, delivered through the mouth, led to the progressive growth of sand dunes at the salt marsh margins.

Since the early 1970s, the mouth has migrated towards the northwest, changing the position of the bare, tidally derived sandflats, the source of dune sand. Consequently, successive dunes, now fixed in place by vegetation, display a varying clockwise orientation, coincident with the migration of the mouth and the growth of salt marsh. Bird Island (pictured) did not exist prior to the installation of the barrages and demonstrates the dynamic nature of the region in which Sugars Beach is located.

There is no evidence that the Murray Mouth had permanently closed since initial survey, but in 1981 reduced flow closed the mouth for the first time.

After artificial opening of the mouth in 1981, major mouth migration was towards the west, but this trend was reversed following clearance by dredging when the mouth began migrating back towards the east in about 2005. This trend continues.

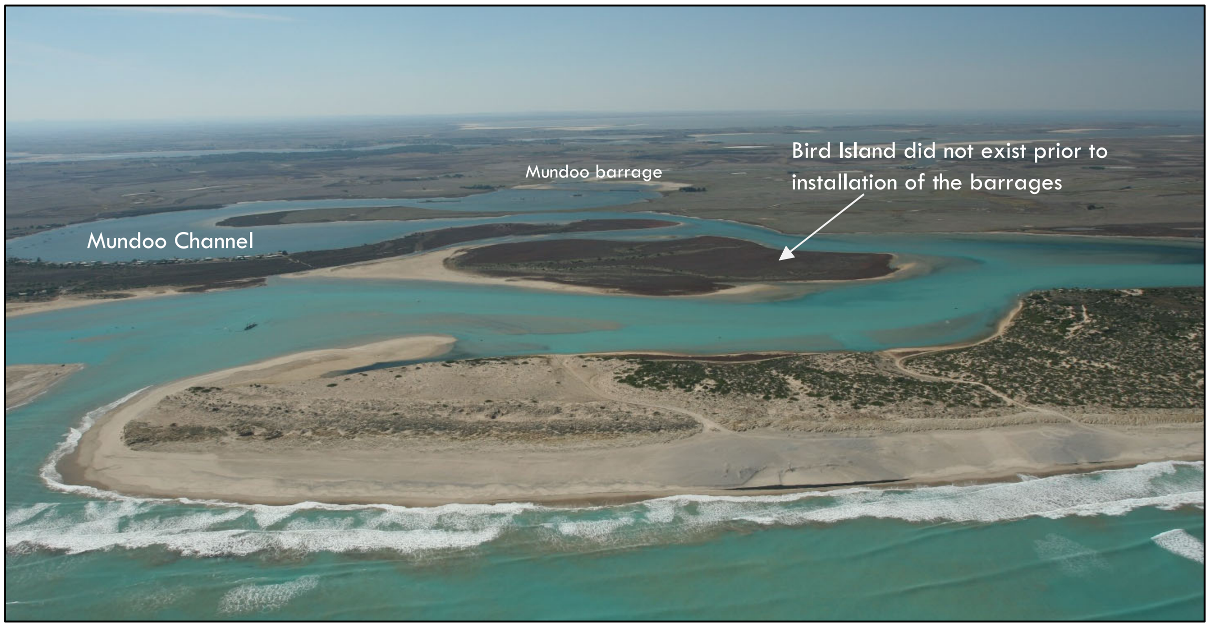
Figure 16: Installation of the barrages reduced the flow of water to the Murray Mouth. The Murray Mouth migrated west in response, sand flats and islands have developed in the flood tidal delta. (Source: Coast Protection Board, 2008)

Macro modification

One major outcome from the installation of the barrages was the vastly reduced flow of water to the Murray Mouth due to upstream extractions.

This altered flow regime shifted the Murray Mouth west and changed the nature of the flood tidal area at the mouth. Bird Island formed due to limited outflows from Mundoo Channel.

Only seawater flows have impacted the formation of land in the Mundoo region for over 100 years.



4. Coastal modifiers - human intervention

URBAN SETTLEMENTS

Urban settlements and associated infrastructure such as roads and services modify the natural terrain by implementing hard surfaces and structures that act as 'hold points' in places that may be subject to erosion both now, or in the future.

Zoning: Mundoo Settlement is zoned **Coastal Settlement** (Zone Map Alex 25). The Principles of Development Control for the Coastal Settlement zone ensure that no increases of density are possible. Further subdivision of land (including leasehold boundaries) is non-complying, and construction of dwellings is limited to replacing existing dwellings at no more than one per existing allotment (leasehold or freehold). See Alexandrina Council Development Plan (130-134).

Surrounding areas are zoned **Conservation** which form part of the Ramsar Wetlands and Key Habitat Area (Overlay Map Alex 25). The Principles of Development Control for the Conservation zone ensure that very limited development can take place within this zone. See Alexandrina Council Development Plan (135-141)

Policy Area: Nil

Referrals

Under current Development Act and Regulations procedures, Development Applications are required to be referred to Coast Protection Board. (Note: it is not known what future referral criteria will exist for referrals under the new planning system.)

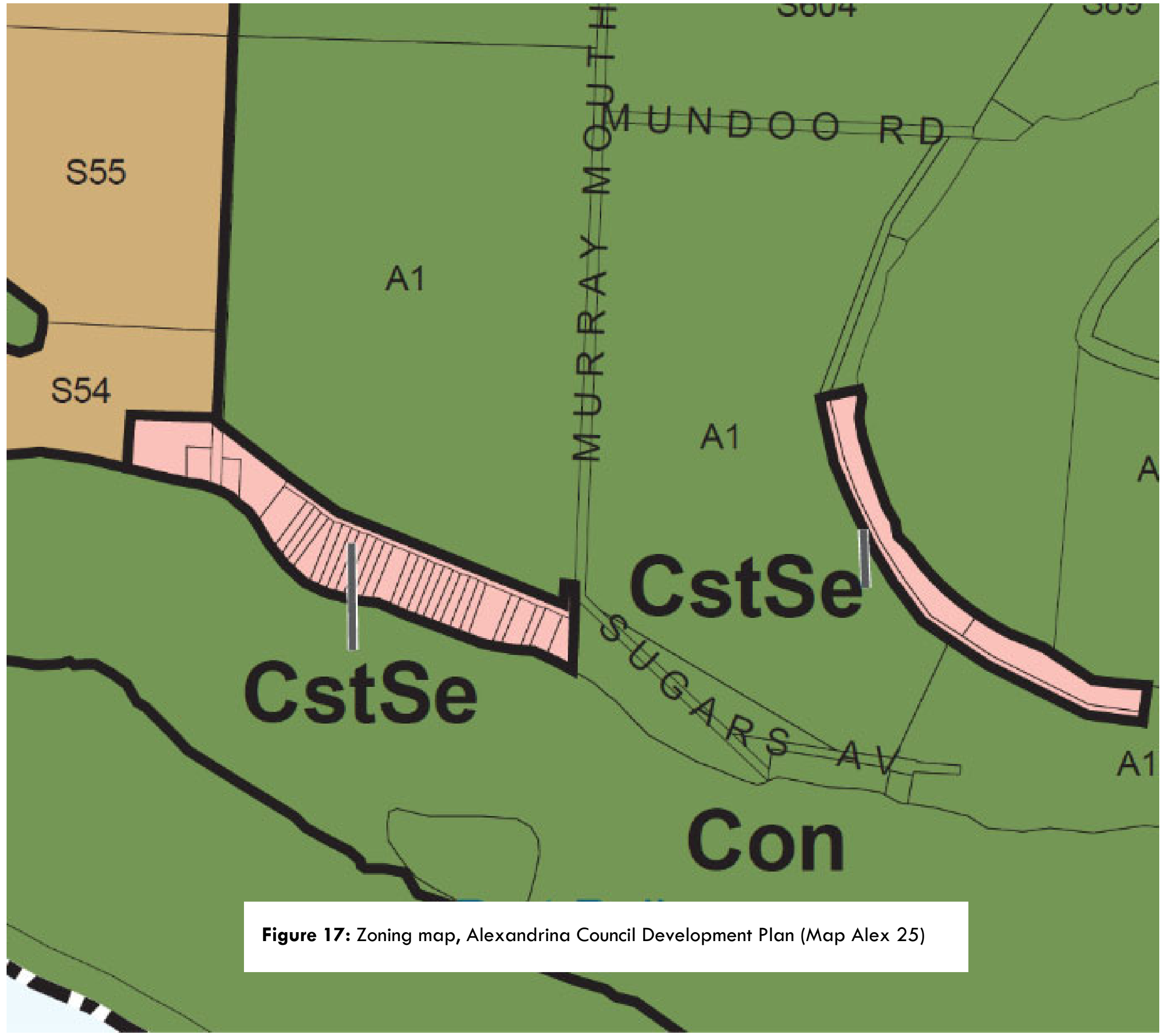


Figure 17: Zoning map, Alexandrina Council Development Plan (Map Alex 25)

4. Coastal modifiers - human intervention

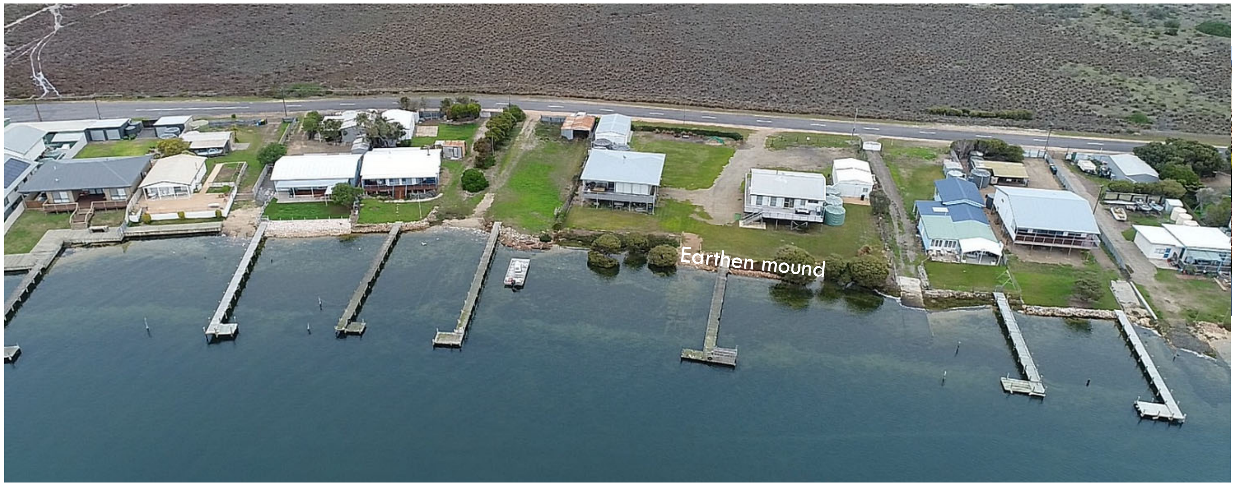
MICRO MODIFICATION – PROTECTION

No formal protection works have been installed by local or state Governments in the Mundoo Channel area.

Private protection works are varied in type and include:

- Rock (of varying types)
- Building rubble (bricks etc)
- Earthen mounds
- Wooden retaining walls
- Nil protection

Approximately 19 private boat ramps exist in the residential section of Mundoo Channel. However, many of these may be unused or declined in quality so that they are now unusable. The construction of the boat ramp facilities in the middle of the settlement may have encouraged boat owners to utilise better facilities than available on their own land.



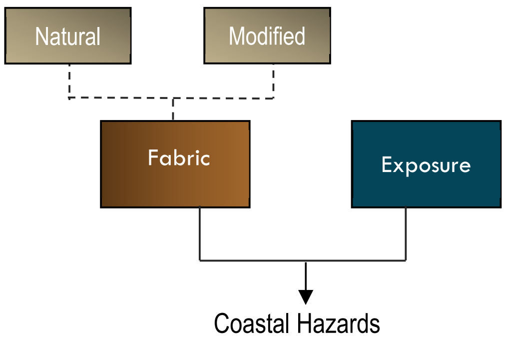
Figures 18-22 : Examples of protection works utilised at Mundoo Channel settlement (Source: Integrated Coasts, 2019)

COASTAL FABRIC

Summary and conclusions

Progress report:

So far, we have completed a review of settlement history and an assessment of the 'geology' or 'fabric' of the cell.



Summary:

Geological layout:

Much of the southern half of Hindmarsh Island consists of an extensive sandflat ranging up to 2 m above present sea level. The geological description is, St Kilda Formation: calcareous, fossiliferous sand and mud of intertidal sand flats, beaches and tidal marshes. Mundoo Channel settlement is positioned on the southernmost portion of this sandflat.

Human intervention

Macro intervention: The barrages installed in the 1930s have reduced flows to the Mouth by up to 90% and permanently changed the ecology. The Murray Mouth migrated west, dunes formed, and vegetation was established.

The Mundoo barrage installed in 1914 means that for over 100 years only seawater flows have had an impact on the land formations around Mundoo settlement.

Micro interventions: No formal protection has been installed by local or State Governments. Individual landowners have installed protection of varying types and quality. Some landowners in the southern portion of the settlement appear to have advanced their landholding into the sea.

Analysis

Comparative photographic analysis demonstrated that the human settlement portions of the shoreline have remained stable. Some landowners in the southern portion of the settlement are likely to have advanced their land holdings seaward.

The shoreline between the boat ramp and the northern portion of the settlement appears to have eroded 10-20m (generally).

The shoreline south of human settlement appears to have eroded 15m.

One explanation for less erosion within human settlement is the interventions that humans make to 'hold the line'.

Erodibility rating: Highly erodible (4)

Mundoo Channel

5. CURRENT EXPOSURE

Evaluating how actions of sea currently impact the coastal fabric by:

- Applying current 1 in 100 sea-flood risk scenario
- Analysing routine high water events (annual).

Two main contexts are evaluated:

- Access and Egress (macro view)
- Impacts to assets (private and public)

5. Current exposure – storm surge

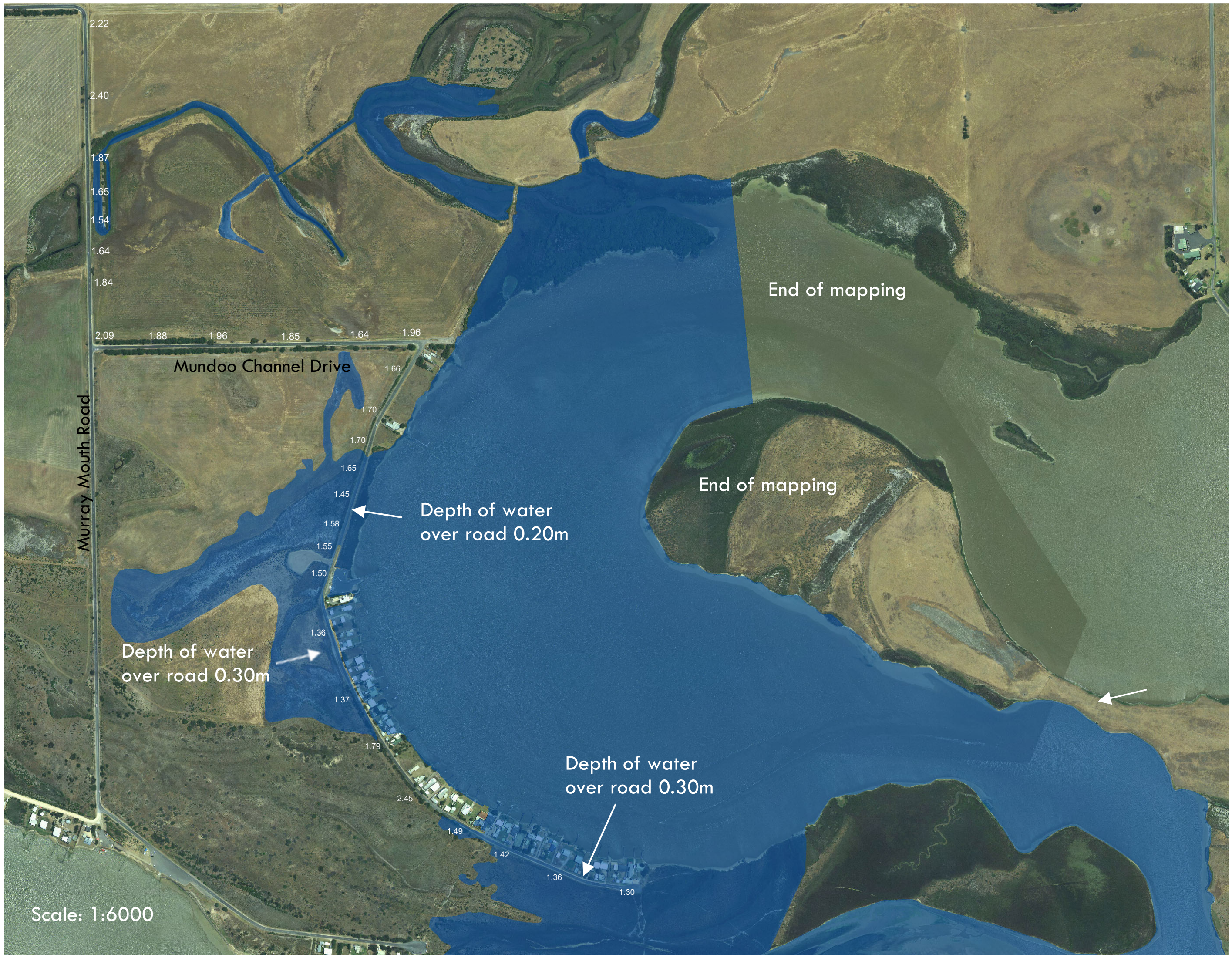
Storm Surge

Cell SF1 and SF2

Mundoo Channel

Current risk:

1 in 100-year event risk



Assessment

Access and Egress

The highest level on record at the Mundoo Barrage occurred on 18 May 1953 at a height of 1.596m AHD.

Coast Protection Board has adopted 1.55m AHD for its current 1 in 100 ARI risk level and 0.20m wave setup.

The modelling indicates that minor flooding would occur over Mundoo Channel Road at depths 0.20m to 0.30m. This may prevent some emergency service vehicles (ambulances) from reach all sections of the settlement.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Current exposure – annual high water

Annual high water

Cell SF1 and SF2

Mundoo Channel

Current risk:

Annual high water

Assessment

Access and Egress

Using data from Mundoo boat ramp gauge and from Mundoo barrage over the last five years, on average the highest annual tidal event is 1.15m AHD.

By way of contrast, the CPB 1 in 10 year event is assigned as 1.35m AHD (see Hindmarsh Island Tidal Study, 1988).

The current annual tidal event does not impact access and egress issues for the settlement.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

5. Current exposure – storm surge

Storm surge

Cell SF1 and SF2

Mundoo Channel

Current risk:

1 in 100-year event risk

Assessment

Flooding of private property

The current 1 in 100-year ARI event risk set by Coast Protection Board for Mundoo Channel is:

Storm surge 1.55m AHD

Wave setup 0.20

Total risk 1.75m AHD

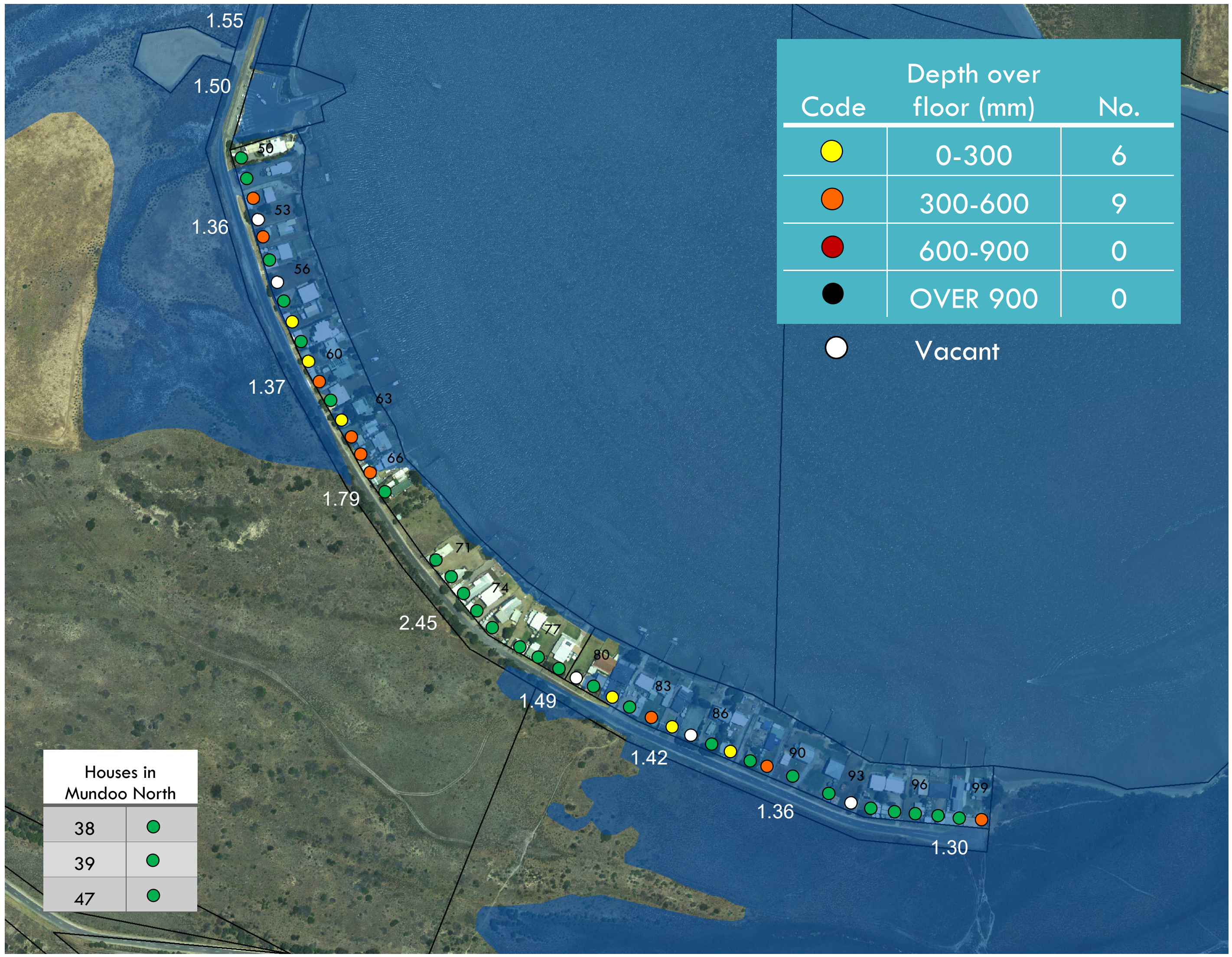
If this event occurred:

- 6 houses would have water up to 300mm over floor level
- 9 houses would have water lever between 300mm and 600mm.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com



5. Current exposure – erosion

Erosion

Cell SF1 and SF2

Mundoo Channel

Current risk:

Erosion

Assessment

Prevailing winds that accompany storm surge conditions blow from the West to the South, and therefore blow offshore from Mundoo settlement.

However, anecdotes from owner of 87 Mundoo Channel Drive (and one other resident) informed this writer that stronger east winds are capable of raising water levels quite quickly so that they impact the rear of properties.

Very little evidence exists for erosion within the settlement.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Current exposure – erosion

Erosion

Cell SF1 and SF2

Mundoo Channel

Current risk:

Erosion

Assessment

Prevailing winds that accompany storm surge conditions blow from the West to the South, and therefore blow offshore from Mundoo settlement.

However, anecdotes from owner of 87 Mundoo Channel Drive (and one other resident) informed this writer that stronger east winds are capable of raising water levels quite quickly so that they impact the rear of properties.

Erosion has occurred between the boat ramp and houses to the north between 1949 and 2009.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

Mundoo Channel

6. FUTURE EXPOSURE

Evaluating how future actions of sea may impact the coastal fabric by:

- Reviewing 1 in 100 scenarios for 2050 and 2100
- Reviewing annual high tide scenarios for 2050 and 2100
- Analysing erosion risk to 2100

Two main contexts are evaluated:

- Access and Egress (macro view)
- Impacts to assets (private and public)

6. Future exposure – storm surge (2050)

Storm surge

Cell SF1 and SF2

Mundoo Channel

2050 risk:

1 in 100-year event risk

Assessment

Access and Egress

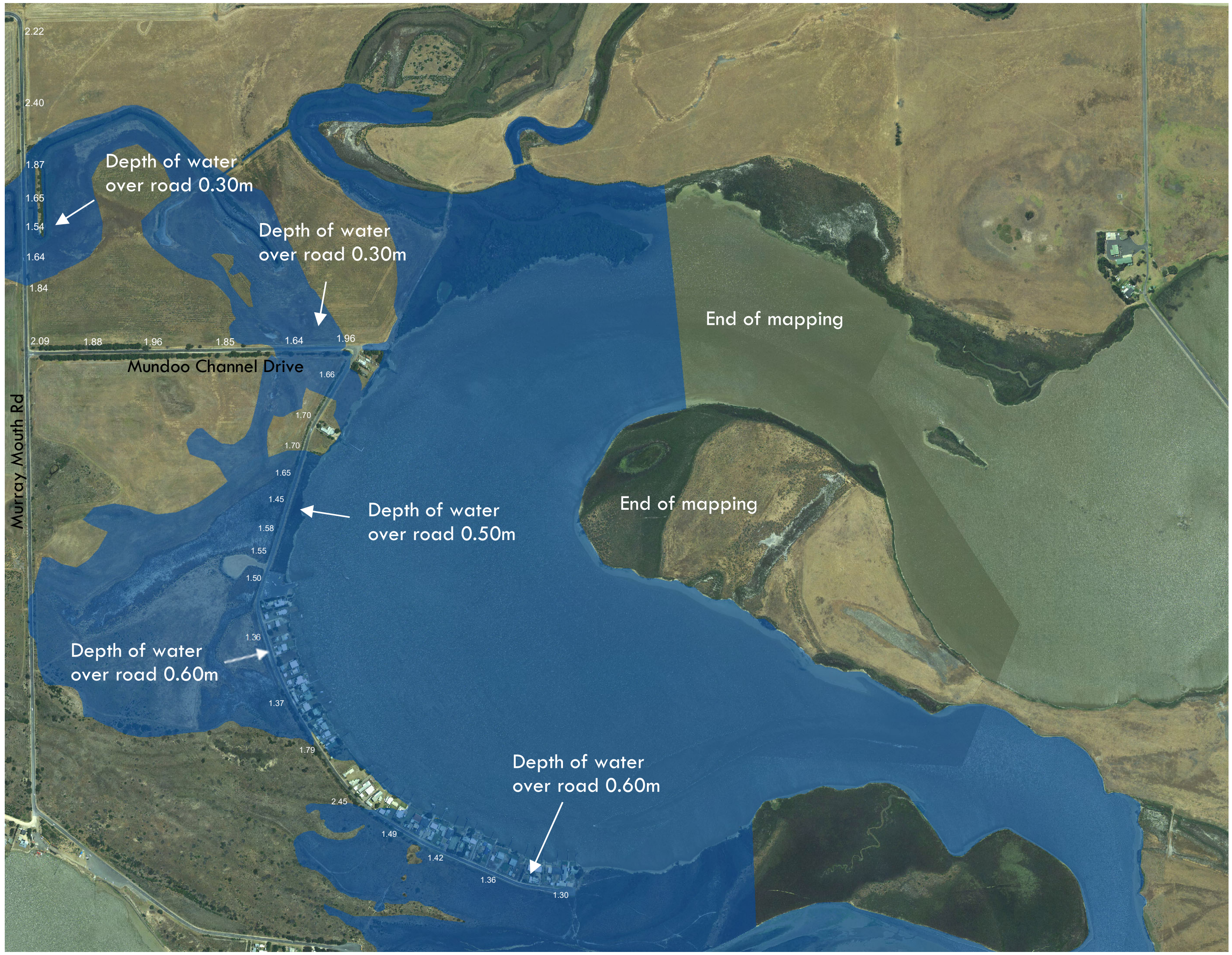
The 1 in 100-year ARI event risk set by Coast Protection Board for 2050:

Storm surge	1.55m AHD.
Wave set-up	0.20m
Risk	1.75m AHD
Plus 0.3m SLR	0.30m
Total risk	2.05m AHD

Modelling at shoreline is 2.05m, modelling inland is 1.85m AHD.

Access and Egress is unlikely to be available to vehicles, especially within the settlement.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



6. Future exposure – storm surge (2100)

Storm surge

Cell SF1 and SF2

Mundoo Channel

2100 risk:

1 in 100-year event risk

Assessment

Access and Egress

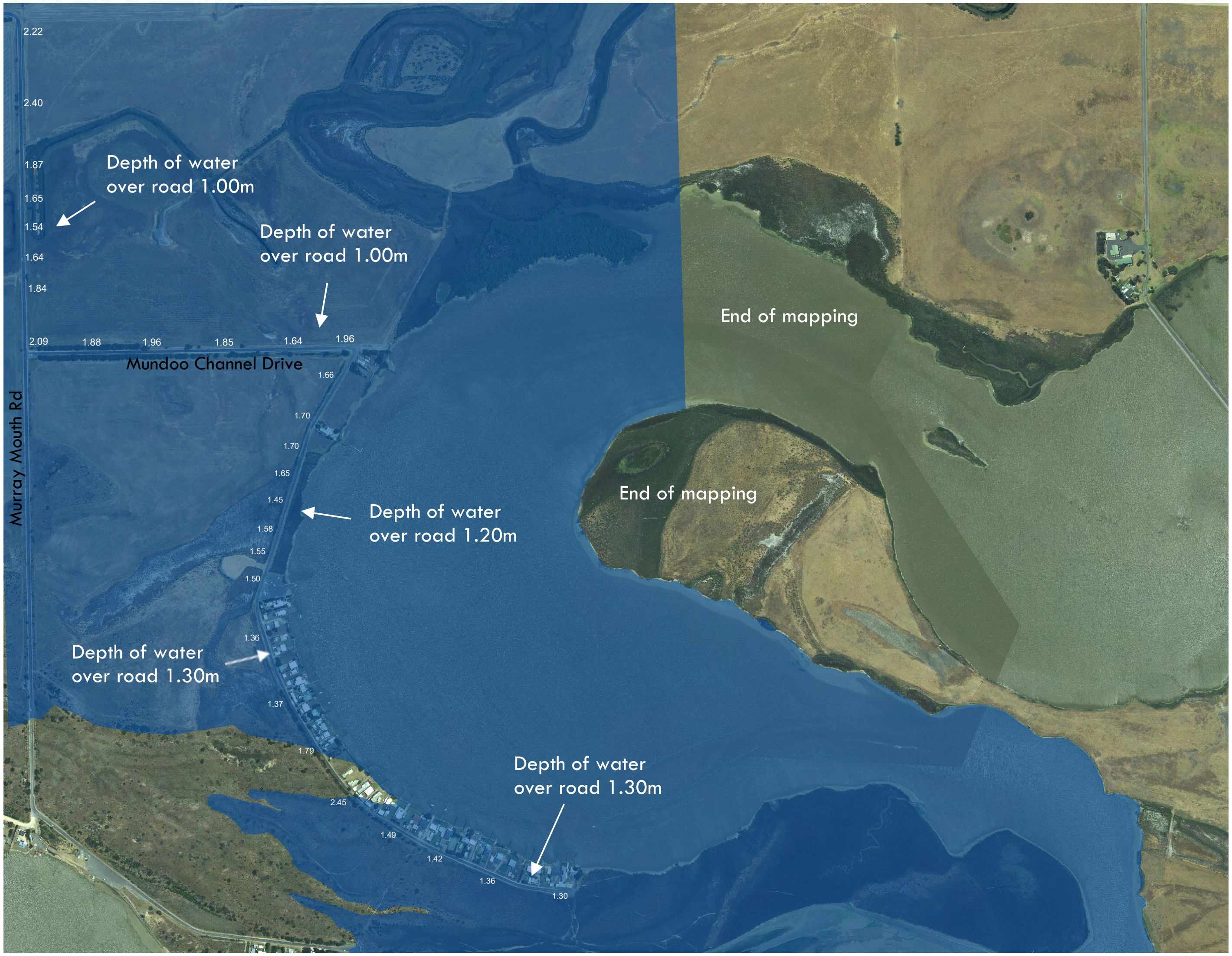
The 1 in 100-year ARI event risk set by Coast Protection Board for 2100 is:

Storm surge	1.55m AHD.
Wave set-up	0.20m
Risk	1.75m AHD
Plus 0.3m SLR	1.00m
Total risk	2.75m AHD

Modelling at shoreline is 2.75m, modelling inland is 2.55m AHD.

Access and Egress will not be possible into the settlement, or within the settlement.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



6. Future exposure – annual high water (2050)

Annual high-water

Cell SF1 and SF2

Mundoo Channel

2050 risk:

Annual high-water risk

Assessment

Access and Egress

On average, over the last five years the highest annual tide has been 1.15m AHD. By way of contrast, CPB 1 in 10 risk event is 1.35m AHD.

0.3m sea level rise has been added to project likely tidal regime in 2050

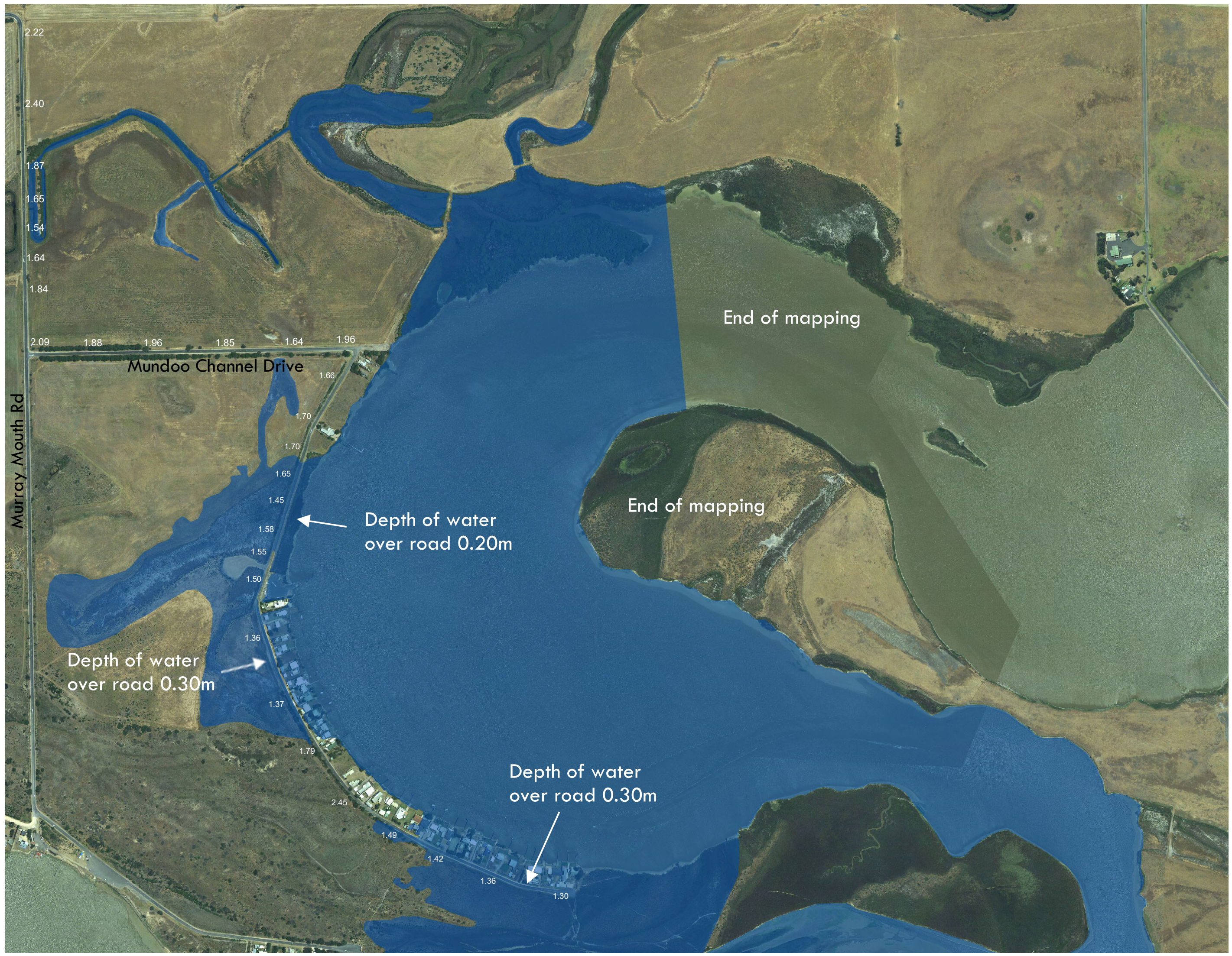
High water:	1.15m AHD
Wave setup:	0.20
	1.35m AHD
SLR	0.30m
Total risk	1.65m AHD

Access and Egress is likely to be possible in most cases.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com



6. Future exposure – annual high water (2100)

Annual high water

Cell SF1 and SF2

Mundoo Channel

2100 risk:

Annual high water risk

Assessment

Access and Egress

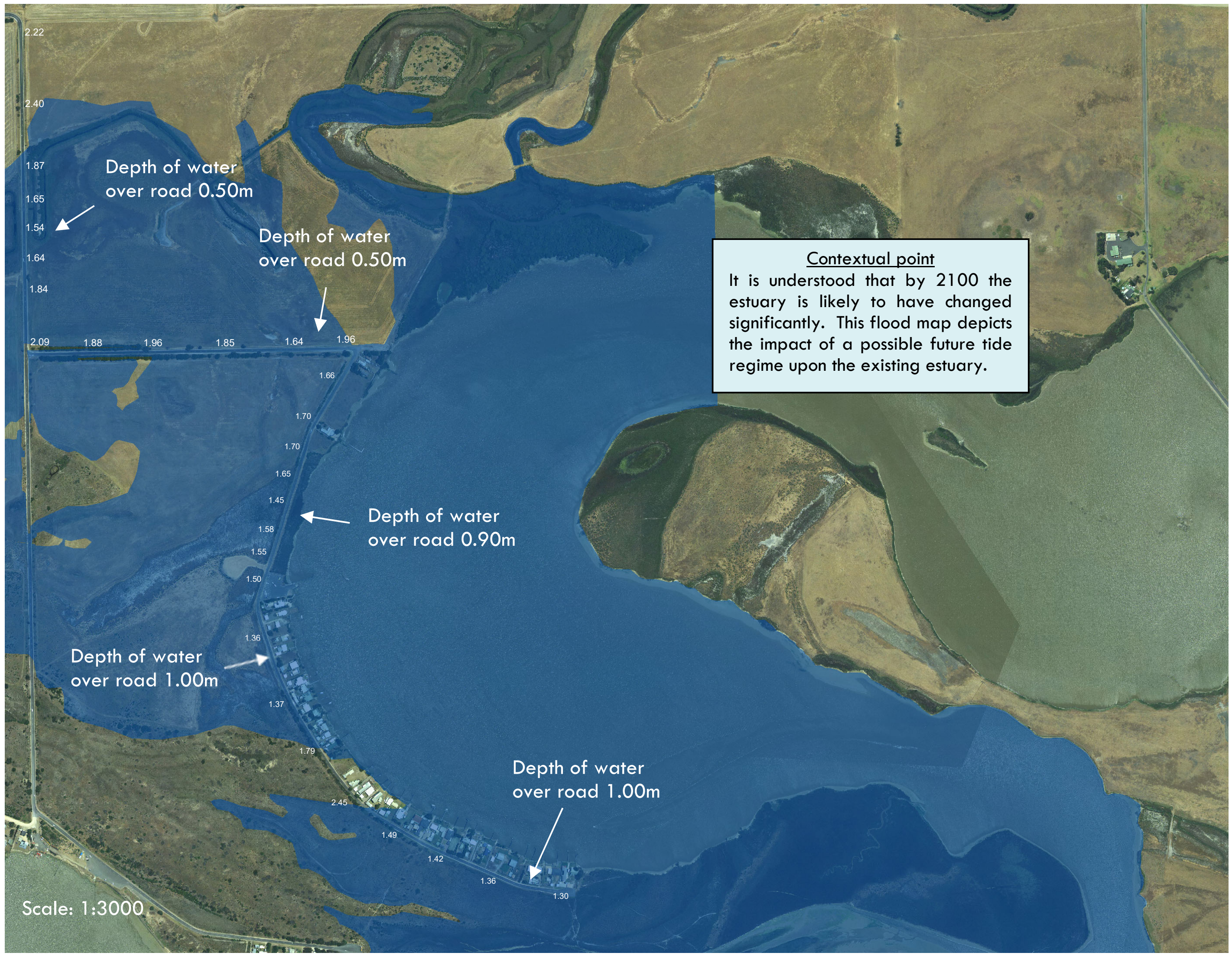
On average, over the last five years the highest annual tide has been 1.15m AHD. By way of contrast, CPB 1 in 10 risk event is 1.35m AHD.

1.0m sea level rise has been added to project likely tidal regime in 2100

High water:	1.15m AHD
Wave setup:	0.20
	1.35m AHD
SLR	1.00m
Total risk	2.35m AHD

Access and egress will not be possible with this high tide.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



6. Future exposure – storm surge (2050)

Storm surge

Cell SF1 and SF2

Mundoo Channel

2050: 1 in 100-year risk

Assessment

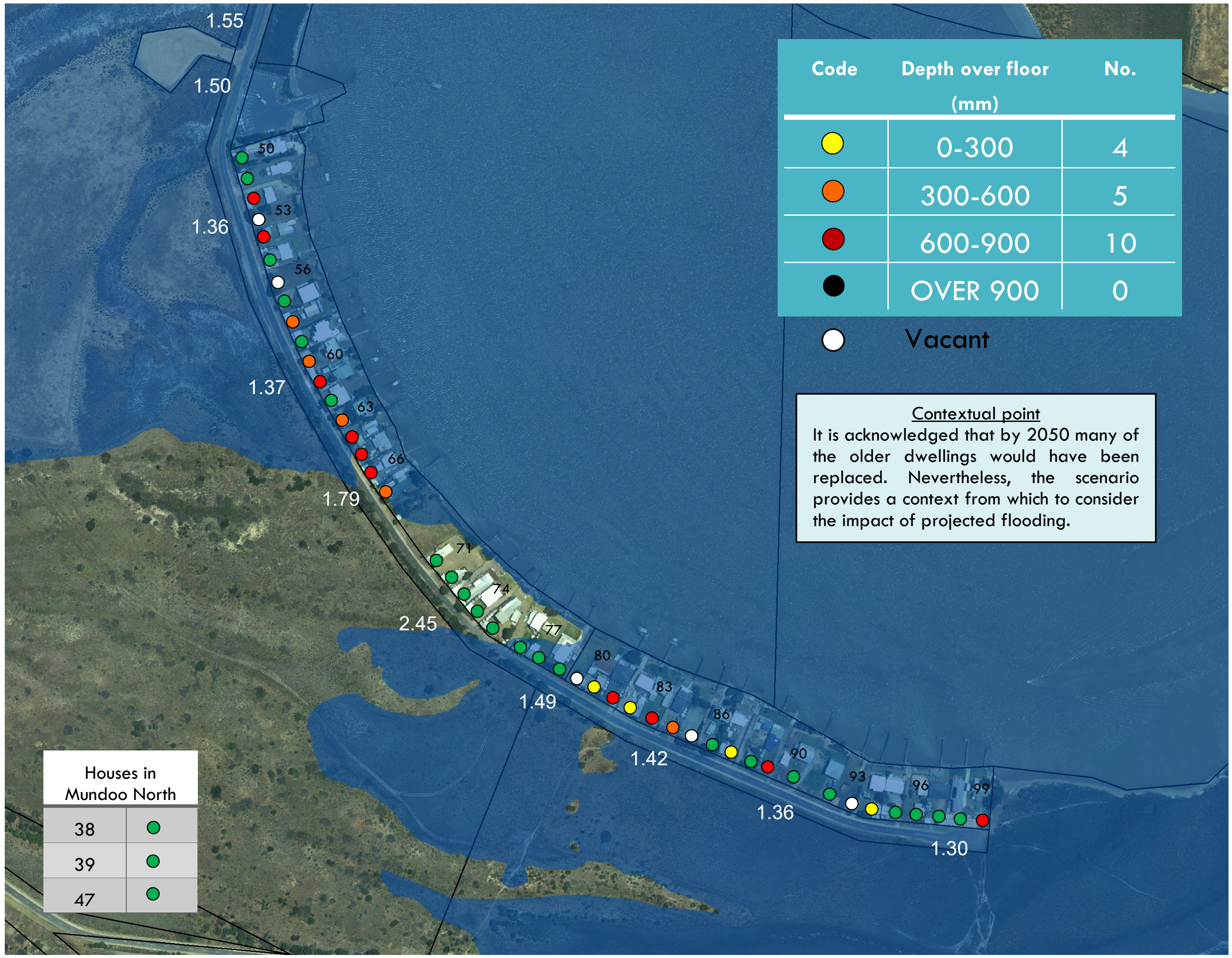
Flooding of private property

The 2050 risk 1 in 100 ARI storm event for Mundoo Channel is:

Storm surge 1.55m AHD
Wave setup 0.20
1.75m AHD
SLR 0.30m
Total risk 2.05

If this event occurred, then:

- 4 houses would have water up to 300mm over floor level
- 5 houses would have water level 300mm to 600mm.
- 10 houses would have water level 600mm to 900mm.



Code	Depth over floor (mm)	No.
Yellow	0-300	4
Orange	300-600	5
Red	600-900	10
Black	OVER 900	0
White	Vacant	

Contextual point
It is acknowledged that by 2050 many of the older dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

Houses in Mundoo North	
38	Green
39	Green
47	Green

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Future exposure – storm surge (2100)

Storm surge

Cell SF1 and SF2

Mundoo Channel

2100 risk:

1 in 100-year event risk

Assessment

Flooding of private property

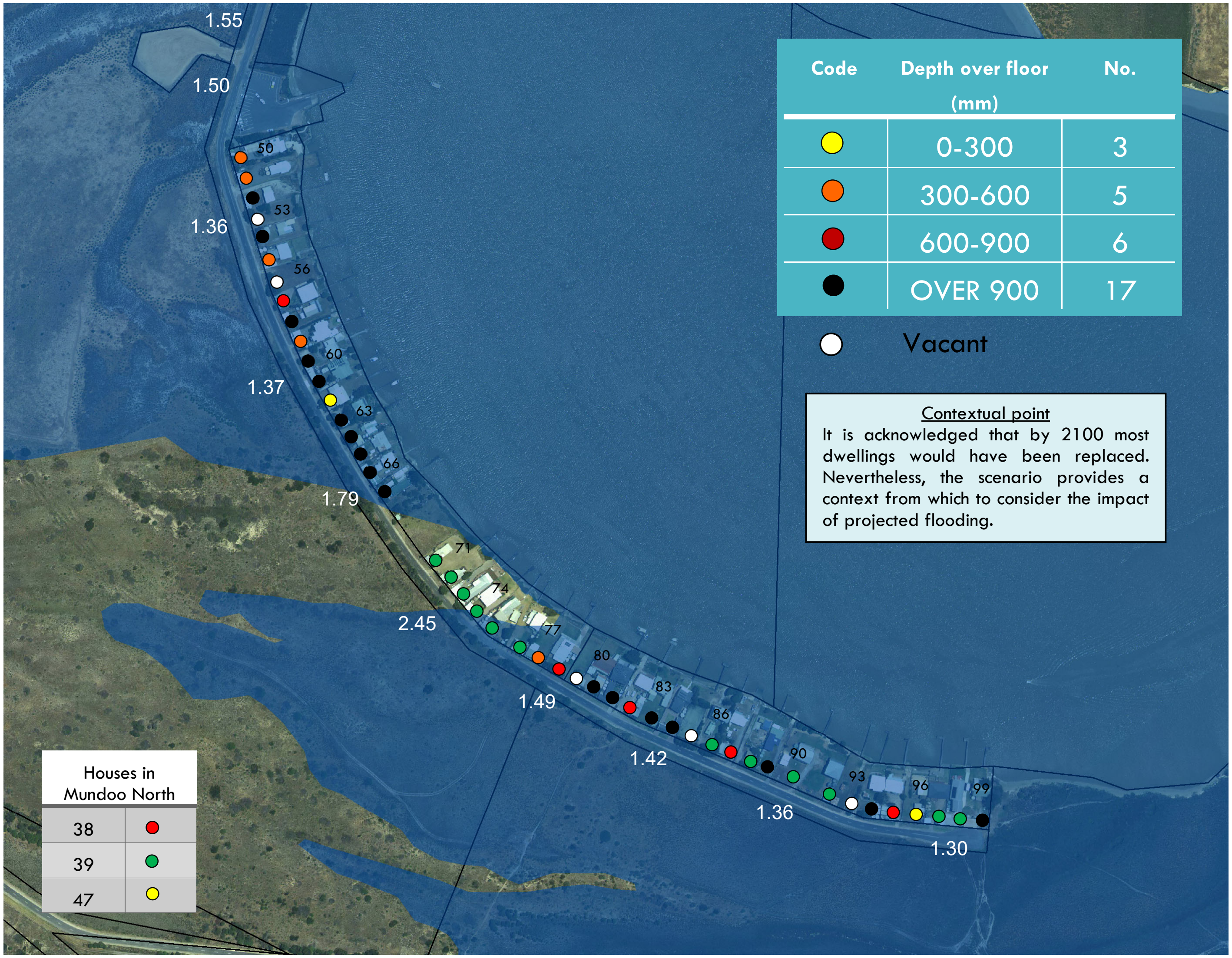
The 1 in 100-year ARI event risk set by Coast Protection Board for 2100:

Storm surge	1.55m AHD
Wave setup	0.20
	1.75m AHD
SLR	1.00m
Total risk	2.75

If this event occurred then:

- 3 houses would have water up to 300mm over floor level
- 5 houses would have water level 300mm to 600mm.
- 6 houses would have water between 600mm and 900mm.
- 17 houses over 900mm

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	3
Orange	300-600	5
Red	600-900	6
Black	OVER 900	17
White	Vacant	

Contextual point

It is acknowledged that by 2100 most dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

Houses in Mundoo North	
38	Red
39	Green
47	Yellow

6. Future exposure – annual high water (2100)

Annual high water

Cell SF1 and SF2

Mundoo Channel

2100 risk:

Annual high-water risk

Assessment

Flooding of private property

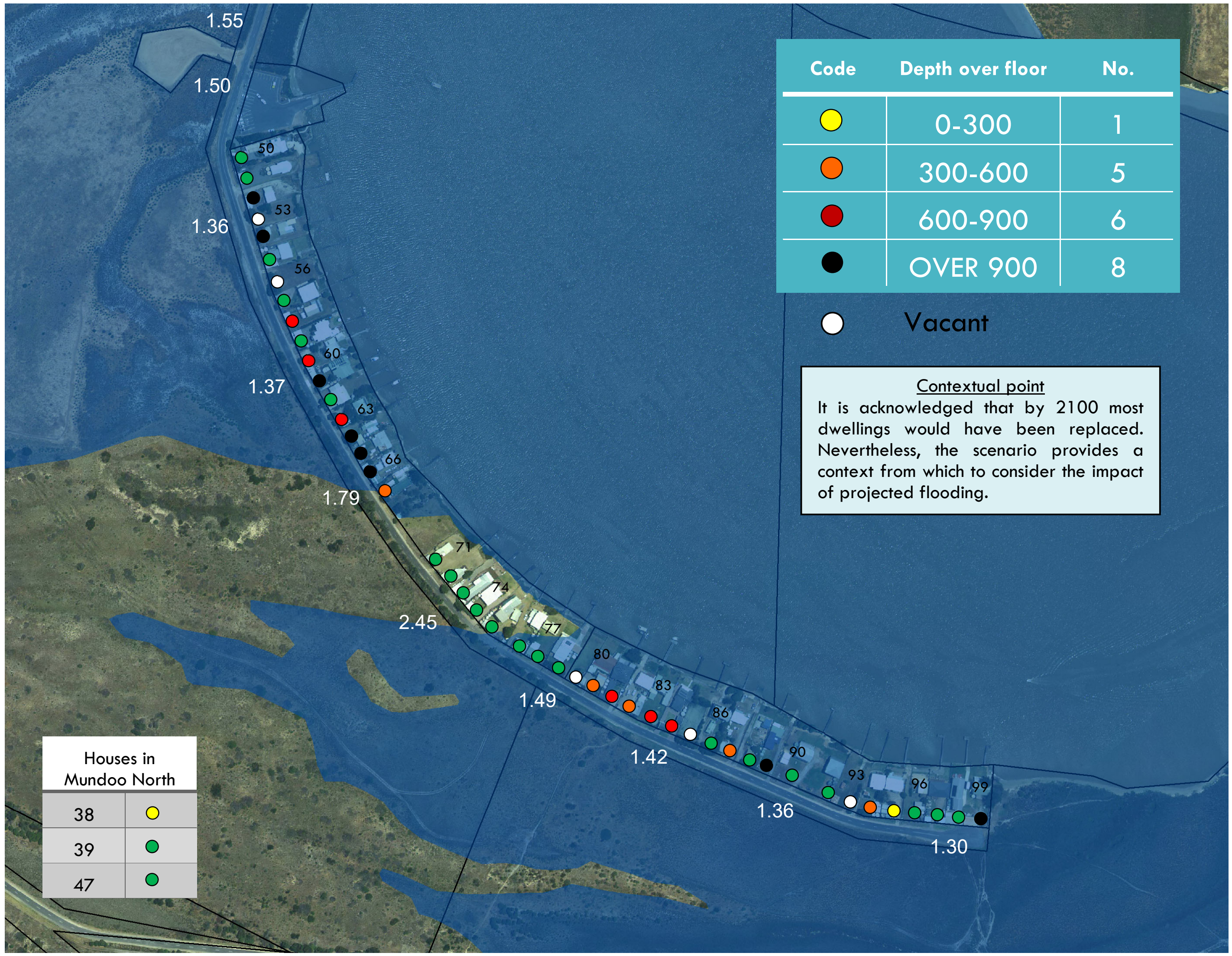
If the 2100 annual high tide occurred at 2.35m AHD (including wave setup), then:

- 1 houses would have water up to 300mm over floor level
- 5 houses would have water level between 300mm and 600mm.
- 6 houses would have water between 600mm and 900mm.
- 8 houses would have water over 900mm deep.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com



6. Future exposure - erosion

Shoreline change due to sea level rise

Mundoo Channel

Macro analysis

The analysis above has demonstrated that the fabric of the area is extremely volatile.

The outlook for the Murray Mouth if dredging were to cease is not known, but with increase sea level, and in the absence of any increase of freshwater flows through the Murray Darling system, the Mouth of the Murray is likely to close. This event would remove the flooding and erosion threat from actions of the sea, but the ecosystem would change significantly.

It is likely that the importance of the River Murray system will result in current and future Governments ensuring that the Mouth stays open.

As noted in the introduction, this study assumes that the barrage system remains operating in accordance with its design purpose of keeping sea water out of the lower lakes.

Mundoo Channel: Micro analysis:

The prevailing winds associated with storm surges from the west to south blow offshore from Mundoo Channel settlement and therefore it can be anticipated that ongoing erosion to the position of the existing shoreline will be minimal.

There is some anecdotal evidence that strong easterly winds will elevate waters adjacent Mundoo Channel. Climate change may also change wind patterns, and this matter should be subject to ongoing monitoring.

Of greater concern than shoreline position is the impact of routine flooding of the terrain and access ways. The modellings for the annual high-water event for 2100 depicts water over roads and terrain at ~1m. Monthly high tide modelling has not been produced as part of this project, but the data shows that parts of the terrain would be routinely flooded. This flooding will not be accompanied by high wave action as would occur in a more exposed coastal setting. However, seawater that rises evenly does not return to the sea in an even manner. When the tide turns the water finds the quickest way back to the sea, and as a result substantial scouring can occur of the terrain and road surfaces (undermining the edge of the road).

Key Point

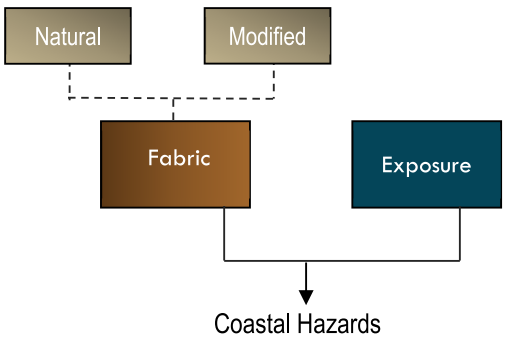
Increased frequency of flooding over the terrain will increase the amount of scouring of the terrain and road surfaces. While the water rises uniformly, when the tide turns, the water finds the quickest way back to the sea, scouring the terrain and undermining road surfaces.

COASTAL EXPOSURE

Summary and Conclusions

Progress report:

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the 'geology' or 'fabric' of the cell. In the last section we also analysed current and future exposure.



Baseline storm event

The highest event on record at the Mundoo Barrages occurred on 18th May 1953 at 1.59m AHD. The modelling indicates that if this event were to reoccur it would significantly impact Mundoo settlement with 13 dwellings having flood over floor levels.

Storm surge

As the 1 in 100-year ARI storm surge event is based on the historical event, the impact of the baseline storm is the same as for this event. Roads would be inundated in a number of places but generally at depths lower than 0.20m.

Annual high-water

The modelling indicates the average annual high water event does not impact access roads of the settlement nor produces flood over any floor levels.

Erosion

Erosion has been minor in Mundoo Channel due to the fact that prevailing winds associated with storm events blow offshore from the settlement. Erosion is more pronounced outside of the settlement area, perhaps due to limited oversight by people.

Future exposure (2050)

Storm surge

If the 1 in 100 ARI storm surge event projected for 2050 occurred then access to the settlement would be impossible, and internal access equally difficult.

Seventeen existing dwellings would have water over floor levels.

Annual high-water (2050)

Scenario mapping upon existing layout indicates that high tides projected for 2050 would inundate internal roads to depth of 0.20m. This may prevent ambulances from accessing the settlement.

Future exposure (2100)

Storm surge and high tide

If the 1 in 100-year ARI event for 2100 occurred upon the existing road layout, depths over the road would be a minimum of 1.00m and in some places exceed 1.30m. The scope of this flood would be very significant and possibly travel kilometres inland.

Annual high water events would be of the magnitude similar to the 1 in 100 ARI event for 2050. Tides of this magnitude would inundate the roads regularly at depths 0.50m to 0.90m.

Erosion

Due to the fact that prevailing winds blow offshore from Mundoo settlement, it can be anticipated that erosion impact will remain low.

However, the scenario modelling does show increased inundation. Later in the century when inundation of the settlement is more routine, it can be expected that erosion of existing banks and road surfaces will escalate. In locations such as Mundoo Channel, the larger impact from erosion is experienced on a receding tide as water finds the fastest way to travel back to the ocean.

Exposure rating (erosion): Very sheltered

Exposure rating (flooding): Highly exposed

7. Inherent hazard risk assessment

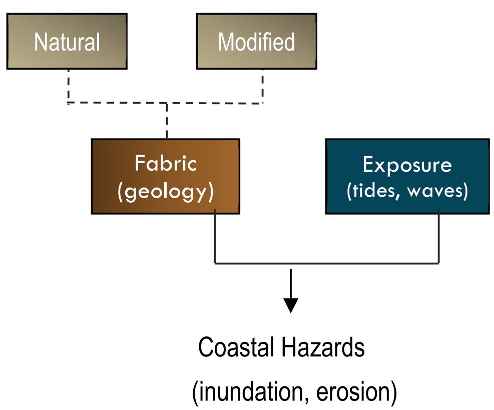
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk.

This reality is most simply understood when considering inundation risk. Whether a coast is at risk from inundation depends entirely on the topography of the coast. If we explain this another way, a low-lying coast is *inherently* more at risk from flooding whereas an elevated coast is inherently not at risk from flooding.

The assessment of the erosion hazard is far more complex, but it is still the relationship of *fabric* to *exposure* that determines whether a coast is *inherently* more at risk from erosion or less at risk.



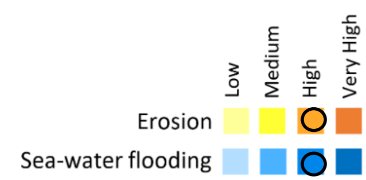
Inundation hazard risk

Modelling of current 1 in 100 ARI year event risk depicts minor flooding of settlements. Therefore, the inherent inundation hazard risk is 'high' .

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (Main report)	River estuary – tidal flat, samphire flat	Very high
Should this rating be amended due to human intervention such as a protection item? If so, how?	No, human intervention is limited to dune fencing.	Very high
Apply an exposure rating (Nature Maps)	Nature Maps does not allocate an exposure rating, but 'very sheltered' is appropriate.	High
Assess any impact on backshore 1	Limited evidence of erosion in Mundoo settlement area (apart from those outside the settlement)	High
Assess any influence from Benthic	Not applicable – river estuary	High
Assess the sediment balance	Not applicable – river estuary	High
Assess any other factors that may warrant a change of inherent hazard risk.	Winds that generally produce the higher wave action within the estuary come from the west, to south west. These winds blow off-shore from Mundoo. However, the nature of the sand-flat (fabric) warrants a 'high' inherent erosion rating.	High

Inherent Hazard Risk – Mundoo Channel



8. HAZARD IMPACTS

In this section we identify and describe the potential hazard impacts within four main receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

8a. Assets at risk (public)

Public assets within Mundoo Channel settlement include:

- Public roads
- Carpark (rubble)
- Fencing
- Boat ramp facility
- Toilet block
- Signage

A current 1 in 100 ARI would flood the carpark and just encroach to the floor level of the amenities block. The flood waters at this level would inundate the road at places but at shallow depths. It is unlikely that the current 1 in 100 ARI sea flood would have a significant impact on assets.

The impact on public assets in the shorter term (next 20-30 years) is expected to be minimal. However, should seas rise as projected, then increased flooding and associated scouring of banks and road surfaces could be expected.

When depth of water exceeds 0.3m, receding water usually scours banks and roads. The impact of increased flooding at levels projected for the end of this century is likely to render the current roadway layout as obsolete.

Figure 23: Visual representation of public assets within Mundoo Channel settlement (including access roads)

Figure 24: Boat ramp facility and public amenities block.

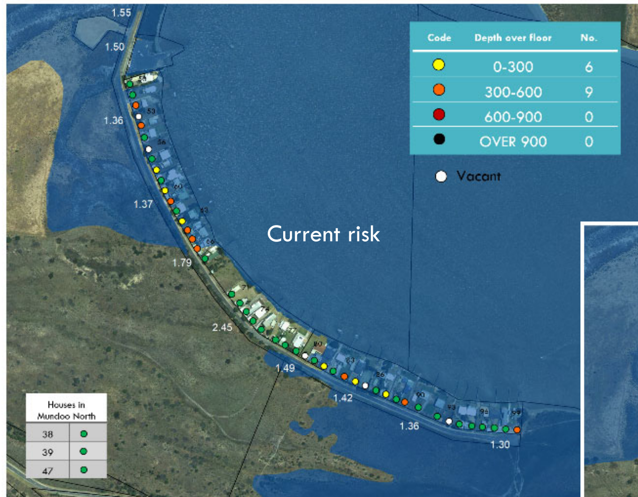
8b. Assets at risk (private)

The scenario flooding undertaken in the previous section demonstrates that should the current 1 in 100 ARI event occur that 15 houses would have water over floors, 9 of these with water at a depth between 0.3m and 0.6m. However, it is relevant to note that of these houses were constructed prior to 1990. (Note, number 63 is listed at DPTI as constructed in 2000, but this relates to a development application for a minor extension of a veranda). Before this time, relevant authorities were not required to take into account sea level rise in assessment.

It is recognised that many of the existing dwellings will be replaced by 2050. However, the 2050 sea-flooding scenario does provide an insight as to the impact of this flood scenario. Nineteen of the existing houses would have flood over floor, with 10 of these with flood depths over 0.6m.

One metre of sea level rise will have a significant impact on private assets. While in theory it would be possible to elevate dwellings, the depth of water over sites would be significant, many with water over 1.5m in depth.

When depth of water exceeds 0.3m, receding water usually scours terrain that is highly erodible. The impact of increased flooding at levels projected for the end of this century is likely to significantly scour residential sites.



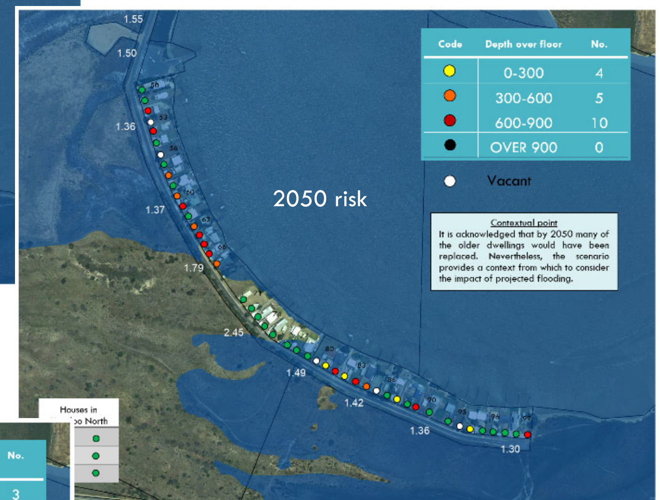
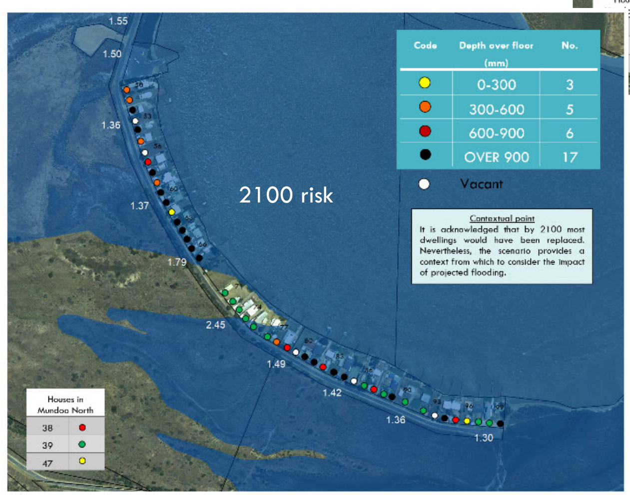


Figure 25: Scenario flood mapping for current risk, 2050 and 2100 projected risk (see pages 30-42)



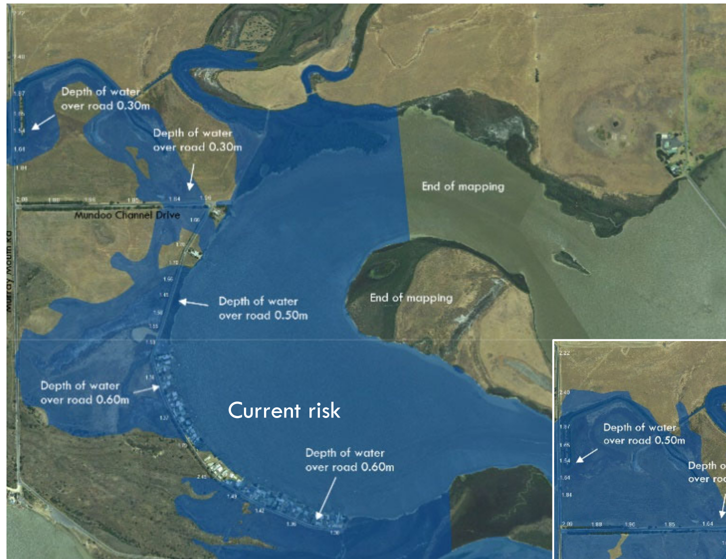
8c. The safety of people

The scenario flooding demonstrates that if seas rise as projected, then increasingly access roads will be cut off in times of flood. While the nature of the flooding is normally benign (in that wave action and rates of flow are low), emergency vehicles will be unable to access Mundoo settlement in the case of accident or health issue.

Furthermore, an increase of accidents in the time of flood is likely, for example electrical faults, slipping, and potentially drowning of people who were young, sick or aged.

Currently, the 1 in 100-year ARI event produces flooding at depths 0.20m over road surfaces. This is likely to be a manageable depth for the current scenario, but as seas rise, then increasingly the safety of people will be at risk.

The flood heights of 1.00m to 1.50m projected for the end of the century will make for a very unsafe environment for people.



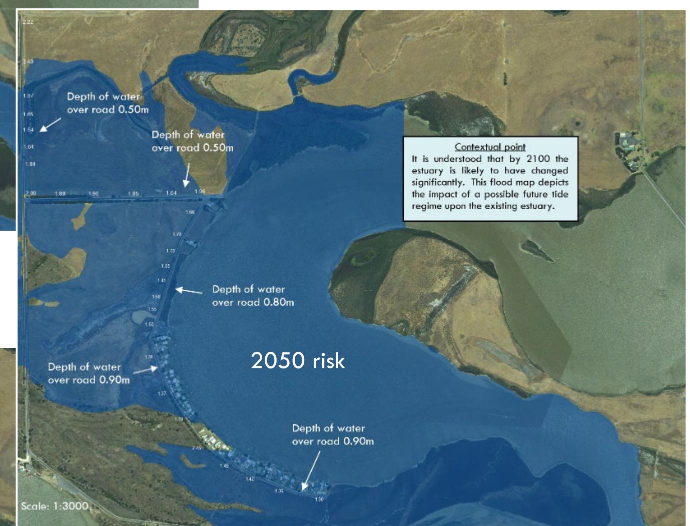
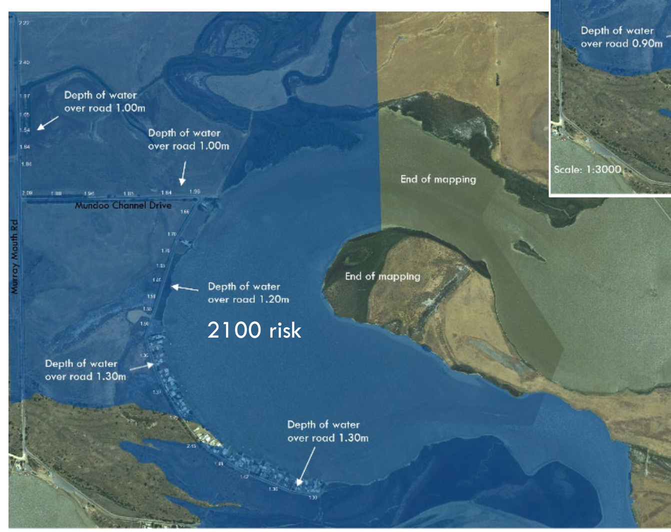


Figure 26: Scenario flood mapping for current risk, 2050 and 2100 projected risk (see pages 30-42)



8d. Ecology at risk

In the shorter term to 2050, large scale impacts to the ecology are not expected as a result of 0.3m sea level rise. However, increased sea water flooding from 2050 onwards is likely to change the ecology of large portions of southern Hindmarsh Island. If seas rise as projected by 1m it is not expected that human intervention could mitigate the impact upon the ecology surrounding Mundoo settlement.

However, as noted by Dr Bourman it is likely that in times when sea level was 1m higher than present that sea water flowed through 'a network of natural spillways' that criss-cross the Hindmarsh Island in the south (see Geomorphology section). It may be relevant to consider the outlook as returning to a time when sea level was higher than present and accommodate changes accordingly.

The Mundoo region is situated within the Ramsar Wetlands and Key Ramsar Habitat Area.

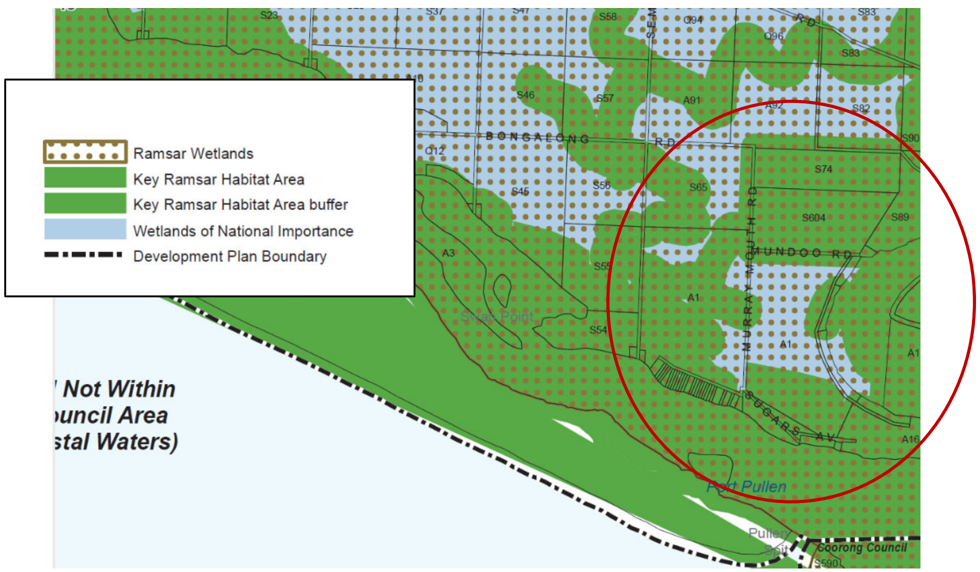


Figure 27: Ramsar conservation classification (Map Alex 25, Development Constraints)

Figure 28: Mundoo Channel settlement – Wetlands of National Importance

Figure 29: North of Mundoo Channel settlement – Wetlands of National Importance

9. RISK ASSESSMENT

In this section we conduct a formal risk assessment of hazard impacts upon the four receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

This risk assessment utilises the risk framework of Alexandrina Council.

9. RISK ASSESSMENT

Inherent hazard rating

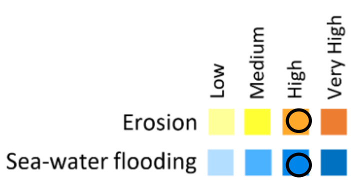
Integrated Coasts has developed a risk classification system to operate over the State of South Australia that categorises the risk to a coastal cell in relation to two main hazards:

- Sea-water flooding
- Erosion

The application of an inherent risk rating does not suggest that areas rated as low are entirely free from vulnerability, nor conversely that areas rated more highly are necessarily vulnerable now. The aim is to assess the underlying inherent vulnerability of the fabric of the coastal location using a process that will also benchmark the locality in the context of all of South Australia.

The visual output from the inherent risk assessment process is purposefully designed so that it is immediately accessible and meaningful to a wide range of personnel involved in managing the coastal environs.

Inherent Hazard Rating



Specific Risk Assessment

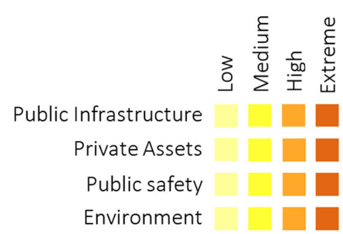
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Ecosystem disruption

The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes that may threaten to disrupt the entire ecological system, for example seawater flooding into freshwater ecologies.

This assessment utilises the Councils risk assessment framework and is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The risk assessment is conducted within either the inundation or erosion risk assessment template (see next page).

Erosion Hazard Rating
(Current outlook 2020)



Erosion Hazard Rating
(Future outlook 2100)

Yet to be assigned

Inundation assessment

Mundoo Channel

Risk identification: Seawater is likely to inundate private and public land in storm surge and in annual high tides

Coastal processes	Mundoo Channel settlement is located within the Mundoo Channel on the seaside of the barrage. Flows of water in the area relate to the tidal regime at the Murray Mouth. Waters from the Mundoo Barrage are controlled. On occasions water is released through the barrages to the sea.

Are any strategies employed to mitigate the risk? No

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Mundoo Channel road, public toilets and carpark, boat ramp facility, signage and fencing.	current	*Unlikely*	*Insignificant*	low
		2100	*Almost certain*	*Significant*	Extreme
Private assets*	Dwellings and associated infrastructure positioned on the south western side of Mundoo Channel. Sea water flooding will increasingly impact dwellings with water over floor levels.	current	*Possible*	*Moderate*	Moderate
		2100	*Almost certain*	*Significant*	Extreme
Safety of people	Increased sea levels and associated flooding will cause access to the settlement to be cut. Inside the settlement, depth of water is likely to be hazardous to people.	current	*Rare*	*Moderate*	Low
		2100	*Possible*	*Moderate*	Moderate
Ecosystem disruption	Hindmarsh Island in the southern portion is set at levels lower than 2m AHD. Increased sea water flooding due to sea level rise will change the ecology of the land surrounding Mundoo Channel, especially in the second half of this century.	current	*Rare*	*Minor*	low
		2100	*Almost certain*	*Significant*	Extreme

Inherent Hazard Rating
Low-lying sandflat within estuary

	Low	Medium	High	Very High
Erosion			X	
Sea-water flooding			X	

Inundation Hazard Rating
(current outlook)

	Low	Moderate	High	Extreme
Public Infrastructure		X		
Private Assets*		X		
Public safety	X			
Eco-system disruption	X			

Inundation Hazard Rating
(future outlook)

	Low	Moderate	High	Extreme
Public Infrastructure				X
Private Assets*				X
Public safety		X		
Eco-system disruption				X

Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Caveat: this assessment is sea-water impact only and does not encompass the possibility of riverine flooding, nor a combination of both impacts.

*Council not necessarily liable for private assets

Summary	Mundoo Channel settlement is generally low set and vulnerable to sea water flooding. If seas increase as projected, it is difficult to envisage how Mundoo Channel would be viable by the end of the century.

10. ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

CoastAdapt notes that there are generally six categories of adaptation responses to climate change in the coastal zone:

- Avoidance
- Hold the line (protect)
- Accommodation (or limited intervention)
- Managed retreat
- Defer and monitor
- Loss acceptance

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. Thus, land that Is projected to become more prone to flooding in future can be scheduled as suitable only for development such as light industry or warehouses, and unsuitable for housing or critical infrastructure.

Engineering

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works strategies such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation damage. These approaches differ from other types of approaches in that they require significant commitments of financial resources and create a physical asset.

Environmental management

Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support continued growth of habitat such as seagrasses or reefs.

It may also include developing artificial reefs to reduce wave erosion of shorelines or engineered solutions to prevent encroachment of saltwater into freshwater systems.

ADAPTATION APPROACHES

There are two broad ways in which adaptation can occur in relation to timing:

- Incremental approach

A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the face of the impacts of climate change.

- Transformative approach

In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant that they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term. A transformative approach may be triggered by an extreme event or a political window when it is recognised the significant change could occur.

ADAPTATION ASSESSMENT

The modelling and assessment indicate that inundation is projected to be the key coastal hazard in the Mundoo Channel region.

An **incremental approach** to adaptation is recommended.

A range of adaptation options for Mundoo Channel settlement are assessed on the following pages.

Further reading and resources

This section of work adopts the framework and understanding of adaptation options from CoastAdapt. Further reading at:

https://coastadapt.com.au/understand-adaptation
https://coastadapt.com.au/adaptation options

[1] CoastAdapt also includes 'community education'.

Adaptation assessment

To evaluate adaptation options when the scenario modelling shows that a settlement is likely to be subject to significant inundation in the future, it is helpful to consider the concept of settlement viability.

Settlement viability

There is no established definition within coastal adaptation study for 'settlement viability', but the common meaning of 'viability' at dictionary.com is useful in this context:

- Ability to live, especially under certain conditions,
- The capacity to operate or be sustained.

Therefore, an assessment of settlement viability considers the ability to maintain access roads, the ability to maintain the stability of sites, and the ability to maintain an environment where people can safely reside and move about.

Science and uncertainty

It is also important to recognise that we are assessing viability of a settlement using scenario modelling which is based on long-term sea-level rise projections. Therefore, we need to acknowledge that there is significant uncertainty as to how these projections may play out over the course of this century. On the other hand, the consensus of most of the scientific community is that the science upon which the projections are based is sound. Furthermore, irrespective of our own personal views, the State Government of SA has adopted a sea level rise policy within its planning instruments that requires assessment of proposed development against 0.3m sea level rise by 2050 and 1.0m sea level rise by 2100.

Therefore, we are obliged to make decisions, short-term and long-term based upon these projections. But it is also important that we deal sensitively about these long-term projections in the context of a settlement such as Mundoo Channel.

SETTLEMENT VIABILITY AT 2100

Based on the evidence presented in this report it is unlikely that the Mundoo settlement would be viable by 2100 if seas rise as projected. (However, this assertion is also based upon the assumptions recorded at pages 5-6. For example, if the Mouth of the Murray closed, then sea level rise would not be an issue for any of the settlements within the Murray Estuary).

First, it is not possible to maintain access and egress into Mundoo Channel area should seas rise by 1m when the road infrastructure is currently set at levels as low as 1.50m AHD. The 1 in 100-year storm surge event would cover roads at depths of 1.0 to 1.3 metres. It would also not seem viable to raise these roads by this height either.

Second, increases of sea level of this magnitude are likely to reshape the landforms which this project has assessed as 'highly erodible'. Water frequently flowing over sites and roads would scour and destabilise the ground upon which roads and dwellings are positioned. Annual high-water flows would cover much of the terrain, at depths of 0.7m to 1.0m. Tidal action would regularly flow over significant amounts of the terrain around Mundoo Channel settlement. On terrain that has been described as a 'sand-flat' and assigned an erodibility status as 'very high', it is difficult to see how Mundoo settlement would be viable by 2100.

Third, it is not practicable to design protection works that would be capable of stopping the flow of water through the settlement from multiple directions. Even if these works were possible, they would be required to be almost 3.0m AHD high.

Fourth, taking into account the above three factors it is unlikely that people could live and move about safely within Mundoo settlement if seas rise as projected by 2100.

In conclusion, while recognising the uncertainty of the projections, but also recognising the need to take the projections into account, it seems unlikely that Mundoo settlement would be viable at 2100 if seas rise as projected.

Long-term adaptation options

Considering our adaptation options, in the long term we may have to adopt either managed retreat or loss acceptance. However, in the shorter term, monitoring sea level rise over the next two decades should bring about a fuller understanding of the longer-term projections. Consideration is also required as to how to avoid placing future development proposals at future risk.

- Avoidance
- Hold the line
- Accommodation
- Managed retreat
- Defer and monitor
- Loss acceptance

Adaptation assessment

SETTLEMENT VIABILITY AT 2050

Considering that sea level rises are only in order of 0.30m by 2050, then it makes logical sense that the settlement will be more viable at 2050 than 2100.

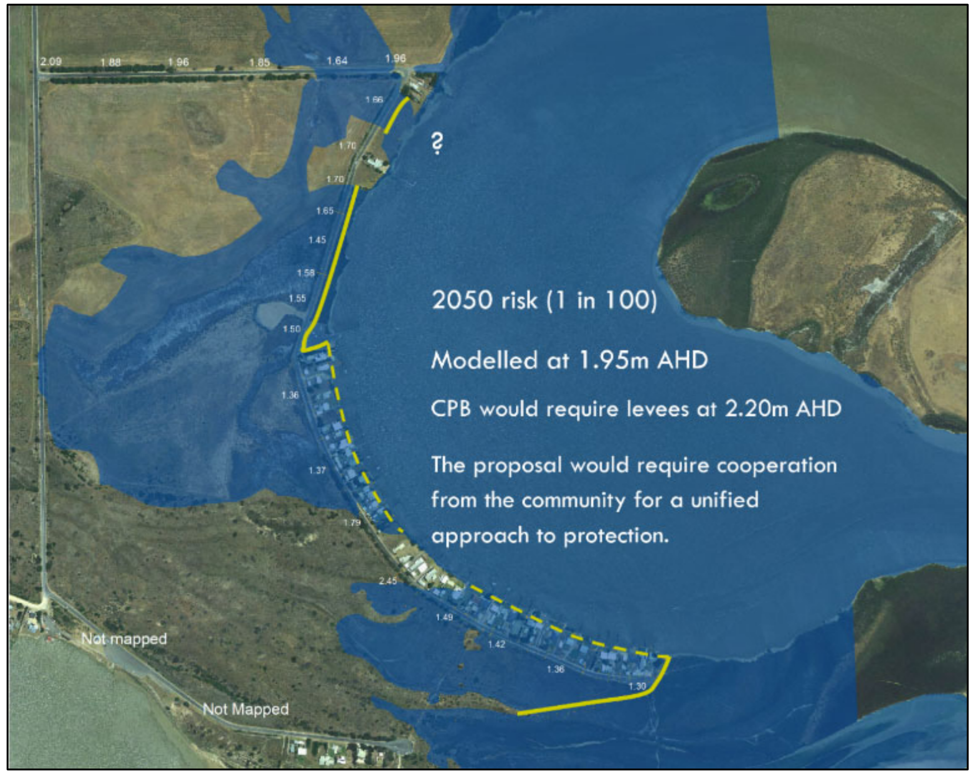
Although the 1 in 100 ARI event at 2050 projections would cover roads by 0.3m to 0.6m, these events by their nature are very rare. Annual high-water flows would only impact roads at depths of 0.1m to 0.3m. In contrast to the 2100 scenario, flows through the settlement and surrounds at 2050 scenario would be much less frequent. Therefore, the viability of the settlement is likely to be much less of a concern at 2050.

While the scenario modelling for 2050 demonstrates that 19 existing dwellings would be impacted by the 1 in 100-year event, all were constructed prior to 1990, and many constructed in the 1960s and 1970s. Furthermore, whether individual dwellings are viable is a different issue than considering whether a settlement is viable in relation to general access, stability, and safety.

There are two basic adaptation options to consider: protection (hold the line) or accommodation (limited intervention).

PROTECTION FOR 2050 SCENARIO.

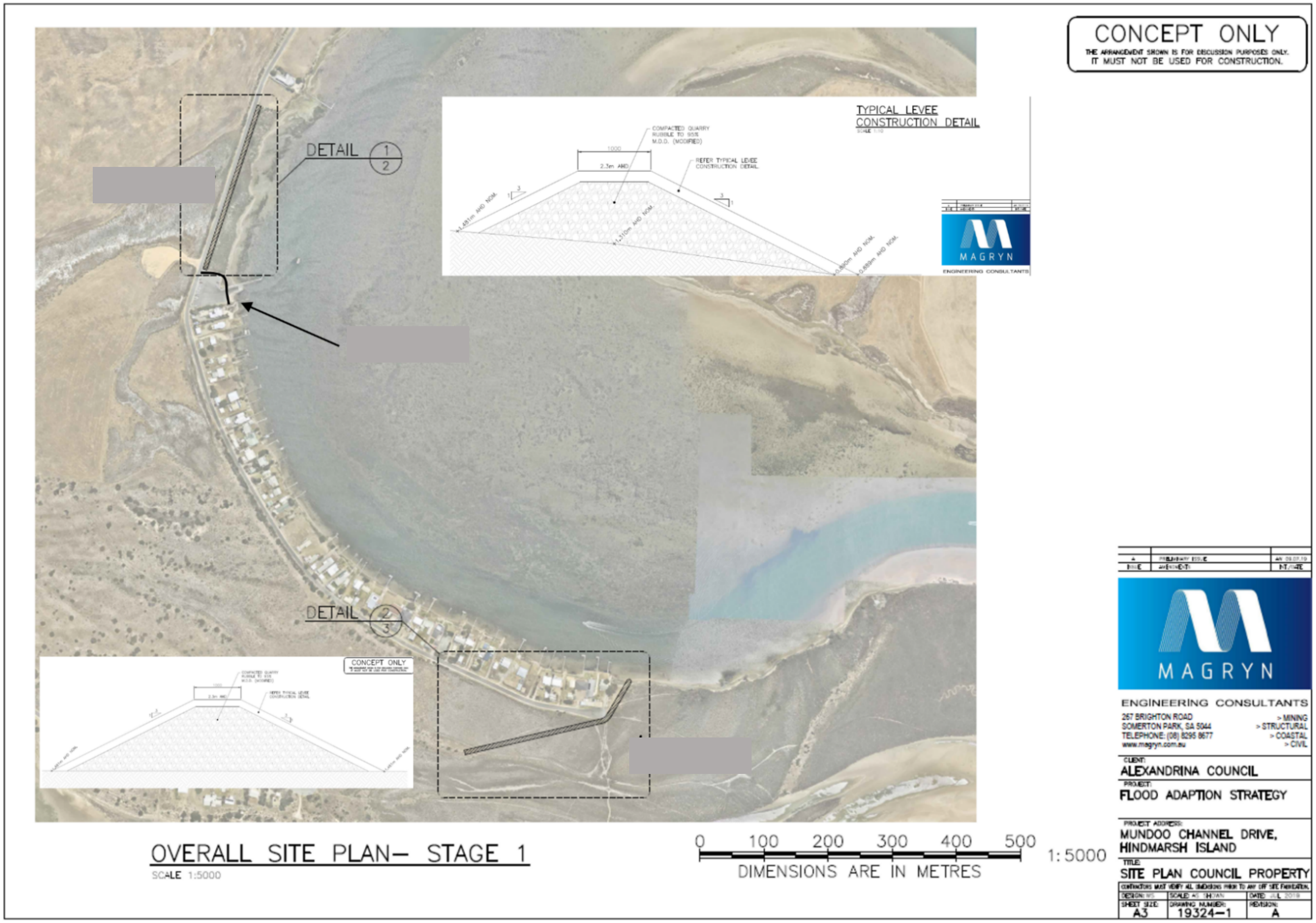
The protection concept in Figures 30-32 and further detailed in preliminary engineering designs on the following pages demonstrate that protection options are likely to be effective for the settlement but would require a cooperative approach between Government and citizens.



Figures 30-32 Low height levees at the northern and southern ends of the settlement would prevent water from flowing around the back of the settlement. A protection strategy would also need to be employed for privately held allotments to prevent water flowing through the settlement from the channel.

Protection proposal (Preliminary Design)

Figure 33: The design concept depicts low height levees at either end of the settlement.



Protection proposal (Preliminary Design)

Figure 34: The design concept depicts how the boat ramp and surrounds could be managed.

Protection proposal (Preliminary Design)

This proposal would require a cooperative approach between Government and property owners (or leaseholders). The State and Local Governments would be responsible to install the various levees, but no evaluation has been conducted within this study as to who would be responsible to pay for these levees. For this proposal to be effective, a protection strategy would also be required for individual land holdings adjacent the channel. The cost of protecting private land holdings is likely to be borne by private citizens.

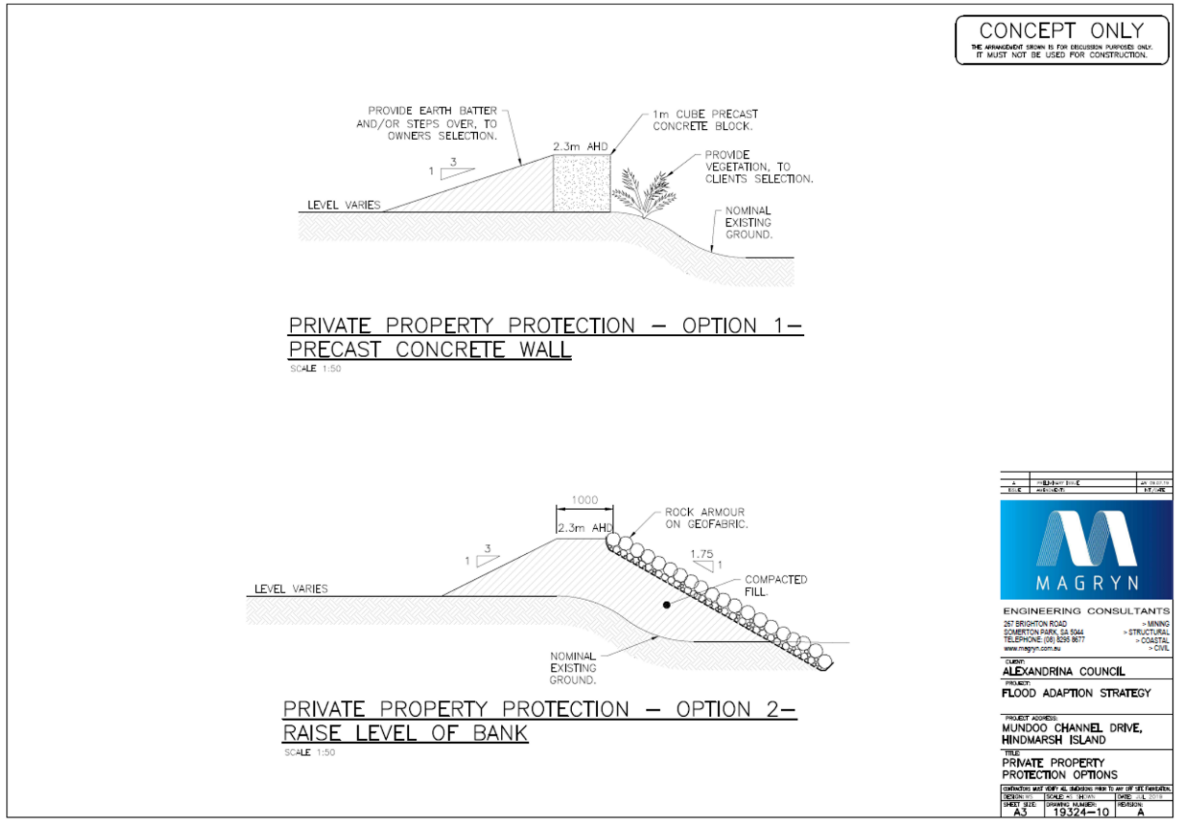
Two design approaches are proposed to provide protection to individual land holdings as part of this preliminary assessment:

(1) Use precast concrete blocks placed between private dwellings and Mundoo Channel.
(2) Raise the level of the bank at the edge of the Channel.

Option 1 is likely to offer the most flexibility to cater for individual site differences and the preferences of the land holders. For example, some residents may choose to place blocks closer to the channel edge, while some may choose to place them adjacent to their houses. The main criteria would be that they are all linked so that there are no gaps in the protection wall.

It is likely that many individual boat ramp facilities may not be viable, but each landowner (or leaseholder) could evaluate how ramping facilities could operate on their property. As a general observation, the public boat ramp at Mundoo Channel seems to be the preferred option for most residents in Mundoo.

Figure 35: Preliminary design concepts for protection between private dwellings and the channel.



Alternative consideration

A proposal was considered to install a levee on the channel side of the internal access road. However, this was not deemed viable from a design perspective and a cost perspective. The reason for considering this proposal was to deal with the possibility that private residents (leaseholders) did not want to consider private protection to their properties. By placing a levee on the channel side of the road, and levees at each end of the internal road, safe access could always be assured within the settlement even if private holdings were undergoing flooding.

Adaptation assessment

ACCOMMODATION OPTIONS FOR 2050 SCENARIO.

A typical accommodation scenario undertakes limited intervention and accepts that some impact from inundation will be experienced within the settlement. For example, it could be accepted that the 1 in 100-year risk event will flood the settlement, and that only minor works will be undertaken to ensure that the annual high-water event, or the 1 in 10-year event (as another example) does not flood the settlement.

An accommodation approach would also accept a higher level of risk in these circumstances. For example, if the 1 in 100-year event occurred within Mundoo, it is possible that emergency vehicles would not be able to access the community. The risk may be unrelated to the inundation event itself, such as someone suffering a medical emergency.

The way to manage an accommodation approach would be to recognise the risks and implement a community emergency management plan to cater for the extreme events. Particular attention would be paid to those with existing medical conditions and also to the 19 existing dwellings that would have flood waters over their floors if the 1 in 100-year event risk occurred in 2050.

ADAPTATION OPTIONS TO CATER FOR CURRENT RISK

The final question to consider is whether the settlement is currently protected from annual high-water events and 1 in 100-year event risks.

The modelling demonstrates that the settlement would be free from inundation from the annual high-water event.

However, the 1 in 100-year event would inundate the roads at depth of 0.2m to 0.3m and this is likely to be deep enough to prevent emergency vehicles (ambulances in particular) from accessing the settlement.

The modelling also demonstrates that 15 houses would have water over floors if the 1 in 100-year event occurred in this current time.

It is recommended that Council implement a form of community emergency management to ensure that those who have floor levels under projected flood levels are appropriately warned, and that consideration is given to managing the various risks associated with the possibility of flooding of access roads.

SUMMARY: PREFERRED OPTIONS

The modelling and assessment indicate that inundation is projected to be the key coastal hazard in the Mundoo Channel region.

An **incremental approach** to adaptation is recommended.

To protect private and public infrastructure over time, a **hold the line** methodology is recommended. Protection options should be pursued to cater for the 2050 sea flood risk. The cost of holding the line is likely to be borne by Council and the community.

In the longer term, if seas rise as projected by 2100, then the viability of the settlement is likely to be in doubt and a **managed retreat** strategy may be required. However, this strategy is unlikely to be necessary until the second half of this century.

In the meantime, **ongoing monitoring** of sea level rise over the next decade or two is likely to improve our understanding of the longer-term projections. Internal monitoring of the impact of flooding events within the settlement will also improve our understanding as to how to manage this settlement over time.

To manage current risks associated with the extreme but rare events (such as the 1 in 100-year event), a **community emergency management plan** should be designed and implemented.

GOOLWA CHANNEL

3. COASTAL FABRIC

The nature of the coastal fabric is a combination of natural geology and human intervention (where applicable).

In this section we evaluate coastal fabric in more detail:

- Overview of the current coastal fabric
- Changes to shoreline over seventy years
- Human intervention (coastal modifiers)

3. Coastal Fabric - natural

Overview

Map: SF2:1

Secondary Cell: Coorong

Tertiary Cell: SF1 and SF2

Minor cell: Goolwa Channel

Form

The form:

Beach

No beach – river estuary

Backshores

Sand flat, predominantly at elevations less than 2m AHD.

Bathymetry

Not applicable

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com
1300 767 333 (free call)

3. Coastal Fabric - natural

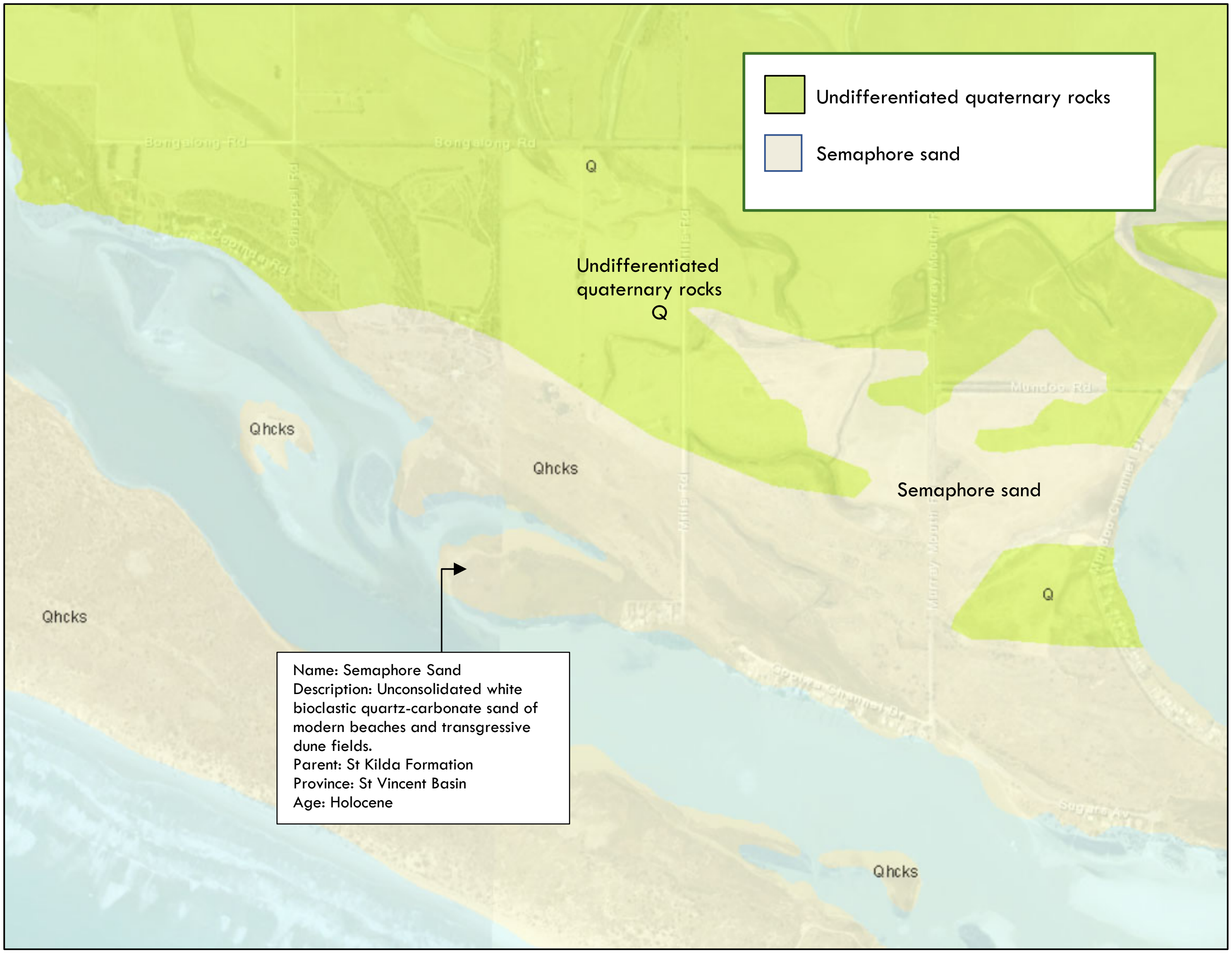
Overview

Map: SF2:1
Secondary Cell: Coorong
Tertiary Cell: SF1 and SF2
Minor cell: Goolwa Channel
Geology

Geology

Most areas underpinned by undifferentiated quaternary rocks
Age: Pleistocene – Holocene

Areas from the southern section are semaphore sand from Holocene period.



3. Coastal fabric - natural

Cell SF2: Section 1

MEDIUM TERM CHANGES

Map SF2:1

Goolwa Channel

Changes 1949 to 2018

Event: 1949

Assessment

Cooinda Road area

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

To provide context, current day roads and associated heights in Australian Height Datum (AHD) are depicted.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 1

MEDIUM TERM CHANGES

Map SF2:1

Goolwa Channel

Changes 1949 to 2018

Event: 1949

Assessment

Cooinda Road area

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

The dotted line represents the location of the shoreline in 1949.

To provide context, current day roads and associated heights in Australian Height Datum (AHD) are depicted.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 1

MEDIUM TERM CHANGES

Map SF2:1

Goolwa Channel

Changes 1949 to 2018

Event: 2009

Assessment

Cooinda Road area

Aerial Photograph from 1949 provides the basis for comparison of change over the last seventy years.

The channel shoreline appears to have undergone very little change in this location.

Minor accretion appears to have occurred in area of shacks (note vegetation line forward of older shoreline in 1949 photograph)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 1

MEDIUM TERM CHANGES

Map SF2:1

Goolwa Channel

Changes 1949 to 2018

Event: 2018

Assessment

Cooinda Road area

to 2009. Vegetation appears to be growing further forward of the 2009 shoreline in the eastern side of this photograph. This may indicate further accretion is underway.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 2

MEDIUM TERM CHANGES

Map SF2:2

Goolwa Channel

Changes 1949 to 2018

Event: 1949

Assessment

Mills Road and Goolwa Channel Dr

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

The dotted line represents the best indication of current shoreline position.

To provide context, current day roads and associated heights in Australian Height Datum (AHD) are depicted.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 2

MEDIUM TERM CHANGES

Map SF2:2

Goolwa Channel

Changes 1949 to 2018

Event: 2009

Assessment

Mills Road and Goolwa Channel Dr

The dotted line on the map indicates shoreline position in 1949.

Minor erosion has occurred on the western end of this photograph.

Major erosion has occurred on the eastern (approx. 38-44m).

See also Section 2 Geomorphology for discussion regarding movement of the Murray Mouth and resulting erosion and accretion in the Sugars Beach area.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 2

MEDIUM TERM CHANGES

Map SF2:2

Goolwa Channel

Changes 1949 to 2018

Event: 2018

Assessment

Mills Road and Goolwa Channel Dr

The coastline appears to be in similar position to 2009.

Some possible areas of accretion are observed in the middle area of the photograph.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 3

MEDIUM TERM CHANGES

Map SF2:3

Goolwa Channel

Changes 1949 to 2018

Event: 1949

Assessment

Sugars Ave

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

The dotted line represents the best indication of current shoreline position.

To provide context, current day roads and associated heights in Australian Height Datum (AHD) are depicted.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 3

MEDIUM TERM CHANGES

Map SF2:3

Goolwa Channel

Changes 1949 to 2018

Event: 2009

Assessment

Sugars Ave

The dotted line on the map indicates shoreline position in 1949.

Major erosion has occurred on the eastern (approx. 40-60m).

The eastern end of Sugars Beach shows signs of accretion.

See also Section 2 Geomorphology for discussion regarding movement of the Murray Mouth and resulting erosion and accretion in the Sugars Beach area.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

3. Coastal fabric - natural

Cell SF2: Section 3

MEDIUM TERM CHANGES

Map SF2:3

Goolwa Channel

Changes 1949 to 2018

Event: 2018

Assessment

Sugars Ave

The dotted line on the map indicates shoreline position in 1949.

Major erosion has occurred on the eastern (approx. 40-60m) since 1949, but nil erosion since 2009.

The accretion observed on the eastern end of Sugars Beach in 2009 (see previous page) has accelerated. See also Section 2 Geomorphology for discussion regarding movement of the Murray Mouth and resulting erosion and accretion in the Sugars Beach area.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4. Coastal fabric - modified

MACRO MODIFICATION – THE BARRAGES

This dynamic estuarine system was transformed by barrage construction in the 1930s, which reduced the tidal flow through the mouth by up to 90%. Increasing amounts of fresh water (75%) were diverted from the river, further aggravating the situation, so that by the mid-1950s lobes of the flood tidal delta were becoming more permanent, allowing colonisation by vegetation.

Surrounded by bare sand, a circular dune initially formed around a small patch of vegetation, which became the core of Bird Island. Wing-like dunes attached to the central dune developed, and their migration was blocked by samphire (salt marsh) vegetation, which colonised the northern half of the island.

A combination of salt marsh expansion and sand supply sourced from bare flood tidal shoals, delivered through the mouth, led to the progressive growth of sand dunes at the salt marsh margins.

Since the early 1970s, the mouth has migrated towards the northwest, changing the position of the bare, tidally derived sandflats, the source of dune sand. Consequently, successive dunes, now fixed in place by vegetation, display a varying clockwise orientation, coincident with the migration of the mouth and the growth of salt marsh. Bird Island did not exist prior to the installation of the barrages and demonstrates the dynamic nature of the region in which Sugars Beach is located.

There is no evidence that the Murray Mouth had permanently closed since initial survey, but in 1981 reduced flow closed the mouth for the first time.

After artificial opening of the mouth in 1981, major mouth migration was towards the west, but this trend was reversed following clearance by dredging when the mouth began migrating back towards the east in about 2005. This trend continues.

Macro modification

One major outcome from the installation of the barrages was the vastly reduced flow of water to the Murray Mouth due to upstream extractions.

This altered flow regime shifted the Murray Mouth west and changed the nature of the flood tidal area at the mouth. The location of the main channel of Goolwa Channel moved to the north at Sugars Beach and caused 40-60m of erosion. The eastern end of Sugars Beach has accreted.

Figure 30: Installation of the barrages reduced the flow of water to the Murray Mouth. The Murray Mouth migrated west in response, the western section of Sugars Beach eroded to the north and the eastern end of Sugars Beach has accreted south.

4. Coastal fabric - modified

URBAN SETTLEMENTS

Urban settlements and associated infrastructure such as roads and services modify the natural terrain by implementing hard surfaces and structures that act as 'hold points' in places that may be subject to erosion both now or in the future.

Owners of private land often protect their land holdings from erosion using a variety of means: rock, building rubble, and earthen embankments. These works are called ad hoc protection works because usually there was no official assessment process prior to these being installed.

Zoning: The main settlement area west of Murray Mouth Road is zoned **Coastal Settlement** (Zone Map Alex 25). The Principles of Development Control for the Coastal Settlement zone ensure that no increases of density are possible.

Settlement on Cooinda Road is zoned **Primary Production** (Zone Map Alex 25).

In both of these areas further subdivision of land (including leasehold boundaries) is non-complying, and construction of dwellings is limited to replacing existing dwellings at no more than one per existing allotment (leasehold or freehold). See Alexandrina Council Development Plan (130-134).

Settlement on Sugars Ave, east of the public carpark, is zoned **Conservation Zone** (Zone Map Alex 25). Land division is restricted so that no new allotments are able to be created (Development Control 22), and no new dwellings are permitted (Development Control 2).

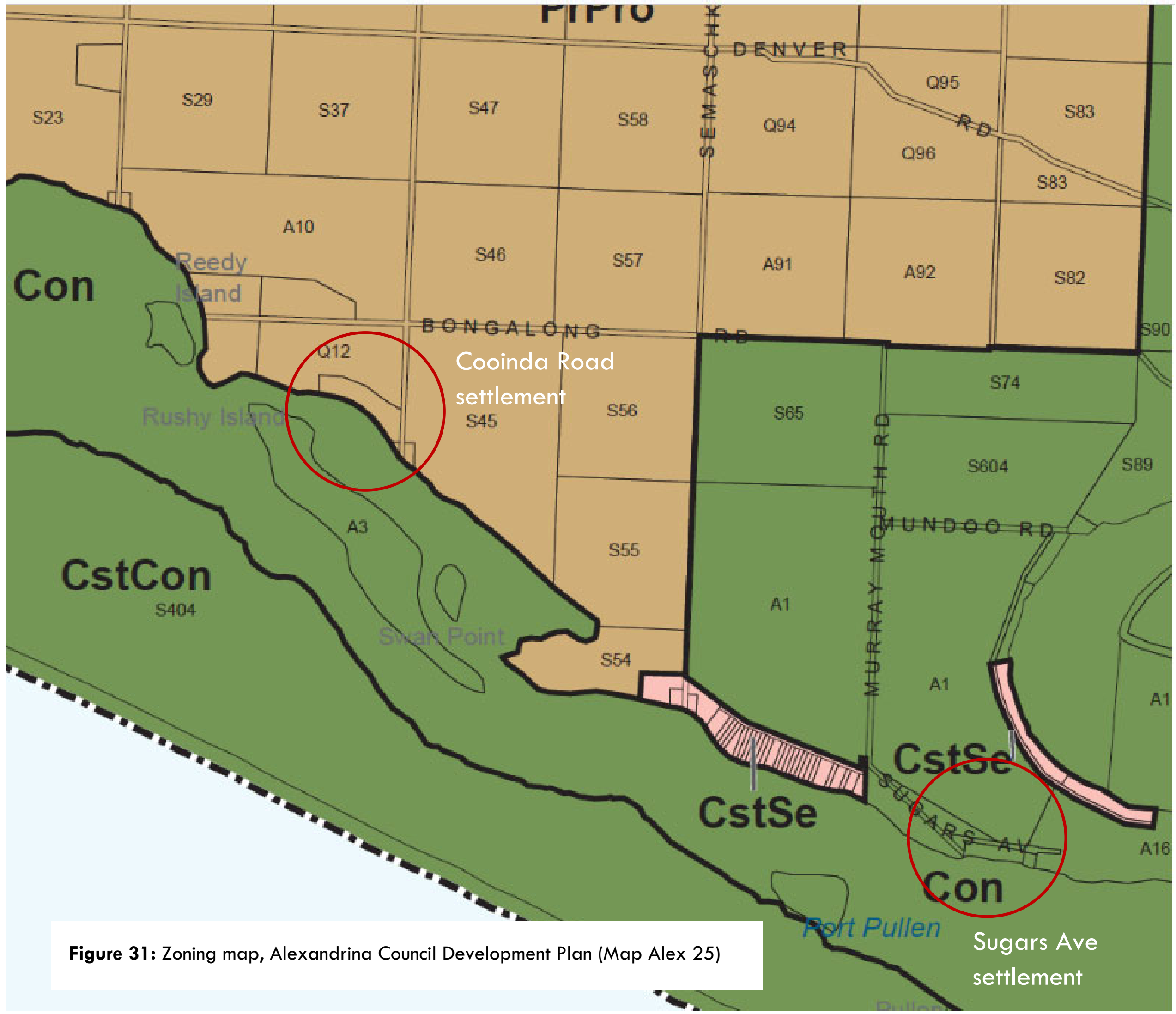
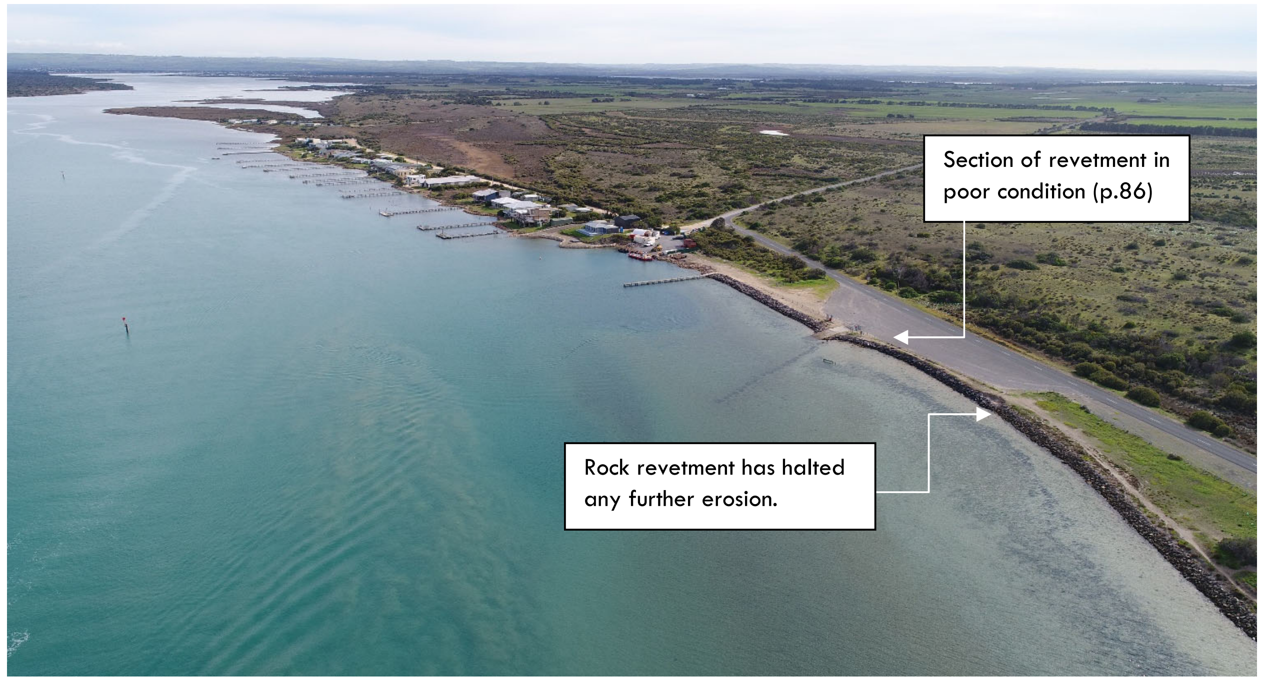


Figure 31: Zoning map, Alexandrina Council Development Plan (Map Alex 25)

4. Coastal fabric - modified

MICRO MODIFICATION – PROTECTION



Rock revetment protection has been progressively installed to the Sugars Beach carpark area that has halted any further erosion.

Magryn Engineering inspected Sugars Beach in February 2019 and noted that the rock revetment to the east of the boat ramp is in poor condition (see p. 86)

Erosion has continued at the eastern end of the rock revetment. However, this location is also the beginning of the portion of coast that is accreting to the south. It is yet to be seen whether the erosion continues at this point or whether further accretion occurs (Figure 33).

Private protection works are varied in type and include:

- Rock (of varying types)
- Building rubble (bricks etc)
- Earthen mounds
- Wooden retaining walls
- Nil protection

Figure 32 : Rock revetment has halted erosion to Sugars Beach area.

Figure 33: Erosion has continued at the eastern end of the rock revetment.

Figure 34: Examples of private protection works

4. Coastal fabric - modified

Magryn Engineering report (February 2019)

The seawall adjacent the eastern side of the boat ramp is generally ineffective and in poor condition. The following was noted:

- Erosion at the top of the seawall generally, with some sections severely eroded. The wall appears to have been overtopped.
- The rock armour has been stacked poorly and too steeply in some sections. There is only one layer of top primary armour generally, allowing smaller secondary armour to displace.
- The primary rock armour appears to be undersized (nominally 400mm diameter).
- Many rocks are scattered along the beach, presumably washed away from the seawall.

The older seawall east of the boat ramp carpark is generally in reasonable condition and has not been overtopped. The following was noted:

- The rock armour is a mixture of large and small rocks (400-500mm diameter primary armour generally). There appears to be only one layer of primary armour.
- Many rocks are scattered along the beach, presumably washed away from the seawall.
- Southern end of the seawall has suffered erosion behind.

Figure 10- Existing seawall adjacent the eastern side of the boat ramp.

Figure 12- Erosion at the back of the existing seawall (eastern side of the boat ramp).

Figure 13- Older seawall east of the boat ramp carpark.

Figure 14- Erosion behind eastern end of the seawall.

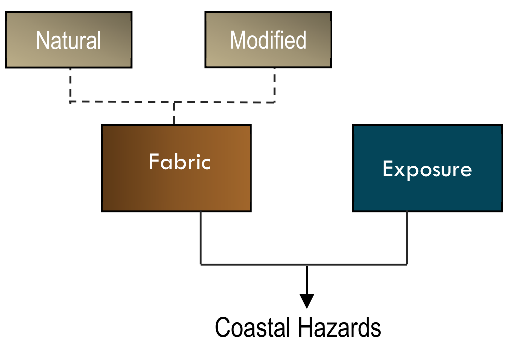
Figure 10,12,13 and 14 from report by Magryn Engineering Consultants (February 2019)

COASTAL FABRIC

Summary and conclusions

Progress report:

So far, we have completed a review of settlement history and an assessment of the 'geology' or 'fabric' of the cell. It is important to note that this analysis only includes the northern bank of Goolwa Channel.



Summary:

<u>Geological layout:</u>

Much of the southern half of Hindmarsh Island consists of an extensive sandflat ranging up to 2 m above present sea level. The geological description is, St Kilda Formation: calcareous, fossiliferous sand and mud of intertidal sand flats, beaches and tidal marshes.

The settlement on the western end of the project area (Cooinda Road) is underpinned by quaternary rocks which may indicate a more stable geological setting.

<u>Human intervention</u>

Macro intervention: The barrages installed in the 1930s have reduced flows to the Mouth by up to 90% and permanently changed the ecology. The Murray Mouth migrated west, dunes formed, and vegetation was established.

Significant erosion occurred in what is now the carpark area of Sugars Beach and to areas to the west (40-60m erosion since 1949)

Accretion has occurred to the east of Sugars Beach carpark area and this trend appears to be continuing.

Micro interventions: Rock revetment has been installed to the Sugars Beach carpark area. A portion of rock revetment east of the boat ramp is in poor condition. Erosion is continuing to occur behind the rock revetment on the eastern end (of the revetment).

Individual landowners have installed protection of varying types and quality.

<u>Analysis</u>

Comparative photographic analysis demonstrated that the riverbank in areas west of Sugars Beach on the Goolwa Channel have been largely stable. This may be a more stable region that is underpinned by quaternary rocks, or because the main river channel has been in the same position since 1949. There is some evidence of minor erosion as well as areas of minor accretion.

In the Sugars Beach region, the riverbank has eroded 40-60m to the north (carpark section and areas west) and significant amount of accretion has occurred to the south in front of the settlement of houses to the east of the carpark (in the vicinity of the lookout). This erosion and accretion is likely to be attributed to the change in location of the river mouth (since 1949) and the shifting of the main river channel to the north.

The northern side of Goolwa Channel has erodibility rating:

Highly erodible (4)

Goolwa Channel

5. CURRENT EXPOSURE

Evaluating how actions of sea currently impact the coastal fabric by:

- Applying current 1 in 100 sea-flood risk scenario
- Analysing routine high-water events (annual).

Two main contexts are evaluated:

- Access and Egress (macro view)
- Impacts to assets (private and public)

5. Current exposure – storm surge

Storm Surge

Cell SF1-2

Goolwa Channel

Current risk:

1 in 100-year event risk

Assessment

Access and Egress

Coast Protection Board has adopted 1.55m AHD for its current 1 in 100 ARI risk level and 0.10m wave setup.

The modelling indicates that water would flow through vacant lots 17-21 and inundate **Goolwa Channel Drive** at depths up to 0.40m. The internal access road to the **Mills Road** settlement would be inundated at depths up to 0.40m. It is possible that water could flow through the dredging base and flood **Sugars Beach Road** but at very low depth (0.1m)

All main access ways remain open in the current 1 in 100 event. Minor flooding would prevent access within settlement Mills Road and Goolwa Channel drive.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Current exposure – annual high water

Annual high water

Cell SF1-2

Goolwa Channel

Current risk:

Annual high water

Assessment

Access and Egress

Using tidal data from the Goolwa barrage over the last five years, on average the highest annual tidal event is 1.20m AHD.

By way of contrast, the CPB 1 in 10 year event is assigned as 1.35m AHD (see Hindmarsh Island Tidal Study, 1988).

The current annual tidal event does not impact access and egress issues for the settlements.

Note: Flooding of the internal access at Mills Street settlement would be very close to overtopping the road.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Current exposure – storm surge

Storm surge

Cell SF1-2

Goolwa Channel

Current risk:

1 in 100-year event risk

Assessment

Flooding of private property

The current 1 in 100-year ARI event risk set by Coast Protection Board for Goolwa Channel is:

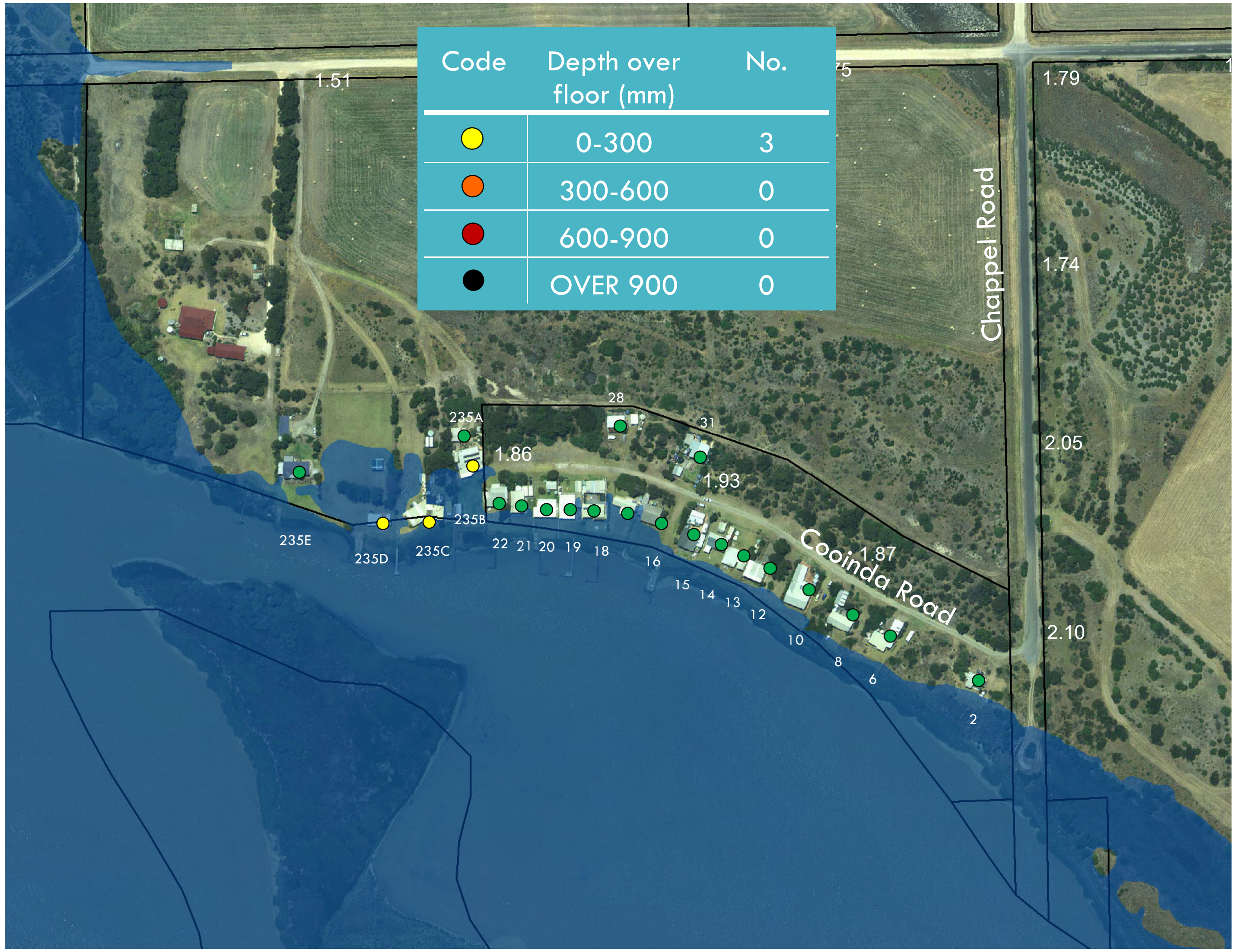
Storm surge 1.55m AHD
Wave setup 0.10
Total risk 1.65m AHD

If this event occurred:

- 3 houses would have water up to 300mm over floor level

This is minor flooding on the western end with water over floors from 0.04m to 0.10m.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	3
Orange	300-600	0
Red	600-900	0
Black	OVER 900	0

5. Current exposure – storm surge

Storm surge

Cell SF1-2

Goolwa Channel

Current risk:

1 in 100-year event risk

Assessment

Flooding of private property

The current 1 in 100-year ARI event risk set by Coast Protection Board for Goolwa Channel is:

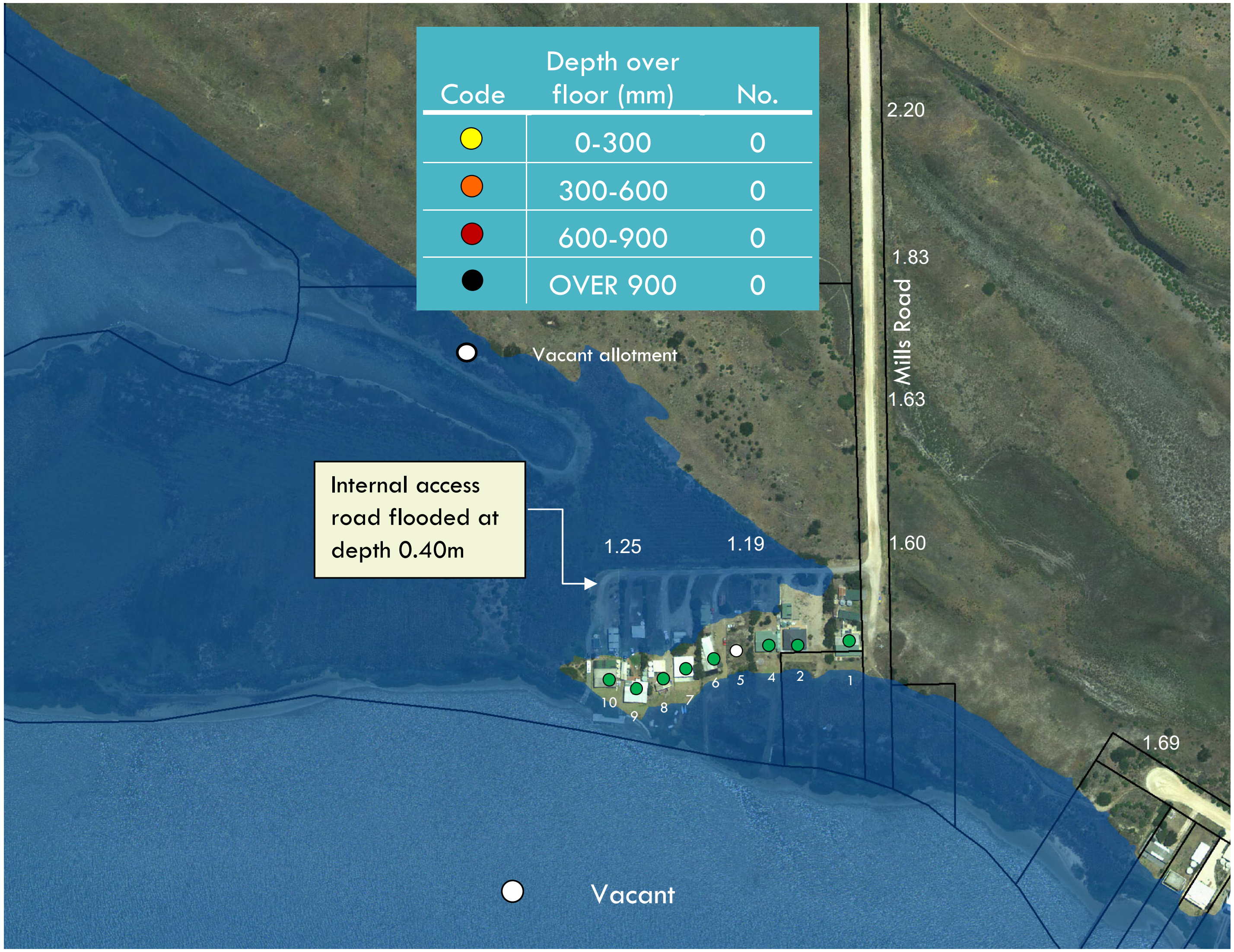
Storm surge 1.55m AHD

Wave setup <u>0.10</u>

Total risk 1.65m AHD

The modelling shows that if this event occurred that no houses would have water over floor levels.

Properties and sheds would be flooded as indicated.



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Current exposure – storm surge

Storm surge

Cell SF1-2

Goolwa Channel

Current risk:

1 in 100-year event risk

Flooding of private property

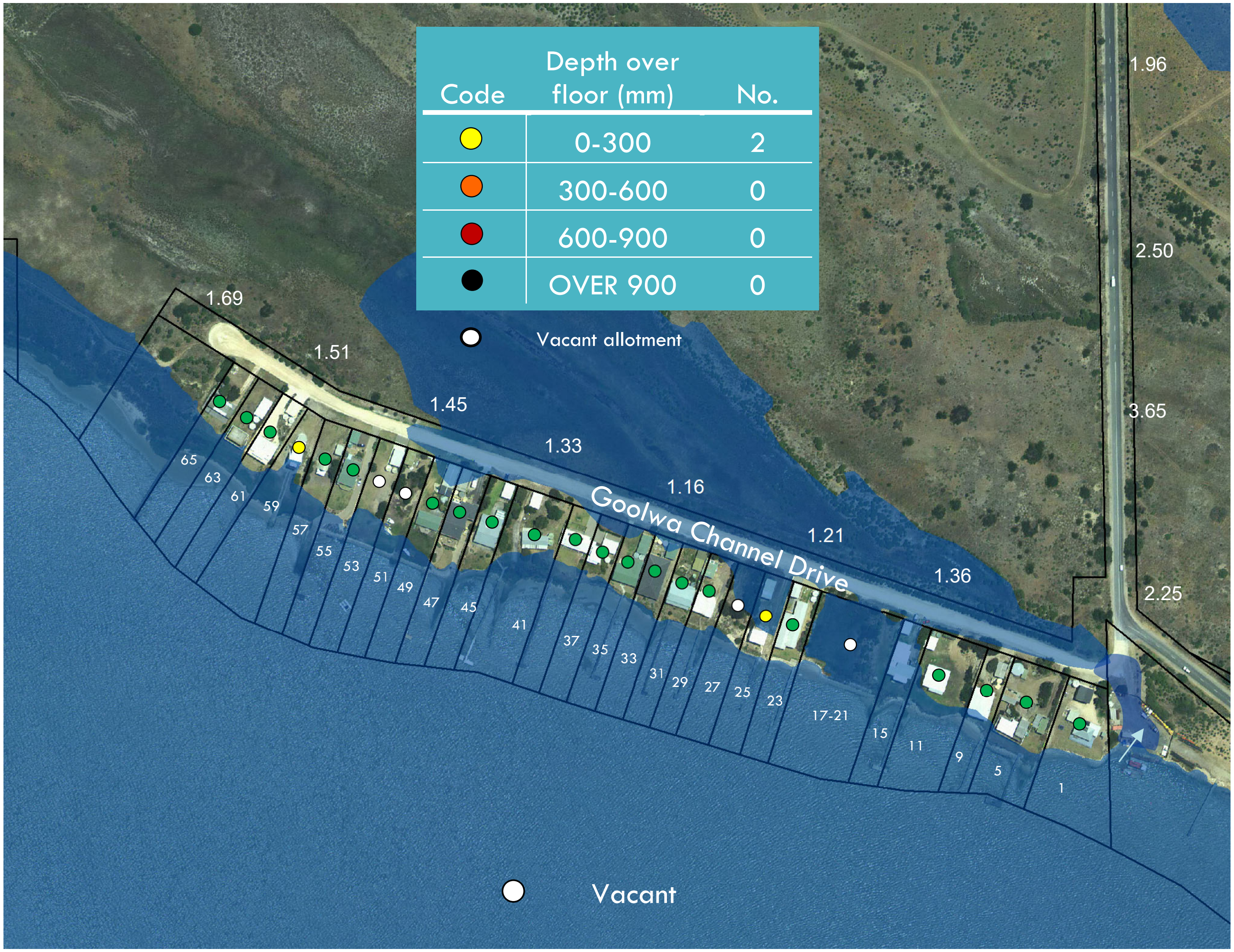
The current 1 in 100-year event risk set by Coast Protection Board for Goolwa Channel is:

Storm surge 1.55m AHD
Wave setup 0.10
Total risk 1.65m AHD

The modelling shows that if this event occurred that 2 houses would have water over floor levels.

Flooding through No 17-21 would cause flooding from the rear of allotments at no 25and 27 and elsewhere as shown. It is possible that flooding of Sugars Beach Drive can occur through the property at the end of Murray Mouth Road.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



5. Current exposure – storm surge

Storm surge

Cell SF1-2

Goolwa Channel

Current risk:

1 in 100-year event risk

Assessment

Flooding of private property

The current 1 in 100-year event risk set by Coast Protection Board for Goolwa Channel is:

Storm surge 1.55m AHD

Wave setup <u>0.10</u>

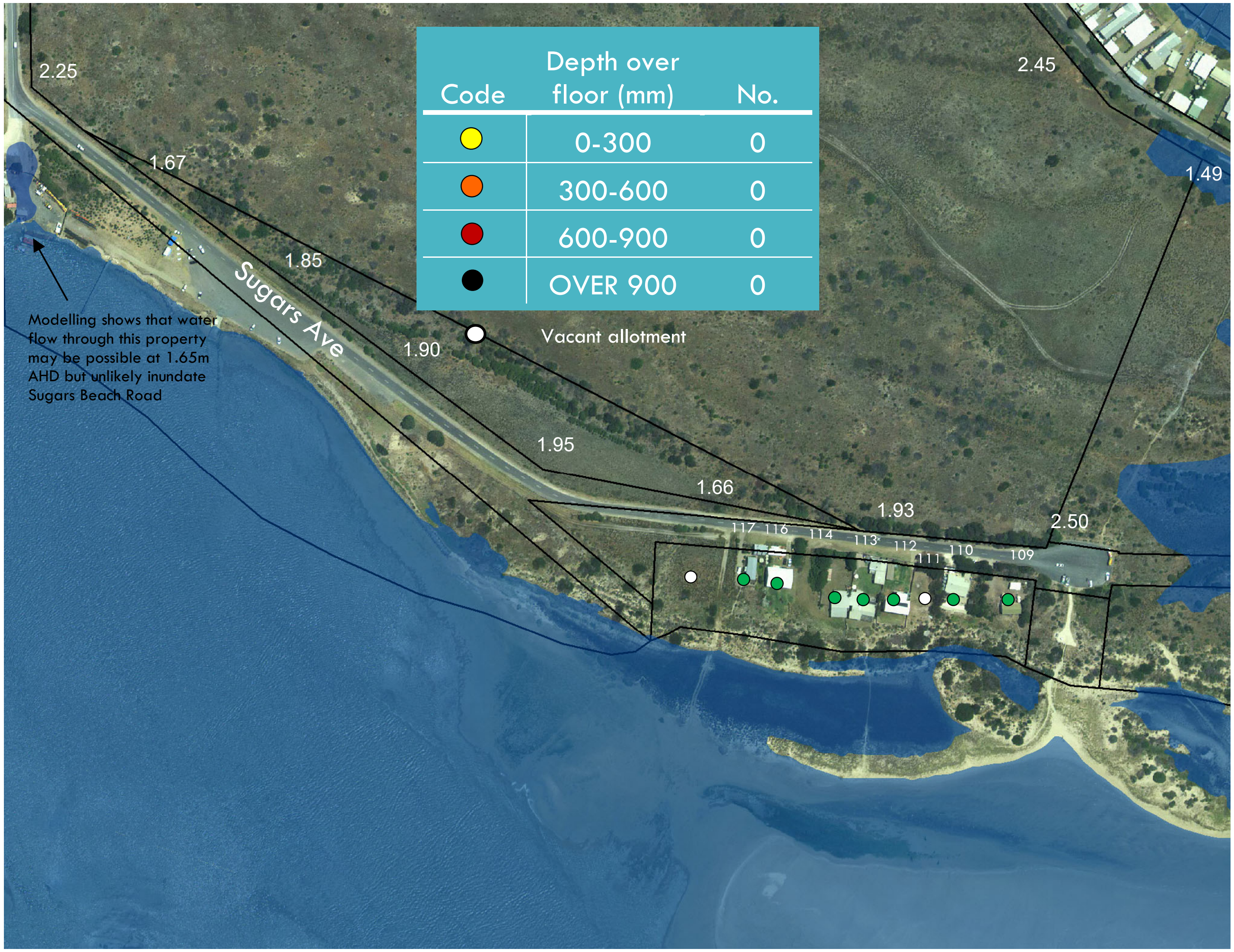
Total risk 1.65m AHD

The modelling shows that Sugars Ave settlement area is not inundated for the current 1 and 100-year risk flood scenario. However, further analysis is required for the property at the end of Murray Mouth Drive (modelling is borderline).

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	0
Orange	300-600	0
Red	600-900	0
Black	OVER 900	0

5. Current exposure – erosion

Erosion

Cell SF1-2

Goolwa Channel

Current risk:

Erosion

Assessment

Prevailing winds that accompany storm surge conditions blow from the West to the South, and therefore blow onshore to the northern side of Goolwa Channel.

This study has identified areas of significant erosion at Sugars Beach carpark area and along Goolwa Channel Road, and significant accretion east of the Sugars Beach carpark (in vicinity of lookout).

In a location that is rated as 'highly erodible, 4), this area will remain volatile and susceptible to erosion.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

Prevailing winds are from the west to the south which blow onshore to Goolwa settlements

Figure 35 : Prevailing winds are from West to South blowing onshore to settlements on northern side of Goolwa Channel.

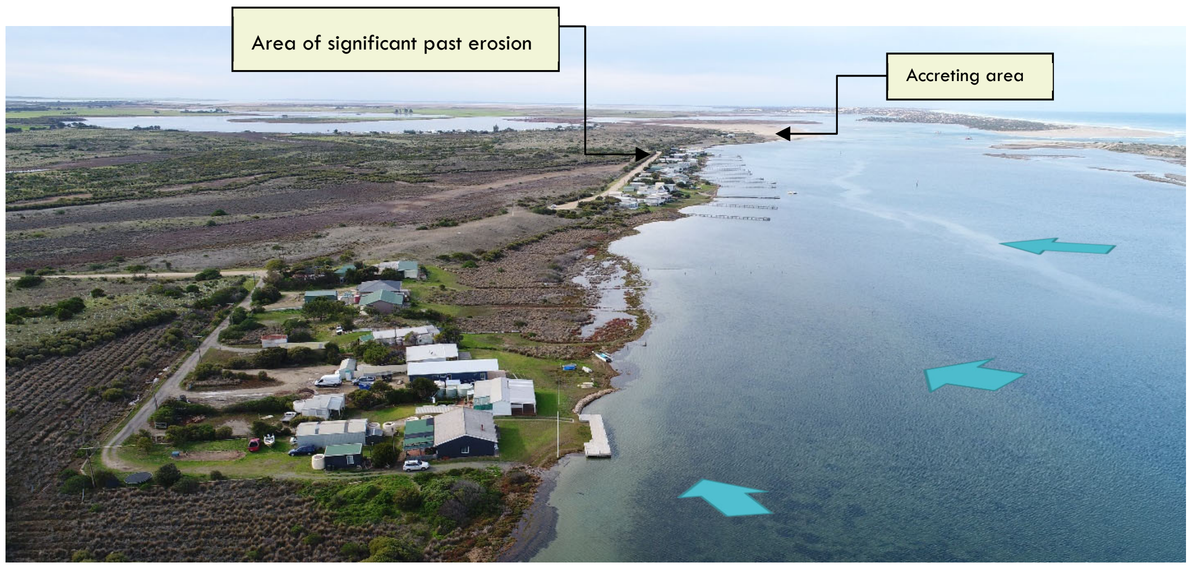


Figure 36: Since 1949 significant erosion has occurred in Sugars Beach area. In last decade or so, the area east of Sugars Beach carpark has accreted.

5. Current exposure – erosion

Erosion

Cell SF1-2

Goolwa Channel

Current risk:

Erosion

Assessment

In a location that is rated as 'highly erodible, 4), this area will remain volatile and susceptible to erosion.

However, as illustrated in photographs on this page, significant portions of the coastline have been protected with rock revetment. The quality and effectiveness of protection within private properties vary greatly.

One public area that is likely to require at least interim protection is located at the eastern end of the rock protection to the carpark (see inset picture)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

The area to the east of the existing rock revetment has been accreting over the last decade. If this trend continues then this may counter act the erosion that is occurring at the end of the rock revetment. Interim protection is recommended (see adaptation proposals at the end of this report).

Figure 37 : Rock revetment protects much carpark area (top left).

Figure 38: The area to east of rock revetment is accreting. Interim protection is likely to be required at the end of the rock revetment.

Figure 39: Private land users have implemented rock protection of varying quality. The allotments with little or no protection are likely to experience ongoing erosion (left).

Goolwa Channel

6. FUTURE EXPOSURE

Evaluating how future actions of sea may impact the coastal fabric by:

- Reviewing 1 in 100 scenarios for 2050 and 2100
- Reviewing annual high tide scenarios for 2050 and 2100
- Analysing erosion risk to 2100

Two main contexts are evaluated:

- Access and Egress (macro view)
- Impacts to assets (private and public)

6. Future exposure – storm surge (2050)

Storm surge

Cell SF1-2

Goolwa Channel

2050 risk:

1 in 100-year event risk

Access and Egress

The 1 in 100-year event risk set by Coast Protection Board for 2050:

Storm surge	1.55m AHD.
Wave set-up	0.10m
Risk	1.65m AHD
Plus 0.3m SLR	0.30m
Total risk	1.95m AHD

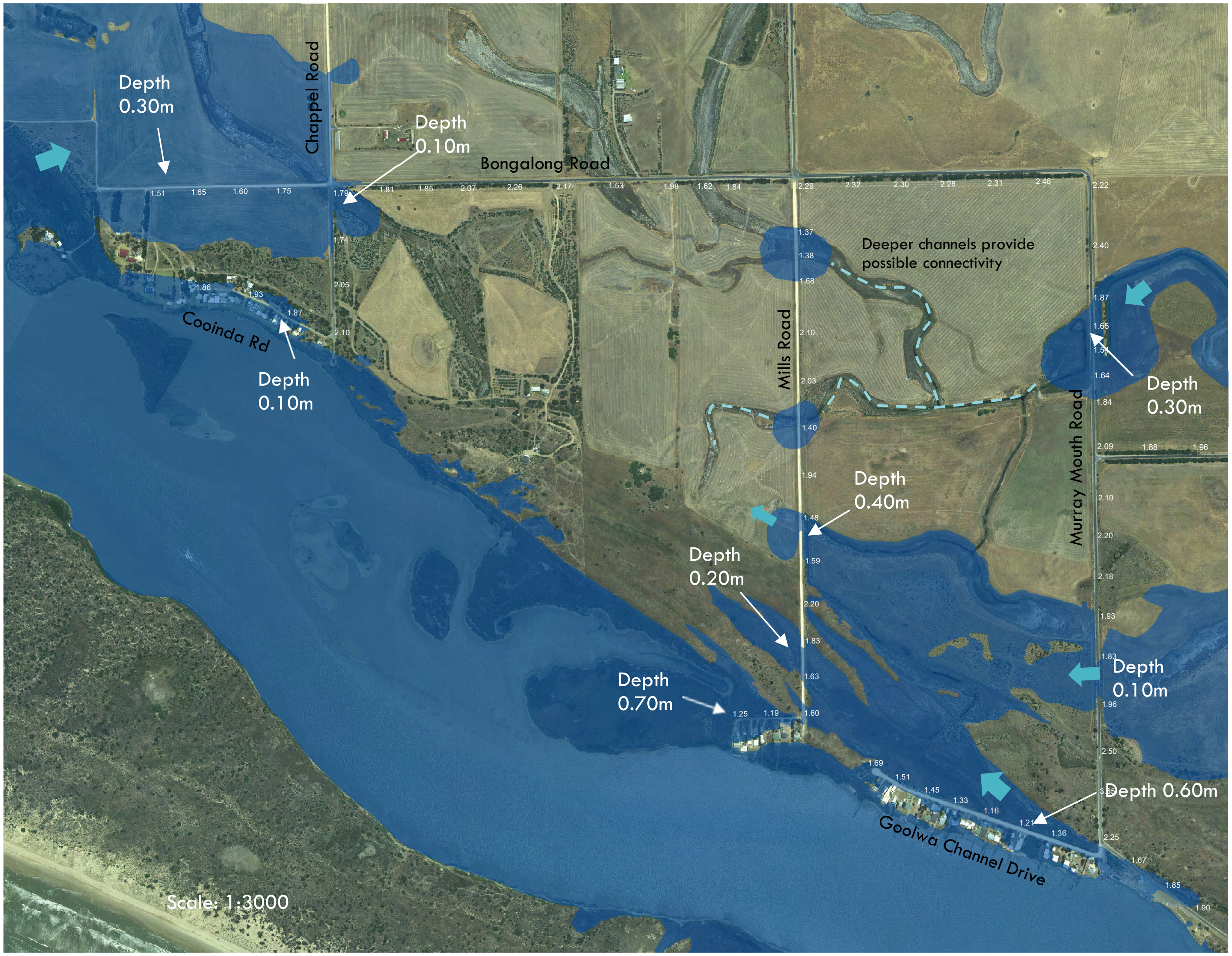
Modelling at shoreline is 1.95m, modelling inland is 1.85m AHD.

Access to Cooinda settlement is likely to be available via Chappel Road.

Access and Egress is unlikely to be available to vehicles along Mills Road and Murray Mouth Road.

Internal access would be impassable within Mills Street and Goolwa Channel Drive settlements.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



6. Future exposure – storm surge (2100)

Storm surge

Cell SF1-2

Goolwa Channel

2100: 1 in 100-year risk

Assessment

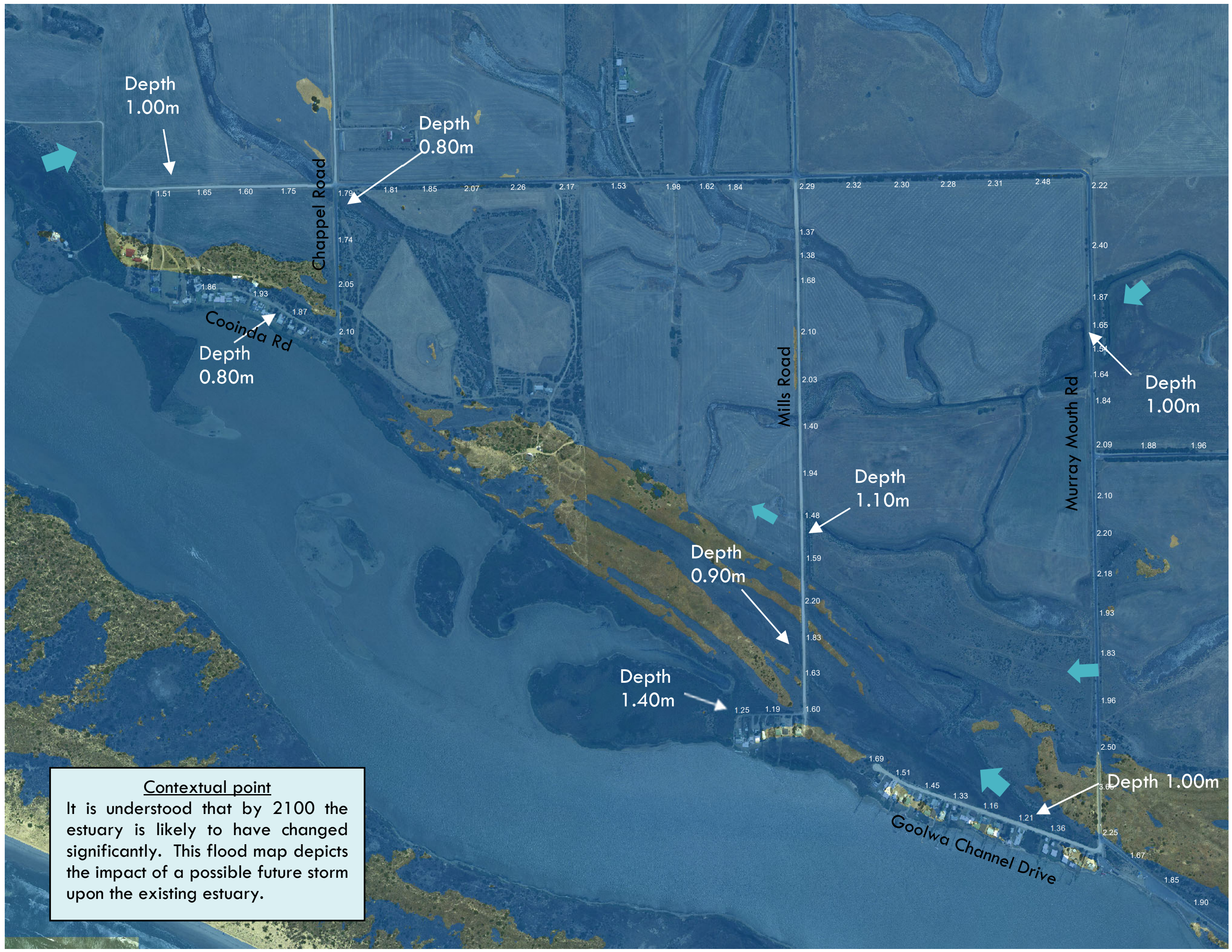
Access and Egress

The 1 in 100-year event risk set by Coast Protection Board for 2100 is:

Storm surge	1.55m AHD.
Wave set-up	0.10m
Risk	1.65m AHD
Plus 0.3m SLR	1.00m
Total risk	2.65m AHD

Modelling at shoreline is 2.65m, modelling inland is 2.55m AHD.

Access and Egress would not be possible into the settlements, or within the settlements.



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Future exposure – annual high water (2050)

Annual high-water

Cell SF1-2

Goolwa Channel

2050 risk:

Annual high-water risk

Access and Egress

On average, over the last five years the highest annual tide has been 1.20m AHD. By way of contrast, CPB 1 in 10 risk event is 1.35m AHD.

0.3m sea level rise has been added to project likely tidal regime in 2050

High water:	1.20m AHD
Wave setup:	0.10
	1.30m AHD
SLR	0.30m
Total risk	1.60m AHD

All main access ways remain open to vehicles. Internal access to Mills Street and Goolwa Channel Drive would be impassable for many vehicles.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Future exposure – annual high water (2100)

Annual high water

Cell SF1-2

Goolwa Channel

2100 risk:

Annual high-water risk

Access and Egress

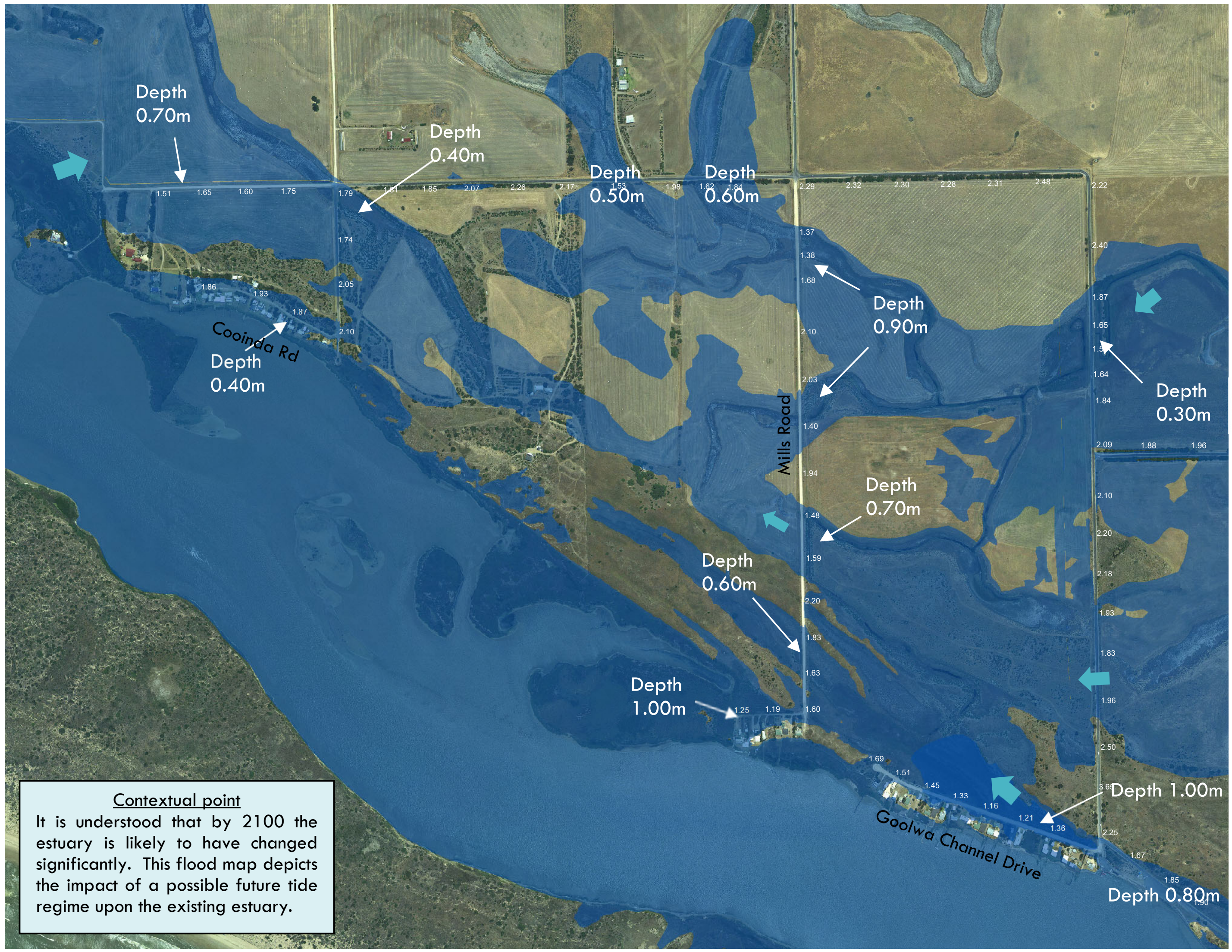
On average, over the last five years the highest annual tide has been 1.20m AHD. By way of contrast, CPB 1 in 10 risk event is 1.35m AHD.

1.0m sea level rise has been added to project likely tidal regime in 2100

High water:	1.20m AHD
Wave setup:	0.10
	1.30m AHD
SLR	1.00m
Total risk	2.30m AHD

Access and egress will not be possible to any of the Goolwa Channel settlements.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Contextual point
It is understood that by 2100 the estuary is likely to have changed significantly. This flood map depicts the impact of a possible future tide regime upon the existing estuary.

6. Future exposure – storm surge (2050)

Storm surge

Cell SF1-2

Goolwa Channel

2050 risk:

1 in 100-year event risk

Flooding of private property

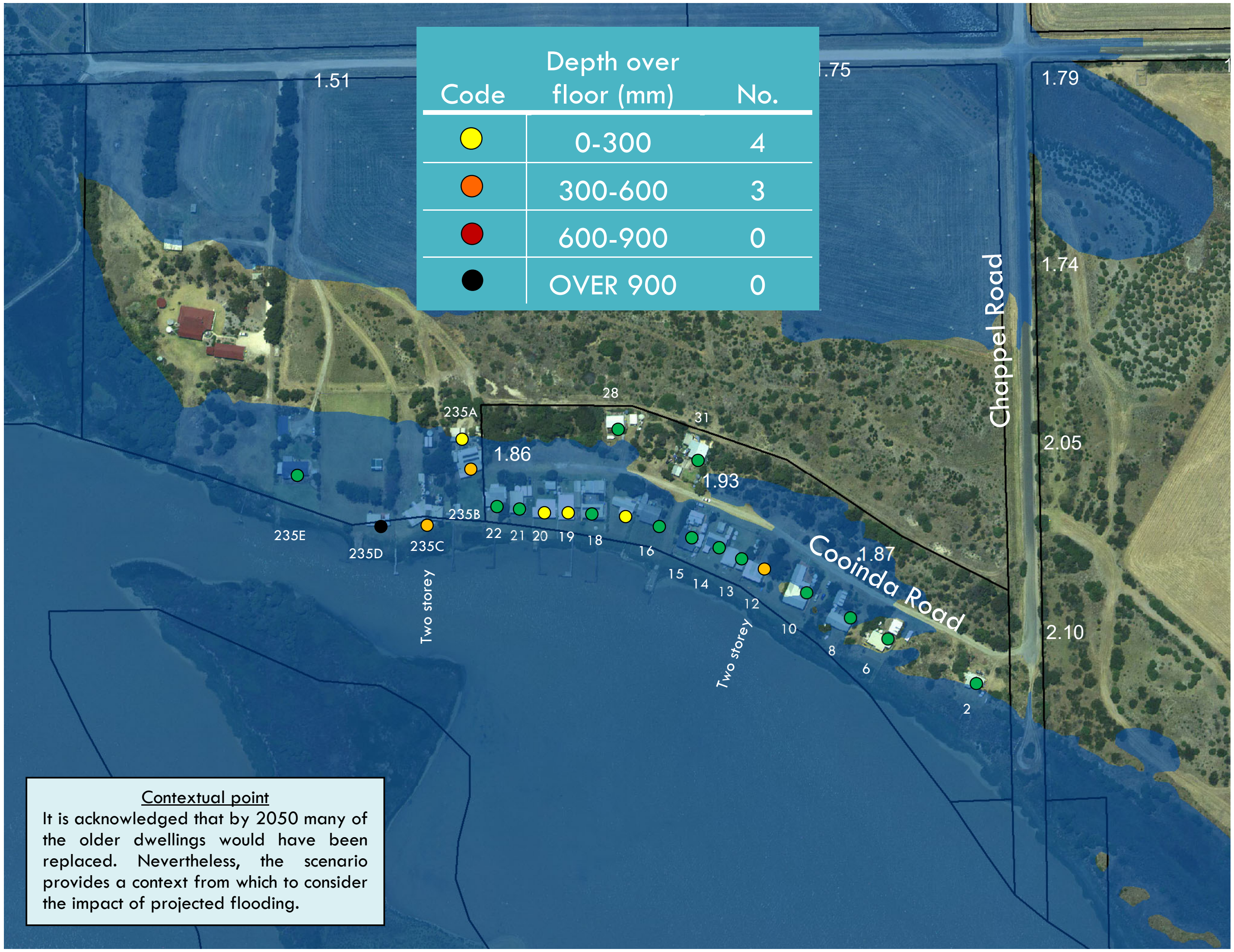
The 2050 risk 1 in 100 ARI storm event for Goolwa Channel is:

Storm surge 1.55m AHD
Wave setup 0.10
1.65m AHD
SLR 0.30m
Total risk 1.95

If this event occurred, then:

- 4 houses would have water up to 300 over floor level
- 3 houses would have water level 300 to 600.

All houses with water modelled over floor levels were constructed prior to 1975.



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Future exposure – storm surge (2100)

Storm surge

Cell SF1-2

Goolwa Channel

2100 risk:

1 in 100-year event risk

Flooding of private property

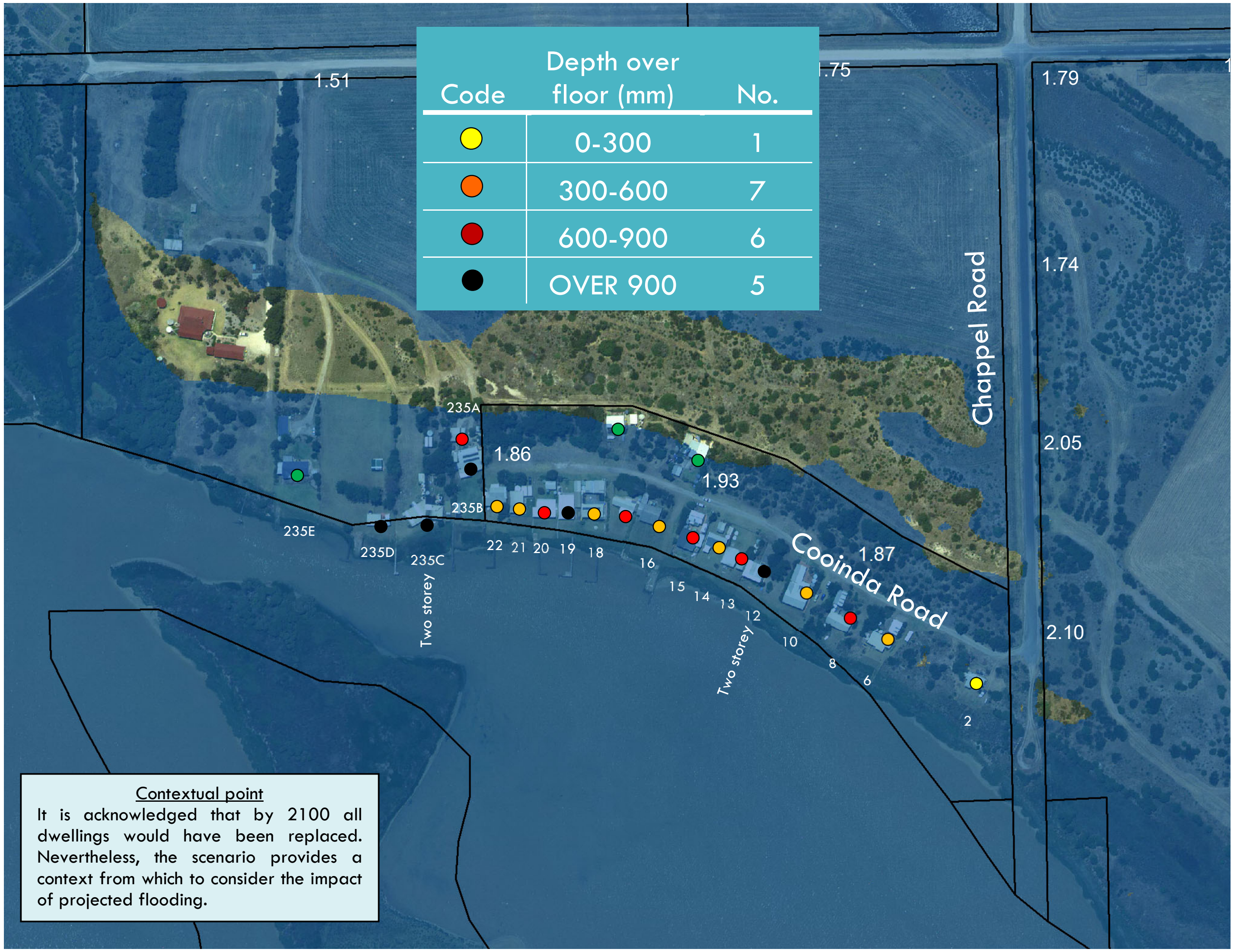
The 1 in 100-year event risk set by Coast Protection Board for 2100 is:

Storm surge	1.55m AHD
Wave setup	0.10
	1.65m AHD
SLR	1.00m
Total risk	2.65

If this event occurred then:

- 1 houses would have water up to 300mm over floor level
- 7 houses would have water level 300mm to 600mm.
- 6 houses would have water between 600mm and 900mm.
- 5 houses over 900mm

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Contextual point

It is acknowledged that by 2100 all dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – annual high water (2100)

Annual high water

Cell SF1-2

Goolwa Channel

2100 risk:

Annual high-water risk

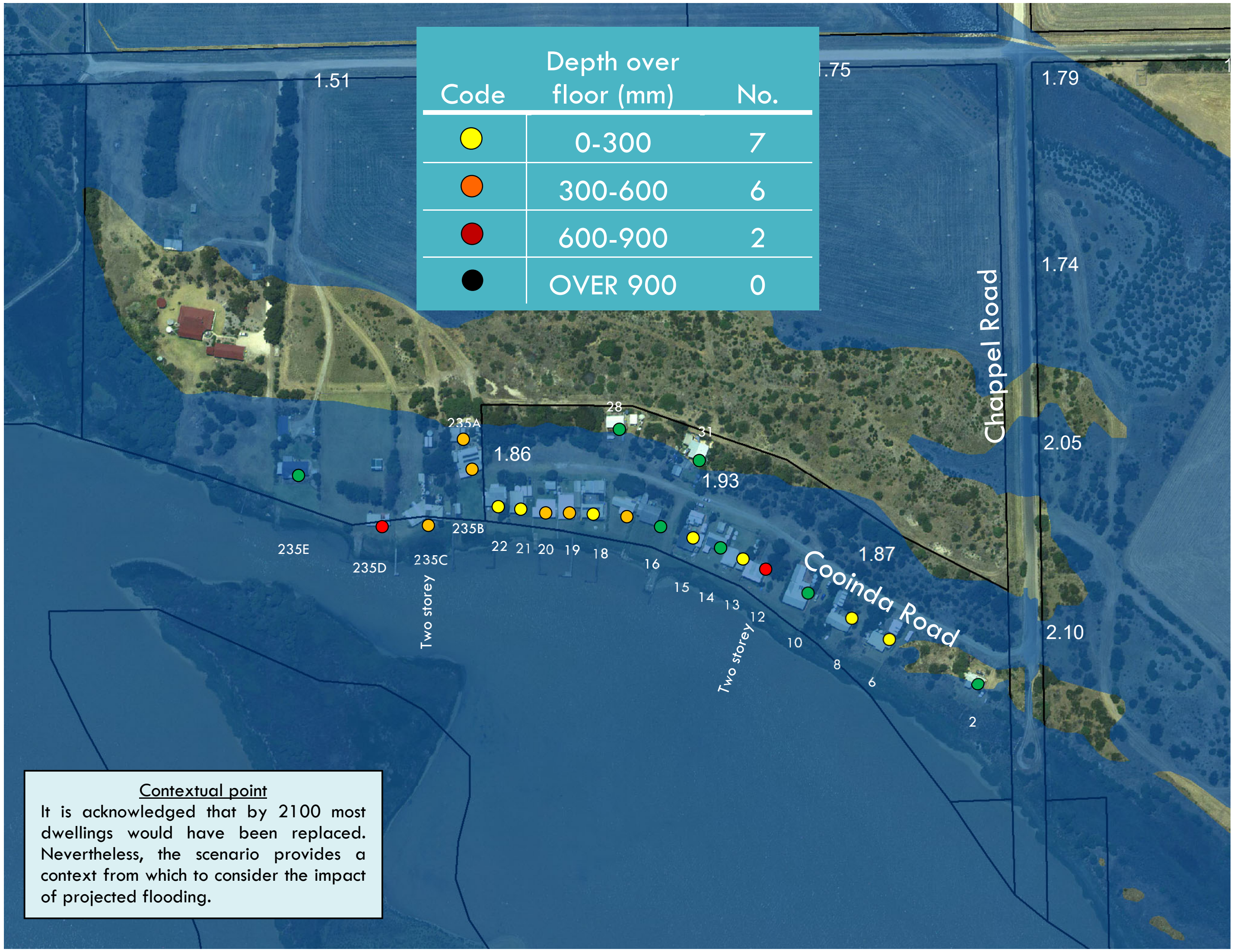
On average, over the last five years the highest annual tide has been 1.20m AHD. By way of contrast, CPB 1 in 10 risk event is 1.35m AHD. 1.0m sea level rise has been added to project likely tidal regime in 2100

High water:	1.20m AHD
Wave setup:	0.10
	1.30m AHD
SLR	1.00m
Total risk	2.30m AHD

If this event occurred then:

- 7 houses would have water up to 300mm over floor level
- 6 houses would have water level 300mm to 600mm.
- 2 houses would have water between 600mm and 900mm.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	7
Orange	300-600	6
Red	600-900	2
Black	OVER 900	0

Contextual point

It is acknowledged that by 2100 most dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – storm surge (2050)

Storm surge

Cell SF1-2

Goolwa Channel

2050 risk:

1 in 100-year risk

Assessment

Flooding of private property

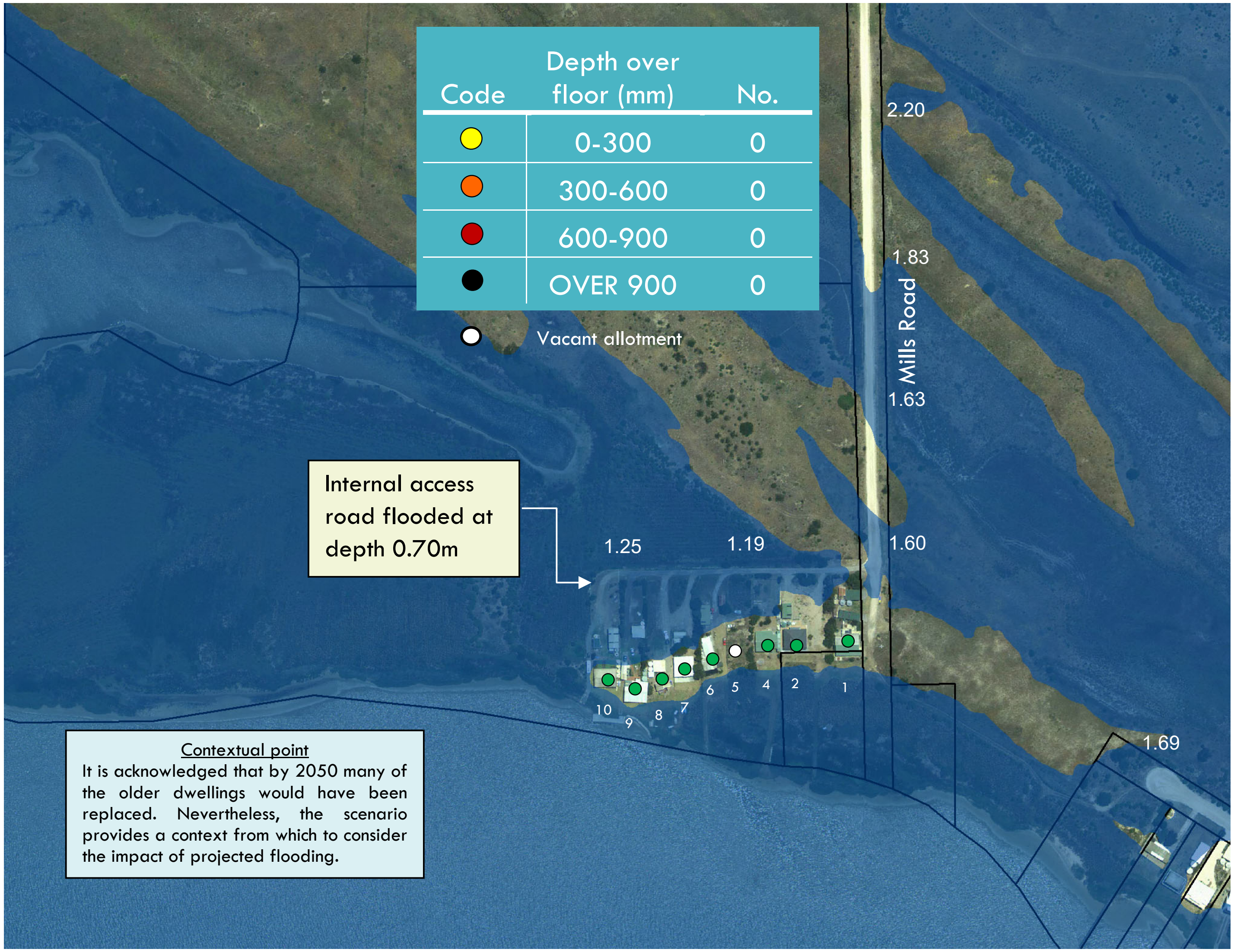
The 2050 risk 1 in 100 ARI storm event for Goolwa Channel is:

Storm surge 1.55m AHD
Wave setup 0.10
1.65m AHD
SLR 0.30m
Total risk 1.95

The modelling shows that if this event occurred that no houses would have water over floor levels.

Properties and sheds would be flooded as indicated.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	0
Orange	300-600	0
Red	600-900	0
Black	OVER 900	0

Contextual point
It is acknowledged that by 2050 many of the older dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – storm surge (2100)

Storm surge

Cell SF1-2

Goolwa Channel

2100 risk:

1 in 100-year event risk

Assessment

Flooding of private property

The 1 in 100-year ARI event risk set by Coast Protection Board for 2100:

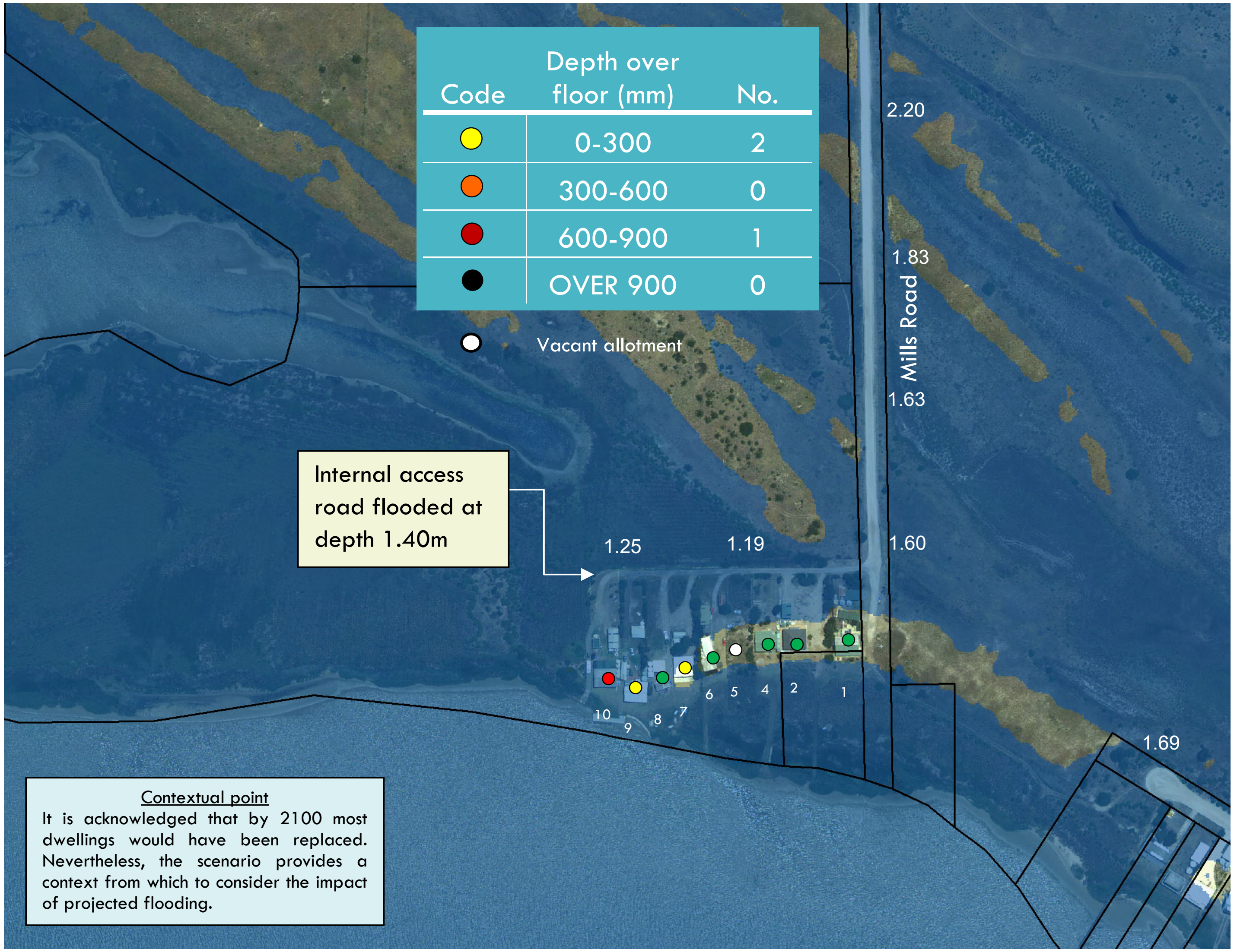
Storm surge	1.55m AHD
Wave setup	0.10
	1.65m AHD
SLR	1.00m
Total risk	2.65

If this event occurred then:

- 2 houses would have water up to 300mm over floor level
- 0 houses would have water level 300mm to 600mm.
- 1 houses would have water between 600mm and 900mm.

Properties and sheds would be flooded as indicated.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



6. Future exposure – annual high water (2100)

Annual high water

Cell SF1-2

Goolwa Channel

2100 risk:

Annual high-water

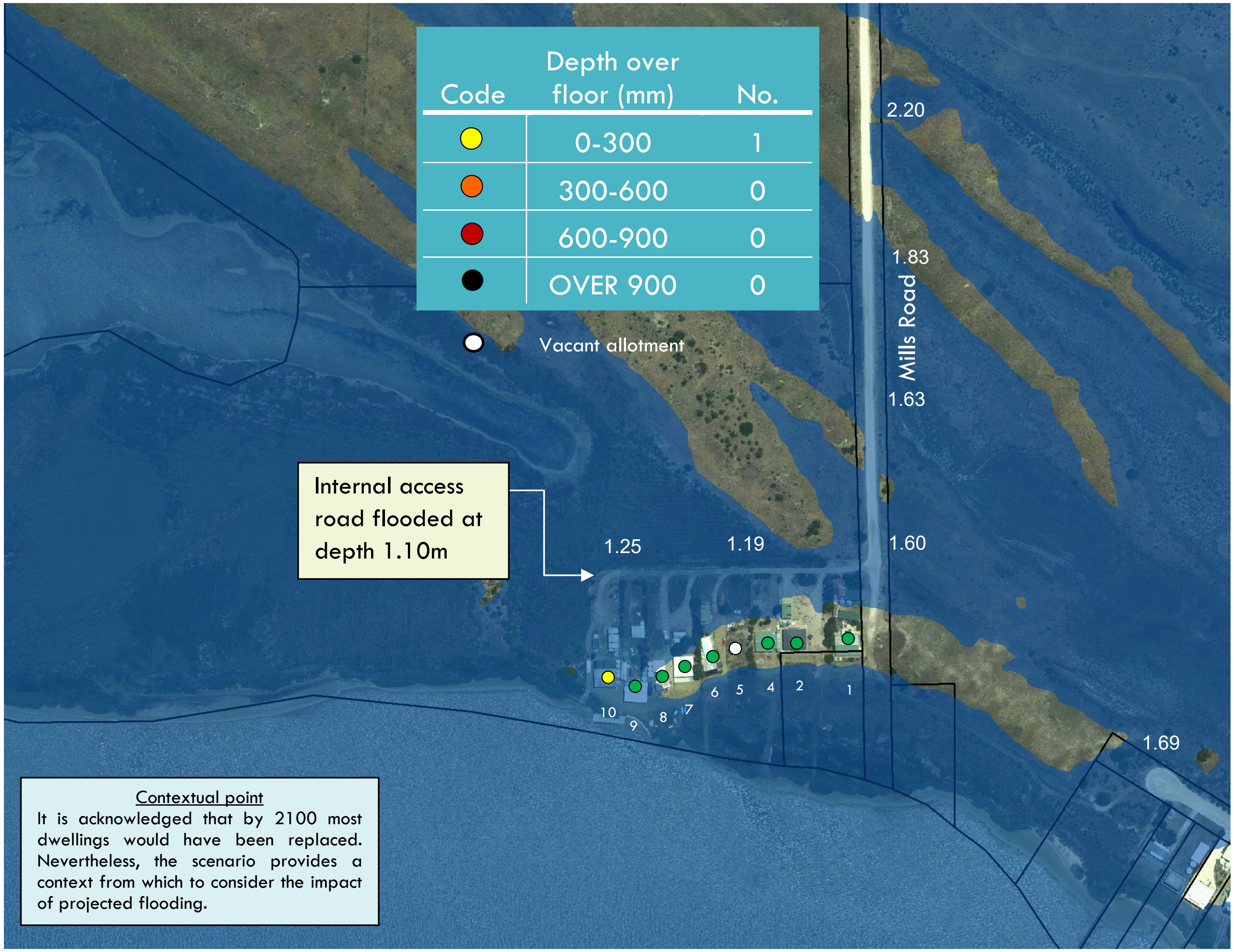
Assessment

Flooding of private property

If the 2100 annual high tide occurred at 2.30m AHD (including wave setup), then:

- 1 houses would have water up to 300 over floor level

Properties and sheds would be flooded as indicated.



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Future exposure – storm surge (2050)

Storm surge

Cell SF1-2
Goolwa Channel
2050 risk:
1 in 100-year risk

Flooding of private property

The 2050 risk 1 in 100 ARI storm event for Goolwa Channel is:

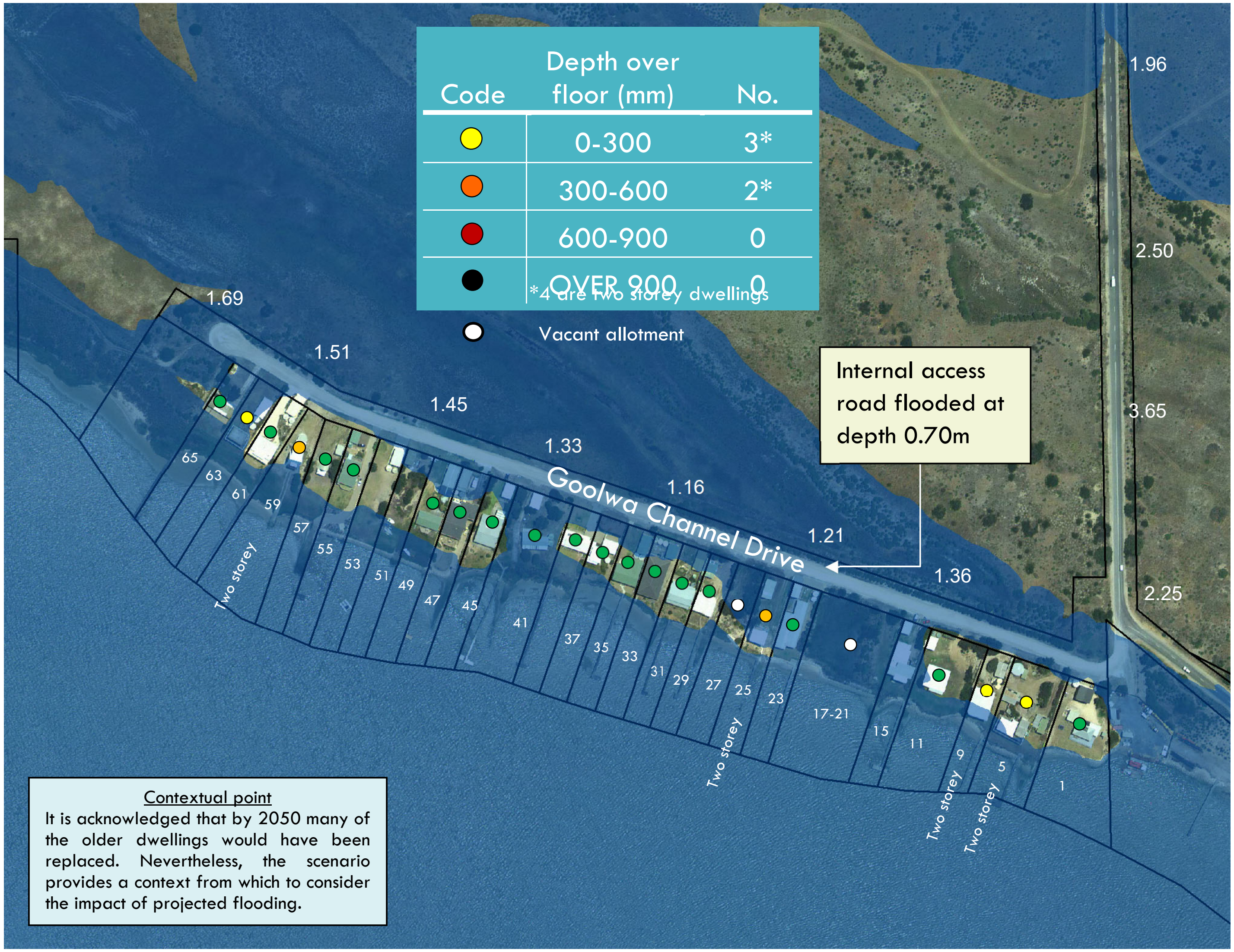
Storm surge	1.55m AHD
Wave setup	0.10
	1.65m AHD
SLR	0.30m
Total risk	1.95

If this event occurred, then:

- 3 houses would have water up to 300 over floor level
- 2 houses would have water level 300 to 600.

4 of these are two storey. All but number 9 (2003) were constructed prior to 1990.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Contextual point
It is acknowledged that by 2050 many of the older dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – storm surge (2100)

Storm surge

Cell SF1-2

Goolwa Channel

2100 risk:

1 in 100-year event risk

Assessment

Flooding of private property

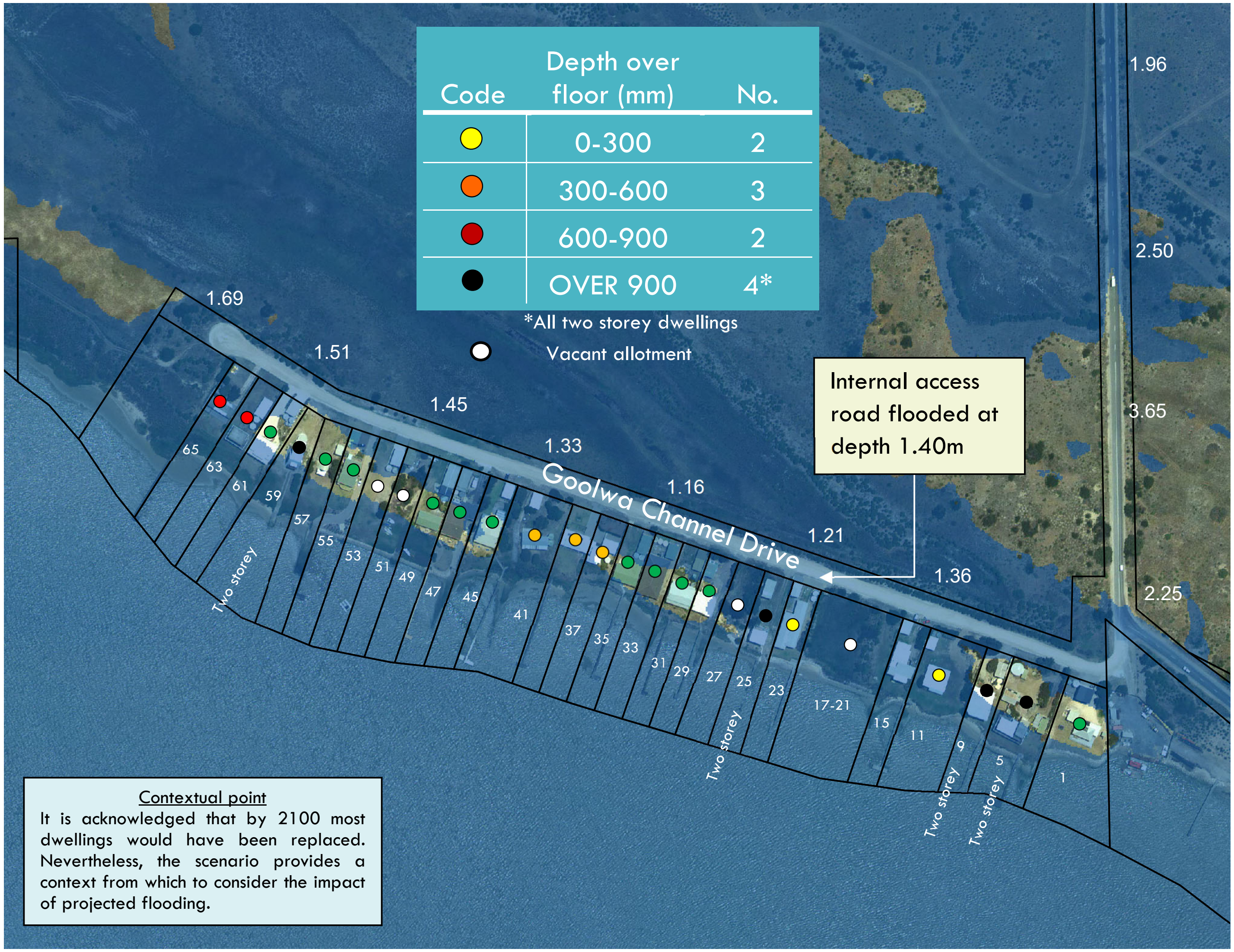
The 1 in 100-year ARI event risk set by Coast Protection Board for 2100:

Storm surge	1.55m AHD	
Wave setup	0.10	
	1.65m AHD	
SLR	1.00m	
Total risk	2.65	

If this event occurred then:

- 2 houses would have water up to 300mm over floor level
- 3 houses would have water level 300mm to 600mm.
- 2 houses would have water between 600mm and 900mm.
- 4 houses over 900mm (these are all two storey dwellings)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	2
Orange	300-600	3
Red	600-900	2
Black	OVER 900	4*

*All two storey dwellings

Contextual point

It is acknowledged that by 2100 most dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – annual high water (2100)

Annual high water

Cell SF1-2

Goolwa Channel

2100 risk:

Annual high-water risk

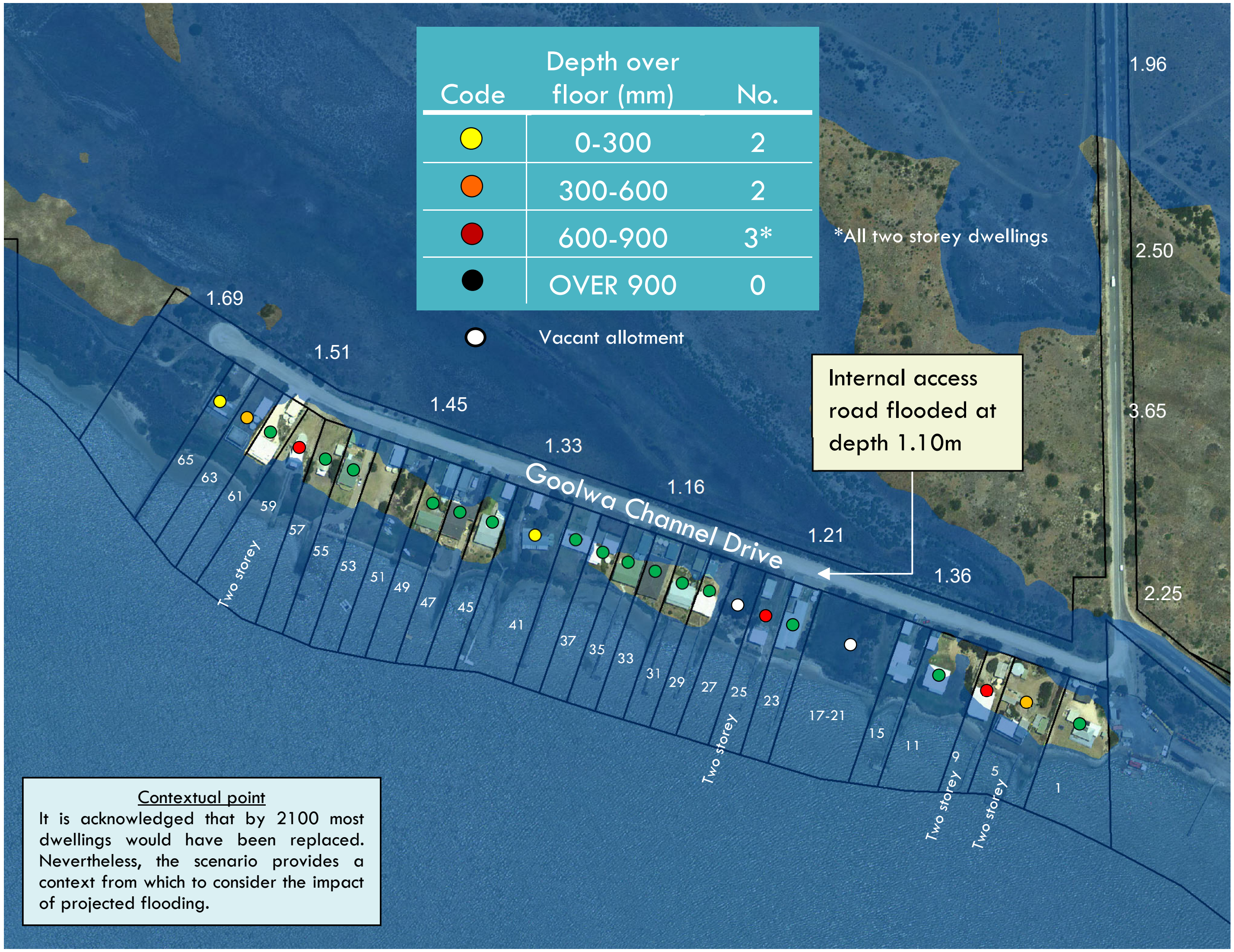
Assessment

Flooding of private property

If the 2100 annual high tide occurred at 2.30m AHD (including wave setup), then:

- 2 houses would have water up to 300 over floor level
- 2 houses would have water level between 300 and 600.
- 3 houses would have water between 600 and 900 (all of these are 2 storey)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	2
Orange	300-600	2
Red	600-900	3*
Black	OVER 900	0

Contextual point

It is acknowledged that by 2100 most dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – storm surge (2050)

Storm surge

Cell SF1-2

Goolwa Channel

2050 risk:

1 in 100-year risk

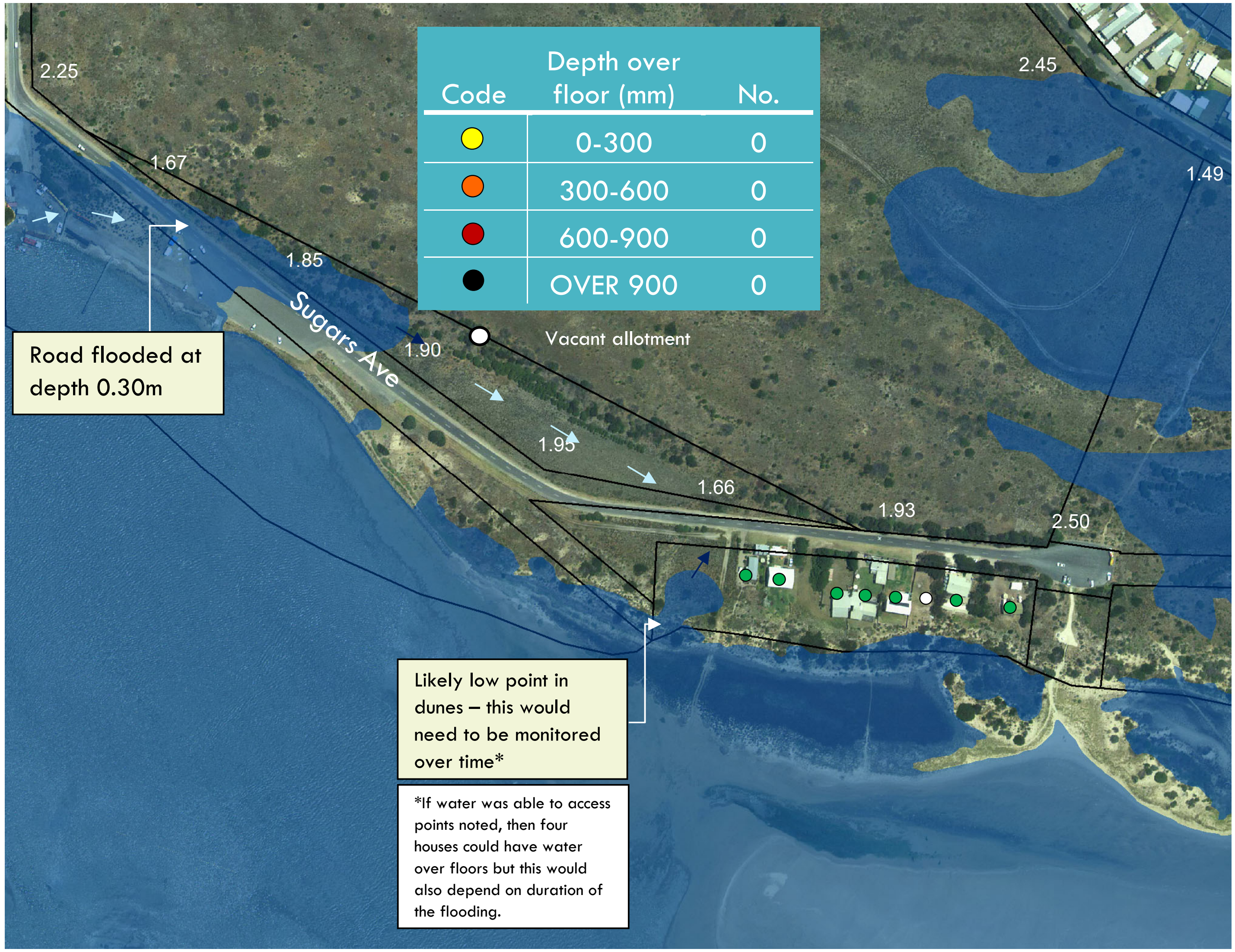
Assessment

Flooding of private property

The 2050 risk 1 in 100 ARI storm event for Goolwa Channel is:

Storm surge 1.55m AHD
Wave setup 0.10
1.65m AHD
SLR 0.30m
Total risk 1.95

More work is required to quantify this risk. The modelling shows that water could flow through the allotment on which SA Government dredging centre is located. A low point in the dunes could also inundate the area.



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Future exposure – storm surge (2100)

Storm surge

Cell SF1-2

Goolwa Channel

2100 risk:

1 in 100-year risk

Assessment

Flooding of private property

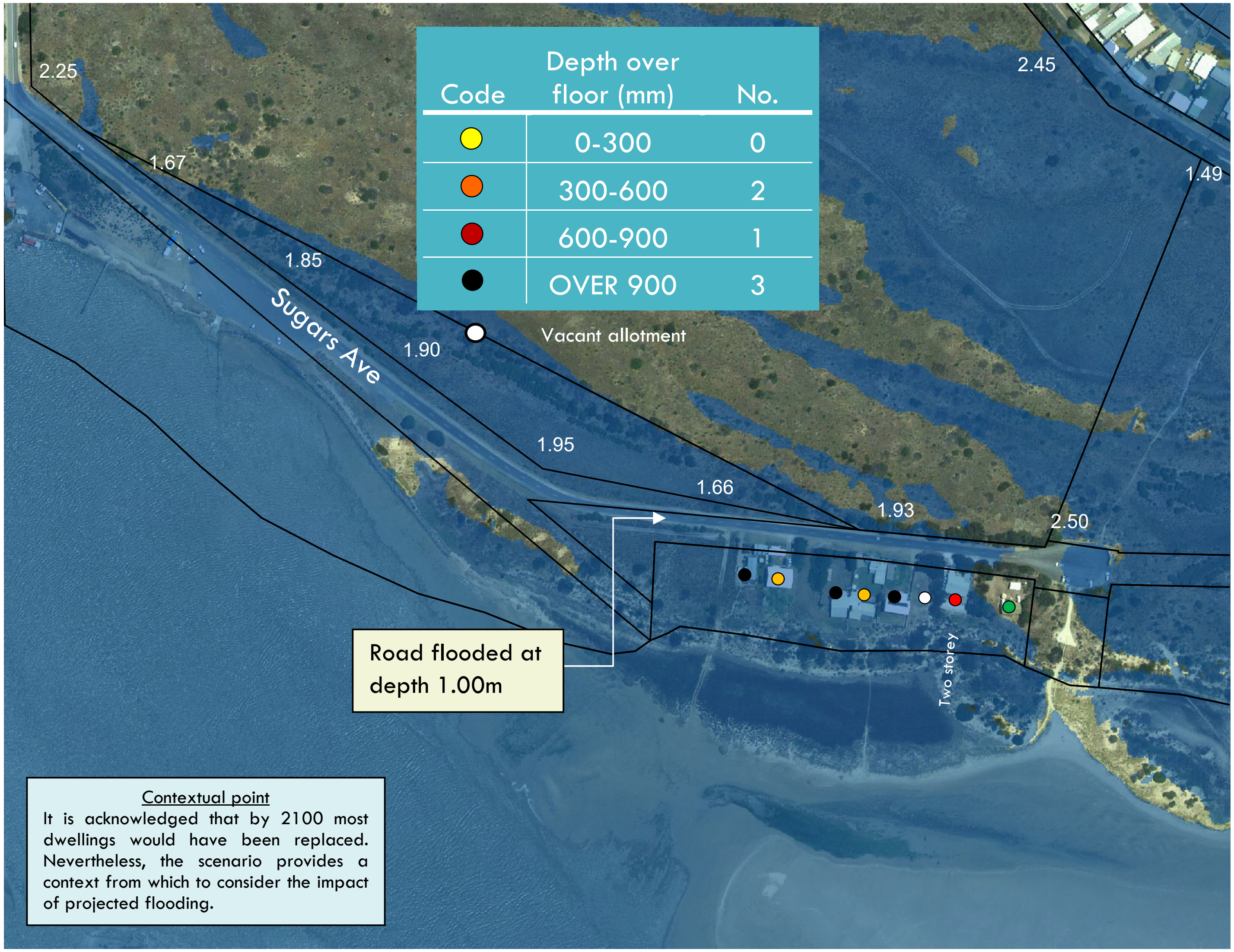
The 1 in 100-year ARI event risk set by Coast Protection Board for 2100:

Storm surge	1.55m AHD	
Wave setup	0.10	
	1.65m AHD	
SLR	1.00m	
Total risk	2.65	

If this event occurred then:

- 0 houses would have water up to 300mm over floor level
- 2 houses would have water level 300mm to 600mm.
- 1 houses would have water between 600mm and 900mm.
- 3 houses over 900mm

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Code	Depth over floor (mm)	No.
Yellow	0-300	0
Orange	300-600	2
Red	600-900	1
Black	OVER 900	3

Contextual point

It is acknowledged that by 2100 most dwellings would have been replaced. Nevertheless, the scenario provides a context from which to consider the impact of projected flooding.

6. Future exposure – annual high water (2100)

Annual high water

Cell SF1-2

Goolwa Channel

2100 risk:

Annual high-water risk

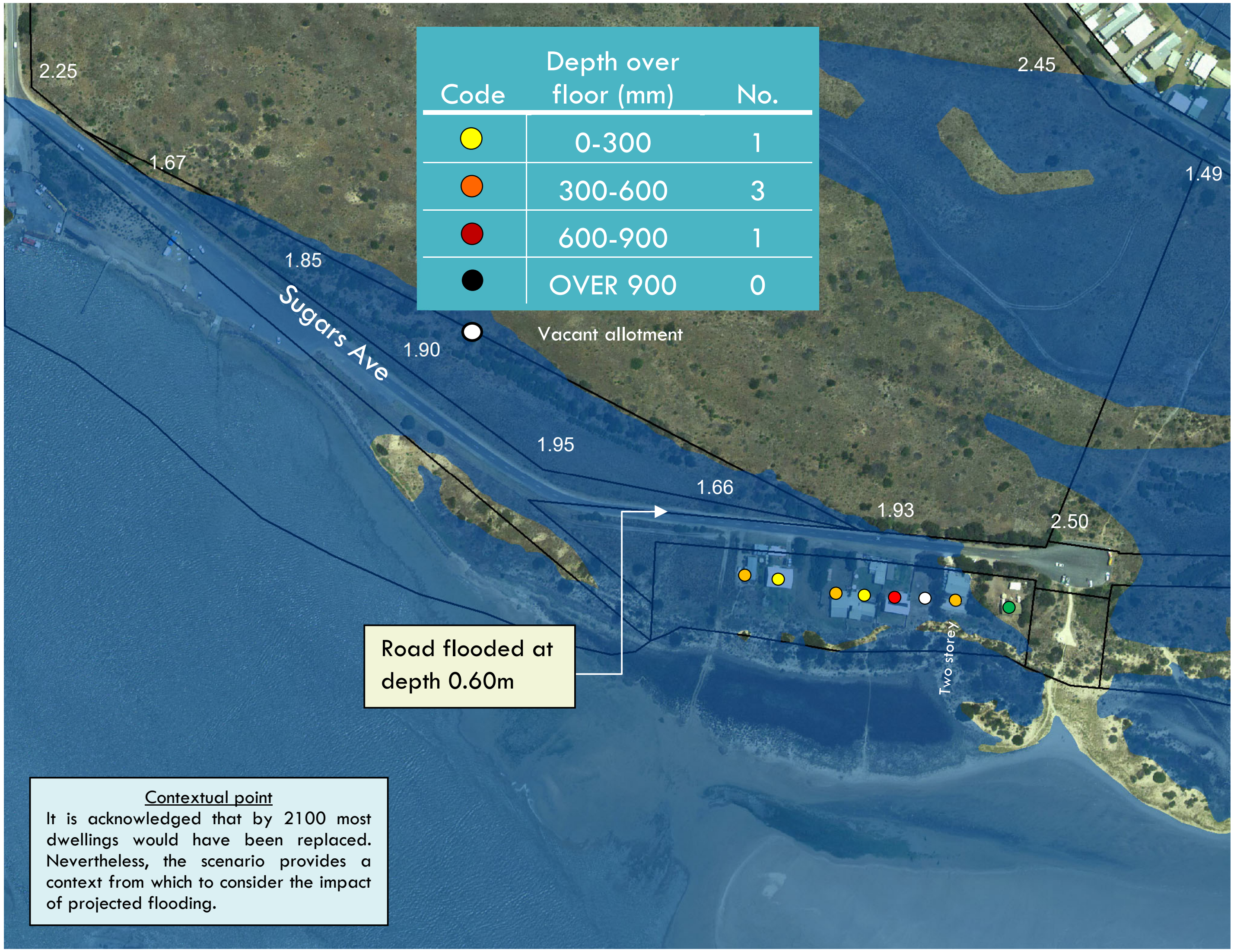
Assessment

Flooding of private property

If the 2100 annual high tide occurred at 2.30m AHD (including wave setup), then:

- 1 houses would have water up to 300 over floor level
- 3 houses would have water level between 300 and 600.
- 1 houses would have water between 600 and 900.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



6. Future exposure - erosion

Shoreline change due to sea level rise

Goolwa Channel

Macro analysis

The analysis above has demonstrated that the fabric of the area is extremely volatile (rating: highly erodible 4).

The outlook for the Murray Mouth if dredging were to cease is not known, but with increase sea level, and in the absence of any increase of freshwater flows through the Murray Darling system, the Mouth of the Murray is likely to close. This event would remove the flooding and erosion threat from actions of the sea, but the ecosystem would change significantly.

It is likely that the importance of the River Murray system will result in current and future Governments ensuring that the Mouth stays open.

As noted in the introduction, this study assumes that the barrage system remains operating in accordance with its design purpose of keeping sea water out of the lower lakes.

Goolwa Channel: Micro analysis:

The prevailing winds associated with storm surges from the west to south blow onshore to the settlements situated on the northern side of the Goolwa Channel. It is likely that areas not currently protected by rock revetment (or other means) will continue to erode.

Of greater concern than shoreline position is the impact of routine flooding of the terrain and access ways. The modellings for the annual high-water event for 2100 depicts water over roads and terrain at ~0.7m.

Monthly high tide modelling has not been produced as part of this project, but the data shows that parts of the terrain would be routinely flooded. This flooding will not be accompanied by high wave action as would occur in a more exposed coastal setting. However, seawater that rises evenly does not return to the sea in an even manner. When the tide turns the water finds the quickest way back to the sea, and as a result substantial scouring can occur of the terrain and road surfaces (undermining the edges of the road).

Note: by way of comparison, generally the terrain and road surfaces are approximately 0.3m higher in the Goolwa Channel area than Mundoo Channel area. In other words, the lower surfaces are about 0.3m higher than the lower surfaces in Mundoo. This would indicate that routine flooding of the terrain will occur later in Goolwa Channel area than Mundoo Channel area as the sea rises. Therefore the impact of flooding and scouring may be more easily managed than Mundoo Channel.

Key Point

Increased frequency of flooding over the terrain will increase the amount of scouring of the terrain and road surfaces. While the water rises uniformly, when the tide turns, the water finds the quickest way back to the sea, scouring the terrain and undermining road surfaces.

Comparative point

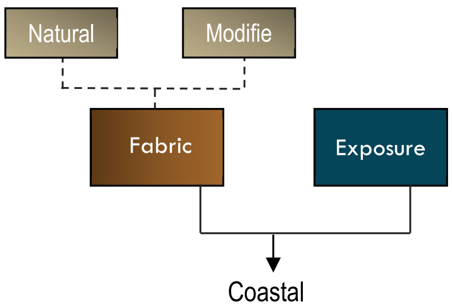
Generally, the terrain and road surfaces are 0.3m higher than within the Mundoo Channel region. This would suggest that ongoing scouring will not occur until later than Mundoo Channel, and the impact may be more easily managed.

COASTAL EXPOSURE

Summary and Conclusions

Progress report:

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the 'geology' or 'fabric' of the cell. In the last section we also analysed exposure.



Baseline storm event

The highest event on record at the Goolwa Barrages occurred on 18th May 1953 at 1.49m AHD. The modelling indicates that if this event were to reoccur it would impact Goolwa Channel settlements with minor flooding (through vacant allotment on Goolwa Channel Drive (no 17-21).

Storm surge

As the 1 in 100-year ARI storm surge event is based on the historical event, the impact of the baseline storm is the same as for this event. The modelling indicates that Goolwa Channel Drive would be inundated to depth of ~0.40m. Five dwellings would have water over floors (but three of these are two storey).

Annual high-water

The modelling indicates the average annual high-water event does not impact access roads of the settlement nor produces flood over any floor levels.

Erosion

Erosion has been significant in the Sugars Beach region with recession between 40-60m since 1949. More recently, east of the carpark, the shoreline has accreted. Erosion is expected to continue to impact areas that are not protected by rock revetment. Less erosion has been occurring at Cooinda settlement area.

Future exposure (2050)

Storm surge

If the 1 in 100 ARI storm surge event projected for 2050 occurred, main access roads to the settlements would have portions of road surfaces inundated at depths 0.10m to 0.40m. Goolwa Channel Drive would be flooded to depth 0.60m – 0.70m

Twelve existing dwellings would have water over floor levels, but four of these are two storey dwellings.

Annual high-water (2050)

Scenario mapping indicates that annual high-water events would not impact main access roads. Water would flow through lots 17-21 on Goolwa Channel Drive and flood this road to depts of 0.30m.

Future exposure (2100)

Storm surge and high tide

If the 1 in 100-year ARI event for 2100 occurred upon the existing road layout, depths over the road would be 0.40 to 1.20m. The scope of this flood would be very significant and possibly travel kilometres inland.

Annual high-water events would inundate the roads regularly at depths 0.50m to 0.90m.

Erosion

Due to the fact that prevailing winds blow onshore, erosion is predicted to be a continuing problem (although some accretion is occurring at some locations).

However, the scenario modelling does show increased inundation. Later in the century when inundation of the settlement is more routine, it can be expected that erosion of existing banks and road surfaces will escalate. In locations such as Goolwa Channel, the larger impact from erosion will be experienced on a receding tide as water finds the fastest way to travel back to the ocean.

Exposure rating (erosion): Very sheltered

Exposure rating (flooding): Highly exposed

7. Inherent hazard risk assessment

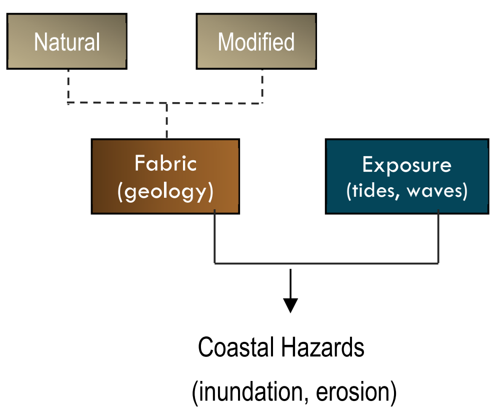
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk.

This reality is most simply understood when considering inundation risk. Whether a coast is at risk from inundation depends entirely on the topography of the coast. If we explain this another way, a low-lying coast is *inherently* more at risk from flooding whereas an elevated coast is inherently not at risk from flooding.

The assessment of the erosion hazard is far more complex, but it is still the relationship of *fabric* to *exposure* that determines whether a coast is *inherently* more at risk from erosion or less at risk.



Inundation hazard risk

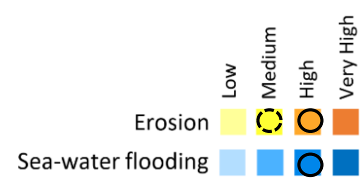
Modelling of current 1 in 100 ARI year event risk depicts minor flooding of settlements. Therefore, the inherent inundation hazard risk is 'high' .

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (Main report)	River estuary – tidal flat, samphire flat	Very high
Should this rating be amended due to human intervention such as a protection item? If so, how?	Rock protection has been installed to much of the riverbank.	High- Very high
Apply an exposure rating (Nature Maps)	Nature Maps does not allocate an exposure rating, but 'very sheltered' is appropriate.	High
Assess any impact on backshore 1	Erosion has been significant, especially in Sugars Beach area.	High
Assess any influence from Benthic	Not applicable – river estuary	High
Assess the sediment balance	Not applicable – river estuary	High
Assess any other factors that may warrant a change of inherent hazard risk.	Nil	High

Rock revetment has been installed to many areas of Goolwa Channel settlements and are rated as 'medium' inherent hazard risk. Those areas not yet protected are rated as 'high'.

Inherent Hazard Risk – Goolwa Channel



8. HAZARD IMPACTS

In this section we identify and describe the potential hazard impacts within four main receiving environments:

- Public assets*
- Private assets
- Safety of people
- Eco-system

*The assessment of public assets is normally restricted to Council owned assets. Electrical infrastructure is normally above-ground. Telecommunications is normally underground. The findings of this study should be distributed to other public asset owners.

8a. Assets at risk (public)

Public assets within Goolwa Channel settlements include:

- Public roads (sealed and unsealed)
- Carpark (Sugars Beach)
- Fencing
- Boat ramp facility
- Protection works (Sugars Beach)
- Signage

A current 1 in 100 ARI would have little impact on public assets apart from inundation of Goolwa Channel Drive (Figure 42). However, erosion is occurring behind the rock revetment to the east of the boat ramp and to the eastern end of the rock revetment (Fig 41).

The impact on public assets in the shorter term (next 20-30 years) is expected to be minimal. However, should seas rise as projected, then increased flooding and associated scouring of banks and road surfaces could be expected.

When depth of water exceeds 0.3m, receding water usually scours banks and roads. The impact of increased flooding at levels projected for the end of this century is likely to render the current roadway layout as obsolete. However, the impact within Goolwa Channel settlements is expected to occur later than the impact at Mundoo Channel.

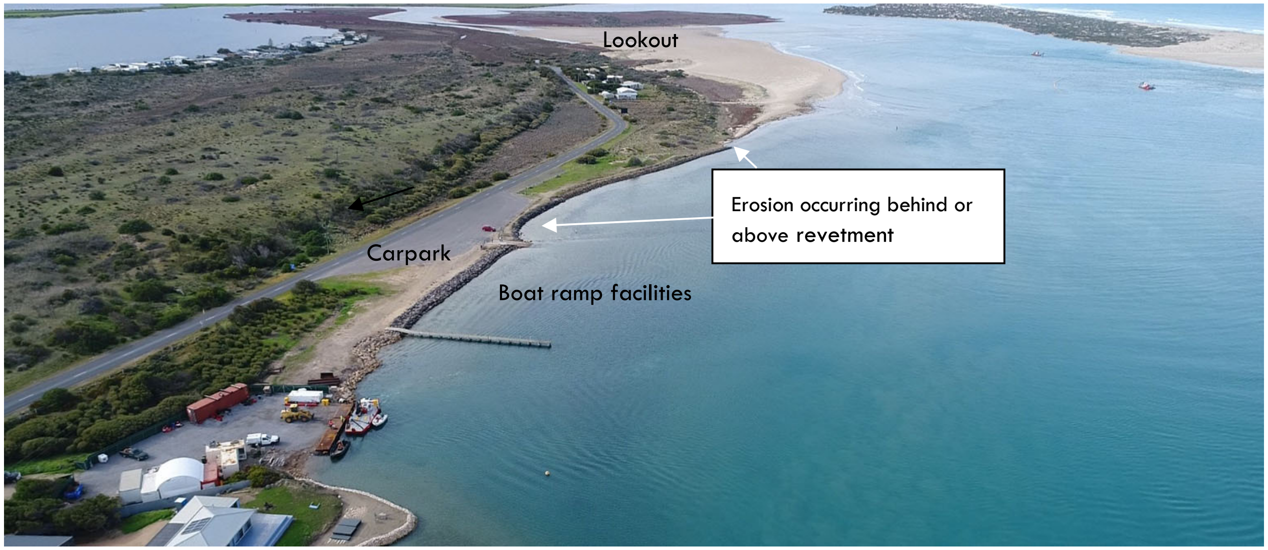


Figure 41-42: Flooding will impact the stability of roads (especially those which are not sealed). The modelling shows that Goolwa Channel Drive is vulnerable to flooding. Mills Road is unsealed and water overtopping these roads is likely to cause scouring.

8b. Assets at risk (private)

The scenario flooding undertaken in the previous section demonstrates that should the current 1 in 100 ARI event occur that 5 houses would have water over floors, all at levels lower than 0.3m. However, three of these are two storey construction. It is relevant to note that these houses were constructed prior to 1990. Before this time, relevant authorities were not required to take into account sea level rise in assessment.

It is recognised that many of the existing dwellings will be replaced by 2050. However, the 2050 sea-flooding scenario does provide an insight as to the impact of this flood scenario. Twelve of the existing houses would have flood over floor, but none of these with depths over 0.6m. (Comparison: Mundoo Channel has 10 dwellings with flood depth greater than 0.6m)

One metre of sea level rise will have a significant impact on private assets, with flooding occurring routinely throughout the year. While in theory it would be possible to elevate dwellings, the depth of water over sites would be significant, many with water over 1.0m in depth.

When depth of water exceeds 0.3m, receding water usually scours terrain that is highly erodible. The impact of increased flooding at levels projected for the end of this century is likely to significantly scour residential sites. (Comparison: Generally terrain and roads are 0.3m higher than Mundoo Channel). Therefore, impact upon the terrain of Goolwa Channel settlements could be expected much later than Mundoo Channel (20-30 years).

Private dwellings *

See pages 90 to 93, and 101 to 112, for more fine-grained analysis of the amount of flood depths over floor levels.

	Dwellings with flood over floor levels				
Settlement	**Current (1 in 100)**	**Current (Annual high-water)**	**2050 (1 in 100)**	**2100 (1 in 100)**	**2100 (Annual high water)**
Cooinda Road	3	0	7	19	15
Mills Road	0	0	0	3	1
Goolwa Channel Drive	2	0	5	11	7
Sugars Ave	0	0	0**	6	5

*This table does not take into account the potential damage to sheds and other infrastructure on privately used property. Referring to the relevant flood mapping will identify other private assets at risk.

**Dune height may be slightly lower than risk height. The height of the dunes in Sugars Beach area will need to be monitored over time.

8c. The safety of people

The scenario flooding demonstrates that if seas rise as projected, then increasingly access roads will be cut off in times of flood. While the nature of the flooding is normally benign (in that wave action and rates of flow are low), emergency vehicles will be unable to access the Goolwa settlements in the case of accident or health issue.

Furthermore, an increase of accidents in the time of flood is likely, for example electrical faults, slipping, and potentially drowning of people who were young, sick or aged.

The current risk 1 in 100-year ARI event does not impact the main access roads of Chappel Road, Mills Road and Murray Mouth Road. Flooding of internal roads at Mills Road and Goolwa Channel Drive would be likely to make these roads impassable to vehicles. However, in both cases, the distance to the main access roads are very short and it is likely that any emergency could be managed by visiting emergency service workers.

The 1 in 100 risk projected for 2050 would impact the main access roads of Mills Road and Murray Mouth Road, and to a lesser extent Chappel Road. The modelling for annual high water demonstrates that main access roads would remain open, whereas internal access is likely to be restricted.

The 1 in 100-year flood heights of 0.80m to 1.40m projected for the end of the century will make for a very unsafe environment for people. Annual high water for 2100 will be more easily managed than within Mundoo Channel.

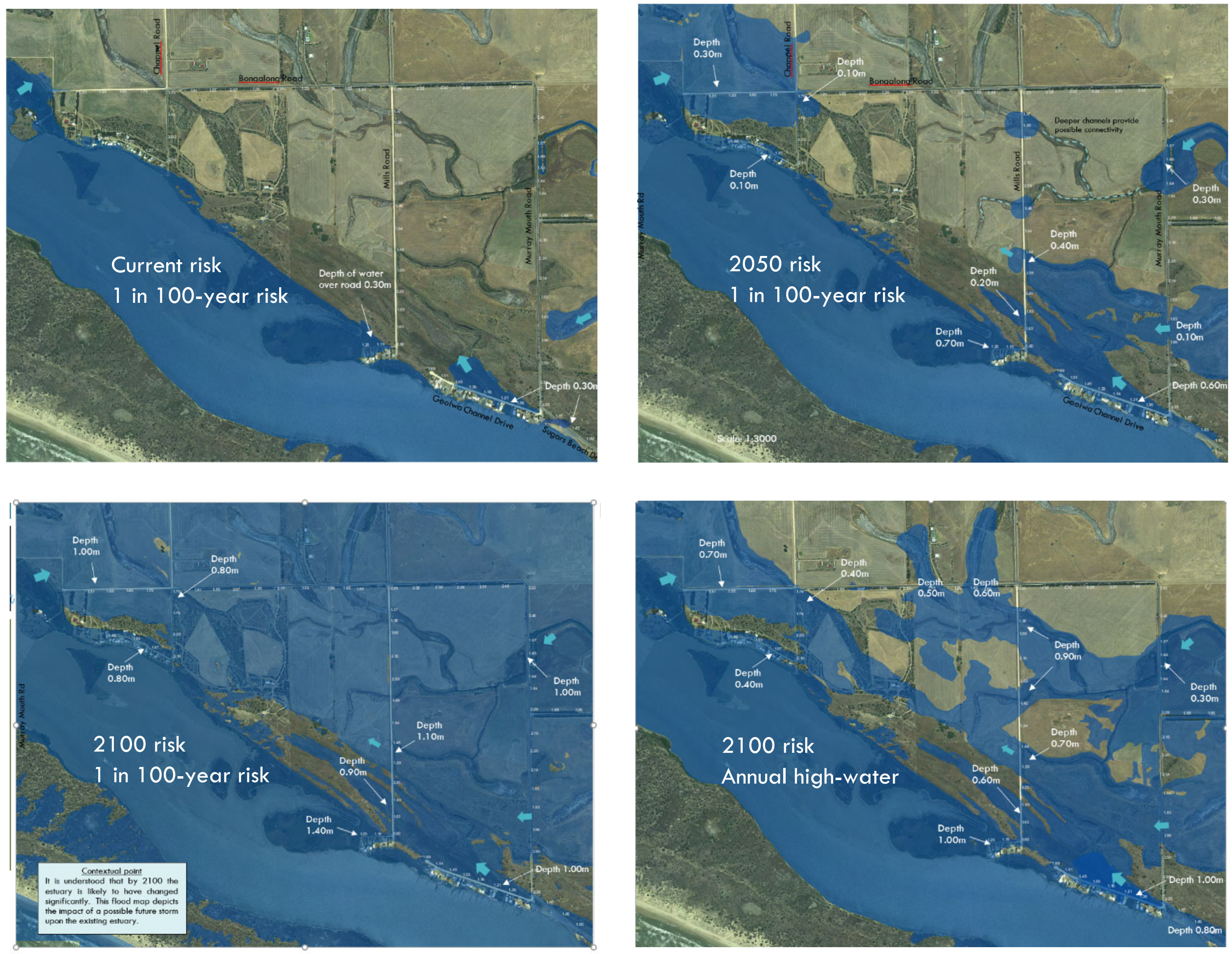


Figure 43: Scenario flood mapping for current risk, 2050 and 2100 projected risk (see pages 30-42)

8d. Ecology at risk

In the shorter term to 2050, large scale impacts to the ecology are not expected as a result of 0.3m sea level rise.

However, increased sea water flooding from 2050 onwards is likely to change the ecology of large portions of southern Hindmarsh Island. If seas rise as projected by 1m it is not expected that human intervention could mitigate the impact upon the ecology surrounding the Goolwa Channel settlements.

However, as noted by Dr Bourman it is likely that in times when sea level was 1m higher than present that sea water flowed through 'a network of natural spillways' that criss-cross the Hindmarsh Island in the south (see Geomorphology section). It may be relevant to consider the outlook as returning to a time when sea level was higher than present and accommodate changes accordingly.

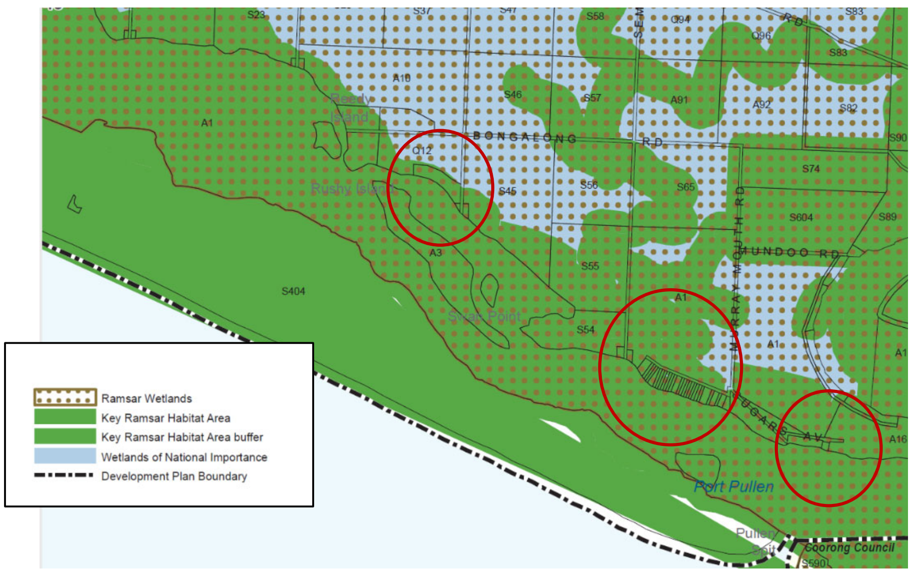


Figure 43: Ramsar conservation classification (Map Alex 25, Development Constraints)

Figure 44: North of Mundoo Channel settlement – Wetlands of National Importance

Figure 45: The southern half of Hindmarsh island is an extensive sandflat with natural spillways that were formed when the Murray Mouth was wider (Coastal Landscapes of SA)

9. RISK ASSESSMENT

In this section we conduct a formal risk assessment of hazard impacts upon the four receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

This risk assessment utilises the risk framework of Alexandrina Council.

9. RISK ASSESSMENT

Inherent hazard rating

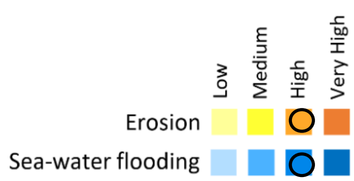
Integrated Coasts has developed a risk classification system to operate over the State of South Australia that categorises the risk to a coastal cell in relation to two main hazards:

- Sea-water flooding
- Erosion

The application of an inherent risk rating does not suggest that areas rated as low are entirely free from vulnerability, nor conversely that areas rated more highly are necessarily vulnerable now. The aim is to assess the underlying inherent vulnerability of the fabric of the coastal location using a process that will also benchmark the locality in the context of all of South Australia.

The visual output from the inherent risk assessment process is purposefully designed so that it is immediately accessible and meaningful to a wide range of personnel involved in managing the coastal environs.

Inherent Hazard Rating



Specific Risk Assessment

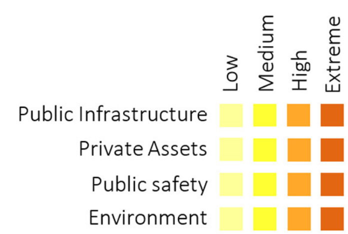
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Ecosystem disruption

The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes that may threaten to disrupt the entire ecological system, for example seawater flooding into freshwater ecologies.

This assessment utilises the Councils risk assessment framework and is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The risk assessment is conducted within either the inundation or erosion risk assessment template (see next page).

Erosion Hazard Rating
(Current outlook 2020)



Erosion Hazard Rating
(Future outlook 2100)

Yet to be assigned

9. Risk assessment

Inundation assessment

Goolwa Channel

Risk identification: Seawater is likely to inundate private and public land in storm surge and in annual high water events

Coastal processes	Goolwa Channel settlements are located on the northern side of Goolwa Channel on the seaside of the barrage. Flows of water in the area relate to the tidal regime at the Murray Mouth. Waters from the Goolwa Barrage are controlled. On occasions water is released through the barrages to the sea.

Are any strategies employed to mitigate the risk? No

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Chappel Road, Mills Road, Murray Mouth Road, Goolwa Channel Road, and Sugars Beach Road, carpark, boat ramp facility, signage and fencing.	current	*Unlikely*	*Insignificant*	low
		2100	*Almost certain*	*Significant*	Extreme
Private assets*	Dwellings and associated infrastructure positioned on the northern side of Goolwa Channel. Sea water flooding will increasingly impact dwellings with water over floor levels.	current	*Possible*	*Minor*	low
		2100	*Almost certain*	*Significant*	Extreme
Safety of people	Increased sea levels and associated flooding will cause access to the settlement to be cut. Inside the settlement, depth of water is likely to be hazardous to people.	current	*Rare*	*Moderate*	Low
		2100	*Possible*	*Moderate*	Moderate
Ecosystem disruption	Hindmarsh Island in the southern portion is set at levels lower than 2m AHD. Increased sea water flooding due to sea level rise will change the ecology of the land, especially in the second half of this century.	current	*Rare*	*Minor*	low
		2100	*Almost certain*	*Significant*	Extreme

Inherent Hazard Rating
Estuary

	Low	Medium	High	Very High
Erosion			X	
Sea-water flooding			X	

Inundation Hazard Rating
(current outlook)

	Low	Moderate	High	Extreme
Public Infrastructure		X		
Private Assets*	X			
Public safety	X			
Eco-system disruption	X			

Inundation Hazard Rating
(future outlook)

	Low	Moderate	High	Extreme
Public Infrastructure				X
Private Assets*				X
Public safety		X		
Eco-system disruption				X

Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Caveat: this assessment is sea-water impact only and does not encompass the possibility of riverine flooding, nor a combination of both impacts.

*Council not necessarily liable for private assets

Summary	Goolwa Channel settlements are generally low set (but overall set about 0.3m higher than Mundoo settlement) and vulnerable to sea water flooding. Currently, the risk to private and public assets is low (with a few exceptions at Mills and Goolwa Channel Drive). If sea level rises as projected then all receiving environments will be impacted, especially towards the end of this century.

9. Risk Assessment

Erosion assessment

Goolwa Channel (SF1-2)

Risk identification: Erosion is currently, or may in the future, cause the shoreline to recede and land unstable.

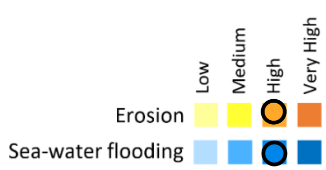
Coastal processes	Goolwa Channel settlements are located on the northern side of Goolwa Channel on the seaside of the barrage. Flows of water in the area relate to the tidal regime at the Murray Mouth. The prevailing winds blow onshore to the Goolwa Channel settlements. Within Sugars Beach region, 40-60m erosion has occurred on the western end, but more recently the eastern section is accreting.

Are any strategies employed to mitigate the risk? Rock revetment to Sugars Beach carpark area. Private protection works of varying quality.

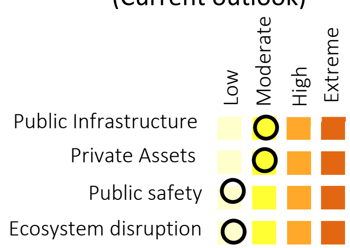
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Chappel Road, Mills Road, Murray Mouth Road, Goolwa Channel Road, and Sugars Beach Road, carpark, boat ramp facility, signage and fencing. Rock revetment protects assets at Sugars Beach, but some portions of revetment in poor condition.	current	*Possible*	*Moderate*	Moderate
		2100	*Almost certain*	*Significant*	Extreme
Private assets*	Dwellings and associated infrastructure positioned on the northern side of Goolwa Channel. Those not protected by rock revetment are likely to experience ongoing erosion (especially in the Sugars Beach region)	current	*Possible*	*Moderate*	Moderate
		2100	*Likely*	*Significant*	Extreme
Safety of people	This assessment does not relate to general beach safety. It relates only to how the safety of people may be exacerbated due to increased sea level (and associated impacts). It is unlikely erosion will increase safety risk.	current	*Rare*	*Minor*	low
		2100	*Rare*	*Minor*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. Erosion is not expected to impact the ecology (apart from causing increasing flooding – see risk assessment for 'sea water flooding')	current	*Rare*	*Minor*	low
		2100	*Unlikely*	*Minor*	low

Inherent Hazard Rating

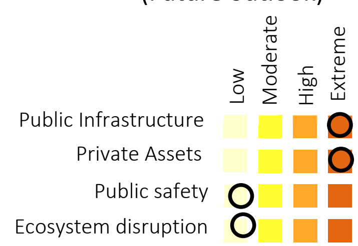
Estuary



Erosion Hazard Rating
(Current outlook)



Erosion Hazard Rating
(Future outlook)



*Council not necessarily liable for private assets

Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment

Summary	Most erosion has occurred in the Sugars Beach area, although more recently, the eastern end of Sugars Beach has been accreting. Rock revetment protects infrastructure in this region. Erosion has been less of an issue further west up the Channel which have experienced minor erosion, and some accretion. If sea level rise causes increase flows across the terrain, then erosion of banks and road surfaces can be expected.

10. ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

CoastAdapt notes that there are generally six categories of adaptation responses to climate change in the coastal zone:

- Avoidance
- Hold the line (protect)
- Accommodation (or limited intervention)
- Managed retreat
- Defer and monitor
- Loss acceptance

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. Thus, land that Is projected to become more prone to flooding in future can be scheduled as suitable only for development such as light industry or warehouses, and unsuitable for housing or critical infrastructure.

Engineering

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works strategies such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation damage. These approaches differ from other types of approaches in that they require significant commitments of financial resources and create a physical asset.

Environmental management

Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support continued growth of habitat such as seagrasses or reefs.

It may also include developing artificial reefs to reduce wave erosion of shorelines or engineered solutions to prevent encroachment of saltwater into freshwater systems.

ADAPTATION APPROACHES

There are two broad ways in which adaptation can occur in relation to timing:

- Incremental approach

A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the face of the impacts of climate change.

- Transformative approach

In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant that they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term. A transformative approach may be triggered by an extreme event or a political window when it is recognised the significant change could occur.

ADAPTATION ASSESSMENT

The modelling and assessment indicate that inundation is projected to be the key coastal hazard in the Goolwa Channel region.

An **incremental approach** to adaptation is recommended.

It is also important to note that the adaptation options for Mundoo Channel were developed prior to undertaking the Goolwa Channel assessment. The two locations are interrelated. For example, flood modelling on p.97 shows that seawater crosses Murray Mouth Road in the 1 in 100-ARI event for 2050. However, if protection options are adopted for Mundoo Channel, then no flows would be experienced across Murray Mouth Road.

Further reading and resources

This section of work adopts the framework and understanding of adaptation options from CoastAdapt. Further reading at:

https://coastadapt.com.au/understand-adaptation
https://coastadapt.com.au/adaptation options

[1] CoastAdapt also includes 'community education'.

Adaptation assessment

To evaluate adaptation options when the scenario modelling shows that a settlement is likely to be subject to significant inundation in the future, it is helpful to consider the concept of settlement viability.

Settlement viability

There is no established definition within coastal adaptation study for 'settlement viability', but the common meaning of 'viability' at dictionary.com is useful in this context:

- Ability to live, especially under certain conditions,
- The capacity to operate or be sustained.

Therefore, an assessment of settlement viability considers the ability to maintain access roads, the ability to maintain the stability of sites, and the ability to maintain an environment where people can safely reside and move about.

Science and uncertainty

It is also important to recognise that we are assessing viability of a settlement using scenario modelling which is based on long-term sea-level rise projections. Therefore, we need to acknowledge that there is significant uncertainty as to how these projections may play out over the course of this century. On the other hand, the consensus of most of the scientific community is that the science upon which the projections are based is sound. Furthermore, irrespective of our own personal views, the State Government of SA has adopted a sea level rise policy within its planning instruments that requires assessment of proposed development against 0.3m sea level rise by 2050 and 1.0m sea level rise by 2100.

Therefore, we are obliged to make decisions, short-term and long-term based upon these projections. But it is also important that we deal sensitively about these long-term projections in the context of a settlement such as those situated within Mundoo and Goolwa Channels.

SETTLEMENT VIABILITY AT 2100

Based on the evidence presented in this report it is unlikely that the Goolwa Channel settlements would be viable by 2100 if seas rise as projected. (However, this assertion is also based upon the assumptions recorded at pages 5-6. For example, if the Mouth of the Murray closed, then sea level rise would not be an issue for any of the settlements within the estuary).

First, it is not possible to maintain access and egress into Goolwa Channel area should seas rise by 1m when the road infrastructure is currently set at levels as low as 1.60m AHD. The 1 in 100-year storm surge event would cover portions of roads at depths of 0.8 to 1.1 metres. It would also not seem viable to raise these roads by this height either.

Second, increases of sea level of this magnitude are likely to reshape the landforms which this project has assessed as 'highly erodible'. Water frequently flowing over sites and roads would scour and destabilise the ground upon which roads and dwellings are positioned. Annual high-water flows would cover much of the terrain, at depths of 0.3m to 0.6m. Tidal action would regularly flow over significant amounts of the terrain around Goolwa Channel settlement. On terrain that has been described as a 'sand-flat' and assigned an erodibility status as 'very high', it is difficult to see how Goolwa Channel settlements would be viable by 2100.

Third, it is not practicable to design protection works that would be capable of stopping the flow of water through the settlement from multiple directions. Even if these works were possible, they would be required to be almost 3.0m AHD high.

Fourth, taking into account the above three factors it is unlikely that people could live and move about safely within Goolwa Channel settlements if seas rise as projected by 2100.

In conclusion, while recognising the uncertainty of the projections, but also recognising the need to take the projections into account, it seems unlikely that Goolwa Channel settlements would be viable at 2100 if seas rise as projected.

Long-term adaptation options

Considering our adaptation options, in the long term we may have to adopt either managed retreat or loss acceptance. However, in the shorter term, monitoring sea level rise over the next two decades should bring about a fuller understanding of the longer-term projections. Consideration is also required as to how to avoid placing future development proposals at future risk.

- Avoidance
- Hold the line
- Accommodation
- Managed retreat
- Defer and monitor
- Loss acceptance

Adaptation assessment

SETTLEMENT VIABILITY AT 2100 (CONT)

The problem with dealing 1m of sea level rise within a low-lying area such as Hindmarsh Island is demonstrated in Figure 46. Tidal water would flow into the area from numerous directions, and these tidal flows are likely to converge. It is also not practical to provide perimeter protection as this would be cost-prohibitive and likely not something that residents and visitors would desire.

However, as noted by Dr Bob Bourman, this area contains a 'network of natural spillways' that criss-cross the Hindmarsh Island mid-Holocene sandflat as distributary channels, effectively dispersing flood waters, as was clearly demonstrated during the 1956 flood (Figure 15, p.15). Dr Bourman also notes that sea level was likely to have been 1m higher in this period (mid-Holocene).

The projections for an increase of sea level of 1m by the end of the century are therefore relevant. It is outside the scope of this project, but in the latter part of this century it may be possible to use these 'distributary channels' to accommodate sea level rises. These distributary channels are usually at low heights above sea level (see examples in Figure 46).

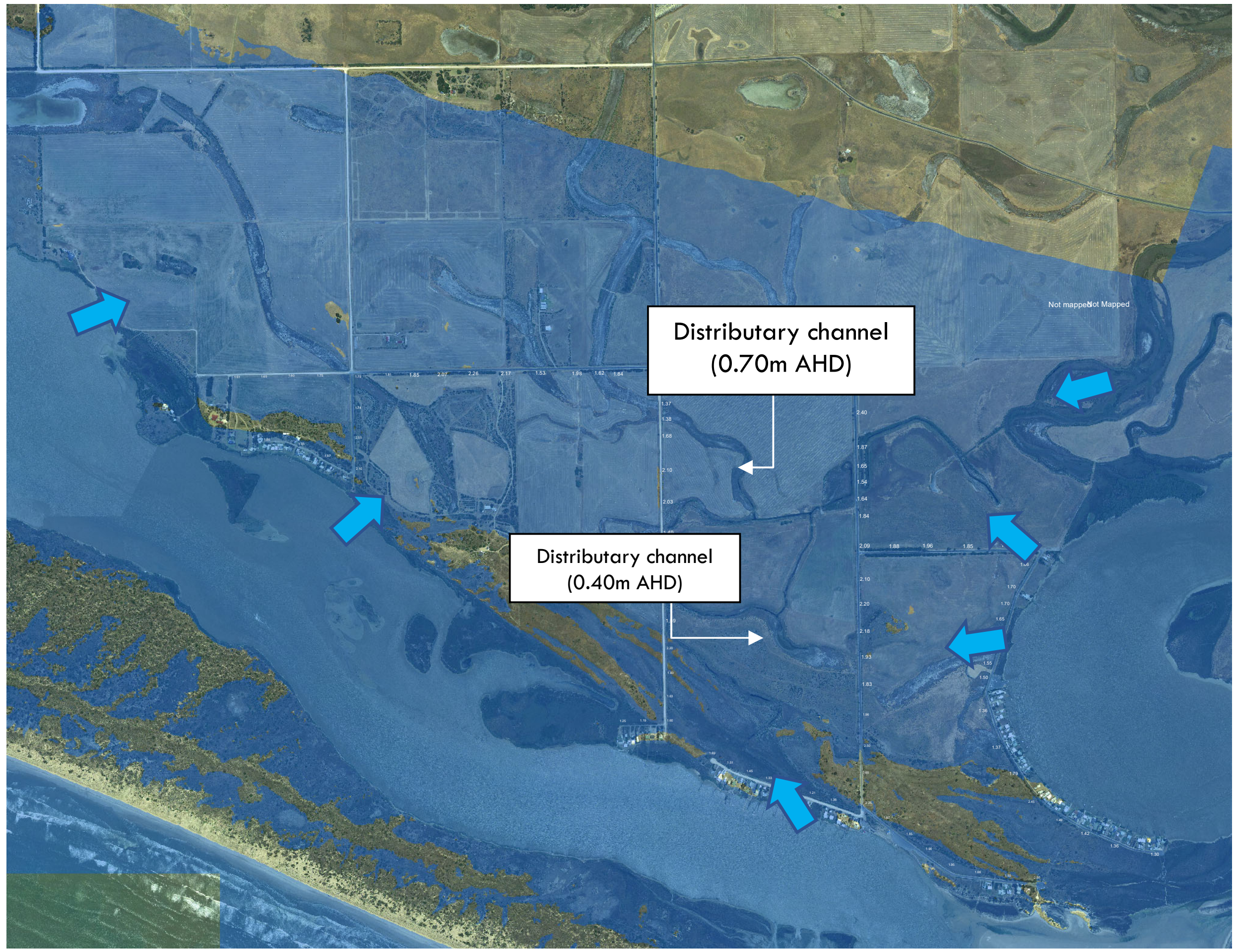


Figure 46 Finding ways to protect against sea level rise projected at 2100 is difficult. Tidal water would enter from all directions and there would likely be a convergence of flows.

Adaptation assessment

DEALING WITH CURRENT RISK

The sea-flood modelling for current 1 in 100-year ARI event demonstrates that the main access roads into the Goolwa Channel settlements are unlikely to be impacted. The exception may be on the western end of Bongalong Road which provides access to a few more isolated houses in this region.

There are four areas within the shack settlements that are vulnerable to the current 1 in 100-year ARI event. These are:

1. Minor flooding within Cooinda settlement
2. Water over internal access road at Mills Road settlement
3. Moderate flooding through allotment 17-21 on Goolwa Channel Drive
4. Possible flooding through property owned by the State Government which is currently used as a base for the dredging program could flow over Sugars Ave but at very low depth (0.1m).

Adaptation options are proposed for each of these on the following pages.

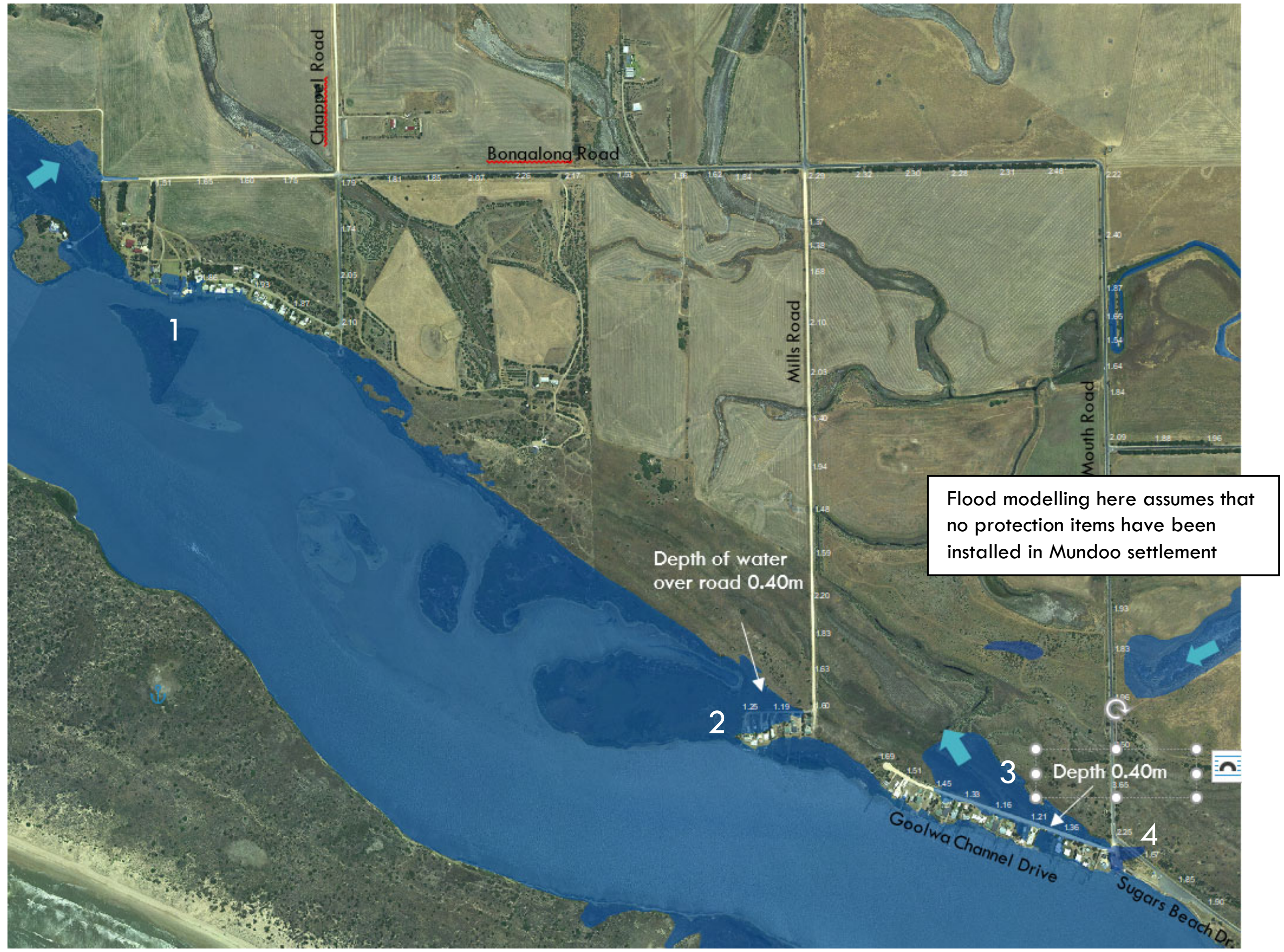


Figure 47 Modelling indicates that main access roads to the settlements situated on Goolwa Channel are not vulnerable to flooding in the current 1 in 100-year sea-flood event but four locations within settlements are vulnerable.

Adaptation proposals

DEALING WITH CURRENT RISK

1. Cooinda Road settlement

The flood modelling for 1 in 100-year ARI risk demonstrates that access within the settlement will not be at risk. Flood modelling indicates that dwellings will be impacted, but only three are likely to have flood over floor levels (all less than 0.3m)

Current sea-flood height set by Coast Protection Board is 1.65m AHD (including wave set-up). Normally, Coast Protection Board requests a 0.25m increase of levee height over the risk level. Therefore, a levee would need to be installed at 1.90m AHD.

An earthen levee approximately 200m positioned along the top of the riverbank at heights 0.3 to 0.5m AHD would protect the houses on the western end of the settlement.

It is likely that the cost of the levee would be borne by the shack owners. The cost would be expected to be minimal. Shack owners should be informed of the current risk to property.

Dwellings in this area were all constructed prior to 1992 prior to the time that Councils were required to take into account sea level rise in assessment of development applications.

Figure 48 Modelling indicates that internal access to Cooinda Road settlement is not at risk in current 1 in 100-year sea flood event but some shack sites are vulnerable to flooding.

Adaptation proposals

DEALING WITH CURRENT RISK

2. Mills Road settlement

The flood modelling for 1 in 100-year ARI risk demonstrates that access within the settlement will be at risk. The modelling indicates that no dwellings will be at risk, but other private property will be impacted (such as sheds).

Current sea-flood height set by Coast Protection Board is 1.65m AHD (including wave set-up). Normally, Coast Protection Board request a 0.25m increase of levee height over the risk level. Therefore, a levee would need to be installed at 1.90m AHD.

An earthen levee approximately 205m positioned adjacent the internal road at heights 0.9m to 1.1m AHD would protect the internal access road. Alternatively, the internal access road could be raised by 0.8m

The internal access road is owned by the landowners and is not a public road. Therefore the cost of any protection items would likely be borne by the landowners.

Figure 49 Modelling indicates that internal access to Mills Road settlement would be vulnerable to flooding in the current 1 in 100-year ARI event.

Adaptation proposals

DEALING WITH CURRENT RISK

3. Goolwa Channel Road settlement

The flood modelling for 1 in 100-year ARI risk demonstrates that Goolwa Channel Drive would be flooded at depths up to 0.5m. The source of this flooding is through lots 17-21 which is owned by the State Government. The flood modelling demonstrates that two houses are likely to be at risk. Number 25 is vulnerable because of the flooding through allotment 17-21. Number 59 is vulnerable to flooding directly from the channel.

Current sea-flood height set by Coast Protection Board is 1.65m AHD. Normally, Coast Protection Board request a 0.25m increase of levee height over the risk level. Therefore, a levee would need to be installed at 1.90m AHD.

An earthen levee approximately 102m positioned parallel to the channel at heights 0.3 to 0.7m AHD would prevent flooding of Goolwa Channel Drive. Conversely, a levee could be positioned adjacent Goolwa Channel Drive at heights 0.4m. However, this would allow flood waters to flow into lots 17-21 (something that is preferable to avoid).

It is likely that the cost of the levee would be borne by State Government and shared with either the landowners at number 11 and 15, or by Council (due to need to protect the road).

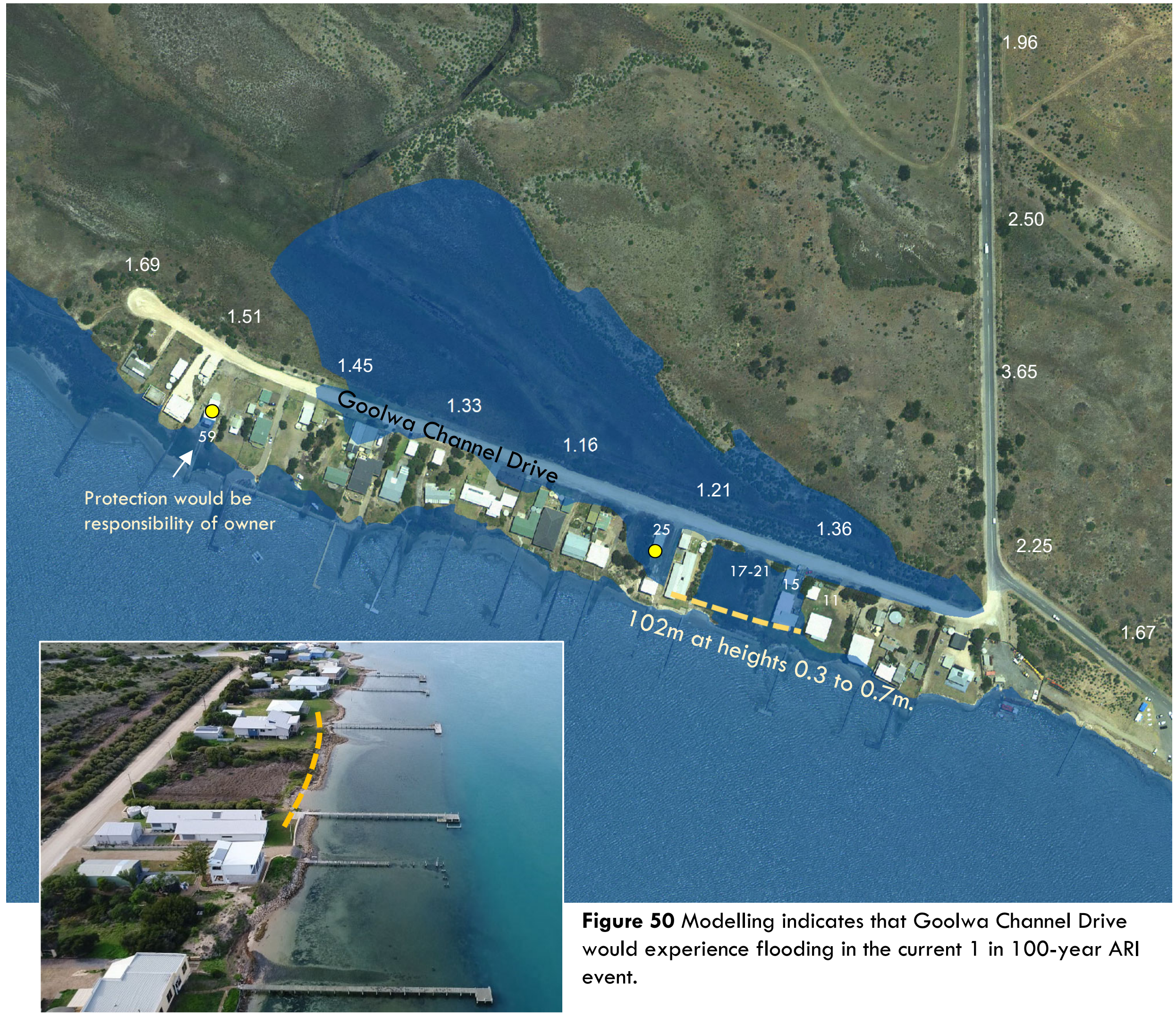


Figure 50 Modelling indicates that Goolwa Channel Drive would experience flooding in the current 1 in 100-year ARI event.

Adaptation proposals

DEALING WITH CURRENT RISK

4. Sugars Ave

Flooding:

The flood modelling for 1 in 100-year ARI risk demonstrates that water may flow the State Government owned property that is current base for dredging operations and contribute to the flooding on Goolwa Channel Drive and also flow across Sugars Avenue.

Note in this location, wave setup may be higher than 0.1m and therefore the flood mapping is likely to be conservative.

It is recommended that the State Government be informed of the findings of this study.

Erosion:

Erosion is currently occurring at the eastern end of the rock revetment at Sugars Beach (inset figure). This location appears to be point between the part of the coast that has undergone accretion (eastern) and the part of the coast that has undergone erosion (western).

Magryn Engineering Consultants inspected the site in February 2019 and has provided preliminary concept designs and costings (see following pages)

Figure 51 Modelling may indicate that seawater could flow through the above pictured property and increase flooding in Goolwa Channel Drive, or flow across Sugars Ave.

Adaptation options

Concept design: Sugars Beach

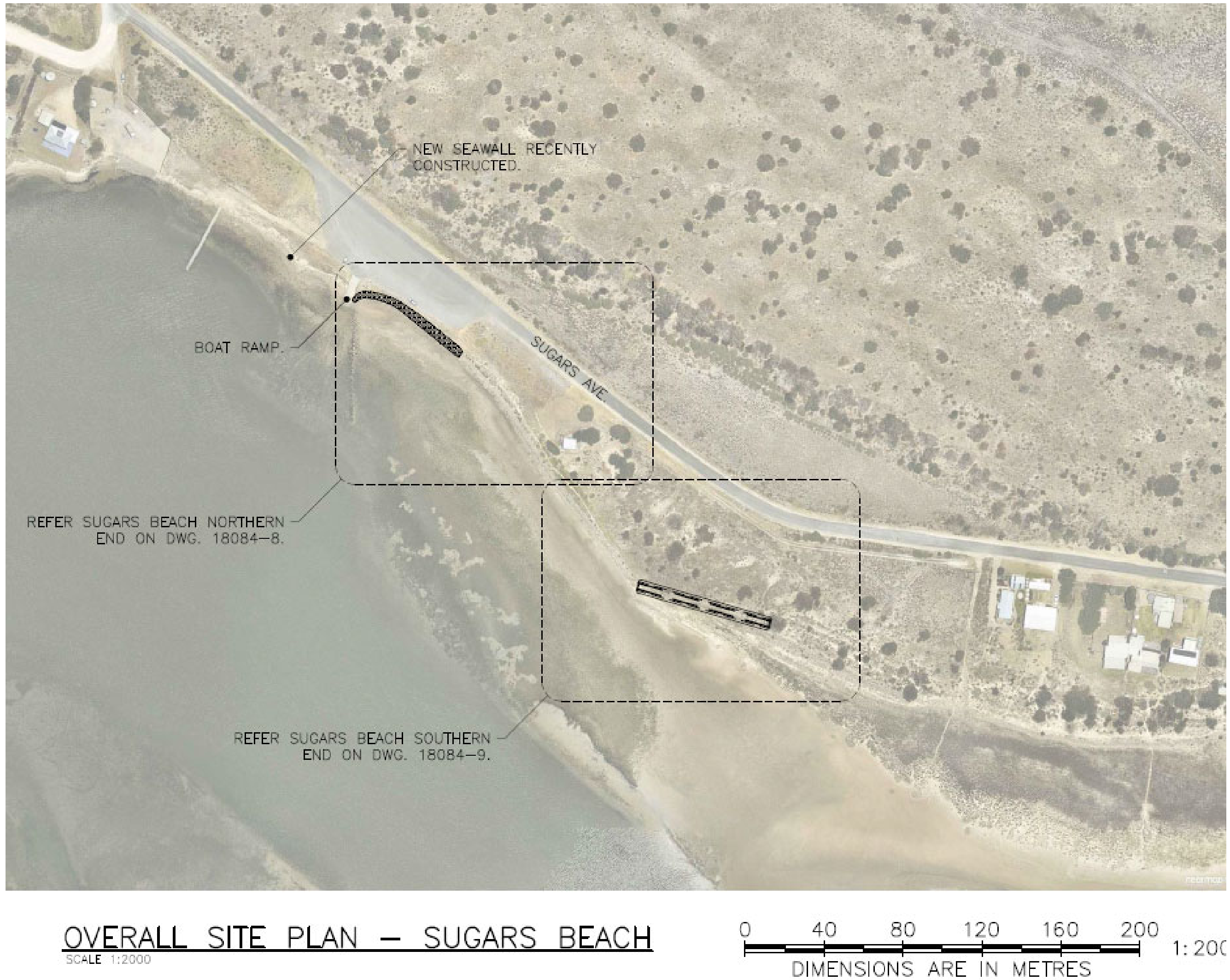
Install rock revetment to east of boat ramp.

Install sandbag end control to bridge the end of the revetment to the main sand dune.

Preliminary cost estimate:

Note: it is likely that the sandbag levee can be installed a significantly less cost.

(See also report by Magryn Engineering)



MAGRYN
ENGINEERING CONSULTANTS
267 BRIGHTON ROAD
SOMERTON PARK, SA 5044
TELEPHONE: (08) 8295 8677
www.magryn.com.au
> MINING
> STRUCTURAL
> COASTAL
> CIVIL

CLIENT: ALEXANDRINA COUNCIL C/– INTEGRATED COASTS

PROJECT: COASTAL ADAPTION STRATEGY

PROJECT ADDRESS: GOOLWA TO CHITON ROCKS

TITLE: OVERALL SITE PLAN SUGARS BEACH

CONTRACTORS MUST VERIFY ALL DIMENSIONS PRIOR TO ANY OFF SITE FABRICATION.

DESIGN: WS	SCALE: AS SHOWN	DATE: FEB. 2019
SHEET SIZE: A3	DRAWING NUMBER: 18084–7	REVISION: A

Adaptation options

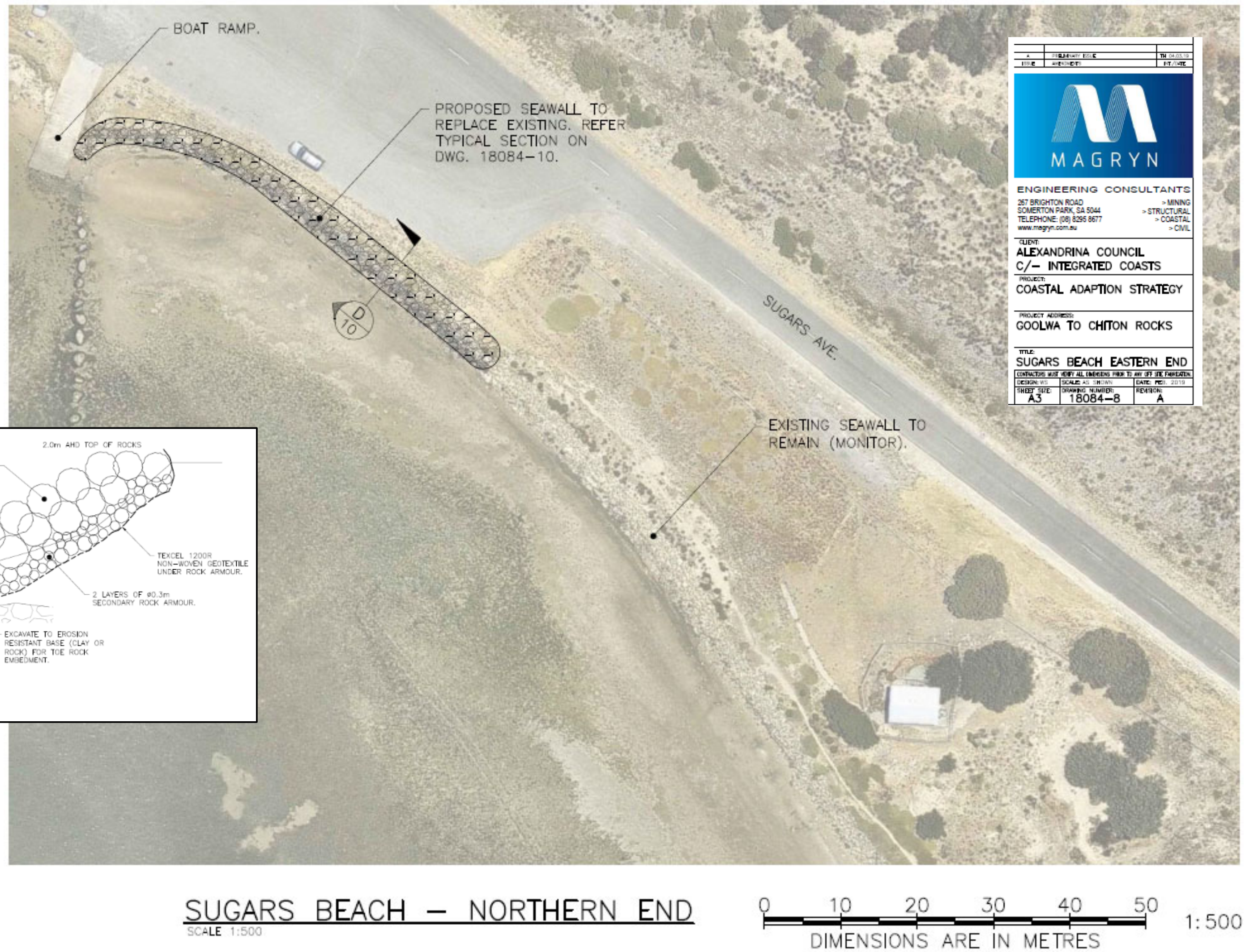
Sugars Beach

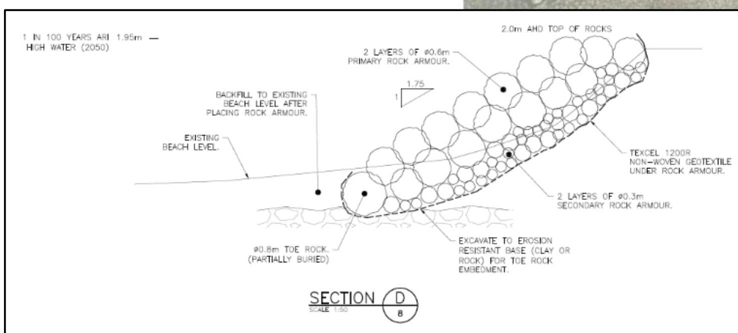
<u>Concept design:</u>

Proposed seawall

Design by Magryn Engineering

(See also report by Magryn Engineering)





Adaptation options

Sugars Beach

Concept design:

Sandbag end control

Design by Magryn Engineering

(See also report by Magryn Engineering)

Adaptation proposals

PREPARING FOR 2050 RISK

Considering that sea level rises are only in order of 0.30m by 2050, then it makes logical sense that the settlement will be more viable at 2050 than 2100 (refer page 129).

Although the 1 in 100 ARI event at 2050 projections would cover roads by 0.2m to 0.4m, these events by their nature are very rare. Annual high-water flows would not impact major access roads (but would impact internal access roads). Therefore, the viability of the Goolwa Channel settlements is likely to be more certain at 2050.

While the scenario modelling for 2050 demonstrates that 12 existing dwellings would be impacted by the 1 in 100-year event, all were constructed prior to 1990, and many constructed in the 1960s and 1970s.

The aim of the proposed protection works is to provide protection to the perimeter of the land area to prevent water from flowing through the interior (including through settlements).

Figure 53 also depicts the protection concept for Mundoo Channel. If these are implemented, then the protection works depicted on Murray Mouth Road are unlikely to be necessary.

There is also considerable overlap in the protection items proposed to deal with the current risk and those proposed to deal with the 2050 risk. In most cases, the levees are required to be higher by 0.3m and usually are required to be longer to cater for increase flows along the banks.

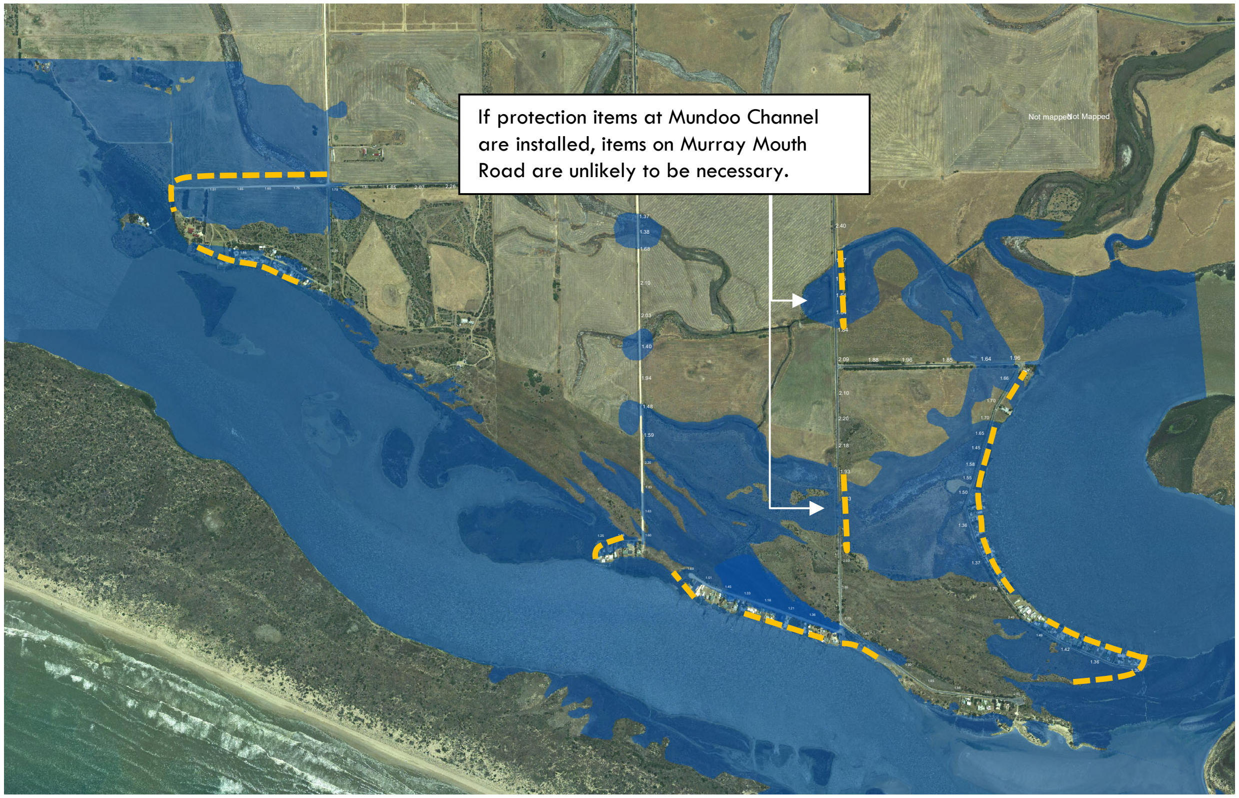


Figure 53: Concept plan for perimeter protection for Goolwa Channel settlements only for 2050 risk. (Note dotted lines do not necessarily indicate the location of protection works. The purpose is to demonstrate perimeter protection for the area)

Note: Employing a perimeter approach to protection will eliminate flows through the centre. However, this approach is unlikely to be effective to cater for projected flows at the end of the century.

Adaptation proposals

PREPARING FOR 2050 RISK

Access and Egress

The sea-flood modelling for the 2050 scenario 1 in 100-year ARI event demonstrates that the main access roads into the Goolwa Channel settlements would suffer minor impacts.

There are five areas where access roads would be impacted:

1. Chappel Road and Bongalong Road
2. Mills Road (but these would not be impacted if protection works are implemented further to the east.
3. Murray Mouth Road (two locations, but neither of these are likely to be impacted if protection items are installed at Mundoo Channel).
4. Goolwa Channel Drive (flows from this point also would impact Mills Road).
5. Sugars Avenue (carpark region)

Adaptation options are proposed for each of these on the following pages.

Adaptation options within settlements

Adaptation options would be required for:

1. Cooinda Road settlement
2. Mills Road settlement
3. Goolwa Channel Drive settlement

Figure 54: Main access roads and areas of settlements where scenario mapping demonstrates vulnerability to the 2050 1 in 100 ARI event.

Adaptation options

PREPARING FOR 2050 RISK

Access issues:

Chappel Road and Bongalong Road

The aim for this portion of Hindmarsh Island is to ensure that access remains open to Mills Road Settlement. However, a longer-term view should be kept on the outlook for the end of the century as well.

While a levee could be installed to the northern side of Bongalong Road, this would be expensive in contrast to the number of dwellings to which this section of road would service. Furthermore, modelling demonstrates that this area will become increasingly vulnerable to flooding.

The ridge behind Cooinda Road settlement is free from inundation even within the 2100 scenario.

The preferred option is to only provide protection to Chappel Road (south of Bongalong Road). This would mean the Cooinda Road shack owners can be assured of access until 2050 by egressing east along Bongalong Road (rather than Chappel Road).

A new access way could be provided to the houses on the western end of Cooinda Road along the ridgeline to Chappel Road.

Raise the road to 2.10m AHD or install levee to western side at 2.10m AHD (road raising is only 0.4m)

Figure 54: Bongalong Road will be increasingly vulnerable to inundation in the latter part of the century. Increasing the height of Chappel Road will provide longevity to the Cooinda Road settlement, and a new access way could be provided along the ridge line for the dwellings that are currently situated to the west of Cooinda Road.

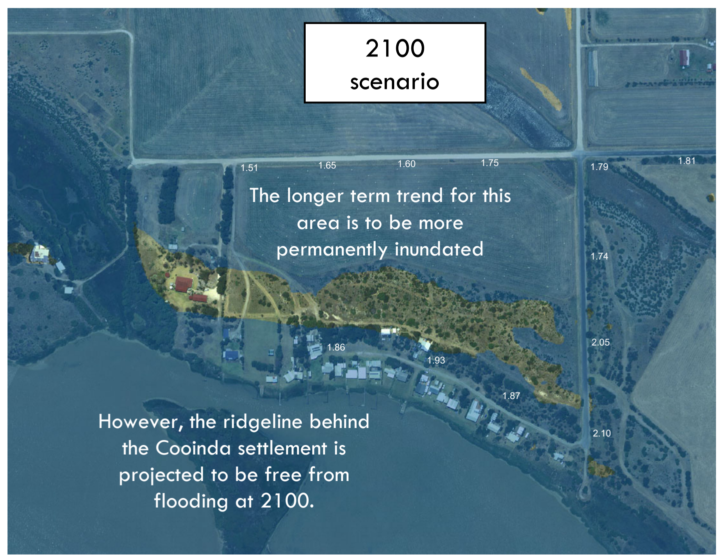


Figure 55: Scenario modelling for the 1 in 100-year ARI projected flood scenario demonstrates that the ridgeline behind Cooinda Road is not impacted.

Adaptation options

PREPARING FOR 2050 RISK

Settlement issues:

Cooinda Road settlement

Internal Access

The risk to the internal road is 1.95m (including wave setup). Raising the internal road by 0.2m to 0.3m would provide longevity of access from the settlement well past projected sea level rise for 2050. Raising the road would also satisfy the Council's preference to providing clear access for emergency service vehicles.

The cost of raising roads is likely to be borne by Council.

Private protection items

The flood mapping indicates that eight houses are projected to have flood over floor levels if the 1 in 100-year ARI risk occurred in 2050. To ensure that water could not swing around behind the extremities of a levee, approximately 400m of levee would be required at heights 0.6m to 0.8m. The cost of implementing the levee is likely to be the responsibility of the shack owners. Note: while the length of this levee is substantial, the height is minimal, and therefore the cost per shack owner could be expected to be low.

Figure 56: Raising the internal access road by 0.2 to 0.3 will maintain access, and if implemented in conjunction with raising of Chappel and Bongalong Roads (p. 136), then access in and around the settlement would be provided to cater for the projected 1 in 100 ARI event for 2050.

Adaptation options

PREPARING FOR 2050 RISK

Access issues:

Murray Mouth Road

If protection options are implemented at Mundoo Channel Road (see above section), then it is likely that access issues for Murray Mouth Road would be solved. However, if it was decided not to pursue protection items at Mundoo Channel, then protection can be provided to Murray Mouth Road to cater for the 1 in 100-year ARI flood risk for projected scenario 2050.

The most cost-effective way of dealing with this risk would be to install earthen levees on the eastern side of Murray Mouth Road for the low portion of road in the north. However further analysis could be undertaken to ascertain how connected this portion of road may be to the ocean (Figure 57).

The section of road in the south end of Murray Mouth Road is already at 1.78m AHD at the lowest point and is therefore likely to be high enough to cater for 1.85m AHD scenario projected for 2050 (Figure 58). However, raising the road at this point by 0.2 – 0.3m would provide longevity to the main access road to Sugars Beach.

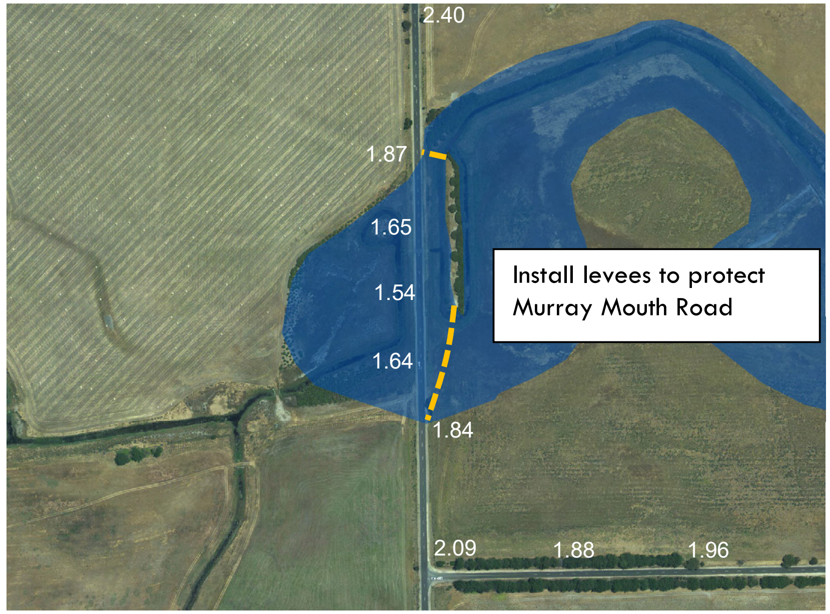


Figure 57: A levee installed on the eastern side of Murray Mouth Road would prevent water flowing over a low section of the road (however, if Mundoo options are implemented, then this levee may not be required).

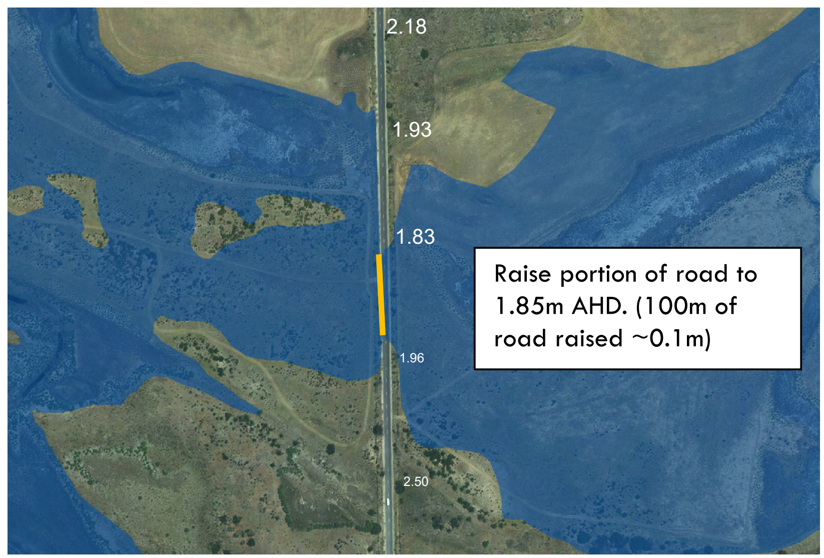


Figure 58: Raising a portion of Murray Mouth Road by 0.1m would prevent water from flowing over the road (however, in reality it would be wise to raise the road higher than this).

Adaptation options

PREPARING FOR 2050 RISK

<u>Access issues:</u>

Goolwa Channel Road

The most difficult location to manage within the Goolwa Channel settlements is Goolwa Channel Drive. The reason for this difficulty is that for the projected scenario for 2050, water would flow on to Goolwa Channel Drive from a number of points. The additional problem is that allowing water to flow over Goolwa Channel Drive is also likely to impact the access along Mills Road (page 135).

The most cost-effective way to manage this issue is for Council, property owners and the State Government share the cost to install levees to the front alignment of dwellings facing Goolwa Channel. Levee heights would likely be predominantly 0.5 to 0.8m, with some sections at 1m high. The alternative proposal would be to raise Goolwa Channel Road, but this would need to be raised 0.4m to 0.8m to cater for projected flood scenario for 2050.

In the first instance, it would make sense to install the levee to Lot 17-21 area at 2.10m high (rather than at 1.80m high (to cater for current event).

<u>Private protection issues:</u>

The cost of any other private protection items would be borne by private landowners.

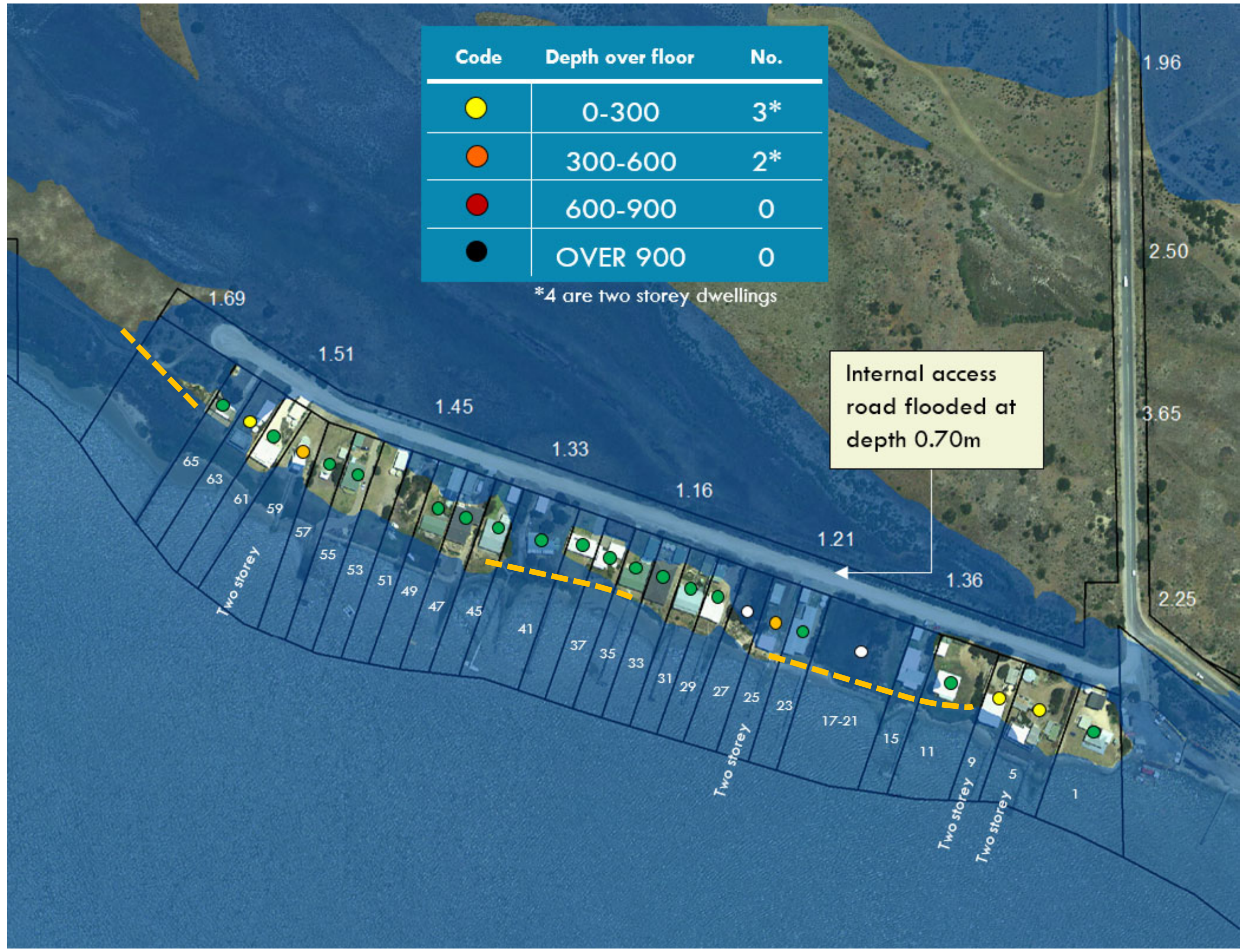


Figure 59: The preferred method to protect Goolwa Channel Drive and areas of land further inland (including Mills Road) is to provide protection to the front alignment of dwellings. The cost of this project would likely be borne by landowners, Council and the State Government. (The cost would be shared because Council has preference to protect the road. In other words, there is a shared benefit).

Adaptation options

PREPARING FOR 2050 RISK

Access issues:

Mills Road

Assuming that the protection items are installed for Goolwa Channel Drive, then tidal water is not likely to inundate Mills Road.

However, within the settlement, the internal road is subject to inundation. There are two options to deal with the impact of this scenario:

1. Raise the internal road to 2.00m AHD (raising the road 0.80m)
2. Install a levee to the perimeter of the internal access road at height of 2.10m AHD.

As the internal road is owned by the landowners and not the Council, the cost of works is likely to be borne by the landowners.

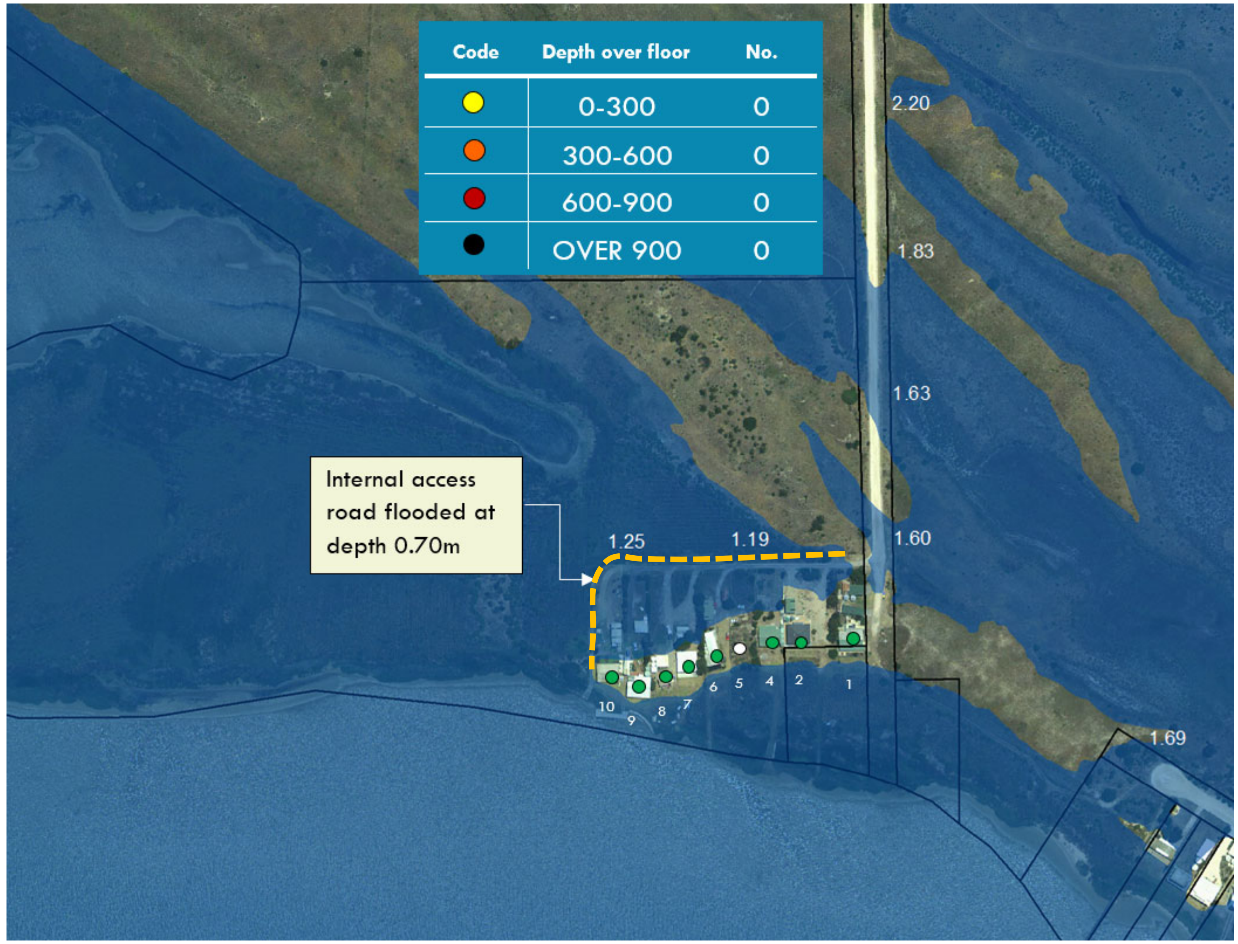


Figure 60: The internal access road to Mills Road settlement is vulnerable to flooding in current and 2050 1 in 100 ARI events. Either raising the access road or constructing a levee adjacent the road would ensure access.

Adaptation options

PREPARING FOR 2050 RISK

Access issues:

Sugars Ave

The flood scenario modelling projected for 2050 shows that water is likely to flow across Sugars Beach. The source of this flooding would occur from two main points:

1. Water would flow through the State Governments property that is currently utilised as a base of operations for dredging.
2. Water would only just over-top the rock revetment that is located along the edge of the carpark. This location is not an immediate threat, and could be raised slightly at a future time, or when tourist facilities are implemented.

(Note: the dotted line appears to be too short for the flooded area. This is because the modelling demonstrates that water flows around behind the existing rock revetment and some sections of the revetment are at sufficient height).

Ongoing monitoring of the height and nature of the dunes on the eastern end will inform the nature of risk over time into the settlement region.

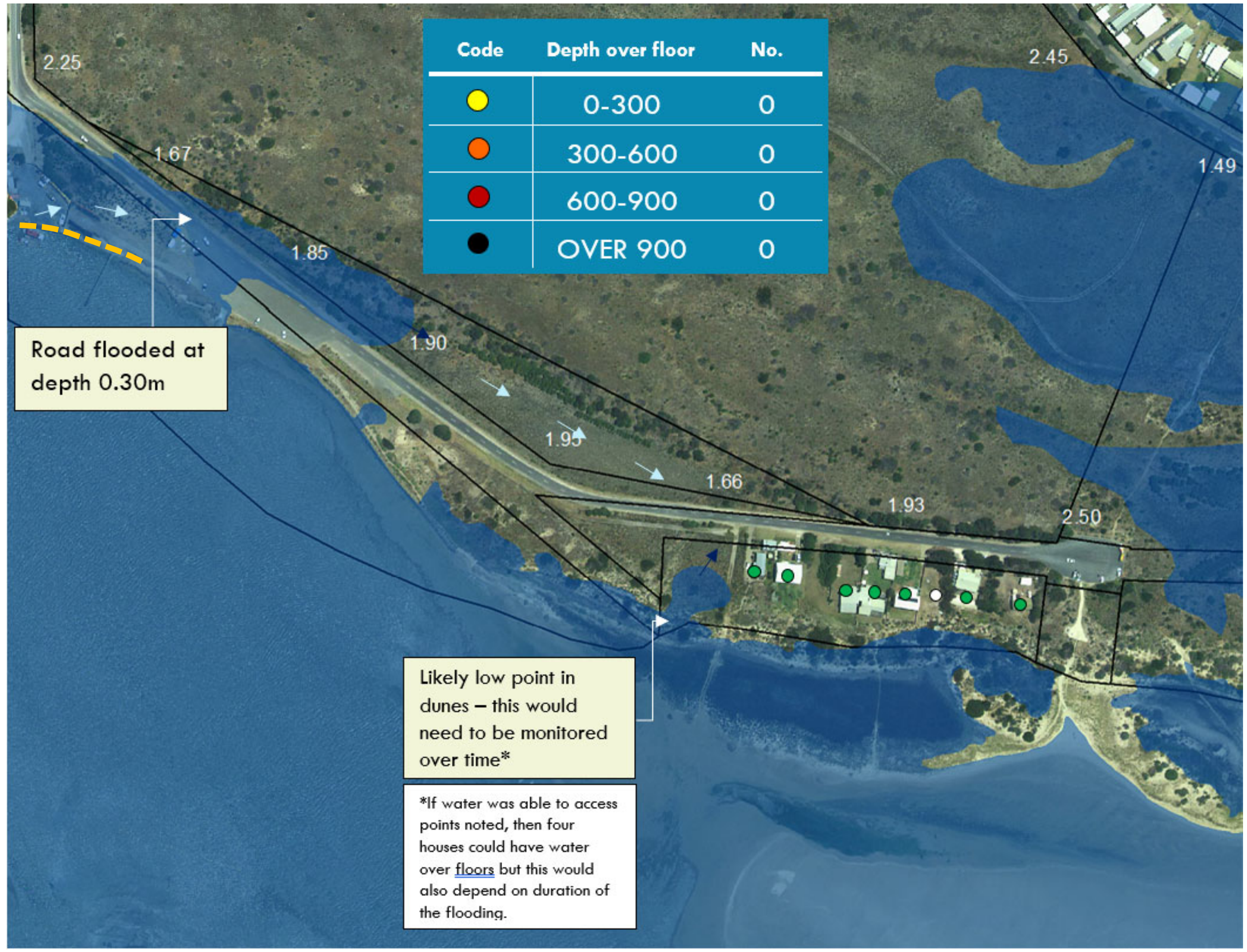


Figure 61: Modelling demonstrates that flooding would occur through the State Government owned property (currently utilised as a base for dredging) and over some sections of the existing rock revetment.

Adaptation options

PREPARING FOR LONGER TERM RISK

As noted above, if sea levels rise as projected in the latter part of this century then it is difficult to see how Goolwa Channel and Mundoo Channel settlements would be viable. There are two basic adaptation options to consider: protection (hold the line) or accommodation (of tidal flows).

Protection options:

Protection options are normally positioned on the perimeter of a land area such as Mundoo and Goolwa Channels to keep all flow of water out of areas inland of the coast. The preliminary finding of this study is that perimeter protection is not likely to be viable in the latter part of this century.

Accommodation options:

If seas rise as projected by the end of this century, then perimeter protection options are not likely to be viable because they cannot control all of the tidal flow that will enter from various directions (see p. 127). However, as noted by Dr Bourman (p. 15), the southern portion of Hindmarsh Island is criss-crossed with distributary channels that were operational when the sea was likely to be ~1m higher. When protection options are no longer viable and some of the roads have become inaccessible, it may be viable to allow the flow of water inland in a controlled manner that utilises the existing channels that remain from when sea level was higher by ~1m. The river bank could be joined to the north by one main more elevated road with culverts positioned within old channels.

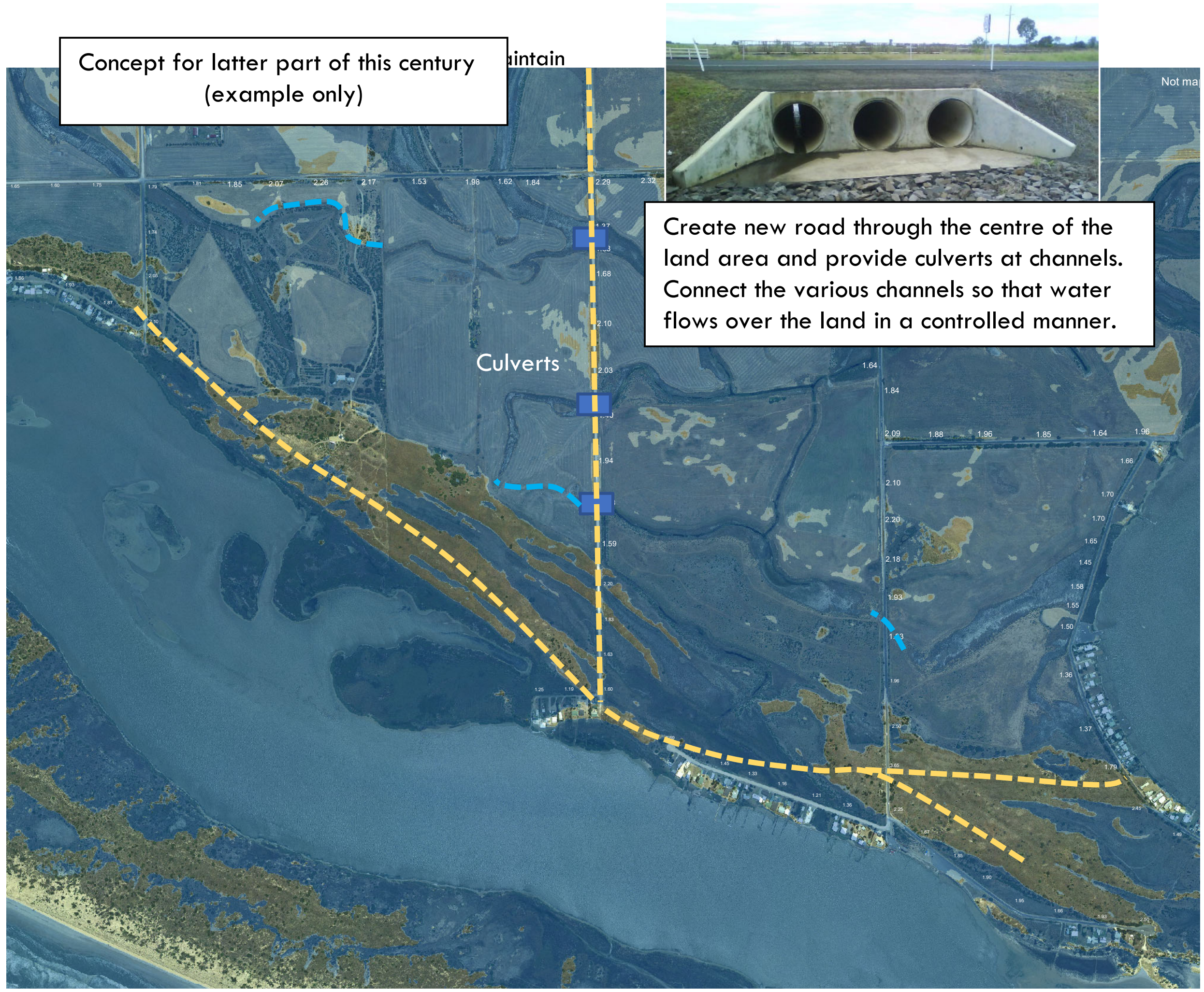


Figure 62: Perimeter protection is unlikely to be viable if seas rise as projected by the end of the century. At some point it may be viable to switch from a protection strategy to an accommodation strategy where tidal waters flow over the terrain in a controlled manner. The flood mapping provided is mapped at 2.20m AHD which is the projected annual high wate event for 2100, but is also likely to be the 1 in 100-year event for ~2070.

Adaptation options

SUMMARY: DEALING WITH CURRENT RISK

Summary

The adaptation proposals for Goolwa Channel and Mundoo Channel cannot be viewed in isolation. Furthermore, the analysis above demonstrates that the risks and therefore the adaptation proposals are interconnected. For example, providing protection at Goolwa Channel Drive also provides protection to Mills Road. Providing protection on Mundoo Channel Drive also provides protection for Murray Mouth Road.

There are also a number of stakeholders involved in the decision and implementation process:

- State Government owns two properties through which flood waters flow
- Council will seek to maintain access roads to settlements so that emergency vehicles can access, and citizens can also move safely about the coastal environs
- Private citizens will desire to protect their own assets.

The list of adaptation proposals on this page have been prioritised for Goolwa Channel settlements.

Proposals to deal with current risk

	Location	Issue	Proposal	Costs	Contingent	Risk
1	Goolwa Channel Drive	Flood water can flow through State owned property and flood Goolwa Channel Drive. One other property at risk.	Install levee adjacent channel edge (but install at height to cater for 2050 event). Inform landowners of current risk.	State Government, Council, landowners	Also protects Mill Road	Current
2	Sugars Ave	Erosion is occurring east of the boat ramp (in 2 places). Rock revetment east of the boat ramp is in poor condition.	Replace with new revetment at appropriate height. Install sandbag end control.	Council		Current
2	Mills Road	Flood water cuts of access to dwellings	Inform owners and recommend installation of levee or raise road.	Landowners	Nil	Current
3	Cooinda Road	Private property (including 3 dwellings) are at risk from inundation.	Inform owners of the risk and recommend protection options.	Landowners	Nil	Current
4	Sugars Ave	It is possible that tidal water can flow through State owned dredging base.	Inform State Government.	State Government.	Longer term, will flood Sugars Ave.	Current (likely)

Adaptation options

Proposals to deal with 2050 risk

SUMMARY: DEALING WITH 2050 RISK

Summary

Generally, it is advisable to implement any protection measures to also cater for 2050 risk. Therefore, those proposed on the previous page can be upscaled to deal with future risk.

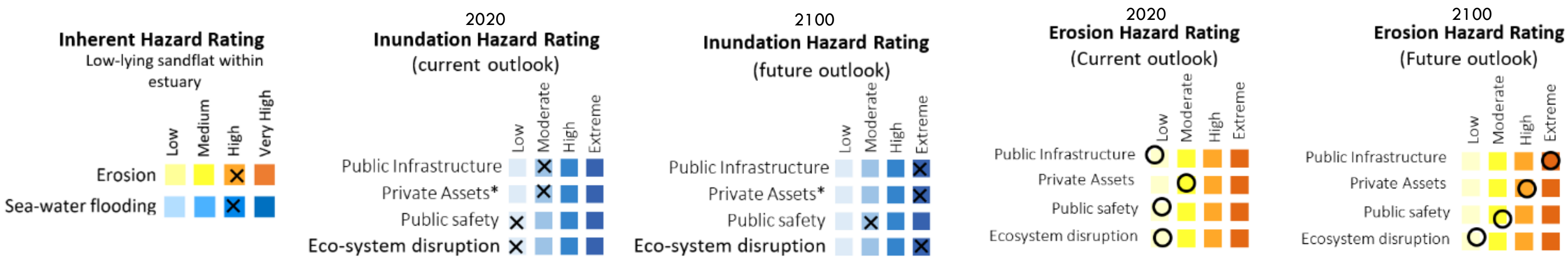
In addition to those listed on the previous page, the following adaptation actions are likely to be required to cater for the 2050 risk.

	Location	Issue	Proposal	Costs	Contingent	Risk
1	Bongalong and Chappel Roads	Flood waters are likely to increasingly impact the western end of Bongalong Road thereby cutting access for shack owners.	Raise a portion of Bongalong and Chappel Road. Create a new access way for the shack owners on the western end of the Cooinda settlement.	Council (but internal access by landowners?)	Also protects Mill Road	2050
2	Murray Mouth Road	If protection items are not implemented at Mundoo Channel, flood flows are likely across Murray Mouth Road.	Either raise the road, or install levee (cost borne by Council).	Council	Also protects Mill Road.	2050
3	Goolwa Channel Road	Flooding of Goolwa Channel Road can occur from water flowing through private properties.	Install levees adjacent to Goolwa Channel (cost shared with private owners)	Council and landowners.	Also protects Mill Road.	2050
4	Sugars Ave	Modelling shows that water will flow through dredging base and over top of rock revetment.	Inform State Government. Raise edge of carpark by 0.2m	State Government and Council	Longer term, will flood Sugars Ave.	2050

Adaptation proposals: Murray Estuary settlements (Cells SF1 - SF2)

Coastal processes	Mundoo Channel and Goolwa Channel settlements are located within Mundoo Channel and Goolwa Channel on the seaside of the barrage. The fabric (geology) of the terrain is described as a 'sand flat' at elevations generally less than 2m AHD. Flows of water in the area relate to the tidal regime at the Murray Mouth. Fresh water flows are controlled by the barrages.

Risk outlook



Adaptation overview:

The overall adaptation proposal for settlements is to 'hold the line' (ie provide protection) to cater for projected sea level rise for 2050. This interim protection will provide a time buffer for further monitoring of sea level rise trends to be identified. The main protection strategy is to install low height levees at the perimeter of Goolwa and Mundoo Channel settlements. In locations where private property (or leasehold property) is situated adjacent to the channels alternative protection strategies are likely to be required, and engagement with the community is required before any firm proposal can be identified. Sugars Beach requires upgrade of existing protection works and installation of sandbag protection to revetment end (east).

Adaptation proposals:

	Adaptation Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type (when required)	Monitoring strategy
Murray Estuary settlements Cell SF1-2	Incremental (monitor and respond)	Community engagement (then identify preferred adaptation response and develop plan.	Hold the line: provide protection (low height levees) to perimeter of Goolwa and Mundoo settlements.	Unknown: subject to further sea rise monitoring.	Engineering: Low height quarry rubble levees. In front of shacks, other methods are likely to be required. Rock revetment required now at Sugars Beach	Impact of storm events upon settlements. Monitoring of sea level rise (within SA)

Proposed protection items for Sugars Beach

Magryn Engineering provided preliminary design and costing for:

- Rock revetment upgrade (east of boat ramp)
- Sandbag control at revetment end (east end)

Provide perimeter protection

Preliminary feasibility suggests that providing perimeter protection to the Mundoo Channel and Goolwa Channel Settlements is viable to protect the settlements against project sea level rise to 2050.

The table on the right estimates the likely cubic metres of material required to construct levees. The table does not include works required at front of Mundoo private properties.

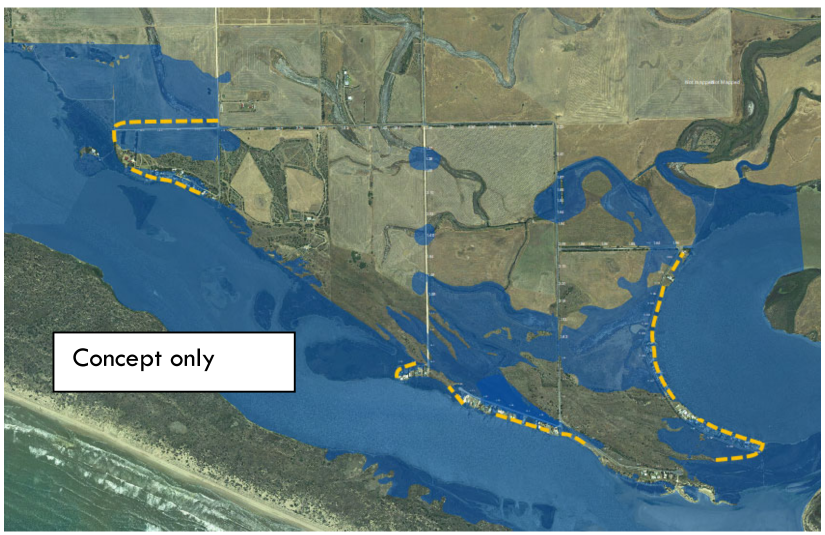


Table: Estimation of cubic metres for installation of low height levees to perimeter of Goolwa and Mundoo Channel settlement

Location	Length (Current)	Length (2050)	Height ~average	Levee m2	Levee m3
Mundoo - South	300m	300m	1.0m	4	1500*
Mundoo - north	220m	270m	1.0m	4	716*
Goolwa Channel Drive (1)	95m	110m	0.9m	3.33	330
Goolwa Channel Drive (2)	46m	65m	0.8m	2.54	132
Goolwa Channel Drive (3)	Nil	115m	0.6m	1.66	115
Mills Road	205	205m	1.0m	4	820
Cooinda Road	225m	470m	0.6m	1.66	468
Chappel Road and Bongalong Road	180m	660m	0.6m	1.66	1095